

Environmental Impact Assessment

Liza Phase 1 Development Project

Esso Exploration and Production Guyana, Limited

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TABLE OF CONTENTS

ENVIRONMENTAL IMPACT STATEMENT I

EIS EXECUTIVE SUMMARY I

EIS 1.0 INTRODUCTION IV

EIS 1.1 PROJECT SPONSOR IV
EIS 1.2 PROJECT CONTEXT IV
EIS 1.3 PURPOSE OF THE PROJECT V
EIS 1.4 REGULATORY FRAMEWORK AND PURPOSE OF THIS EIA V

EIS 2.0 PROJECT DESCRIPTION VI

EIS 2.1 Drilling and SURF/FPSO Installation vii
EIS 2.2 Production Operations viii
EIS 2.3 Decommissioning ix
EIS 2.4 Onshore, Marine, and Aviation Support ix
EIS 2.5 Project Workforce ix
EIS 2.6 Project Schedule x
EIS 2.7 Public Consultation x
EIS 2.8 Alternatives x

EIS 3.0 PROJECT IMPACTS XII

EIS 3.1 PLANNED ACTIVITIES XII
EIS 3.1.1 Air Quality xii
EIS 3.1.2 Marine Water Quality xiii
EIS 3.1.3 Marine Sediments and Marine Benthos xiv
EIS 3.1.4 Marine Biological Resources xv
EIS 3.2 UNPLANNED EVENTS XVI
EIS 3.3 CUMULATIVE IMPACTS XVIII
EIS 3.4 DEGREE OF IRREVERSIBLE DAMAGE XIX
EIS 3.5 ENVIRONMENTAL AND SOCIOECONOMIC MANAGEMENT PLAN XIX

EIS 4.0 CONCLUSIONS AND RECOMMENDATIONS XX

EIS 4.1 CONCLUSIONS XX
EIS 4.2 RECOMMENDATIONS XXII

ENVIRONMENTAL IMPACT ASSESSMENT 1

1.0 INTRODUCTION 1

1.1 PURPOSE OF THIS EIA 2
1.2 EEPGL EXPLORATION WELL DRILLING HISTORY 3
1.3 GOALS AND OBJECTIVES OF THE EIA 3
1.4 COMPONENTS OF THE EIA 4

2.0 PROJECT DESCRIPTION 13

2.1 PROJECT LOCATION 13
2.2 OVERVIEW OF THE DEVELOPMENT CONCEPT 16
2.2.1 Development Concept 16
2.2.2 Applicable Codes, Standards, and Management Systems 18
2.3 DRILLING AND WELL DESIGN 18
2.3.1 Drilling Program 18
2.3.2 Typical Well Design 19
2.3.3 Drilling Fluids 22
2.3.4 Well Cleanup and Ancillary Processes 23
2.4 SUBSEA, UMBILICALS, RISERS, AND FLOWLINES 23
2.4.1 Well Flow Connections 25
2.4.2 FPSO Topside Subsea Control System 26
2.4.3 Risers, Flowlines, Umbilicals, and Manifolds 26
2.5 FLOATING PRODUCTION, STORAGE, AND OFFLOADING VESSEL 28
2.5.1 General Description 28
2.5.2 FPSO Topsides 32
2.5.3 FPSO Process Systems 32
2.5.4 FPSO Utility Systems 35
2.5.5 Power Generation System 36
2.5.6 Integrated Control and Safety System (ICSS) 37
2.5.7 Communication Systems 37
2.5.8 Additional Vessel Systems 37
2.5.9 Safety and Personnel Protection Systems 39
2.6 INSTALLATION, HOOK-UP, AND COMMISSIONING 39
2.7 PRODUCTION OPERATIONS 40
2.7.1 Common Flow Assurance Additives 41
2.7.2 Hydrogen Sulfide (H_2S) Management 42
2.7.3 Marine Safety 42
2.7.4 Offloading Tankers 43
2.8 ONSHORE, MARINE, AND AVIATION SUPPORT 44
2.8.1 Onshore Supply and Support Activities 44
2.8.2 Logistical Support 46
2.9 END OF OPERATIONS (DECOMMISSIONING) 49
2.10 MATERIALS, EMISSIONS, DISCHARGES, AND WASTES 49
2.10.1 Materials Inventory 50
2.10.2 Emissions 52
2.10.3 Discharges 54
2.10.4 Waste Management 57
2.11 EMBEDDED CONTROLS 60
2.12 PROJECT WORKFORCE 63
2.13 WORKER HEALTH AND SAFETY 64
2.14 PROJECT SCHEDULE 64
2.15 PROJECT BENEFITS 65

2.16 ALTERNATIVES 66
2.16.1 Location Alternatives 66
2.16.2 Development Concept Alternatives 66
2.16.3 Technology Alternatives 66
2.16.4 No-go Alternative 67
2.16.5 Summary of Alternatives 67

3.0 ADMINISTRATIVE FRAMEWORK 69

3.1 NATIONAL LEGAL FRAMEWORK 69
3.1.1 National Constitution of Guyana 69
3.1.2 National Constitution of Guyana 69
3.1.3 The Guyana Geology and Mines Commission Act 70
3.1.4 The Petroleum Act 70
3.1.5 Other Resource-Specific National Environmental and Social Laws 71
3.2 NATIONAL POLICY FRAMEWORK 74
3.2.1 National Development Strategy 74
3.2.2 National Environmental Action Plan 74
3.2.3 Integrated Coastal Zone Management Action Plan 75
3.2.4 Protected Areas Act 75
3.2.5 Guyana's National Biodiversity Strategy and Action Plan (NBSAP) 75
3.2.6 Low Carbon Development Strategy and the Green Economy 76
3.2.7 Guyana Energy Agency's Strategic Plan 76
3.3 INTERNATIONAL CONVENTIONS AND PROTOCOLS 76
3.4 EEPGL'S OPERATIONS INTEGRITY MANAGEMENT SYSTEM 82

4.0 METHODOLOGY FOR PREPARING THE ENVIRONMENTAL IMPACT ASSESSMENT 83

4.1 SCREENING 84
4.2 SCOPING AND TERMS OF REFERENCE 84
4.3 ASSESSING EXISTING CONDITIONS 85
4.4 INTERACTION WITH DESIGN AND DECISION-MAKING PROCESS 85
4.5 STAKEHOLDER ENGAGEMENT 85
4.5.1 Stakeholder Engagement Plan 86
4.5.2 Stakeholder Identification and Engagement Strategy 86
4.5.3 Stakeholder Engagement Process 87
4.5.4 Stakeholder Comments and Considerations 90
4.6 ASSESSMENT OF IMPACTS AND IDENTIFICATION OF MITIGATION 93
4.7 MITIGATION, MANAGEMENT, AND MONITORING 97

5.0 SCOPE OF THE ENVIRONMENTAL IMPACT ASSESSMENT 99

5.1 THE AREA OF INFLUENCE 99
5.2 PROJECT INTERACTIONS WITH ENVIRONMENTAL AND SOCIOECONOMIC RECEPTORS 102
5.3 RESOURCES/RECEPTORS ASSESSED IN THE EIA 103

6.0 DESCRIPTION OF THE EXISTING ENVIRONMENT 111

6.1 PHYSICAL RESOURCES 111
6.1.1 Air Quality and Climate 111
6.1.2 Sound 113
6.1.3 Marine Geology and Sediments 115
6.1.4 Oceanographic Conditions/Marine Water Quality 124
6.2 BIOLOGICAL RESOURCES 131
6.2.1 Protected Areas and Special Status Species 131
6.2.2 Coastal Habitats 137
6.2.3 Coastal Wildlife and Shorebirds 141
6.2.4 Seabirds 142
6.2.5 Marine Mammals 147
6.2.6 Marine Turtles 154
6.2.7 Marine Fish 158
6.2.8 Marine Benthos 163
6.3 SOCIOECONOMIC RESOURCES 169
6.3.1 Administrative Divisions in Guyana 169
6.3.2 Population Distribution 171
6.3.3 Education 173
6.3.4 Land Use 174
6.3.5 Economy 176
6.3.6 Employment and Livelihoods 186
6.3.7 Community Health and Wellbeing 192
6.3.8 Marine Use and Transportation 198
6.3.9 Social Infrastructure and Services 204
6.3.10 Cultural Heritage 213
6.3.11 Ecosystem Services 218

7.0 ASSESSMENT OF POTENTIAL IMPACTS 221

7.1 PHYSICAL RESOURCES 222
7.1.1 Air Quality and Climate 222
7.1.2 Sound 232
7.1.3 Marine Geology and Sediments 232
7.1.4 Marine Water Quality 238
7.2 BIOLOGICAL RESOURCES 248
7.2.1 Protected Areas and Special Status Species 248
7.2.2 Coastal Habitats 253
7.2.3 Coastal Wildlife and Shorebirds 254
7.2.4 Seabirds 254
7.2.5 Marine Mammals 259
7.2.6 Marine Turtles 275
7.2.7 Marine Fish 282
7.2.8 Marine Benthos 291

7.2.9 Ecological Balance and Ecosystems 296
7.3 SOCIOECONOMIC ENVIRONMENT 301
7.3.1 Project Activities and Receptors 301
7.3.2 Economic Conditions 303
7.3.3 Employment and Livelihoods 306
7.3.4 Community Health and Wellbeing 310
7.3.5 Marine Use and Transportation 314
7.3.6 Social Infrastructure and Services 324
7.3.7 Cultural Heritage 331
7.3.8 Land Use 334
7.3.9 Ecosystem Services 337
7.3.10 Indigenous Peoples 337
7.4 UNPLANNED EVENTS 338
7.4.1 Introduction 338
7.4.2 Physical Resources 355
7.4.3 Biological Resources 359
7.4.5 Transboundary Impacts 384

8.0 CUMULATIVE IMPACT ASSESSMENT 389

8.1 SCOPE OF THE CUMULATIVE IMPACT ANALYSIS 389
8.1.1 Potentially Eligible Resources 389
8.1.2 Other (non-Project) Relevant Activities 390
8.1.3 Relevant Resources 391
8.1.4 Geographical Extent of Analysis 392
8.1.5 Time Frame for Analysis 392
8.2 RESOURCE/RECEPTOR-SPECIFIC CUMULATIVE IMPACT ASSESSMENT 392
8.2.1 Special Status Species 392
8.2.2 Marine Mammals 393
8.2.3 Marine Turtles 394
8.2.4 Marine Fish 395
8.2.5 Community Health and Wellbeing 396
8.2.6 Marine Use and Transportation 397
8.2.7 Social Infrastructure and Services 397

9.0 ENVIRONMENTAL AND SOCIOECONOMIC MANAGEMENT PLAN FRAMEWORK 399

9.1 INTRODUCTION 399
9.2 REGULATORY AND POLICY FRAMEWORK 399
9.3 ESMP STRUCTURE 400
9.4 GENERAL ESMP GUIDING PRINCIPLES 402
9.5 MANAGEMENT PLAN CONTENTS 402
9.6 MANAGEMENT OF CHANGE 402

10.0 CONCLUSIONS AND SUMMARY OF IMPACTS 403

10.1 PLANNED EVENTS 403
10.2 UNPLANNED EVENTS 403
10.3 CUMULATIVE IMPACTS 404
10.4 DEGREE OF IRREVERSIBLE DAMAGE 404
10.5 PROJECT BENEFITS 404
10.6 SUMMARY 405

11.0 RECOMMENDATIONS 407

12.0 PROJECT TEAM 413

13.0 REFERENCES 415

INTRODUCTION 415
ADMINISTRATIVE FRAMEWORK 415
DESCRIPTION OF THE EXISTING ENVIRONMENT 415
ASSESSMENT OF POTENTIAL IMPACTS 427
PERSONAL COMMUNICATIONS 433

APPENDICES

A: Signatures for EIA Preparers
B: EIA Team CVs
C: EIA Review Checklist
D: Air Quality Monitoring Report
E: 2014 EBS Report
F: 2016 EBS Report
G: Flora and Fauna of Shell Beach
H: IUCN Listed Species
I: Birds of Guyana
J: MMO Executive Summaries and Summary of Data
K: List of Marine Fishes of Guyana
L: Air Quality Modeling Report
M: Water Quality Modeling Report
N: Underwater Noise Modeling Report

LIST OF TABLES

Table EIS-1 FPSO Key Design Rates viii
Table EIS-2 Resources and Receptors Considered in this EIA xii
Table EIS-3 Summary of Production Operations Discharges xiv
Table EIS-4 Coastal Resources Potentially Impacted by an Oil Spill xviii
Table EIS-5 Marine Resources Potentially Impacted by an Oil Spill xviii
Table EIS-6 Summary of Residual Impact Ratings xxi
Tab1e 1-1 EEPGL Stabroek Exploration Well Drilling History 3
Table 1-2 EIA Review Checklist "Roadmap" 4
Table 2-1 FPSO Key Design Rates 29
Table 2-2 Project Materials and Chemicals 51
Table 2-3 Annual Air Emissions Summary 53
Table 2-4 Summary of Drilling and Completion-Related Discharges 55
Table 2-5 Summary of Commissioning and Production-Related Discharges 56
Table 2-6 Summary of Estimated Annual Project Waste Generation and Management Methods 58
Table 2-7 List of Embedded Controls 60
Table 2-8 Workforce Estimates 64
Table 3-1 Resource-Specific Environmental and Social Laws 71
Table 3-2 International Agreements Relevant to Environmental and Socioeconomic Issues in Guyana 77
Table 4-1 Themes in Scoping Comments Received and Consideration in EIA 91
Table 4-2 Evaluation of Impact Significance 93
Table 4-3 Evaluation of Risk 96
Table 5-1 Summary of Resources/Receptors Retained for Further Consideration in EIA and Corresponding Potential Impacts, Primary Sources of Potential Impacts, and Analytical Approach 105
Table 5-2 Resources and Receptors Excluded from Further Consideration in the EIA 109
Table 6-1 Major Geologic Formations of the Guyana Basin 115
Table 6-2 Summary Results for Sediment Metals, Reported in $\mu g\ g^{-1}$ dry weight 117
Table 6-3 Summary Results for Sediment Hydrocarbons 119
Table 6-4 EBS Water Column Heavy Metals Concentrations 131
Table 6-5 Protected Areas in Guyana 132
Table 6-7 Definitions of IUCN Red List Threatened Categories 136
Table 6-8 Seabird Species Known to Occur in Guyana 144

Table 6-9 Marine Mammals with Ranges that include Waters Offshore Guyana 147
Table 6-10 Marine Mammal Species Visually Observed during EEPGL Activities Since 2014 151
Table 6-11 Data Compiled from PSO Observations June 2014 to September 2016 152
Table 6-12 Fish Bycatch from the Nearshore Shrimp Trawling Fishery 2012-2015 (mt) 160
Table 6-13 Fish Species Observed in the Stabroek Block during EEPGL Activities Since 2014 160
Table 6-14 List of Common Macrofauna Families between the 2014 and 2016 Environmental Survey Reports 165
Table 6-15 Regional Population Distribution in Guyana 171
Table 6-16 Economic Sectors and Contribution to GDP, 2015 176
Table 6-17 Primary Characteristics of Marine Fisheries in Guyana 182
Table 6-18 Health Facilities in the Coastal Regions 195
Table 6-19 Number of Educational Facilities in Guyana's Coastal Regions 209
Table 6-20 Policing Divisions in Guyana 211
Table 7-1 Project Activities and Potential Impacts – Air Quality and Climate 223
Table 7-2 Annual Air Emissions Summary 224
Table 7-3 WHO Ambient Air Quality Guidelines 226
Table 7-4 Modeling Results Summary at Potential Onshore Receptor Locations 229
Table 7-5 Estimated Annual Project GHG Emissions 231
Table 7-6 Air Quality and Climate - Pre-Mitigation and Residual Impact Significance Ratings 232
Table 7-7 Project Activities and Potential Impacts – Marine Geology and Sediments. 233
Table 7-8 Summary of Modeling Results for Drill Cuttings Discharge Scenarios 234
Table 7-9 Marine Geology and Sediments - Pre-Mitigation and Residual Impact Significance Ratings 237
Table 7-10 Project Activities and Potential Impacts – Marine Water Quality 239
Table 7-11 Summary of TSS Modeling Results for Drill Cuttings Discharge Scenarios 240
Table 7-12 Summary of Project-related Discharges 241
Table 7-13 Summary of Discharges and Modeled Constituents for Installation and Production Operations 244
Table 7-14 Summary of Modeling Results for Most Conservative Bounding Case (predictions at 100 m reference distance) 246
Table 7-15 Magnitude Ratings for Modeled Hydrotesting and Production Operations Discharges 247

Table 7-16 Marine Water Quality - Pre-Mitigation and Residual Impact Significance Ratings 248
Table 7-17 Definitions for Magnitude Ratings for Special Status Species 250
Table 7-18 Definitions for Receptor Sensitivity Ratings for Special Status Species 250
Table 7-19 Special Status Species - Pre-Mitigation and Residual Impact Significance Ratings 252
Table 7-19 Special Status Species - Pre-Mitigation and Residual Impact Significance Ratings 253
Table 7-20 Project Activities and Potential Impacts – Seabirds 255
Table 7-21 Seabirds - Pre-Mitigation and Residual Impact Significance Ratings 259
Table 7-22 Project Activities and Potential Impacts – Marine Mammals 260
Table 7-23 Acoustic Threshold Levels for Onset of Permanent Threshold Shifts (PTS) in Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs) . 266
Table 7-24 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 1 – FPSO Operations 267
Table 7-25 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 2 – Installation of the FPSO Vessel, Including Mooring the FPSO and Using Several Construction and Service Vessels 267
Table 7-26 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 3 – Installation of a Drill Center, Including Operation of a Drill Ship and a Pipelaying Vessel 268
Table 7-27 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 4 – Operation of a Vertical Seismic Profiler 268
Table 7-28 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 5 – Installation of Manifold Foundation Piles 268
Table 7-29 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 6 – Installation of Mooring Piles for the FPSO 269
Table 7-30 Definitions for Receptor Sensitivity Ratings for Impacts to Special Status Species 272
Table 7-31 Impact Magnitude and Receptor Sensitivity Ratings - Marine Mammals 272
Table 7-32 Marine Mammals - Pre-Mitigation and Residual Impact Significance Ratings 274

Table 7-33 Project Activities and Potential Impacts – Marine Turtles 275
Table 7-34 Definitions for Receptor Sensitivity Ratings for Impacts to Special Status Species 279
Table 7-35 Impact Magnitude and Receptor Sensitivity Ratings - Marine Turtles 280
Table 7-36 Summary of Impacts Significance Ratings and Recommended Mitigation Measures - Marine Turtles 281
Table 7-37 Project Activities and Potential Impacts – Marine Fish 282
Table 7-38 Definitions for Magnitude Ratings for Potential Impacts to Marine Fish 289
Table 7-39 Definitions for Receptor Sensitivity Ratings for Impacts to Marine Fish 290
Table 7-40 Summary of Impact Significance Ratings and Recommended Mitigation Measures - Marine Fish 290
Table 7-41 Project Activities and Potential Impacts – Marine Benthos 292
Table 7-42 Area of Benthic Habitat Disturbed by FPSO and SURF Subsea Infrastructure Installation 294
Table 7-43 Marine Benthos - Pre-Mitigation and Residual Impact Significance Ratings 296
Table 7-44 Definitions for Magnitude Ratings for Potential Impacts to Ecological Balance and Ecosystems 299
Table 7-45 Definitions for Receptor Sensitivity Ratings for Impacts to Ecological Balance and Ecosystems 300
Table 7-46 Summary of Impact Significance Ratings and Recommended Mitigation Measures – Ecological Balance and Ecosystems 300
Table 7-47 Socioeconomic Receptors and Potential Impacts as a Result of Project Activities 302
Table 7-48 Project Activities and Potential Impacts – Economic Conditions 304
Table 7-49 Definitions for Receptor Sensitivity for Impacts to Economic Conditions 305
Table 7-50 Economic Conditions – Pre-Mitigation and Residual Impact Significance Ratings 306
Table 7-51 Project Activities and Potential Impacts – Employment and Livelihoods 307
Table 7-52 Definitions for Scale Ratings for Potential Impacts on Employment and Livelihoods 308
Table 7-53 Definitions for Receptor Sensitivity Ratings for Employment and Livelihood Impacts 309
Table 7-54 Employment and Livelihoods – Pre-Mitigation and Residual Impact Significance Ratings 310
Table 7-55 Project Activities and Potential Impacts - Community Health and Wellbeing 311

Table 7-56 Definitions for Scale Ratings for Potential Impacts on Community Health and Wellbeing 311
Table 7-57 Definitions for Receptor Sensitivity Ratings for Community Health and Wellbeing Impacts 313
Table 7-58 Community Health and Wellbeing – Pre-Mitigation and Residual Impact Significance Ratings 314
Table 7-59 Project Activities and Potential Impacts – Marine Use and Transportation 316
Table 7-60 Definitions for Scale Ratings - Potential Impacts on Maritime Use and Transportation 318
Table 7-61 Magnitude Ratings – Potential Impacts on Marine Use and Transportation 319
Table 7-62 Definitions for Receptor Sensitivity Ratings – Potential Impacts to Maritime Use and Transportation 319
Table 7-63 Sensitivity Ratings for Marine Use and Transportation Receptors 320
Table 7-64 Marine Use and Transportation Pre-Mitigation and Residual Impact Significance Ratings 322
Table 7-65 Project Activities and Potential Impacts – Social Infrastructure and Services (Housing and Utilities) 324
Table 7-66 Definitions for Scale Ratings for Potential Impacts on Housing and Utilities 325
Table 7-67 Definitions for Receptor Sensitivity Ratings for Housing and Utilities Impacts 325
Table 7-68 Housing and Utilities Pre-Mitigation and Residual Impact Significance Ratings 326
Table 7-69 Project Activities and Potential Impacts – Onshore and Air Transportation 327
Table 7-70 Magnitude of Impacts – Onshore and Air Transportation 328
Table 7-71 Receptor Sensitivity Ratings – Onshore and Air Transportation 329
Table 7-72 Onshore and Air Transportation – Summary of Pre-Mitigation and Residual Impacts 330
Table 7-73 Summary of Relevant Project Activities and Potential Key Impacts 331
Table 7-74 Definitions for Scale Ratings for Potential Impacts on Cultural Heritage Impacts 332
Table 7-75 Definitions for Sensitivity Ratings for Potential Impacts on Cultural Heritage 333
Table 7-76 Summary of Pre-Mitigation and Residual Impacts – Cultural Heritage 334
Table 7-77 Project Activities and Potential Impacts – Land Use 335
Table 7-78 Definitions for Scale Ratings for Potential Impacts on Land Use 335

Table 7-79 Definitions for Receptor Sensitivity Ratings for Land Use Impacts 336
Table 7-80 Summary of Pre-Mitigation and Residual Impacts – Land Use 336
Table 7-81 Levels of Likelihood for Unplanned Event Impact Assessment 338
Table 7-82 Possible Hydrocarbon Spill Scenarios by Tier 340
Table 7-83 Oil Thickness (g/m^2) and Appearance on Water (NRC, 1985) 344
Table 7-84 Resources/Receptors Potentially Impacted by Unplanned Events 355
Table 7-85 Risk Rating for Oil Spill Impacts to Air Quality 356
Table 7-86 Risk Rating for Oil Spill Impacts on Marine Geology and Sediments 357
Table 7-87 Risk Rating for Oil Spill Impacts on Water Quality 359
Table 7-88 Risk Rating for Oil Spill Impacts on Protected Areas and Special Status Species 362
Table 7-89 Risk Rating for Oil Spill Impacts on Coastal Habitats 363
Table 7-90 Risk Rating for Oil Spill Impacts on Coastal Wildlife and Shorebirds 365
Table 7-91 Risk Rating for Oil Spill Impacts on Seabirds 366
Table 7-92 Risk Ratings for Oil Spill Impacts on Marine Mammals 367
Table 7-93 Risk Rating for Oil Spill Impacts on Marine Turtles 368
Table 7-94 Risk Rating for Oil Spill Impacts on Marine Fish 370
Table 7-95 Risk Rating for Oil Spill Impacts on Marine Benthos 371
Table 7-96 Risk Rating for Oil Spill Impacts on Ecological Balance and Ecosystems 373
Table 7-97 Risk Rating for Oil Spill Impacts on Economic Conditions / Employment and Livelihoods 375
Table 7-98 Risk Rating for Oil Spill and Vehicle/Vessel Impacts on Community Health and Wellbeing 377
Table 7-99 Risk Rating for Oil Spill/Vessel Collision on Marine Use and Transportation 378
Table 7-100 Risk Rating for Oil Spill and Vehicular Accident Risks to Social Infrastructure and Services 380
Table 7-101 Summary of Oil Spill Risk to Cultural Heritage 381
Table 7-102 Potential Ecosystem Services Receptors and Impacts from a Large Marine Oil Spill 382
Table 7-103 Risk Rating for Oil Spill Impacts on Ecosystem Services 383
Table 7-104 Risk Rating for Oil Spill Impacts on Indigenous Peoples 384
Table 8-1 Eligibility of Resources/Receptors for Cumulative Impact Analysis 390
Table 8-2 Identification of Relevant Resources/Receptors for the Cumulative Impact Analysis 391
Table 10-1 Summary of Residual Impact Ratings 406

Table 11-1 List of Proposed Embedded Controls 408
Table 11-2 List of Proposed Mitigation Measures 411
Table 12-1 Project Team 413

LIST OF FIGURES

Figure EIS-1 Location of the Liza Project Development Area within the Stabroek Block v
Figure EIS-2 Preliminary Liza Phase 1 Field Layout vi
Figure EIS-3 Typical Drill Ship vii
Figure EIS-4 FPSO vii
Figure EIS-5 Typical FPSO Offloading to a Conventional Tanker ix
Figure EIS-6 Preliminary Project Schedule x
Figure 1-1 Location of the Liza Project Development Area within the Stabroek Block 1
Figure 2-1 Subsea Project Development Area for FPSO Installation, SURF, and Drill Centers within Stabroek Block 14
Figure 2-2 Surface Project Development Area for FPSO and Drill Centers within Stabroek Block 15
Figure 2-3 Preliminary Liza Phase 1 Field Layout 17
Figure 2-4 Typical Drill Ship 19
Figure 2-5 Provisional Casing Program for Development Drilling Program 20
Figure 2-6 Typical Subsea Drilling System 22
Figure 2-7 Representative SURF System 24
Figure 2-8 Example of Wire Brush Cleaning Pig 24
Figure 2-9 Representative Subsea Trees, FLETs, Jumpers, and Manifold 25
Figure 2-10 Representation of Riser Connected to FPSO 26
Figure 2-11 Representative Integrated Dynamic Umbilical Cross Section 27
Figure 2-12 Representative Subsea Manifold 28
Figure 2-13 Computer Simulated Picture of Planned Liza Phase 1 FPSO 30
Figure 2-14 General Schematic of a Converted FPSO Topsides and Hull 31
Figure 2-15 Process Flow Diagram 33
Figure 2-16 General Offloading Configuration 38
Figure 2-17 Preliminary Safety Exclusion Zones during Drilling, Installation, and Offloading Operations 43
Figure 2-18 Typical Shorebase Quay 45
Figure 2-19 Typical Laydown Yard 46

Figure 2-20 Typical Logistics Support Vessels 47
Figure 2-21 Potential Drilling and Operations Stage Peak Fleet Profile 48
Figure 2-22 Typical Waste Management Facilities at a Local Shorebase 59
Figure 2-23 Vertical Infrared Unit with Wet Scrubber and Oxidizer at Typical Waste Management Facilities 59
Figure 2-24 Preliminary Project Schedule 65
Figure 3-1 Operations Integrity Management System 82
Figure 4-1 Environmental Application Invitation for Public Comment 88
Figure 4-2 Sample Draft Terms of Reference Invitation for Public Comment - Regions 2 and 3 89
Figure 4-3 Impact Prediction and Evaluation Process 94
Figure 5-1 Direct Area of Influence 100
Figure 5-2 Indirect Area of Influence 101
Figure 6-1 Typical Distribution of Mudbanks and Mangroves on Guyana's Coast 116
Figure 6-2 Marine Currents in the Vicinity of the Project Development Area 126
Figure 6-3 Vector Stick Plot for Stations on the Stabroek LADCP Transect 127
Figure 6-4 LADCP Locations 128
Figure 6-5 Protected Areas of Guyana 133
Figure 6-6 Shell Beach Protected Area 134
Figure 6-7 Guyana's Ecoregions 138
Figure 6-8 Guyana's Mangrove Distribution (Georgetown west to Venezuelan Border) 140
Figure 6-9 Mangrove Photographs 140
Figure 6-10 Location of IBAs with Importance to Seabirds Relative to Stabroek Block 146
Figure 6-11 Locations of Marine Mammal Sightings Relative to the Stabroek Block 153
Figure 6-12 Location of Sea Turtle Sightings and Satellite Tracks Relative to the Stabroek Block 157
Figure 6-13 Approximate Locations of Biological Observations Made Since 2014 161
Figure 6-14 Abundance of Major Taxonomic Groups Identified in 2016 EBS 165
Figure 6-15 Benthos Photographed in the Vicinity of the Liza-1 Well 166
Figure 6-16 Representative Photographs of the Circa-Littoral Sandy Mud Biotope Photographed in the Vicinity of the Liza-1 Well 168
Figure 6-17 Guyana's Administrative Regions and Townships 170
Figure 6-18 Regional Distribution of Ethnicity, 2012 172
Figure 6-19 Amerindian Population by Region, 2012 173

Figure 6-20 Land Cover in Coastal Guyana 175
Figure 6-21 Rice Field in Region 2 Pomeroon-Supenaam 177
Figure 6-22 Annual Rice Production, 2011-2015 178
Figure 6-23 Sluice Gate (Koker) in Charity (Region 2) at High Tide 179
Figure 6-24 Aerial View of Sugar Plantations in Region 2 180
Figure 6-25 Annual Sugar Production, 2011-2015 180
Figure 6-26 Annual Coconut Production, 2011-2015 181
Figure 6-27 Commercial Fisheries Catch Volumes, 2007-2015 183
Figure 6-28 Fish Yields from Aquaculture, 2009-2015 184
Figure 6-29 Annual International Visitors to Guyana, 2000-2015 186
Figure 6-30 Salted Fish Drying Outside a Fisherperson's Home in Region 2 188
Figure 6-31 Fresh Fish Being Sold at Stabroek Market in Georgetown 188
Figure 6-32 Fishing Boat Landed on a Coastal Mudflat in Region 2, September 2016 190
Figure 6-33 Speedboats Docked in Parika, Region 3 191
Figure 6-34 Malaria Incidence by Region, 2010 193
Figure 6-35 TB Incidence Rate by Region, 2010 194
Figure 6-36 Annual Number of HIV and AIDS Cases, 2001-2014 194
Figure 6-37 Percent of Population with Access to Improved Water Sources by Region, 2014 196
Figure 6-38 Percent of Population with Electricity by Region, 2014 197
Figure 6-39 Household Access to Telecommunications, 2014 198
Figure 6-40 Offshore Shipping Lanes 201
Figure 6-41 Fishing Zones and Ports 202
Figure 6-42 Maritime Transportation Facilities 203
Figure 6-43 Proportion of Housing Types by Region 204
Figure 6-44 Proportion of Home Ownership Types by Coastal Region 205
Figure 6-45 Demerara Harbour Bridge 206
Figure 6-46 Electricity Generation in Guyana, 2009-2015 208
Figure 6-47 Locations of Schools that Occur in Near-coastal Portions of Regions 1-6 210
Figure 6-48 Locations of Security Facilities in Immediate Vicinity of Guyana's Coast 212
Figure 6-49 SSS Targets UD08, UD011, and UD021 Found within the Main AUV Survey Area 215
Figure 6-50 SSS Target SC17 in the Main AUV Survey Area 216
Figure 6-51 SSS Target SC110 in the Main AUV Survey Area 216

Figure 6-52 SSS Mosaic Showing SSS Targets, Including the Potential SGSCS Trinidad-Guyana Cable, in the Skipjack Survey Area 217
Figure 7-1 Evaluation of Impact Significance 221
Figure 7-2 Air Quality Modeling Domain 228
Figure 7-3 Definitions for Magnitude Ratings for Potential Impacts on Air Quality 230
Figure 7-4 Auditory Weighting Functions for Marine Mammal Hearing Groups as Recommended by Southall el al. (2007) 263
Figure 7-5 Auditory Weighting Functions for Marine Mammal Hearing Groups as Recommended by Finneran (2015) 263
Figure 7-6 Unplanned Events Risk Matrix 338
Figure 7-7 Typical Impacts on Marine Organisms across a Range of Oil Classes 342
Figure 7-8 Weathering Processes Acting on Spilled Oil 342
Figure 7-9 Stochastic Map for Scenario 8 – Unmitigated 2,500-Barrel Release of Crude Oil (December through May) 346
Figure 7-10 Deterministic Map for Scenario 8 – Unmitigated 2,500-Barrel Release of Crude Oil (December through May) Depicting Weathering and Fate 347
Figure 7-11 Oil Mass Balance Graph for Scenario 8 – Unmitigated 2,500-Barrel Release of Crude Oil (December through May) Depicting Weathering and Fate 348
Figure 7-12 Stochastic Map for Scenario 9 – Unmitigated 20,000-Barrel-per-Day Release of Crude Oil for 30 days (December through May) 349
Figure 7-13 Deterministic Map for Scenario 9 – Unmitigated 20,000-Barrel-per-Day Release of Crude Oil for 30 days (December through May) Depicting Weathering and Fate 350
Figure 7-14 Oil Mass Balance Graph for Scenario 9 – Unmitigated 20,000-Barrel-per-Day Release of Crude Oil for 30 days (December through May) Depicting Weathering and Fate 351
Figure 9-1 ESMP Structure 401

LIST OF ACRONYMS

%	percent
%BFROC	percentage of base fluid retained on cuttings
°C	degrees Celsius
µg/m3	micrograms per cubic meter
µPa	micro pascal
AASM	Airgun Array Source Model
AMS	Alarm Management System
AOI	Area of Influence
AQS	air quality standards
AUV	Automated Underwater Vehicle
bbl	barrel(s)
BOEM	U.S. Bureau of Ocean Energy Management
BOP	blowout preventer
BOPD	barrels of oil per day
CARICOM	Caribbean Community
CBP	chlorinated by-products
CCC	criterion continuous concentrations
CCR	central control room
CFC	chlorofluorocarbon
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMC	criterion maximum concentrations
CO	carbon monoxide
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
CPACC	Caribbean Planning for Adaptation to Climate Change
CPI	Carbon preference index
CR	Critically Endangered
CREE	Center for Rural Empowerment and the Environment
CSC	International Convention for Safe Containers
CTD	conductivity, temperature, and depth
dB	decibel
DC	drill center
DDIA	Declared Drainage and Irrigation Areas
DP	Dynamic Positioning
EBS	environmental baseline surveys
EEA	European Environment Agency
EEPGL	Esso Exploration and Production Guyana Limited
EIA	Environmental Impact Assessment
EITI	Extractive Industries Transparency Initiative
EMT	emergency medical technician
EN	Endangered
EPA	Guyanese Environmental Protection Agency
ESMP	Environmental and Socioeconomic Management Plan
EUNIS	European Nature Information System

EX .....Extinct
EZZ.....Exclusive Economic Zone
F&G .....Fire and Gas
FAL.....Convention on Facilitation of International Maritime Traffic
FEED .....Front-End Engineering and Design
FGSI.....Fugro GeoServices Incorporated
FLET .....flowline end termination
FPSO.....Floating Production, Storage, and Offloading
FSO .....Floating Storage and Offloading
FSV .....Fast Supply Vessel
ft.....Feet/Foot
Fugro .....Fugro Marine Geoservices, Inc.
Fugro EMU .....Fugro EMU Limited
FWRAM.....Full Waveform Range-dependent Acoustic Model
GDP .....Gross Domestic Product
GEA.....Guyana Energy Agency
GEMSS-GIFT.....Generalized Integrated Fate and Transport
GGMC.....Guyana Geology and Mines Commission
GHG .....greenhouse gas
GINA.....Government Information Agency
GLSC .....Guyana Lands and Surveys Commission
GMPHOM.....Guide to Manufacturing and Purchasing Hoses for Offshore Moorings
GPHC.....Georgetown Public Hospital Corporation
GRA.....Guyana Revenue Authority
GT&T .....Guyana Telephone & Telegraph
GuySuCo .....Guyana Sugar Corporation
GWI .....Guyana Water Inc.
GYD.....Guyanese dollar
H_2S .....hydrogen sulfide
ha .....hectares
HFC .....High-frequency cetaceans
HVAC .....Heating, Ventilation, and Air Conditioning
IBA.....Important Bird Area
ICSS .....Control and Safety System
ICZM.....Integrated Coastal Zone Management
IDB.....Inter-American Development Bank
IFC .....International Finance Corporation
ILO.....International Labor Organization
IMF .....International Monetary Fund
IMO .....International Maritime Organization
IOGP.....International Oil and Gas Producers
ITCZ .....Inter-Tropical Convergence Zone
IUCN.....International Union for Conservation of Nature
IUU .....Illegal, Unreported, and Unregulated
IWC .....International Whaling Commission
JNCC .....Joint Nature Conservation Committee
kbd.....thousands of barrels per day

kHz.....kilohertz
km.....kilometers
LADCP.....Lowered Acoustic Doppler Current Profiler
LC.....Least Concern
LCDS.....Low Carbon Development Strategy
LFC.....Low-frequency cetaceans
LME.....Large Marine Ecosystem
MA.....Millennium Ecosystem Assessment
MACT.....Maximum Acceptable Toxicant Concentration
MARAD.....Maritime Administration
MARPOL 73/78.....International Convention for the Prevention of Pollution by Ships, 1973, as modified by the Protocol of 1978
MBES.....multi-beam echo sounder
MDG.....Millennium Development Goal
MFC.....Mid-frequency cetaceans
mg/L.....milligrams per liter
mi.....miles
MICS.....Multiple Indicator Cluster Survey
MMO.....marine mammal observation/observer
MOC.....North Atlantic Meridional Overturning Circulation
MONM.....Marine Operations Noise Model
MoNRE.....Ministry of Natural Resources and Environment
MPV.....Multi-Purpose Vessel
MSC.....Marine Sustainability Council
mscfd.....million standard cubic feet per day
MW.....megawatt
M-weighted.....Auditory weighting functions for marine mammals
N/A.....not applicable
NABF.....non-aqueous base fluid
NADF.....non-aqueous drilling fluid
NBC.....North Brazil Current
NBSAP.....National Biodiversity Strategy and Action Plan
NDC.....Neighbourhood Democratic Councils
NDIA.....National Drainage and Irrigation Authority
NDS.....National Development Strategy
NTD.....Neglected Tropical Diseases
NEAP.....National Environmental Action Plan
NGO.....non-governmental organization
nm.....nautical mile
NO_2.....nitrogen dioxide
NOAA.....U.S. National Oceanic and Atmospheric Administration
NOM.....naturally occurring organic matter
NT.....Near Threatened
O&G.....oil and grease
OAS.....Organization of American States
OCIMF.....Oil Companies International Marine Forum

OI ..... Operations Integrity
OIMS ..... Operations Integrity Management System
OSH ..... Occupational Safety and Health
OSR ..... Oil Spill Response
OSRP ..... Oil Spill Response Plan
P&A ..... plugged and abandoned
PA/GA ..... public address and general alarm system
PAH ..... Polycyclic aromatic hydrocarbons
PC ..... Project Contribution
PCS ..... Process Control System
PDA ..... Project Development Area
PEC ..... Predicted Environmental Concentration
PM_{10} particulate matter with aerodynamic diameter of less than 10 micrometers
$PM_{2.5}$ ..... particulate matter with aerodynamic diameter of less than 2.5 micrometers
POB ..... personnel on board
POP ..... Persistent Organic Pollutant
ppb ..... parts per billion
PPE ..... personal protective equipment
ppm ..... parts per million
ppt ..... parts per trillion
Pr/Ph Ratio ..... Ratio of pristane to phytane
Project ..... Liza Phase 1 Development Project
PSC ..... Private Sector Commission
PSV ..... Platform Supply Vessel
PTS ..... Permanent Threshold Shift
RMS ..... root mean square
RO ..... reverse osmosis
ROV ..... remotely operated vehicle
SBP ..... sub-bottom profiler
SBPA ..... Shell Beach Protected Area
SC ..... Scientific Committee
SCAT ..... Shoreline Clean-up Assessment Technique
SDU ..... Subsea Distribution Unit
SEA ..... Strategic Environmental Assessment
SEL ..... sound exposure level
SEP ..... Stakeholder Engagement Plan
SGSCS ..... Suriname-Guyana Submarine Cable System
SHC ..... Saturated and aliphatic hydrocarbons
SIS ..... Safety Instrumented System
SO_2 ..... sulfur dioxide
SOLAS ..... International Convention for the Safety of Life at Sea
SPAW ..... Specially Protected Areas and Wildlife
SPL ..... sound pressure level
SRU ..... Sulfate Removal Unit
SSHE ..... Safety, Security, Health, and Environment

STCW .....International Convention on Standards of Training, Certification and Watchkeeping
SURF .....Subsea, Umbilicals, Risers, and Flowlines
TB.....Tuberculosis
THC.....total hydrocarbons
TIP .....Technical Information Paper
TOC.....total organic carbon
ToR .....Terms of Reference
TSS.....total suspended solids
TV .....Tug Vessel
UCM.....Unresolved complex mixture
UNAIDS .....Joint United Nations Program on HIV/AIDS
UNESCO.....United Nations Educational, Scientific and Cultural Organization
UNFCC .....United Nations Framework Convention on Climate Change
UPS.....uninterruptible power supply
USD .....U.S. Dollars
USEPA .....U.S. Environmental Protection Agency
VLCC .....Very Large Crude Carrier
VOC.....volatile organic compounds
VSP .....Vertical Seismic Profile
VU .....Vulnerable
WBDF.....water-based drilling fluids
WHO.....World Health Organization
WRC.....Wider Caribbean Region
WRF.....Weather Research and Forecasting

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GLOSSARY

Term	Definition
Anthropogenic	Made by humans, or attributable to human activity.
Barrel	The basic unit for measuring oil. A barrel is equal to 42 U.S. gallons.
Biogenic	Made by living organisms, or attributable to the activity of living organisms.
Biomagnification	Increasing concentration of a persistant substance, usually a pollutant or toxin, in the tissues of organisms at successively higher levels in a food chain
Borehole (or wellbore)	A deep, narrow hole drilled in the earth for the purpose of extracting a core, releasing gas, oil, water, etc.
Casing	Steel pipe inserted into an oil or gas well to prevent the wall of the borehole from caving in, to prevent movement of fluids from one formation to another, and to improve the efficiency of extracting petroleum (for producing wells).
Circumtropical	Distributed throughout the world's tropical latitudes.
Congregatory	Tending to gather in large groups on a cyclical or otherwise regular and/or predictable basis
Crude oil	Liquid petroleum as it comes out of the ground. The properties of crude oil , such as color, gravity, and viscosity, can vary.
Cuttings (or drill cuttings)	Broken bits of solid material produced as the drill bit advances through the borehole in the rock or soil. Cuttings are usually carried to the surface by the drilling fluid circulating up from the drill bit, and can be separated from the drilling fluid using a variety of treatment methods (e.g., centrifuge).
Development well	A well drilled in a proven area in a field for the purposes of producing hydrocarbons.
Drill ship	A self-propelled floating offshore drilling unit that is a ship constructed to permit a well to be drilled from it. Drill ships are generally the preferred option for drilling wells in deep, remote waters.
Drilling fluids (or drilling mud)	Specially-formulated fluids, also called drilling mud, which are typically a mixture of barite, clay, water, and other chemical additives. Drilling fluids are circulated into the borehole to lubricate and cool the rotary drill bit, to lift the cuttings out of the borehole and to the surface, and to help maintain well control.
Equivalent barrels (or barrel of oil equivalent [BOE])	A unit of energy based on the approximate energy released by burning one barrel of crude oil. Quantities of natural gas and natural gas liquids are often translated into barrels of oil equivalent (BOE). The energy content of six thousand cubic feet of gas (6 MCF) is roughly equivalent to one barrel of

Term	Definition
	oil.
Exploration	The search for oil and gas. Exploration operations include aerial surveys, geophysical surveys, geological studies, core testing and the drilling of test (wildcat) wells.
Exploratory well	A well drilled to 1) find oil or gas in an undiscovered or unproven area (wildcat), or 2) extend the limits or depths of a known area.
Flare (or Flaring)	In the oil industry: An system of piping and burners used to dispose (by burning) of surplus gas or vapors produced with the oil.
Floating Production Storage and Offloading (FPSO) vessel	A floating vessel that is used for offshore oil and gas operations and is designed to process hydrocarbons and store oil until the oil can be offloaded onto a tanker ship or transported via pipeline. The processing equipment (or topsides) is located on the FPSO's deck, while the oil storage is below the deck within the hull of the vessel.
Flowline	The surface pipe through which oil travels from a well to processing equipment or to storage.
Hydrostatic test	A way in which pressure vessels such as pipelines, plumbing, gas cylinders, boilers and fuel tanks can be tested for strength and leaks. The test involves filling the vessel or pipe system with a liquid, usually water, which may be dyed to aid in visual leak detection, and pressurizing the vessel to the specified test point. Pressure tightness can be tested by shutting off the supply valve and observing whether there is a pressure loss.
Ichthyoplankton	Fish eggs and larvae that drift with the ocean currents, usually near the surface, prior to developing directional swimming ability.
Injection well	A well in which fluids, such as gas or water, are injected to increase pressure in the reservoir and drive the oil remaining in the reservoir to the vicinity of production wells.
Lagrangian	Type of gridless atmospheric model in which pollutant particles move according to the wind field, buoyancy, and turbulence effects. Term is often used to differentiate such models from Eulerian models, which use a gridded field.
Laydown area	An area that has been cleared for the temporary storage of equipment and supplies. Laydown areas are usually covered with rock and/or gravel to ensure accessibility and safe maneuverability for transport and offloading of vehicles.
Marine safety exclusion zone	A specific area of water where persons, vessels, and other activities are prohibited as the area has been designated for exclusive use by an activity; a form of safety control measure utilized to keep unauthorized persons and vessels away from a higher risk activity/event.
Natural gas	A highly compressible, highly expansible mixture of hydrocarbons, which at atmospheric conditions of temperatures and pressure, are in a gaseous

Term	Definition
	phase.
Oil field	The surface area covering one or more reservoirs containing oil. The oil field also usually includes the reservoir, the wells, and the production equipment, etc.
Overboard water	Another name for produced water or brine produced from oil and gas wells.
Platform	An immobile structure used in offshore drilling on which the drilling rig, crew quarters, and other related items are located.
Plugging of well	The sealing off of the fluids in the stratum penetrated by a well so that the fluid from one stratum will not escape into another or to the surface.
Produced water	Water that comes up a well with the oil and gas. Produced water is usually high in salinity. After leaving the well, the produced water is separated from the oil and gas. Can also be referred to as formation water, saltwater, or oilfield brine.
Production well	A well that is used to retrieve petroleum or gas from an underground deposit.
Refinery	The facility where the characteristics of petroleum or petroleum products are changed.
Reservoir	A porous and permeable sedimentary rock containing commercial quantities of oil and gas.
Risers	The pipe and special fittings used on floating offshore drilling rigs to establish a seal between the top of the wellbore, which is on the ocean floor, and the drilling equipment, located above the surface of the water. A riser pipe serves as a guide for the drill stem from the drilling vessel to the wellhead and as a conductor of drilling fluid from the well to the vessel. The riser consists of several sections of pipe and includes special devices to compensate for any movement of the drilling rig caused by waves. Risers are also used to connect subsea equipment to a surface facility such as an FPSO.
Shorebase	The land based facility that provides logistical and material support for offshore activities and facilities.
Spread mooring anchor system	A group of mooring lines distributed from the bow and stern of a vessel (FPSO) to anchors on the seafloor. The vessel is positioned in a fixed heading, which is determined by the sea and weather conditions. The symmetrical arrangement of anchors helps to keep the vessel on its fixed heading location. The spread mooring system does not allow the vessel to weathervane, which means to rotate in the horizontal plane due to wind, waves or current.

Term	Definition
Structural casing	The outer layer of large diameter, heavy-wall pipe installed in wells drilled from floating installations to isolate very shallow sediments from subsequent drilling, resist the bending moments imposed by the marine riser, and to help support the wellhead installed on the conductor casing.
Tree	The assembly of valves, pipes and fittings used to control the flow of oil and gas from the casing head.
Wellhead	A structure that is installed at the top of a natural oil or gas well. Its main function is to ensure a safe operation and manage the flow of oil or gas from the well into the gathering-system. It is a system composed of valves, spools and assorted adapters that control the pressure of the production well. It acts as an interface between the surface facilities and the casing-strings in the wellbore.

ENVIRONMENTAL IMPACT STATEMENT

EIS Executive Summary

Esso Exploration and Production Guyana Limited (EEPGL) proposes the "Liza Phase 1 Development Project" (Project) to develop the Liza field located in the Stabroek Block offshore Guyana. EEPGL obtained an offshore prospecting license for the Stabroek Block from the Government of Guyana. In 2015, oil was discovered in the Liza field within the eastern half of the Stabroek Block approximately 190 km (~120 mi) offshore from Georgetown in waters approximately 1,500 to 1,900 meters (m) deep. Subsequent surveys and exploratory drilling have identified a reservoir of oil in a sandstone formation approximately 3,600 m below the seabed (approximately 5,400 m below sea level). This reservoir is estimated to have a recoverable resource of 0.8 to 1.4 billion oil-equivalent barrels.

EEPGL (45%), together with Hess Guyana Exploration Limited (30%) and CNOOC Nexen Petroleum Guyana Limited (25%), are parties to a Petroleum Agreement with the Government of Guyana. Under this agreement, and in light of the Liza field discovery, EEPGL has applied for a Petroleum Production Licence and submitted a Project Development Plan to the Minister Responsible for Petroleum.

A key permit required for EEPGL to develop the Liza field is the Environmental Authorisation from the Guyana Environmental Protection Agency (EPA) in accordance with the Guyana Environmental Protection Act of 1996 (EP Act Cap. 20:05). As part of its regulatory role, the EPA, considering recommendations from the Environmental Advisory Board (EAB) and Guyana Geology and Mines Commission (GGMC), is responsible for deciding whether and under what conditions to grant EEPGL's Application for Environmental Authorisation (Application), which was filed with the EPA on July 5, 2016. Based on an initial assessment of the Project, the EPA determined that an Environmental Impact Assessment (EIA) was required. The purpose of the EIA is to provide the factual and technical basis required by EPA, EAB, and the GGMC to make an informed decision on EEPGL's Application. EEPGL has conducted a robust public consultation program to both inform the public about the Project and to understand community and stakeholder concerns so this feedback could be incorporated and addressed in the EIA, as applicable.

EEPGL proposes to drill approximately 17 subsea development wells and use a Floating Production Storage and Offloading (FPSO) vessel to process, store, and offload the recovered oil. The FPSO will be connected to the wells via separate production (oil, gas, and produced water), gas injection, and water injection flowlines and risers, and associated subsea equipment. The Project will also involve shorebase facilities and marine/aviation services to support development drilling, FPSO and subsea equipment installation, production operations, and ultimately decommissioning. EEPGL will utilize proven and industry accepted standards and has incorporated many embedded controls into the overall Project design to minimize environmental and socioeconomic impacts. It could take up to four years to drill the wells, with drilling planned to begin as early as 2018. The initial production is expected to begin by mid-2020, with operations continuing for at least 20 years. The Project is expected to employ up to

600 persons during well drilling, approximately 600 persons at the peak of the installation stage, and up to about 140 persons during production operations.

The planned activities of the Project are predicted to have minor impacts on physical resources (i.e., air quality, marine sediments, and water quality), no impacts on coastal biological resources, minor impacts on marine biological resources, and largely positive impacts on socioeconomics. These predictions are based on the fact that the bulk of the Project activity will occur approximately 190 km (~120 miles) offshore, and the Project will capture and re-inject produced natural gas, which is not used as fuel on the FPSO, back into the Liza reservoir; treat required wastewater streams prior to discharge to the sea; have a very small physical footprint (e.g., infrastructure construction disturbs only about 0.3 km^2 of benthic habitat); and use Marine Mammal Observers (MMO) during selected activities to minimize the potential impacts to marine mammals due to auditory injury and ships strikes.

Unplanned events, such as a large oil spill, are considered unlikely to occur because of the extensive preventative measures employed by EEPGL. Nevertheless, an oil spill is considered possible, and EEPGL has conducted oil spill modeling to evaluate the range of likely spill trajectories and rates of travel. The location of the Project 190 km (~120 mi) offshore, prevailing northwest currents, the light nature of the Liza field crude oil, and the region's warm waters would all help minimize the severity of a spill. Accounting for these factors, the modeling indicates only a 5 to 10 percent probability of any oil reaching the Guyana coast, without taking into consideration the effectiveness of any oil spill response, and in the unlikely event that a spill were even to occur.

Although the probability of an oil spill reaching the Guyana coast is very small, a spill at a Liza well would likely impact marine resources found near the well, such as sea turtles and certain marine mammals that may transit or inhabit the area impacted by a spill. Air quality, water quality, seabirds, and marine fish could also be impacted, although likely to a lesser extent because the duration of acute impacts would not be long and the impacts are reversible. A spill could potentially impact Guyanese fishermen if commercial fish and shrimp were impacted. The magnitude of this impact would depend on the volume and duration of the release as well as the time of year the release were to occur (e.g., whether a spill would coincide with the time of year when these species are more common). Effective implementation of the Oil Spill Response Plan (OSRP) would help mitigate this risk by further reducing the ocean surface area impacted by a spill and thereby reduce oil exposure to these species.

As described above, although a large oil spill is considered unlikely and the probability of reaching the Guyana coast is very low, nevertheless, given the sensitivity of many of the resources that could be potentially impacted by a spill (e.g., Shell Beach Protected Area, marine mammals, critically endangered and endangered sea turtles, coastal Guyanese and Amerindian communities reliant on ecosystem services for sustenance and their livelihood), preparation for spill response is warranted. Therefore, we believe it is critical that EEPGL commit to regular oil spill response training exercises, document the availability of appropriate response equipment on board the FPSO, and demonstrate that offsite equipment could be mobilized for a timely response.

It is recommended that all EEPGL embedded controls, recommended mitigation measures, and appropriate Environmental and Socioeconomic Management Plans, including an OSRP, be adopted. With the implementation of such controls, mitigation measures, and management plans, the Liza Phase 1 Development Project is expected to pose only minor risks to the environmental and socioeconomic resources of Guyana, while potentially offering significant economic benefits to the residents of Guyana.

EIS 1.0 INTRODUCTION

This Environmental Impact Statement (EIS) has been prepared for the Liza Phase 1 Development Project (Project) in accordance with the Guyana Environmental Protection Agency (EPA) Environmental Impact Assessment Guidelines (November 2000) and the Project Final Terms of Reference (February 2017).

This EIS was prepared by Environmental Resources Management (ERM), which is an international environmental and social consulting firm with extensive experience in the preparation of Environmental Impact Assessments (EIA) for offshore oil and gas development projects. ERM is also a Guyana EPA registered consultant. EIA Appendix B provides the Curriculum Vitae of the key members of the EIA team.

ERM did not encounter any specific difficulties in preparing the EIA. The information provided on the Project and the resources found in the Project Development Area (PDA) were adequate for ERM to prepare a robust impact assessment.

EIS 1.1 Project Sponsor

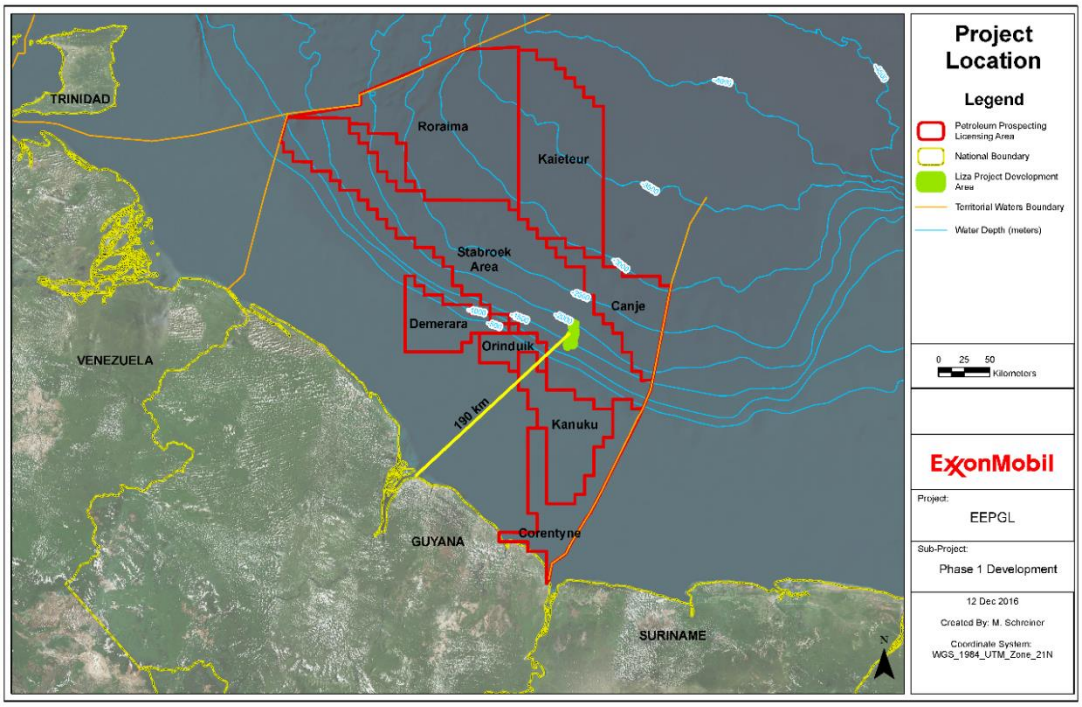
The Project Sponsor is a joint venture among Esso Exploration and Production Guyana Limited (EEPGL), Hess Guyana Exploration Limited (Hess), and CNOOC Nexen Petroleum Guyana Limited (Nexen). EEPGL will be the operator of the Project, and is used in this EIA to represent the joint venture. EEPGL, which is an affiliate of Exxon Mobil Corporation, was formed on October 16, 1998 and subsequently registered in Guyana on June 29, 1999. Exxon Mobil Corporation, either directly or through subsidiaries, conducts oil and gas exploration activities worldwide.

EIS 1.2 Project Context

EEPGL obtained an offshore petroleum prospecting license for the Stabroek Block from the Government of Guyana. In 2015, oil was discovered in the Liza field within the eastern half of the Stabroek Block approximately 190 kilometers (~120 miles) offshore from Georgetown in waters approximately 1,500 to 1,900 meters (m) deep (Figure EIS-1). Subsequent surveys and exploratory drilling have identified a reservoir of oil in a sandstone formation approximately 3,600 m below the seabed (approximately 5,400 m below sea level). This reservoir is estimated to have a recoverable resource of 0.8 to 1.4 billion oil-equivalent barrels.

EEPGL, together with Hess and Nexen, are parties to a Petroleum Agreement with the Government of Guyana. Under this agreement, and in light of the Liza field discovery, EEPGL has applied for a Petroleum Production Licence and submitted a Project Development Plan to the Minister Responsible for Petroleum.

Figure EIS-1 Location of the Liza Project Development Area within the Stabroek Block



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

EIS 1.3 Purpose of the Project

The purpose of the Project is to achieve safe and efficient production of hydrocarbons from the Liza field. A confidential Petroleum Agreement between EEPGL, Hess, Nexen, and the Government of Guyana defines how revenues from the Project are to be shared between the parties. The Government of Guyana would begin receiving oil revenues when oil is produced.

EIS 1.4 Regulatory Framework and Purpose of this EIA

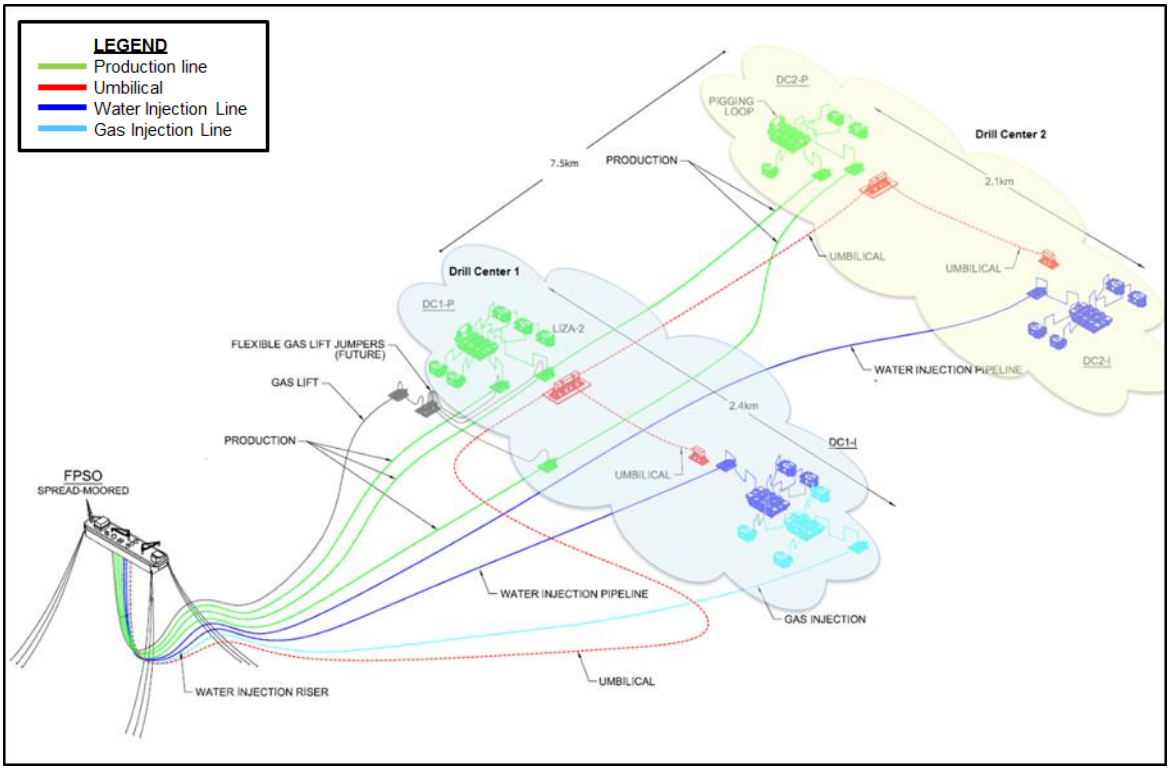
In order to develop the Liza field, EEPGL needs to obtain approval of an Application for Environmental Authorisation (Application) from the Guyana EPA in accordance with the Guyana EP Act (Cap. 20:05). Toward that end, EEPGL filed its Application with the EPA on July 5, 2016. As part of its regulatory role, the EPA, taking into consideration recommendations from the Environmental Advisory Board (EAB) and GGMC, is responsible for deciding whether and under what conditions to grant EEPGL's Application. Based on an initial assessment of the Project, the EPA determined that an EIA was required. The purpose of this EIA is to provide the factual and technical basis required by EPA, EAB, and the GGMC to make an informed decision on EEPGL's Application. If approved, the EPA would issue an Environmental Permit[1] with the terms and conditions necessary to effectively protect the environment.

[1]-The Environmental Authorisation granted by the EPA is also commonly referred to as an environmental permit, and may be used interchangeably.

EIS 2.0 PROJECT DESCRIPTION

The Project proposes to develop the offshore resource by drilling approximately 17 subsea development wells and using a Floating Production Storage and Offloading (FPSO) vessel to process, store, and offload the recovered oil. The FPSO will be connected to the wells via associated equipment, collectively referred to as subsea umbilicals, risers, and flowlines (SURF), to transmit produced fluids (i.e., oil, gas, produced water) from production wells to the FPSO, as well as treated gas and water from the FPSO to the injection wells. The Project drilling and production operations activities will collectively occur in what is referred to as the Project Development Area (PDA), which is an approximately 50 km² area located approximately 190 km (~120 mi) offshore (Figure EIS-2). The Project will also involve use of onshore shorebase facilities and marine/aviation services to support development drilling, SURF and FPSO installation, production operations, and ultimately decommissioning.

Figure EIS-2 Preliminary Liza Phase 1 Field Layout



Natural gas will be produced in association with the produced oil. EEPGL will use some of the recovered gas as fuel on the FPSO, and proposes to re-inject the remaining gas back into the Liza reservoir, which will assist in optimizing management of the reservoir. Alternative uses of gas for future phases are being studied and would be addressed in a separate environmental authorization.

Phase 1 will consist of essentially three stages: (1) Drilling and Installation, (2) Production Operations, and (3) Decommissioning. Each of these stages is described briefly below.

EIS 2.1 Drilling and SURF/FPSO Installation

Figure EIS-3 Typical Drill Ship



EEPGL will use one or two drill ships (Figure EIS-3), to drill the development wells. The approximately 17 development wells are currently planned to include eight production wells (for recovering the oil), six water wells (to inject water into the Liza reservoir to maintain pressure), and three gas wells (to re-inject recovered gas not used on the FPSO into the reservoir). The wells will be clustered around two drill centers. For safety reasons, a 500 m marine safety exclusion zone around the drill ships and major installation vessels will be established to avoid interactions with unauthorized vessels. For each well, the initial section (i.e., structural casing section) will feature a pipe inserted into the borehole and cemented in place. This section will be drilled using water based drilling fluids (WBDF), and drill cuttings from this section will be discharged to the seafloor near the well. Subsequent (lower) sections of the wells will be drilled using low-toxicity non-aqueous drilling fluids (NADF) with low to negligible aromatic content. The used cuttings from the lower sections will be directed to the drill ship, where the drilling fluids will be recovered for reuse to the extent practicable and the cuttings will be treated to limit the percentage of fluid retained on the cuttings. After treatment, the cuttings are then discharged to the sea.

Once each well is drilled, a wellhead and tree are installed and the well is connected to a manifold, which is connected, as appropriate to an umbilical and production, gas, or water flowline. The flowlines will be laid on the seafloor, and risers will connect the seafloor infrastructure to the FPSO. The flowlines and risers will be hydrostatically tested with treated seawater to ensure no leakage. After the testing, the hydrostatic water used to test the water and gas injection flowlines will be discharged near the seafloor, and the fluid used to test the production flowlines will be recovered and treated prior to discharging overboard.

Figure EIS-4 FPSO



The FPSO (Figure EIS-4) will be a converted double hull tanker with the capacity to store 1.6 million barrels of stabilized crude oil. The FPSO will be secured to the seafloor by a 16- to 20-point spread mooring anchor system. The FPSO and the mooring system are designed to remain in place for at least 20 years and to sustain extreme (100-year return period) environmental conditions. The FPSO will also provide living quarters

and associated utilities for approximately 140 personnel. For safety reasons, the FPSO will have a two nautical mile exclusion zone to avoid interactions with unauthorized vessels.

EIS 2.2 Production Operations

The FPSO will be designed to separate the recovered reservoir fluids into its oil, water, and gas phases (Table EIS-1). The oil will be treated to remove impurities (e.g., sulfate and other salts) and then sent to storage tanks in the hull. The water from the reservoir (referred to as produced water) will be treated to remove hydrocarbons and will then be discharged to the sea. The FPSO will dehydrate, compress, and re-inject the produced natural gas into the Liza reservoir, although some of the gas will be used as fuel on the FPSO, and some gas may be occasionally flared on a non-routine, temporary basis. The FPSO will also have the capacity to treat (by filtration, deaeration, and sulfate removal) seawater for injection into the reservoir to maintain reservoir pressure (and offset the withdrawal of reservoir fluids) to enhance oil production.

Table EIS-1 FPSO Key Design Rates

Service	Design Rate*
Oil Production	100,000 barrels per day (bpd) (designed to safely operate at sustained peaks of 120,000 bpd)
Produced Water	100,000 bpd
Total Liquids	150,000 bpd
Produced Gas	180,000,000 standard cubic feet per day
Gas Injection	160,000,000 standard cubic feet per day (assumes some produced gas will be used as fuel gas for the FPSO)
Water Injection	190,000 bpd

* Project facilities will have the potential to safely operate at sustained peaks above the design rate. For purposes of this EIA, potential impacts generated by the Project (e.g., air emissions) were based on a potential peak production volume of 144,000 bpd to be conservative in the analysis.

The FPSO will offload produced crude oil to conventional oil tankers on a regular basis. The tanker, under the guidance of a Mooring Master, will maneuver to within approximately 120 m (390 feet) of the FPSO and hold position with the aid of up to three tugboats (Figure EIS-5). Crude oil will be pumped from the FPSO storage tanks to an offloading tanker using a floating hose at a rate of approximately one million barrels of oil in about 28 hours.

Figure EIS-5 Typical FPSO Offloading to a Conventional Tanker



EIS 2.3 Decommissioning

Prior to the end of operations (estimated at approximately 20 years), EEPGL will initiate detailed planning for facility decommissioning, including filing a Notice of Intent for Decommissioning to the GGMC and EPA. All development wells will be permanently plugged and abandoned. It is expected that the SURF equipment and the FPSO mooring lines will be abandoned in place on the seafloor in accordance with standard industry practice (subject to the decommissioning plan). The FPSO will be disconnected from its mooring system and towed to a shipyard for decommissioning.

EIS 2.4 Onshore, Marine, and Aviation Support

Shorebases, laydown areas, warehouses, fuel supply, and waste management facilities will support the Project across the Project stages as described above. EEPGL is planning to utilize shorebases in Guyana and Trinidad to support the Project. Marine support will include various supply vessels with an average of 12 trips per week during drilling and installation and about 7 trips per week during production operations. These vessels are planned to originate from shorebases in Guyana and/or Trinidad. Aviation support is expected to average about 30 to 35 flights per week during drilling and installation and about 20 to 25 flights during production operations.

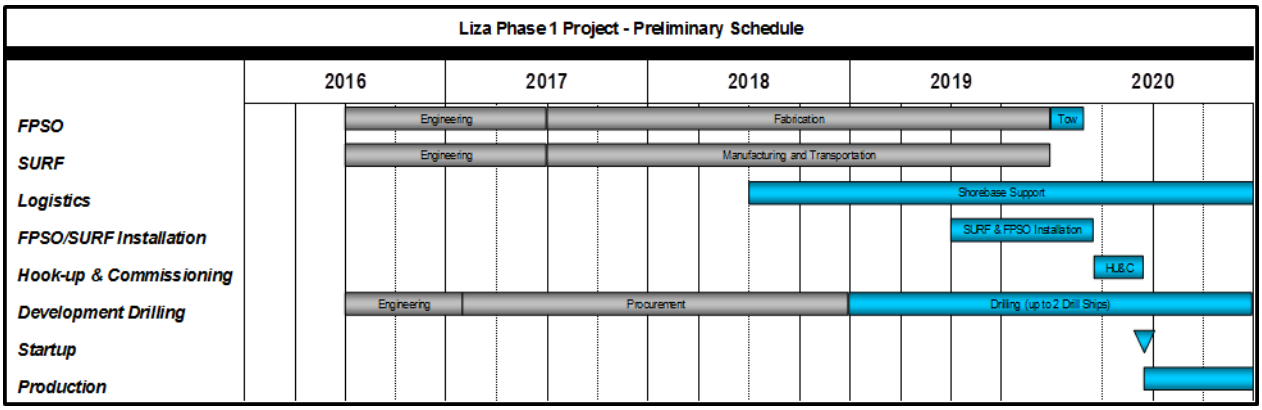
EIS 2.5 Project Workforce

EEPGL estimates it will require a workforce of approximately 600 persons at the peak of the development well drilling, approximately 600 persons at the peak of the installation stage, approximately 150 shorebase and marine logistical support onshore staff (some of whom will be Project-dedicated while others will be shared resources) at the peak of installation and drilling activities, approximately 100 to 140 persons at peak of production operations, and approximately 60 persons at the peak of decommissioning.

EIS 2.6 Project Schedule

It could take up to four years to drill the approximately 17 wells, with drilling planned to begin in 2018 or 2019. Installation of the SURF and FPSO are likely to be initiated in 2019 to be ready for initial production by mid-2020, with operations continuing for at least 20 years (Figure EIS-6).

Figure EIS-6 Preliminary Project Schedule



EIS 2.7 Public Consultation

EEPGL has conducted a robust public consultation program to both inform the public about the Project and to understand stakeholder concerns so this feedback could be incorporated into the EIA, as applicable. EEPGL has held various workshops with the government and others regarding offshore oil and gas development. EEPGL and/or ERM have held meetings with over 30 Guyana government agencies/commissions, many elected officials and Regional Administrators, over 15 professional or business associations, various international and domestic non-governmental organizations, several universities and research institutes, various religious and ethnic organizations, and the media. EEPGL and ERM participated in two sector agency scoping meetings, with over 150 attendees of which approximately 100 were members of the general public. These were followed by six public scoping meetings in Regions 1 through 6, which had over 300 attendees, of which over 200 were public participants.

EIS 2.8 Alternatives

The EIA considered a range of potential Project alternatives, as summarized below.

- Location Alternatives - The location of the Project, and the development wells in particular, is driven by the location of the resource to be recovered. There are no meaningful differences in location alternatives for the FPSO, SURF equipment, and drill centers within the PDA, as the nature of the seafloor and the water surface are not expected to vary appreciably across the area; thus, no environmental or social benefits would be achieved by minor location modifications.

- Development Concept Alternatives –
    - Facility Type: Given the water depth and distance to shore of the Liza field, the development alternatives are primarily limited to floating production systems (e.g., FPSO, semi-submersible, tension leg platforms). With the exception of the FPSO concept, the other deepwater production systems would necessitate the use of a separate Floating Storage and Offloading (FSO) vessel for oil storage and offloading, which would increase environmental impacts. The FPSO was chosen because it is a more efficient, stand-alone solution for deepwater oil processing and storage, and is also the environmentally preferred alternative.
    - Gas Disposition: Three primary alternatives were considered for addressing associated gas produced during Phase 1 operations: gas re-injection, gas export, and continuous flaring. Gas re-injection was determined to be feasible for Phase 1, and it also provides benefits in reservoir management. As such, produced gas not used as fuel gas on the FPSO will be re-injected under normal operations. Continuous flaring of gas on a routine basis is not preferred, primarily due to the associated air emissions. Gas export alternatives continue to be evaluated, particularly given challenges related to commercialization of associated gas. The FPSO has been designed to allow for future gas export should an export alternative be identified.
- Technology Alternatives – EEPGL is using the most appropriate industry-proven technology in developing the Project in terms of well drilling, drilling fluids, equipment selection, development concepts, and environmental management. EEPGL's parent company ExxonMobil and its contractors have extensive experience in delivering offshore deepwater development projects around the world, particularly with FPSO and SURF components, and are applying that knowledge, experience, and technology in the development of the Project in Guyana.
- No-go Alternative – Under this alternative the Project would not be executed and the existing conditions in the PDA would remain unaffected by the Project, and the potential positive and negative impacts assessed would not be realized. Therefore, evaluating the no-go alternative means evaluating the tradeoff between positive and negative impacts.

Overall, the proposed Project reflects optimized locational siting, appropriate development concept, use of industry-proven technology, and also selection of the environmentally preferred action alternative.

EIS 3.0 PROJECT IMPACTS

This section summarizes the predicted environmental and socioeconomic impacts of the Project resulting from planned activities and potential unplanned events (specifically an oil spill), as well the Project's contributions to cumulative impacts on important resources and receptors. The resources/receptors considered in this analysis are listed in Table EIS-2. The impacts of the Project were evaluated against the conditions of the existing environment, as described in the Section 6 of the EIA.

Table EIS-2 Resources and Receptors Considered in this EIA

Physical Resources	Biological Resources	Socioeconomic Resources
Air Quality and Climate	Protected Areas and Special Status Species	Economic Conditions
Sound	Coastal Habitats	Employment and Livelihoods
Marine Geology and Sediments	Coastal Wildlife and Shorebirds	Community Health & Wellbeing
Marine Water Quality	Seabirds	Marine Use and Transportation
	Marine Mammals	Social Infrastructure and Services
	Marine Turtles	Cultural Heritage
	Marine Fish	Land Use
	Marine Benthos	Ecosystem Services
	Ecological Balance and Ecosystems	Indigenous Peoples

EIS 3.1 Planned Activities

The Project is an offshore oil development and all drilling, installation, production operation, and decommissioning activities will occur over 190 km (~120 miles) off the coast of Guyana. The Project should not disturb any natural onshore habitats. There may be a minor increase in traffic congestion near the onshore shorebases, and a Road Safety Management Procedure should mitigate those impacts. The Project will generate benefits for the citizens of Guyana through revenue sharing with the Government of Guyana, a minor increase in employment, and select Project purchasing from Guyanese businesses. The only resources with the potential to incur any meaningful adverse impacts from planned Project activities would be air quality and marine-oriented resources (i.e., marine sediments, water quality, and biological resources), which are discussed briefly below.

EIS 3.1.1 Air Quality

Emissions generated by the Project generally emanate from three source categories: (a) specific point sources such as the power generating units and diesel engines on drill ships and on the FPSO, (b) non-routine flaring used to combust produced gas when not consumed as fuel gas on FPSO or re-injected, and (c) general area sources such as support vessels, construction vessels, tug boats, and helicopters. Such emissions contribute to increases in the ambient air concentrations of certain pollutants.

The CALPUFF model was used to assess the dispersion of air pollutants and the potential impact for onshore human receptors. For all modeled constituents, the maximum onshore concentrations predicted to result from Project activities are negligible relative to World Health Organization (WHO) guidelines (the highest being less than or equal to 1 percent of the WHO guideline).

The Project will also emit greenhouse gases (GHGs) throughout its predicted lifecycle, with peak emissions during steady-state production operations stage estimated to be approximately 980 kilotonnes of CO_2-equivalents per year. There are no applicable regulatory criteria against which these GHG emissions can be compared, but these emissions are disclosed in accordance with good international practice to aid in managing GHG emissions at a national and international level. EEPGL proposes to re-inject recovered natural gas (which is not used as fuel on the FPSO) back into the Liza reservoir, which represents a significant reduction in potential GHG emissions versus that which would result from routine gas flaring.

EIS 3.1.2 Marine Water Quality

The Project will impact marine water quality in a localized manner via planned discharges during well drilling, hydrostatic testing of the flowlines and risers following installation, and production operations stages.

During well drilling as each well is started, the Project will release a small volume of WBDF and cuttings at the seafloor. Low toxicity NADF will be used for the remainder of the well drilling, but will be captured, recovered to the extent practicable, and reused. EEPGL would treat the drill cuttings to reduce the drilling fluids retained on the cuttings prior to discharging overboard. Modeling indicates that the residual NADF on the cuttings may have a localized, minor impact on water quality.

During installation, the subsea flowlines and risers must be hydrostatically tested to confirm there are no leaks. Treated seawater is used for this purpose to prevent biofouling. A hydrate inhibiting substance, such as methanol or ethylene glycol, will also be used to prevent formation of hydrates during commissioning of the production and gas injection lines. After the completion of the testing, the hydrostatic test water and hydrate inhibitor from the gas injection line will be released at the seafloor. The hydrostatic test water and hydrate inhibitor from the production lines will be returned to the FPSO, treated, and discharged from the overboard water line. These discharges would be a one-time, short term impact, and the treated seawater and hydrate inhibitor would be quickly diluted within the water column.

During production operations, the FPSO will discharge five primary effluent streams to the ocean (Table EIS-3). The FPSO systems associated with these discharges will be designed to ensure applicable discharge criteria are met, which may require treatment in some cases. Modeling indicates that concentrations of chemical constituents would be reduced to insignificant levels within approximately 100 meters of the discharge point.

Table EIS-3 Summary of Production Operations Discharges

Discharges	Source	Potential Contaminants	Discharge Rate	Comments
Cooling Water	Process water to dissipate heat from FPSO systems, no hydrocarbon contact	Temperature, Chlorine	≤ 700,000 bpd	Discharge will meet internationally recognized standards limiting increases in ambient water temperature.
Produced Water	Water separated from reservoir fluids	Oil & grease, Residual production and water treatment chemicals	≤ 100,000 bpd	Will be treated to meet internationally recognized limits on oil & grease content.
Sulfate Removal and Potable Water Processing Brines	Removal of sulfates from seawater prior to injection; potable water processing	Biocide, Chlorine, Oxygen scavenger, Scale inhibitor	≤ 100,000 bpd	Discharge meets applicable standards without treatment.
Domestic & Sanitary Wastewater	Personnel black and gray water, food wastes	Nutrients, chlorine, bacteria	9,000 bpd	Will be treated in accordance with internationally recognized standards prior to discharge.
Offloading Tanker Ballast Water	Offloading tanker will discharge ballast water as it loads oil from the FPSO	None anticipated	≤ 1,100,000 barrels during each loading	Discharge will be conducted in accordance with internationally recognized standards.

EIS 3.1.3 Marine Sediments and Marine Benthos

The drilling of wells and the placement of flowlines and other subsea equipment will physically disturb approximately 0.3 km^2 of the sea bottom. After the initial structural casing section is installed, the remaining NADF drill cuttings will be returned to the drill ship for treatment to remove associated drilling fluids prior to discharge to the sea in order to meet acceptable discharge thresholds. The planned discharge of NADF drill cuttings will result in the localized accumulation of cuttings on the seafloor, primarily around the well locations, with the distribution of deposition determined by oceanographic conditions. Modeling has indicated that the discharge of these cuttings will not significantly impact sediment quality because of the

relatively low toxicity and expected dispersion. Overall, the Project impact on marine sediments will be negligible.

Marine benthos (organisms living on the seafloor) could also be impacted by Project-related seafloor disturbance by potential smothering from the drill cuttings. Based on surveys of the seafloor, however, benthic organisms, primarily consisting of polychaete worms, occur at low densities. Modeling indicates that smothering effects from drill cuttings would be limited to a very small area around the well (approximately 43 m diameter area).

EIS 3.1.4 Marine Biological Resources

Marine resources (i.e., seabirds, fish, mammals, and turtles) have the potential to be impacted by the Project, but it was determined that the significance of these impacts range from minor to negligible for the reasons explained below.

The Project could impact seabirds by interfering with their migration (i.e., lights serving as attraction), and potential exposure to the radiant heat from the flare. The Project lighting will be downcast to minimize its attraction potential and flaring will be non-routine and temporary (i.e., during select maintenance activities), so the overall Project impact on seabirds was determined to be negligible.

The Project could impact marine fish by deterioration of water quality from the discharges described above and the potential to entrain (suck in) fish at the cooling water intake. Modeling indicates that water quality will return to near background conditions within 100 m of the FPSO, so the area impacted will be very small, and fish are mobile and are known to avoid areas with degraded water quality. Water intakes will be designed to minimize the entrainment of fish.

Marine mammals may be impacted by two types of sound: continuous sound from vessels and machinery operating in the PDA, and by comparatively louder, shorter duration impulse sound from Vertical Seismic Profiling (VSP) and driven piles. Both the continuous sound and impulse sound sources would be loud enough to cause injury in the immediate vicinity of the source, but would attenuate to non-injurious levels approximately 10 m horizontal distance from the vessels, approximately 100 m from the VSP, and approximately 1300 m from the driven piles (at depths > 1000m). Many of the larger baleen whales and dolphins would naturally avoid the area of potential effect (especially around Drill Center 2) because it would be deeper than their typical maximum dive depths. Others, such as sperm whales, dive deep enough that they could potentially be exposed to injurious sound levels throughout the PDA, however it would not be expected that they would be exposed for continuous time periods predicted to be necessary to result in injury. Vessel strikes would likely pose more of an immediate threat than auditory injury. Marine observers will be used to monitor for mammals present prior to or approaching during the VSP, and soft start procedures will be used to allow any mammals in the immediate vicinity of the VSP and pile driving to vacate the area before sound levels reach potentially injurious levels in accordance with JNCC guidelines. Vessel crews will also lookout for marine mammals to minimize the potential for vessel strikes.

Marine turtles are generally considered to be less sensitive to marine sound than marine mammals, so underwater sound from Project activities would not have the same potential to impact marine turtles as marine mammals. The most significant potential Project-related impacts on marine turtles would be from marine vessel strikes and the same measures employed to manage risks of strikes on mammals would help manage risks of strikes on turtles. Numbers of vessel trips are modest in relation to existing vessel activity in Guyana waters; thus, impacts to marine turtles are not anticipated to result in a significant impact.

EIS 3.2 Unplanned Events

An unplanned event is defined as an event that is not planned to occur as part of the Project (e.g., accidents), but that could potentially occur. Since these events are not planned, they are evaluated using methods different from those used for planned events, specifically taking into consideration the *likelihood* that an unplanned event will occur. For purposes of the Project, three types of unplanned events were identified and considered – hydrocarbon spill, vessel collision, and onshore vehicular accident. While a vessel collision and a vehicular accident could result in injuries, significant injuries or fatalities would be expected to be rare occurrences considering likely vessel and vehicle speeds in areas where risk of collisions is highest. Thus, vessel collisions and vehicular accidents are considered to have small, temporary, and localized impacts. The remainder of this section focuses on the potential impacts from an oil spill.

The Project will be producing, processing, storing, and offloading oil as its core activity, so the risk of an oil spill would be present. EEPGL has identified nine spill scenarios, including spills of different types of hydrocarbons (e.g., crude oil, marine diesel, fuel oil, lubricating oil, NADF), with several being applicable for spills at the shorebases and on vessels in the Demerara River estuary (e.g., from supply vessel) or in the Atlantic Ocean (e.g., from a well, drill ship, supply vessel, tanker, FPSO). The largest of these scenarios considers a loss of well control incident at the seafloor releasing 20,000 barrels of oil per day for 30 days.

EEPGL's well control philosophy is focused on blowout prevention using safety and risk management systems, management of change procedures, global standards, and trained experienced personnel. EEPGL has a mature program that emphasizes attention to safety, well control, and environmental protection. This includes proper preparation for wells (e.g., well design, well control equipment inspection and testing), detecting changes in pressure quickly, and efficiency in the process for temporary closing of a well (personnel training and proficiency drills).

In addition to these prevention measures, EEPGL also has developed a detailed Oil Spill Response Plan (OSRP) to ensure an effective response to an oil spill, if one were to occur. The OSRP identifies the organizations that would respond to a release event depending on the magnitude and complexity of the spill. The OSRP clearly delineates the responsibilities of each entity that would take part in a response and describes how EEPGL would mobilize both its own resources and those of its oil spill response contractors, as well as notifying the government of Guyana with respect to mobilizing its resources.

Due to the precautionary measures proposed by EEPGL to prevent and control an oil spill, as described above, the likelihood of an oil spill occurring is expected to be unlikely. Nevertheless, EEPGL has conducted oil spill modeling and coastal sensitivity mapping to identify and characterize the resources/receptors with the potential to be exposed to oil in the event of a spill. An overview of this modeling and mapping is provided below.

The spill modeling evaluated the range of possible trajectories and rate of travel of an oil slick from an extended loss of well control (20,000 barrels of oil per day for 30 days). Several factors would inherently reduce the severity of an oil spill occurring in the Liza offshore development area and would increase subsequent ecosystem recovery rates, including the following:

- Location of Spill – a Liza well control incident would occur approximately 190 km (~120 mi) offshore. It would take some time for oil to reach the Guyana shoreline, which allows time to implement the Project's OSRP, and also allows more time for evaporative and dispersive forces to act on the spilled material.
- Prevailing Currents – the Guiana Current is a strong, nearly year round westerly flowing current along the coast of Guyana. Modeling indicates that this current significantly reduces the probability of spilled oil reaching the sensitive coastal resources of Guyana.
- Properties of Spilled Oil – the Project will be producing a light crude oil, which has low smothering potential and tends to spread readily on the ocean surface, both of which can reduce severity of impacts to shoreline resources.
- Climate – the relatively warm year-round waters of the Project area would keep any spilled oil less viscous, which helps clean-up operations such as skimming and pumping.

The modeling predicted that surface oil would generally travel towards the northwest in all scenarios during both the summer and winter seasons. The oil spill model indicates that even in the unlikely event of an oil spill, there is only a 5 to 10 percent chance of shoreline oiling in Guyana. It is important to note that this modeling does not account for any oil spill response (e.g., aerial, vessel or sub-sea dispersant application, offshore containment and recovery, source control operations), so any preventative measures taken to keep oil from reaching the coast during a response would further reduce the potential of shoreline oiling in Guyana below the estimated 5 to 10 percent.

It is highly unlikely oil spilled in the Liza field would reach the Guyana shoreline in the case of an actual spill. In addition to the low probability of oil reaching the Guyana shoreline in the absence of any spill response, it would take 5 to 15 days for oil to reach shore. This would allow ample time for mobilization of spill response resources to further reduce the risk of oil actually reaching the shoreline. Despite this, if oil were to reach the Guyana shoreline, those resources most at risk would include protected areas (i.e., Shell Beach), coastal habitats (especially mangroves and marshes), and coastal wildlife (especially birds and furbearers), as well as coastal communities and indigenous peoples dependent on fishing in the ocean and other ecosystem services (Table EIS-4). However, the combination of the low probability of an oil spill actually reaching the shoreline and the time available to allow for spill response, results in the residual risk to these resources being considered minor.

Table EIS-4 Coastal Resources Potentially Impacted by an Oil Spill

Resource	Potential Impact	Residual Risk Rating
Protected Areas	Per oil spill model, Shell Beach Protected Area and its vicinity could be impacted if oil were to reach the Guyana shoreline.	Minor
Coastal Habitats and Wildlife	Mangroves and wetlands are common habitats along the Guyana coastline (and support many species) and are considered sensitive to oil contamination.	Minor
Ecosystem Services, Coastal Communities and Indigenous Peoples	Many rural coastal communities, and especially Indigenous communities, rely on many ecosystem services (e.g., for food, housing materials, medicinal plants, income producing products, flood protection) for sustenance and livelihoods.	Minor

Even though the probability of a spill impacting the coastal resources of Guyana is very low, such an oil spill would likely have adverse impacts on marine resources in the area impacted by the spill. Those resources most at risk would be water quality, seabirds, marine mammals, and marine turtles, as described in Table EIS-5. Effective implementation of the OSRP would help mitigate this risk by further reducing the ocean surface area impacted by a spill and oil exposure to these species.

Table EIS-5 Marine Resources Potentially Impacted by an Oil Spill

Resource	Potential Impact	Residual Risk Rating
Marine Water Quality	Dissolution of some spilled oil into the water column, but light oil expected to degrade quickly and the impacts are reversible.	Moderate
Seabirds	Seabirds are typically among the species most impacted by an oil spill because they spend significant time on the water surface and so may come in contact with the spilled oil, but seabirds are primarily transient in the PDA.	Minor
Marine Mammals	Ingestion and respiratory irritation from inhalation of vapors at the water surface, and the potential for fouling of baleen whale plates, which are used to feed.	Moderate
Marine Turtles	Dermal irritation from contact with oil, ingestion, and respiratory irritation from inhalation of vapors at the water surface.	Moderate

EIS 3.3 Cumulative Impacts

The Project is located approximately 190 km (~120 mi) offshore, so there are few opportunities for the Project to cumulatively impact resources that would be impacted by other activities. There is the potential for other future offshore Guyana oil and gas exploration and possibly development. If such non-Project activities were to occur, the Project and non-Project activities together could cumulatively impact some resources such as Marine Mammals (via vessel strikes or sound), Marine Turtles (vessel strikes), Marine Fish (degraded water quality and seawater entrainment), Community Health and Wellbeing (increased demand on limited medical treatment capacity), Marine Use and Transportation (marine congestion especially near

Georgetown harbor), and Social Infrastructure and Services (increased demand for limited housing, utilities, and services). Many of the above potential impacts that require offshore interaction between the Project and others have a limited chance of co-occurring, given the size of the Stabroek Block. Thus, potential cumulative impacts were considered to be of Minor significance.

EIS 3.4 Degree of Irreversible Damage

The planned Project would not cause irreversible damage to any onshore areas of Guyana. There would be a very minor (approximately 0.3 km^2) permanent loss of benthic habitat as a result of the installation of wells, flowlines, and other subsea equipment, which may be proposed to be left in place upon decommissioning. However, this equipment can ultimately provide the substrate for recolonization of the impacted areas. Even in the unlikely event of an oil spill, little irreversible damage would be expected, although it could take a decade or more for all resources to fully recover, depending on the on the volume and duration of the release as well as the time of year the release were to occur.

EIS 3.5 Environmental and Socioeconomic Management Plan

An Environmental and Socioeconomic Management Plan (ESMP) has been developed to manage and mitigate the impacts identified in the EIA. The ESMP includes the following:

- Environmental and Socioeconomic Management Plan Framework
- Environmental Management Plan, including:
  - Air Quality Management
  - Water Quality Management
  - Waste Management Plan
  - Marine Ecosystems Management
- Socioeconomic Management Plan, including:
  - Stakeholder Engagement Plan
  - Grievance Management
  - Transportation and Road Safety Management
  - Cultural Heritage Management and Chance Finds
- Environmental and Socioeconomic Monitoring Plan
- Oil Spill Response Plan, including
  - Oil Spill Modeling
  - Coastal Sensitivity Mapping
  - Emergency Preparedness and Response Procedures
- Preliminary End of Operations Decommissioning Plan

EIS 4.0 CONCLUSIONS AND RECOMMENDATIONS

EIS 4.1 Conclusions

The planned Project is predicted to have minor impacts on physical resources (i.e., air quality, marine sediments, and water quality), no impacts on coastal biological resources, minor impacts on marine biological resources, and largely positive impacts on socioeconomics. These predictions are based on the fact that the bulk of the Project will occur approximately 190 km (~120 miles) offshore, and the Project will capture and re-inject produced natural gas; treat all significant wastewater streams prior to discharge to the sea; have a very small footprint (e.g., only physically disturb about 0.3 km^2 of benthic habitat); and use MMOs during VSP operations to minimize the potential for auditory damage and injury from ship strikes to marine mammals. The Project will generate benefits for the citizens of Guyana through revenue sharing with the Government of Guyana, a minor increase in employment, and select Project purchasing from Guyanese businesses.

Unplanned events, such as a potential oil spill, are considered unlikely to occur because of the extensive preventative measures employed by EEPGL. Nevertheless, an oil spill is considered possible, and oil spill modeling has been conducted to evaluate the range of likely spill trajectories and rates of travel. The location of the Project 190 km (~120 miles) offshore, prevailing northwest currents, the light nature of the Liza field crude oil, and the region's warm waters would all help minimize the severity of a spill. Accounting for these factors, the modeling indicates only a 5 to 10 percent probability of oil reaching the Guyana coast, without taking into consideration the effectiveness of any oil spill response.

Although the probability of an oil spill reaching the Guyana coast is very small, a well control spill at a Liza well would likely impact marine resources found near the well, such as sea turtles and certain marine mammals (especially baleen whales) that may transit or inhabit the area impacted by a spill. Air quality, water quality, seabirds, and marine fish could also be impacted, although likely to a lesser extent because the duration of acute impacts would not be long and the impacts are reversible. A spill could potentially impact Guyanese fishermen if commercial fish and shrimp were impacted. The magnitude of this impact would depend on the volume and duration of the release as well as the time of year the release were to occur (e.g., whether a spill would coincide with the time of year [May to September] when these species are more common in the PDA). Effective implementation of the OSRP would reduce this risk by further reducing the ocean surface area impacted by a spill and oil exposure to these species.

Table EIS-6 provides a summary of the predicted residual (taking into consideration proposed mitigation measures) impact significance ratings for impacts to each of the resources/receptors that may result from each of the Project stages (i.e., well drilling, SURF/FPSO installation, production operations, and decommissioning), unplanned event (i.e., oil spill), and cumulative impacts.

Table EIS-6 Summary of Residual Impact Ratings

Resource	Drilling and Installation	Production Operations	Decommissioning	Oil Spill*	Cumulative Impacts
Air Quality and Climate	Negligible	Negligible	Negligible	Minor	Negligible
Sound	None	None	None	Minor	None
Marine Geology/Sediments	Negligible	None	None	Minor	Negligible
Marine Water Quality	Negligible	Negligible	Negligible	Moderate	Negligible
Protected Areas	None	None	None	Minor	None
Special Status Species:**					
• Critically Endangered and Terrestrial Species	Negligible	Negligible	Negligible	Minor	Minor
• Vulnerable/Near Threatened Species (sharks & bony fish)	Minor	Minor	Minor	Minor	Minor
• Endangered Fish and Black Capped Petrel	Negligible	Negligible	Negligible	Minor	Minor
Coastal Habitats	None	None	None	Minor	None
Coastal Wildlife/Shorebirds	None	None	None	Minor	None
Seabirds	Negligible	Negligible	Negligible	Minor	Negligible
Marine Mammals	Moderate	Negligible	Negligible	Moderate	Minor
Marine Turtles	Minor	Negligible	Negligible	Moderate	Minor
Marine Fish	Minor	Negligible	Negligible	Minor	Minor
Marine Benthos	Negligible	Positive	Positive	Minor	Negligible
Ecological Balance & Ecosystems	Negligible	Minor	Negligible	Minor	Negligible
Economic Conditions	Positive	Positive	Positive	Minor	Negligible
Employment/Livelihoods	Positive	Positive	Positive	Minor	Negligible
Community Health & Wellbeing	Minor	Minor	Minor	Minor	Minor
Marine Use/Transportation					
• Commercial cargo and fishing	Negligible	Negligible	Negligible	Minor	Minor
• Subsistence fishing	Minor	Minor	Minor	Minor	Minor
Social Infrastructure /Services	Negligible	Negligible	Negligible	Minor	Minor
Cultural Heritage	Negligible	Negligible	Negligible	Minor	Negligible
Land Use	Negligible	Negligible	Negligible	None	Negligible
Ecosystem Services	None	None	None	Minor	None
Indigenous Peoples	None	None	None	Minor	None

*Based on oil spill modeling of a well control event in the PDA that indicates oil reaching Guyana shoreline is highly unlikely (5-to 10 percent probability).
** Excludes listed sea turtles, which are covered in the Marine Turtles resource category.

The Project will also generate benefits for the citizens of Guyana in several ways:

- Through revenue sharing with the Government of Guyana, although the details of this revenue sharing is confidential. The type and extent of benefits associated with revenue sharing will depend on how decision makers in government decide to prioritize and allocate funding for future programs, which is unknown and outside the scope of the EIA;

- By procuring select Project goods and services from Guyanese businesses to the extent reasonably practicable; and
- By hiring Guyanese nationals where reasonably practicable, although the potential magnitude of hiring will be limited.

In addition to direct revenue sharing, expenditures, and employment, the Project would also likely generate induced economic benefits as other non-Project related businesses benefiting from direct Project purchases or worker spending will re-invest locally or expand spending in the area, thereby also generating more local value-added tax. These beneficial "multiplier" impacts will occur throughout the Project life.

EIS 4.2 Recommendations

ERM recommends the following measures be considered by EPA, GGMC, and the EAB as conditions of any approval of the Project:

- Embedded Controls – incorporate all of the proposed embedded controls (see EIA Chapter 11).
- Mitigation Measures – adopt the recommended mitigation measures (see EIA Chapter 11).
- Management Plans – implement the proposed Environmental and Socioeconomic Management Plan.
- Oil Spill Response –EEPGL has proactively embedded many controls into the Project design to prevent a spill from occurring, and we agree that a spill is unlikely. But given the sensitivity of many of the resources that could be impacted by a spill (e.g., Shell Beach Protected Area, marine mammals, critically endangered and endangered sea turtles, Amerindian communities reliant on ecosystem services for sustenance and their livelihood), we believe it is critical that EEPGL commit to regular oil spill response drills, simulations, and exercises, document the availability of appropriate response equipment on board the FPSO, and demonstrate that offsite equipment could be mobilized for a timely response.

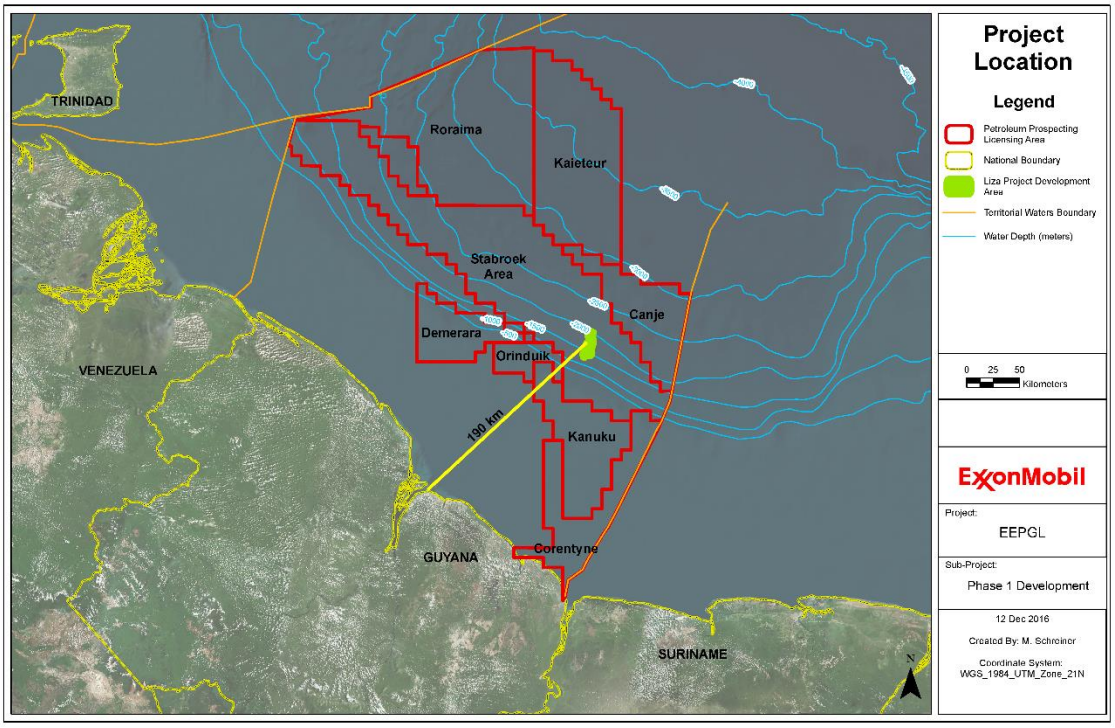
With the adoption of such embedded controls, mitigation measures, and management plans, and requirements for emergency response preparedness, the Liza Phase 1 Development Project is expected to pose only minor risks to the environmental and socioeconomic resources of Guyana, while potentially offering significant economic benefits to the residents of Guyana.

ENVIRONMENTAL IMPACT ASSESSMENT

1.0 INTRODUCTION

Esso Exploration and Production Guyana Limited (EEPGL)[2], together with its joint venture partners Hess Guyana Exploration Limited and CNOOC Nexen Petroleum Guyana Limited, is seeking an environmental authorization for the first phase of oil field development of the Liza prospect in the eastern half of the Stabroek Block (hereafter referred to as the Liza Phase 1 Development Project, or the Project), which is located approximately 190 km (~120 mi) offshore from Georgetown (Figure 1-1). Based on exploration and assessment activities in the Stabroek Block, including three exploration wells (Liza-1, Liza-2, and Liza-3, respectively), EEPGL believes these reservoirs potentially contain a recoverable resource of between 0.8 and 1.4 billion oil equivalent barrels.

Figure 1-1 Location of the Liza Project Development Area within the Stabroek Block



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

[2] EEPGL will be the operator of the Project, and is used in this EIA to represent the joint venture.

1.1 Purpose of this EIA

Guyanese law requires EEPGL to obtain an environmental authorization from the Guyana Environmental Protection Agency (EPA) to undertake the Project. The EPA oversees the effective management, conservation, protection, and improvement of the environment in Guyana. In this role, the EPA is responsible for managing the environmental authorization process. EEPGL filed an Application for Environmental Authorisation (Application) with the EPA on July 5, 2016. Based on an initial assessment of the Application, the EPA determined that an Environmental Impact Assessment (EIA) was required in support of the Application.

The purpose of this EIA is to provide the factual and technical basis required by EPA to make an informed decision on EEPGL's Application for Environmental Authorisation[3] to permit the Project. After submission and review of this EIA, the EPA takes into account recommendations from the Environmental Advisory Board (EAB) and the Guyana Geology and Mines Commission (GGMC), the public's comments, and EPA's own review, including support from technical experts within other ministries, in deciding whether and under what conditions to grant EEPGL's Application.

The GGMC has several functions, including promoting and regulating the exploration and development of the country's mineral and petroleum resources. The Petroleum Division of the GGMC is responsible for promoting Guyana's petroleum potential and monitoring exploration and production activities. GGMC oversees EEPGL's Prospecting Licence, under which offshore exploration and drilling activities (e.g., Liza 1, 2, and 3 wells) were conducted, and has received EEPGL's application for a Petroleum Production Licence and associated Development Plan for the first phase of the Liza field development. GGMC will also provide technical input into the review of the EIA, as discussed above, and will consider the findings of the EIA as part of its evaluation of EEPGL's application for Petroleum Production Licence for the Liza Phase 1 Project.

The EAB is an independent body that contributes to the development and review of the EIA and makes recommendations to the EPA on whether the EIA should be accepted, amended, or rejected and whether the environmental authorization should be granted, and if so, under what terms and conditions.

This EIA was prepared by Environmental Resources Management (ERM), which is an international environmental and social consulting firm with extensive experience in the preparation of EIAs for offshore oil and gas development projects. In the Project's Final Terms of Reference (ToR), EPA approved ERM as the independent consultant to undertake the EIA. This EIA has been prepared in compliance with the Guyana Environmental Protection Act (EP Act, Cap.20:05), the Environmental Protection (Authorisation) Regulations (2000), the Environmental Impact Assessment Guidelines – Volume 1, Version 5 (2004), the Environmental Impact Assessment Guidelines – Volume 2, Version 4 (2000), other applicable Guyana

[3] The Environmental Authorisation granted by the EPA is also commonly referred to as an environmental permit, and may be used interchangeably.

regulations, international good practice, EEPGL's corporate standards, and in accordance with ERM's standard practice.

1.2 EEPGL Exploration Well Drilling History

EEPGL has drilled five exploration wells within the Stabroek Block offshore Guyana, with a sixth well planned in 2017, as indicated in Table 1-1 below. After completion of the exploration testing, each of these wells was closed consistent with good industry practice. EEPGL has plans to explore in other blocks, but no drilling has yet occurred outside of Stabroek Block.

Tab1e 1-1 EEPGL Stabroek Exploration Well Drilling History

Well Name	Year Drilled	Result
Liza-1	2015	Successful (oil found)
Liza-2	2016	Successful
Liza-3	2016	Successful
Skipjack	2016	Dry well (no oil found)
Payara	2016	Successful
Snoek	Planned for 2017	Not available

1.3 Goals and Objectives of the EIA

The goals of the EIA are to:

- Provide the factual and analytical basis required by EPA and the GGMC to make an informed decision on EEPGL's Application for Environmental Authorisation to permit the Project; and
- Provide a basis for EEPGL to understand and appropriately avoid or manage the risks imposed by the Project via design or other management measures.

In support of those goals and in accordance with the EIA Final ToR, which were approved by the EPA on February 17, 2017, the underlying objectives of the EIA are to:

- Describe the Project, including its various components and activities and full life cycle through to decommissioning;
- Describe the existing conditions within the Project's Area of Influence (AOI);
- Identify and assess the potential direct and indirect environmental and socioeconomic impacts that could credibly result from the Project using a risk-based assessment process;
- Evaluate the potential for cumulative impacts;
- Describe a strategy to manage the identified significant adverse impacts of the Project;
- Characterize potential positive benefits of the Project; and
- Recommend monitoring to assess the effectiveness of the management strategy.

1.4 Components of the EIA

As required by the Guyana EP Act (Cap. 20:05) and further described in the Guyana Environmental Impact Assessment Guidelines, this EIA includes the required components of an EIA:

- Project Description – see Chapter 2 of the EIA;
- Environmental Baseline Studies – see Chapter 6 of the EIA;
- Environmental Assessment – see Chapters 7, 8, and 10 of the EIA;
- Environmental Impact Statement – provided at the beginning of the EIA; and
- Environmental and Socioeconomic Management Plan – the Environmental and Social Management Plan (ESMP) Framework is provided as Chapter 9 of the EIA.

EEPGL has elected to submit these components as one document.

The *Environmental Impact Assessment Guidelines Volume 1 – Rules and Procedures for Conducting and Reviewing EIAs* (November 2004) includes as Appendix 2 an EIA Review Checklist. Provided below in Table 1-2 is an EIA "roadmap" that shows where all of the Checklist "Items Evaluated" can be found in this EIA.

Table 1-2 EIA Review Checklist "Roadmap"

EIA Review Checklist Items	Corresponding EIA Reference
1. Adherence to the ToR *Adherence to the ToR must be verified simply by checking that all items and information requested in the ToR have been presented, regardless of the content or quality of such information.*	• Adherence to the ToR confirmed
2. Multidisciplinary Team *The accuracy of the EIA depends on the qualifications of the multidisciplinary team not only regarding the EIA process and methods but also regarding their knowledge of the several stages of the specific type of project. Therefore, individual CVs should be submitted as part of the EIA Annexes. Signatures of each member of the team must be affixed.*	• Chapter 12 lists all team members and references, Appendix A provides signatures, and Appendix B includes all CVs.
3. Inter-disciplinary Achievement *An EIA must present information regarding the interactions and integration between the physical, biological and socio-economic aspects of the environment in that particular area of the study.*	• Chapter 7 includes assessment of all three categories of resources

EIA Review Checklist Items	Corresponding EIA Reference
4. Executive Summary *The Executive Summary, also referred to as the non-technical summary, should provide a brief description of the project and information regarding the potential impacts of the project, arranged in order of significance, along with the proposed mitigation/compensatory measures for each impact. The summary should end with the consultants' recommendations.*	• Executive Summary included in EIS
5. Project Description *The process of environmental impact assessment depends on the full understanding of the project proposal and accurate identification of the project actions. If actions are unclear, sufficiently detailed impacts are not likely to be identified with the accuracy and specificity needed to enable the development of appropriate mitigation measures.* *5.01 Is the project proposal fully understood?* *5.02 Are all phases identified (e.g. planning, construction, operation and decommissioning)?* *5.03 Is the geographical area for each phase identified?* *5.04 Are the land use requirements for each phase identified?* *5.05 Is there an inventory of the nature and quantity of materials used in the production process?* *5.06 Are there inventories of the type and quantity of products, by-products and effluents expected to be produced by the project?* *5.07 Is there an inventory of the type and quantity of residues?* *5.08 Are the levels of emissions expected detailed with respect to* *- Noise?* *- Vibration?* *- Light?* *- Heat?* *- Radiation?* *- Gases?* *- Liquids?* *Are the types and levels of any other emissions included?* *5.09 Is information on employment provided?*	• 5.01 – see Chapter 2 • 5.02 – see Section 2.3 (Drilling), 2.6 (Installation, Hookup, and Commissioning), 2.7 (Production Operations), and 2.9 (Decommissioning) • 5.03 – see Section 2.1, all stages occur within this same area • 5.04 – see Section 2.8, only onshore supply and support has any land requirements • 5.05 – see Section 2.10 • 5.06 – see Section 2.10 • 5.07 – see Section 2.10 • 5.08 – Noise impacts are quantified in Section 7.2.5; thermal and liquid discharges are quantified in Section 7.1.4; and air (gaseous) emissions are quantified in Section 7.1.1 • 5.09 – see Section 2.12

EIA Review Checklist Items	Corresponding EIA Reference
6. Identification and Description of Alternatives *The assessment of sound alternatives is necessary to validate the EIA process. Therefore reasonable alternatives have to be fully and comprehensively considered. As a minimum, one of the following alternatives must be considered: location, project layout, technology, scheduling, project scale.* *6.01 Did the developer consider alternatives?* *6.02 Was the "no-project" scenario considered?* *6.03 Were the environmental factors adequately presented for each alternative?* *6.04 Is the final choice adequate?*	• 6.01 – see Section 2.16 • 6.02 – see Section 2.16 • 6.03 – see Section 2.16 • 6.04 – see Sections 2.16 and 10
7. Definition and Justification of Physical Boundaries (Direct and Indirect Area of Influence) *Inconsistency in identifying the correct areas of influence will inevitably lead to inconsistency in the baseline data and the impact analysis. The indirect area of influence is the area likely to be affected by indirect, secondary and/or long term impacts.*	• See Section 5.1
8. Analysis of the Legal Aspects Involved *The analysis of the legal framework involves more than a list of legal Acts. It involves assessing the consequences for the project of enforcing all the environmental legislation and regulations regarding the proposed site and sectoral requirements related to the proposed activity.*	• See Sections 3.1 through 3.3
9. Identification of Other Existing Planned Activities or Projects in the Area of Influence *This information is of utmost importance to ensure that land-use and other types of conflicts do not arise later during the project implementation.* *9.01 Has the compatibility between the proposal and the identified existing activities been analysed?* *9.02 Are the activities compatible?* *9.03 Does the inventory of existing activities match what is observed?*	• See Chapter 8, which discusses other activities in the AOI, as part of the Cumulative Impact Assessment • 9.01 – see Section 8.1.2 • 9.02 – see Section 8.1.2 • 9.03 – see Section 8.1.2

EIA Review Checklist Items	Corresponding EIA Reference
10. Adequacy and Completeness of Relevant Baseline Data *Baseline data must be specific and relevant to the area of influence. General and superficial information does not allow for the use of adequate impact prediction techniques.* *10.01 Is the information presented specific and relevant?* *10.02 Were difficulties in attaining information (if any) documented?* *10.03 Have the impact indicators identified been adequately covered (see Section 13)*	• See Chapter 6 • 10.01 – see Chapter 6 • 10.02 – see Chapter 6 • 10.03 – see Chapter 6
11. Appropriateness of EA Methods *The use of appropriate EA methods is necessary to ensure reliability of the results of the EIA study. Each type of EA method has different strengths and vulnerabilities regarding its appropriateness to perform each step of the EIA study. Some EA methods are unable to provide the means of identification of cause-effect relationships; others do not enable the identification of indirect, secondary and/or long-term impacts. Scientific and technical accuracy of the EIA methods used must therefore be evaluated to ensure the reliability of the conclusions drawn from the impact assessment.*	• See Chapter 4 for a description of the EIA methodology • See Chapter 7, which includes description of analytical approach for each resource
12.1. Physical Impacts *- Have all the identified impacts on air, water, soil, noise, landscape and natural resources been checked against the relevant impacts defined in the ToR?* *- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)?* *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?* *- Have the social implications of the impacts been assessed?*	• See Section 7.1, which addresses impacts to physical resources
12.2. Biological Impacts *- Have all the identified impacts on flora, fauna, rare / endangered species, sensitive ecosystems, species habitats and ecological balance been checked against the relevant impacts in the ToR.*	• See Section 7.2, which addresses impacts to biological resources

EIA Review Checklist Items	Corresponding EIA Reference
- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)? *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?* *- Have the social implications of the impacts been assessed?* *- Have cause/effect relations been properly identified?*	
12.3. Social and Health Impacts *Have all the identified impacts on the social and health context been checked against the relevant impacts defined in the ToR?* *- Are impacts identified with respect to human health, demographic and household characteristics, employment opportunities, size and distinguishing characteristics of resident population, the provision of social services and infrastructure?* *- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)?* *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?* *- Have the social implications of the impacts been assessed?* *- Have cause/effect relations been properly identified?* *- To what extent does the project protect/improve human health?* *- To what extent does the project protect/improve human living conditions?*	• See Section 7.3, which addresses impacts to socioeconomic resources
12.4. Cultural, Historical and/or Archeological Impacts *- Have all the identified impacts related to cultural, historical and/or archeological sites and heritage been checked against the relevant impacts defined in the ToR?* *- Are impacts identified with respect to **cultural heritage**?* *- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)?* *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?*	• See Section 7.3.7, which addresses cultural heritage resources

EIA Review Checklist Items	Corresponding EIA Reference
- Have the social implications of the impacts been assessed? *- Have cause/effect relations been properly identified?*	
12.5. Economic Impacts *- Have all the identified impacts on the economy (local, regional, national) been checked against the relevant impacts defined in the ToR?* *- Are impacts identified with respect to economic assets and activities?* *- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)?* *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?* *- Have the social implications of the impacts been assessed?* *- Have cause/effect relations been properly identified?* *- Are impacts identified with respect to income generation for the community and at the National Level?* *- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)?* *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?* *- Have the social implications of the impacts been assessed?* *- Have cause/effect relations been properly identified?*	• See Section 7.3, which addresses economic resources (combined with other socioeconomic resources)
12.6. Other impacts *- Have all other impacts been checked against the relevant impacts defined in the ToR?* *- Are impacts identified with respect to _____?* *- Are impacts characterized (positive/negative, direct/indirect, primary/secondary, short/medium/long term, reversible/irreversible, temporary/permanent, local/regional/national/strategic, avoidable/unavoidable)?* *- Have the magnitudes been estimated?* *- Have the impacts been assigned a significance?*	• Other potentially impacted resources not specifically listed above have been included, such as marine sediments, marine use and transportation, and indigenous peoples.

EIA Review Checklist Items	Corresponding EIA Reference
- Has the social distribution of the impacts been identified? *- Have cause/effect relations been properly identified?*	
13. Cumulative Impacts *There may be cases where an activity/project will contribute to a cumulative impact on the environment although individually it may not have a significant environmental impact. This may be as a result of the presence of similar activities within the vicinity of the project.* *13.01 Have cumulative impacts been adequately identified and characterized?* *13.02 Have the magnitudes been estimated?* *13.03 Have the impacts been assigned a significance?* *13.04 Has the social distribution of the impacts been identified?* *13.05 Have cause/effect relations been properly identified?*	• 13.01 - see Chapter 8 • 13.02 – see Section 8.2 • 13.03 – see Section 8.2 • 13.04 – see Section 8.2 • 13.05 – see Section 8.2
14. Impact Indicators *Impact indicators are the parameters used to estimate the magnitude of the impacts.* *14.01 Were the impact indicators used adequate for all the impacts identified?*	• See Chapter 4, which outlines approach for characterizing magnitude of impacts • See Chapter 7, which assesses magnitude for impacts
15. Prediction Techniques *Impact prediction techniques are necessary to enable the estimation of the magnitude of the impacts. Without the use of adequate impact prediction techniques, accurate impact analysis is not possible.* *15.01 Have the impact prediction techniques used been described?* *15.02 Are they adequate?*	• 15.01 – see Chapter 4, which describes the impact assessment methodology used; Chapter 7 describes methodology and results of analytical approaches for each resource/receptor • 15.02 – see Chapter 4
16. Magnitude of Impacts *Magnitude is the estimate of the absolute measure/value/dimension of the difference between the environmental situation of a given parameter before and after the project is implemented. In the majority of cases – physical, biological and economic impacts – it must be expressed in* ***quantitative*** *values. The estimation of the magnitude of each relevant impact is one of the most important steps in impact analysis. It ensures the accuracy of the EIA and allows for the*	• See Chapter 4, which describes the approach for characterizing magnitude of impacts • Chapter 7 assesses magnitude for impacts for each resource/receptor

EIA Review Checklist Items	Corresponding EIA Reference
identification of appropriate and cost-effective mitigation measures. Have the magnitude of all the relevant impacts been adequately estimated (refer to impact indicators – Section 14)?	
17.0 Importance/Significance of Impacts *Usual methods involve objective criteria regarding the ecological and social relevance of the project* *17.01 Is the relative importance/significance of each impact with regard to the environmental factor affected, and with regard to the other impacts given?* *17.02 Is the significance based on objective criteria in order to minimize subjectivity of judgments?*	• 17.01 – see Chapter 4, which describes the approach for characterizing the importance and significance of impacts • 17.02 – see Chapter 7, which describes the methodology and results of analytical approaches for each resource/receptor
18 Social Distribution of Impacts *Identifies which social groups will be affected by the positive and the negative impacts. These groups are often not the same. The balance between positive and negative impacts cannot be done without the correct identification of the social distribution of the impacts, because it would not have scientific and technical relevance.*	• See Chapter 7.3, which addresses impacts to socioeconomic resources (specifies affected groups)
19 Stakeholder Participation *19.01 Are the results of stakeholder participation, such as the results of interviews, hearings etc. clearly documented?* *19.02 Have questionnaires used been included?* *19.03 Are the extent and method of stakeholder participation adequate?* *19.04 Are the conclusions drawn valid, based on available data?*	• 19.01 – see Section 4.5 • 19.02 – No specific questionnaires were used, but numerous Key Informant Interviews, informal meetings, capacity building workshops as well as two Agency/Sector scoping meetings and six public scoping meetings from Regions 1-6 were held. • 19.03 – see Section 4.5 • 19.04 – see Section 4.5
20 Analysis and Selection of Best Alternative *Selection must be based on criteria derived from the impact assessment, and appropriate analysis and decision-making methods must be used.*	• See Section 2.16 and Chapter 10
21 Environmental Management Plan (EMP)	• See Chapter 9 and the ESMP

EIA Review Checklist Items	Corresponding EIA Reference
An EMP is sometimes called an Impact Management Plan. It is a necessary step to ensure that the developer is effectively committed to the implementation of the mitigation measures. It is also a useful corporate management tool. Does the EMP, as a minimum, present *- The set of mitigation, remedial or compensatory measures?* *- A detailed description of each one, with indication and criteria for their effectiveness?* *- Detailed budgets for each one?* *- Timetables for implementation?* *- Assignment of responsibilities, including an Environmental Manager?* *- The Environmental Policy*	
22 Monitoring *Monitoring is a necessary step to ensure cost-effectiveness of the EMP. It is usually addressed under the EMP (see Section 20) Does the monitoring plan, as a minimum, address* *- What is going to be monitored (impact indicators)?* *- Where will samples be taken?* *- How the samples will be analysed (method/technique)?* *- Criteria used to evaluate the results?* *- Financial and human resources required?*	• See Section 9.6 and the ESMP
23 Implementation Plan for the Mitigation Measures and the Environmental Management Plan *Implementation mechanisms must be in place to ensure effective implementation of the mitigation measures and all other recommendations that might arise from the EIA study. It usually involves the assignment of a person responsible for environmental management and an approved timetable for implementation of measures.*	• See Chapter 9 and the ESMP

2.0 PROJECT DESCRIPTION

Previous seismic testing and exploratory drilling have determined the presence of a high porosity sandstone reservoir of crude oil with an estimated recoverable resource of 0.8 to 1.4 billion oil-equivalent barrels in an area referred to as the Liza field, located within the eastern half of the Stabroek Block.

The purpose of this Project is to develop the Liza field and produce the oil in what is referred to as the Liza Project Development Area (PDA). Phase 1 of the Project will consist of the drilling of approximately 17 development wells, the installation and operation of Subsea Umbilicals, Risers, and Flowlines (SURF) equipment, the installation and operation of a Floating Production, Storage, and Offloading (FPSO) facility, and ultimately Project decommissioning. The Project will also involve onshore facilities and marine/aviation services to support development drilling, installation, production operations, and decommissioning.

This section discusses the following information related to the Project:

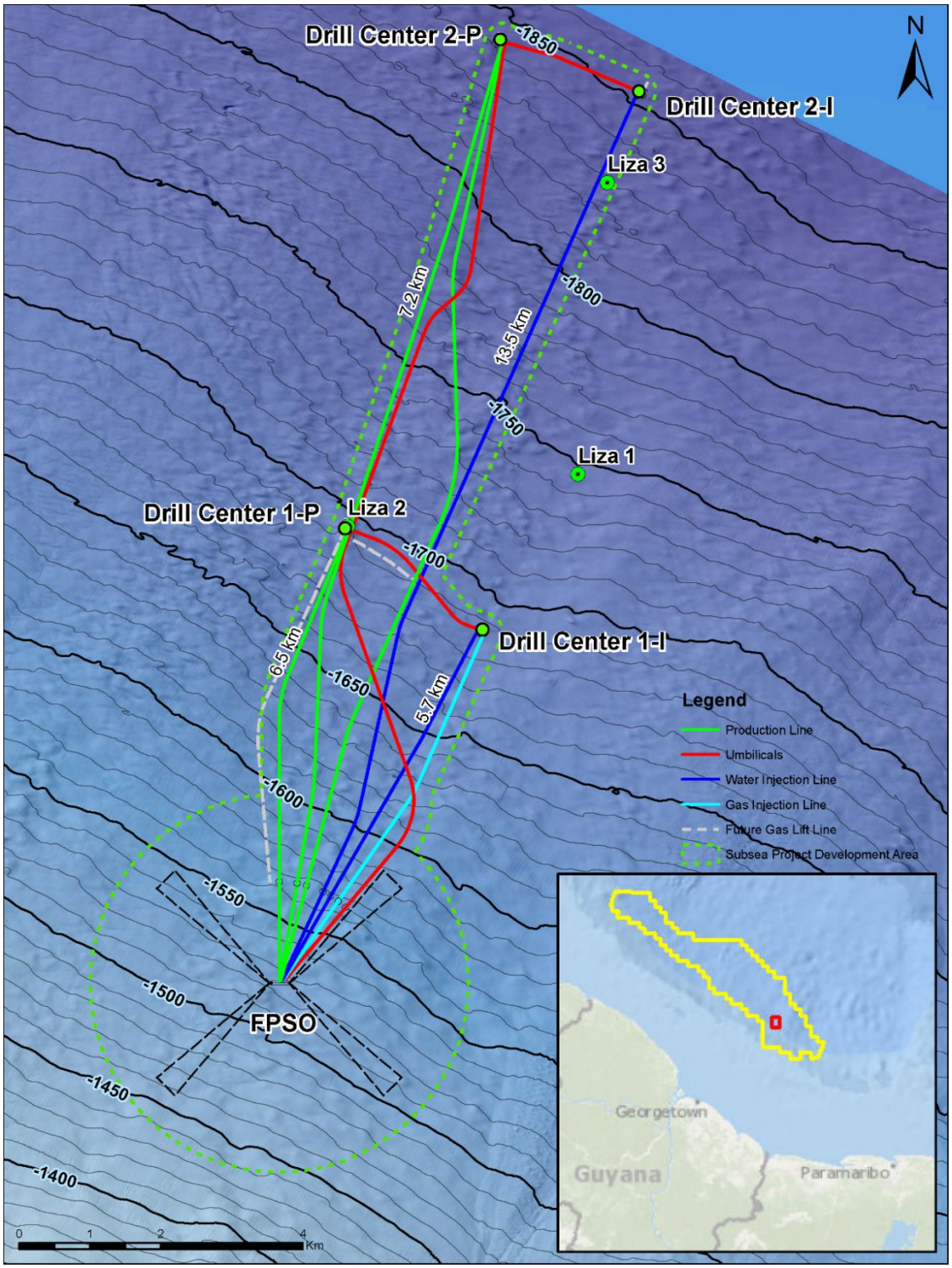
- Project location;
- Overview of development concept;
- Drilling and well design;
- SURF;
- FPSO vessel, including topsides facilities and the vessel mooring system;
- Installation, hook-up, and commissioning activities;
- Production operations, including offloading by conventional tankers;
- Onshore, marine, and aviation support;
- End of operations (decommissioning);
- Materials, emissions, discharges, and wastes;
- Embedded controls;
- Project workforce;
- Worker health and safety;
- Project schedule; and
- Project alternatives.

2.1 Project Location

The Stabroek Block, which covers an area of approximately 26,800 km^2, is oriented roughly parallel to the Guyana coastline, extending across the entire width (northwest to southeast) of Guyana territorial waters. Figure 1-1 illustrates the location of the Liza PDA, which is located approximately 190 km (~120 mi) from the coastline northeast of Georgetown, within the Stabroek Block.

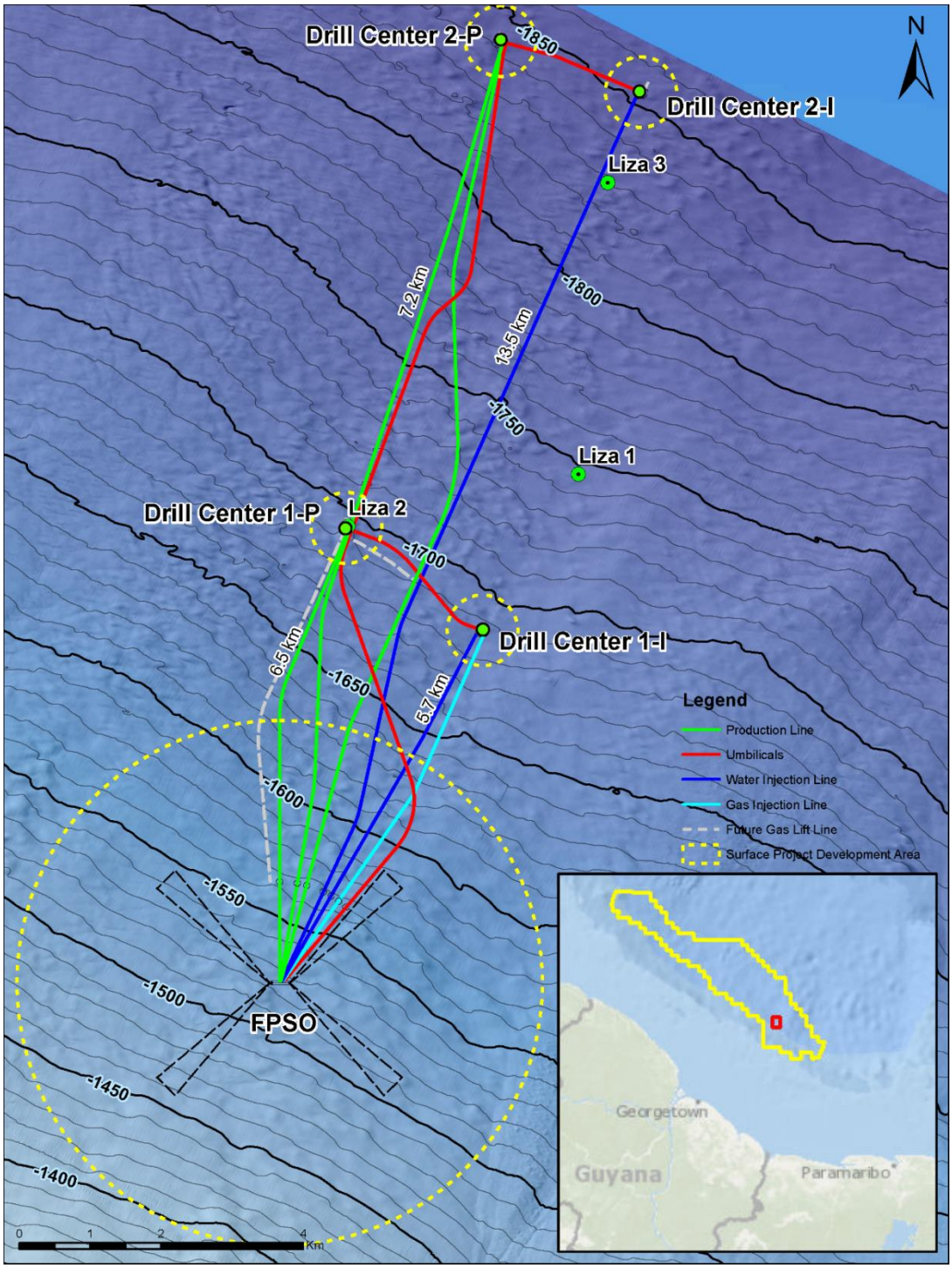
Figures 2-1 and 2-2 illustrate the preliminary conceptual layout of the FPSO, SURF equipment, and drill centers within the Stabroek Block; their proximity to the Liza-1, Liza-2 and Liza-3 exploration wells; and the subsea and surface extents of the PDA, respectively.

Figure 2-1 Subsea Project Development Area for FPSO Installation, SURF, and Drill Centers within Stabroek Block



Note: Locations on figure subject to change.

Figure 2-2 Surface Project Development Area for FPSO and Drill Centers within Stabroek Block



Note: Locations on figure subject to change.

The locations of the future development wells will be finalized before Project implementation; however, the decision has been made that the wells will be drilled from two main drill centers[4].

During the development drilling, installation of the FPSO/SURF facilities, and production operations stages, work may be performed in the area denoted on Figure 2-1 as the Subsea PDA, covering an estimated 4,500-5,000 hectares (ha). Most of this subsea area will not be physically disturbed; the estimated subsea area to be disturbed during installation of SURF equipment and the FPSO mooring system (see Figure 2-1) is approximately 400,000 m^2 (30 ha) (incorporating a 50 percent contingency factor).

During the development drilling and FPSO production operations stages, work may be performed on the surface of the ocean within the area denoted on Figure 2-2 as the Surface PDA, also covering an estimated 4,500-5,000 ha. As further described in subsequent sections and represented on Figure 2-2, some of the ocean surface would have operational constraints that would restrict unauthorized vessels from entering a defined safety exclusion zone during drilling, installation, and production operations. Note, however, that while Figure 2-3 shows four potential exclusion zones around the drilling locations, a maximum of only two drill ships will be operating at any one time. The safety exclusion zones for the large installation vessels are not specifically denoted on Figure 2-2; however, exclusion zones similar to those for the drill ships will be maintained for these vessels while working in the PDA.

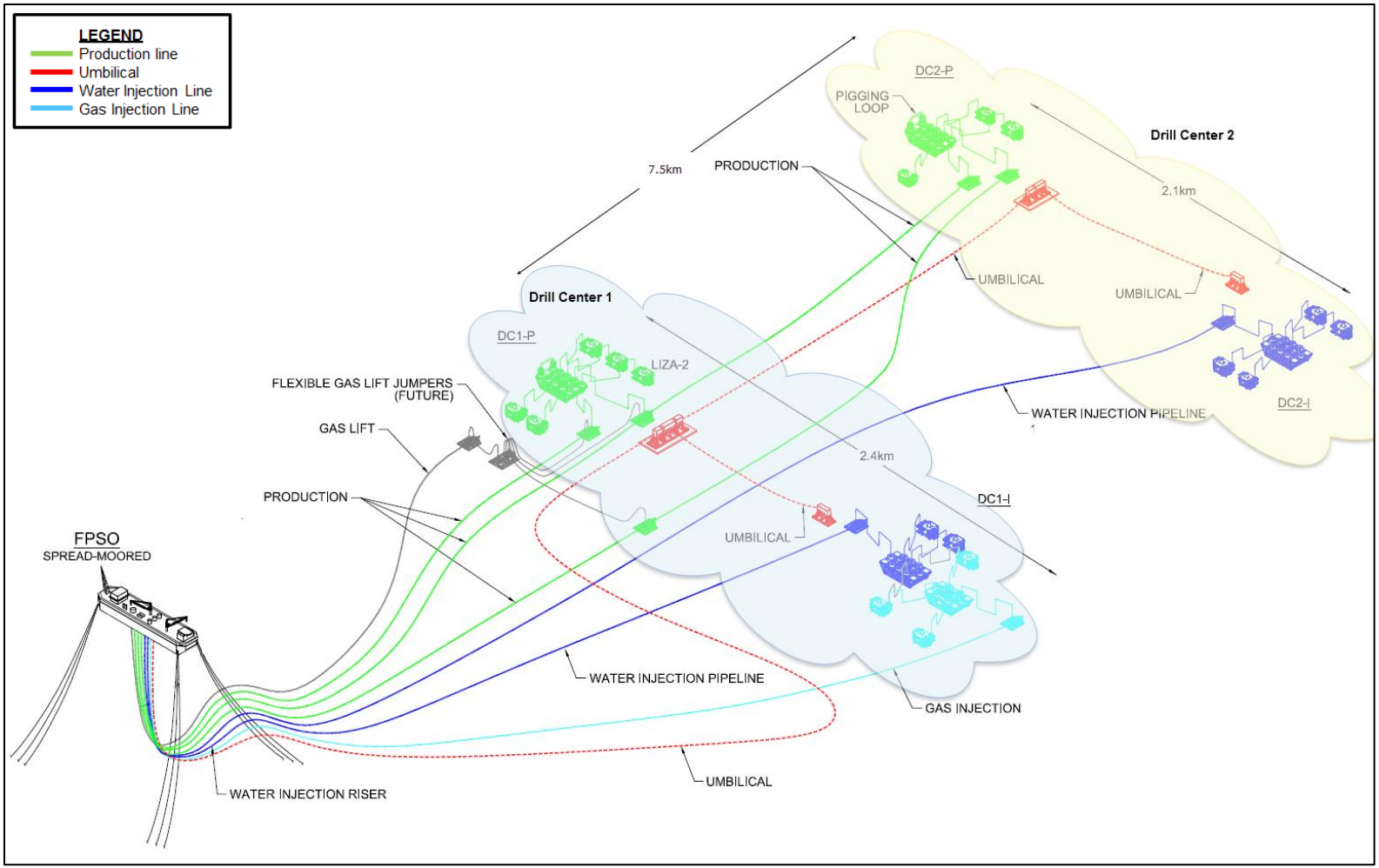
2.2 Overview of the Development Concept

2.2.1 Development Concept

The Liza field will be developed during Phase 1 with approximately 17 development wells drilled from two drill centers, each with separate production, gas, and water injection manifolds. Figure 2-3 illustrates the preliminary field layout of the proposed Liza field development, which includes the development wells, SURF, and a spread-moored FPSO vessel. The facility layout will continue to evolve during the design development process. The various components shown on Figure 2-3 are further described in the relevant Drilling, SURF, and FPSO sections in this chapter.

[4] A drill center is defined as a group of wells (including production, water injection, and/or gas injection wells) clustered around one or more manifolds. Each drill center incorporates separate manifolds that are separated by several kilometers and are designed for production or injection. For example, Drill Center 1 will be separated into 1-P (production) and 1-I (injection) components.

Figure 2-3 Preliminary Liza Phase 1 Field Layout



The development wells consist of production wells, water injection wells, and gas injection wells. A portion of the associated gas (i.e., gas entrained in the wellstream) produced from the reservoir will be used onboard the FPSO as fuel gas, and the remaining balance will be re-injected back into the reservoir via the gas injection wells. Alternative uses of gas for future phases are being studied and would be addressed in a separate or amended EIA. Water injection will be used as needed to maintain reservoir pressure for optimal production over the life cycle of the Project.

The Liza field will be developed using a spread-moored FPSO (see Section 2.5). The FPSO will be a converted double hull Very Large Crude Carrier (VLCC) that will support the topsides facilities, process the produced wellstream from the production wells, and store the processed crude oil. Offloading of the processed crude oil for export will occur directly to conventional tankers in a tandem configuration. Subsea production, gas, and water injection wells and manifolds will be tied back to the FPSO via flowlines and risers (see Section 2.4).

2.2.2 Applicable Codes, Standards, and Management Systems

The various aspects of engineering design and operations will be carried out according to applicable Guyana statutory requirements, applicable international design codes and standards, as well as the EEPGL Operations Integrity Management System (OIMS)[5] and the EEPGL Safety, Security, Health, and Environment (SSHE) policies[6]. EEPGL and its contractors will have structured management systems to verify the ongoing application of all necessary codes, standards, procedures, and SSHE management systems. An overview of the EEPGL OIMS Framework is included in Section 3.

2.3 Drilling and Well Design

2.3.1 Drilling Program

The Project proponent is considering the use of up to two drill ships, similar to the drill ship shown on Figure 2-4, to drill the development wells during Phase 1. Both drill ships may be operated simultaneously. Drilling operations may occur prior to, during, and after the installation of the FPSO and SURF components.

[5] http://corporate.exxonmobil.com/company/about-us/safety-and-health/operations-integrity-management-system
[6] The SSHE policies are part of the overall Standards of Business Conduct policy: http://corporate.exxonmobil.com/en/company/about-us/guiding-principles/standards-of-business-conduct

Figure 2-4 Typical Drill Ship



During the drilling process, drill ships will require various tubulars, instruments, and devices (collectively referred to as the drill string) to conduct the well construction process, which will be as follows: drilling the borehole, running and cementing casings, and installing the completion and production tubing. The drilling program will employ high-angle and extended reach drilling technologies. These technologies allow wells to reach targets up to approximately 4 km (~2.5 mi) from the drilling seabed location. The wells will be clustered around two drill centers rather than distributed over the producing reservoir. This approach reduces the number of drilling locations, thereby reducing the area potentially impacted by drilling operations including discharged drill cuttings[7]. The planned development drilling program and its cuttings management approach is consistent with industry practices, considered protective of the environment, and has been the basis for the Liza-1, Liza-2 and Liza-3 exploration wells.

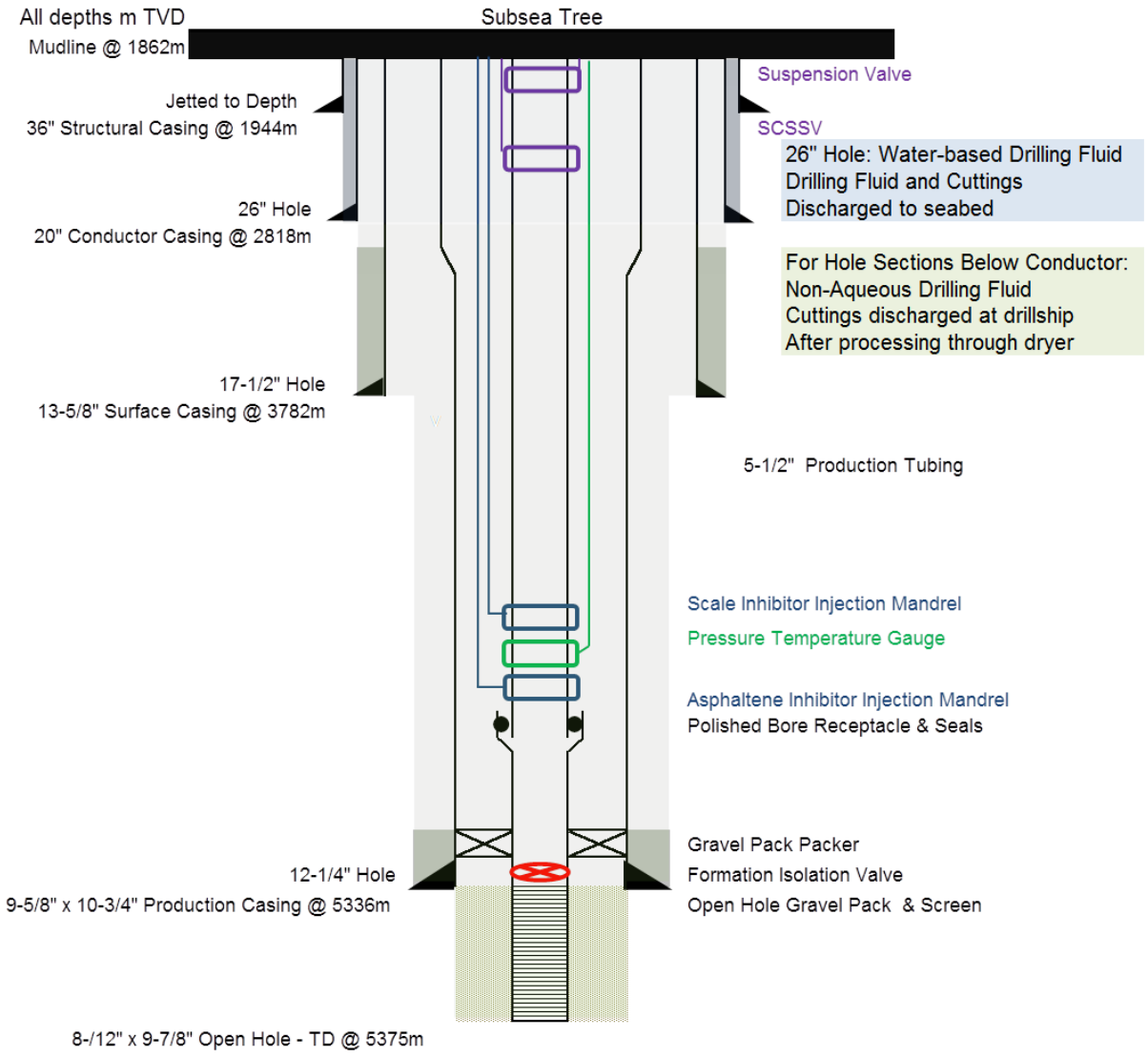
2.3.2 Typical Well Design

Once the borehole is started for a well, pipe (also known as casing) must be inserted into the borehole and cemented in place (to keep the well from collapsing and to seal the casing to the formation). As shown on Figure 2-5, various sized casings will be progressively set as the wells are drilled deeper. The size and strength of the casings to be used in the design of the well takes into account the peak reservoir temperature and pressure conditions that may be encountered during drilling and during production operations when the wells are flowing reservoir fluids. After each casing string cement job is completed, pressure testing will be performed to confirm

[7] Drill cuttings are the broken bits of solid material produced as the drill bit advances through the borehole in the rock or soil. The cuttings are usually carried to the surface by drilling fluid circulating up from the drill bit.

integrity according to standard industry practices. A provisional well program and design, including casing types and sizes, setting depths, drilling fluid types, and discharge locations for the development drilling program is shown on Figure 2-5.

Figure 2-5 Provisional Casing Program for Development Drilling Program



The first (i.e., most shallow) section of each well, also known as the structural casing section, will be jetted or drilled with seawater. Drill fluids and cuttings from this section will be discharged to the sea at the mudline without treatment per standard industry practice.

For each subsequent section of the well to be drilled, the drill string will be removed and the casing will be lowered into the hole to prevent its collapse. Wet cement will then be pumped down the casing and forced into the annular space between the hole and the outside of the casing, as well as into the annular space between the present and previously set casing.

The conductor casing, which is designed to hold back seabed surface soils and support the weight of the entire well, is then set and cemented back to the seabed. Drilling fluids and cuttings from this section will be discharged to the sea at the mudline per standard industry practice.

A drilling riser will be deployed to connect the conductor casing and the drill ship, and the blowout preventer[8] (BOP) will be installed. Marine drilling risers with buoyant joints and tension will be used to connect the wells via the BOP to the drill ship. BOPs will be periodically tested during the well construction process.

After this point, all returns of drilling fluids and cuttings will be directed to the drill ship for treatment (i.e., solids control and centrifugal cuttings dryer system) to reduce solids in the fluids as well as the fluids retained on cuttings. After treatment, the cuttings will be discharged to the sea from the drill ship. Based on prior analysis from the Liza-1 exploration program, cuttings disperse in the ocean current as they descend through the water column, which typically prevents significant accumulations of cuttings in any particular location on the seafloor.

The surface casing will then be set and cemented in competent rock at a depth below the mudline to allow drilling to the top of reservoir. The production casing will be set and cemented at the top of reservoir, and it is the casing string in which the production tubing is run.

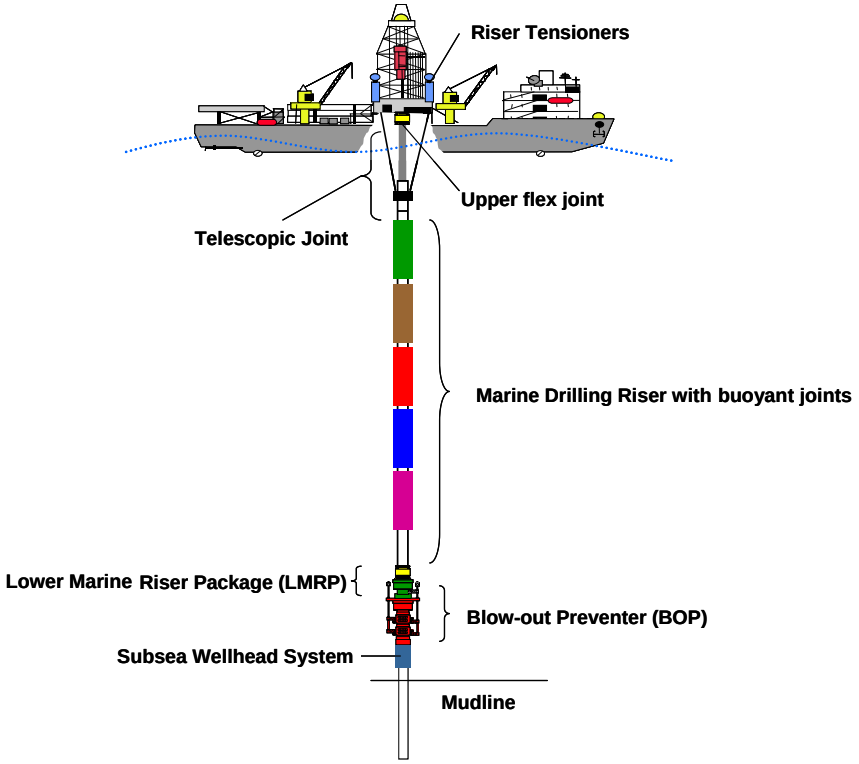
The production tubing carries the reservoir fluids from the production zone to the wellhead when the wells are flowing. The production tubing includes the subsurface safety valve (SSSV), which is designed to mitigate the uncontrolled release of fluids from the reservoir during the production process. The production tubing also protects the production casing from corrosion and deposition of by-products, such as sand, paraffins, and asphaltenes.

After the production tubing is run, the well will be suspended (i.e., flow prevented) by installing barriers to flow; the riser and BOPs will be removed; and the subsea tree will be installed and tested. At that point, the well is ready for future connection to the SURF components.

Figure 2-6 shows the various components of a typical subsea drilling system.

[8] Blowout preventers are secondary safety devices that are installed at the top of a well, which may be closed in order to prevent the uncontrolled flow of liquids and gases in the event of a loss of well control during drilling operations.

Figure 2-6 Typical Subsea Drilling System



2.3.3 Drilling Fluids

Two categories of drilling fluids will be used: water-based drilling fluids (WBDF) and low-toxicity non-aqueous drilling fluids (NADF) in which the continuous phase is an International Oil and Gas Producers Association (IOGP) Group III non-aqueous base fluid (NABF) with low to negligible aromatic content. WBDF will be used when drilling the upper sections of the well. To avoid formation of hydrates (ice-like crystals) due to the cold water temperature and high pressure, salt or organic inhibitors may be added to the WBDF.

Based on wellbore stability analysis and experience gained from Liza-1 and Liza-2 drilling, NADF will be required to maintain borehole stability while drilling all well sections below the conductor casing.

Cuttings treatment equipment will be installed on the drill ships to allow recovery of NADF and reduce the percentage of NABF retained on cuttings (%BFROC). The cuttings will be discharged to the sea after treatment, in accordance with standard industry practice. The use of cuttings dryers on other similar projects has significantly reduced the %BFROC.

During completion activities, a solids-free weighted brine composed of a fresh water base with water–soluble salts will be utilized. Viscosified brine-based fluid will be utilized during displacement and gravel packing operations. The brine will be filtered through diatomaceous earth and cartridge filters. Brine, gravel pack fluids, proppant, diatomaceous earth (fossilized skeletal remains of marine diatoms), and filtered solids will be discharged to the sea in accordance with standard industry practice.

Any unused or used and recovered drilling fluids and products will be re-used, recycled or disposed of in accordance with applicable regulations and best practices. A preliminary list of the types of drilling, completion and treatment fluids that may be utilized can be found in Section 2.10.

2.3.4 Well Cleanup and Ancillary Processes

To facilitate well cleanup, development wells will be drilled, completed, and tied-back to the FPSO. Completion and treatment fluids and solids left in the wellbore will be flowed back to the FPSO, where they will either be treated and discharged or collected for onshore disposal. The wells will not be cleaned up to the drill ship using temporary well test equipment; but, rather, all wells will be cleaned up through the subsea tree/flowlines/production equipment on the FPSO. Such small quantities of fluids will be incorporated with the crude product from other wells. Resulting gas and water will be processed along with fluids from other wells. No well tests of the Phase 1 development wells are planned.

Vertical Seismic Profile (VSP) data may be collected to improve velocity modeling and reduce uncertainty in reservoir mapping. VSP surveys can be used to correlate the surface-seismic data to the information on the physical properties and characteristics of the hydrocarbons gained from drilling the well. VSP data provides further time/depth information to improve knowledge and understanding of the structure and stratigraphy of the reservoir.

A VSP survey, which can be conducted from a drill ship or other support vessel, requires a sound source (commonly compressed air) and a receiver. Data is acquired by the receiver, which is installed within the wellbore. The source may be located with zero offset from the well (directly above the wellbore), at a fixed offset (a defined lateral distance from the well), walk away (at a range of offsets), or walk above (at zero offset to the down hole well location). The final scope of the VSP survey and specific geophysical tools to be used is still under review.

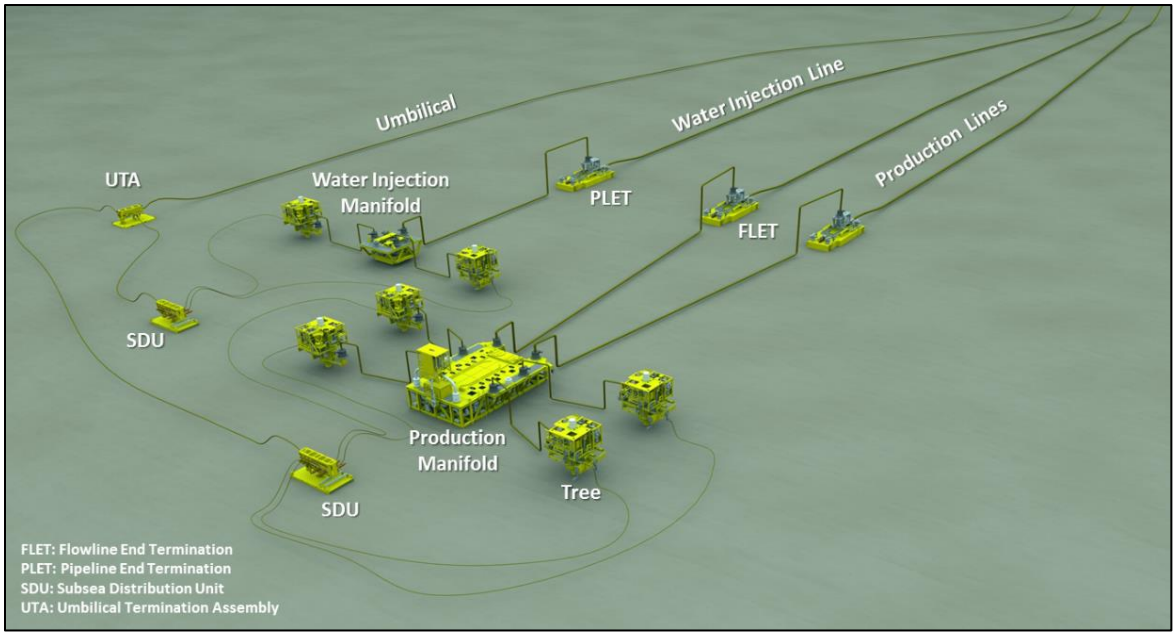
2.4 Subsea, Umbilicals, Risers, and Flowlines

The SURF facilities concept for the Project is comprised of subsea production trees, and gas/water injection trees clustered around subsea manifolds in two subsea drill centers. The risers, flowlines, and umbilicals[9] will connect the subsea facilities on the seafloor to the FPSO. The production manifolds will consolidate the production fluid from the individual production wells to the flowlines, and the injection manifolds will distribute injection gas/water to the individual gas/water injection wells. The subsea production control system on the FPSO will monitor and control the subsea facilities through an umbilical and subsea control distribution system that supplies power, communication, hydraulic fluid, and chemicals. The hydraulic fluid for operating the subsea hydraulic valves will be a low-toxicity, water soluble hydraulic fluid. The SURF system will be designed to withstand the full shut in pressure from the production wells, and the gas/water injection components will be designed to withstand the

[9] An umbilical is a cable and/or hose that provides the electrical, hydraulic, chemical, and communications connections needed to provide power and control between the FPSO and subsea equipment.

highest required injection pressures. Overpressure protection will be provided on the FPSO, in accordance with industry standards, to protect the subsea systems. Figure 2-7 shows an illustration of a representative SURF system similar to what is currently being designed for the Project.

Figure 2-7 Representative SURF System



Note: Schematic is not necessarily representative of number of drill centers or wells.

The production drill centers will be connected to the FPSO with round-trip piggable production flowlines. A pig is a specially designed device that is placed in the riser/flowline at a launcher at one end and pushed by pressure until it reaches the receiving trap or catcher at the other end. Pigging is performed to aid and assist in the maintenance, operations, cleaning, and inspection of flowlines. Figure 2-8 shows an example of a pig.

Figure 2-8 Example of Wire Brush Cleaning Pig

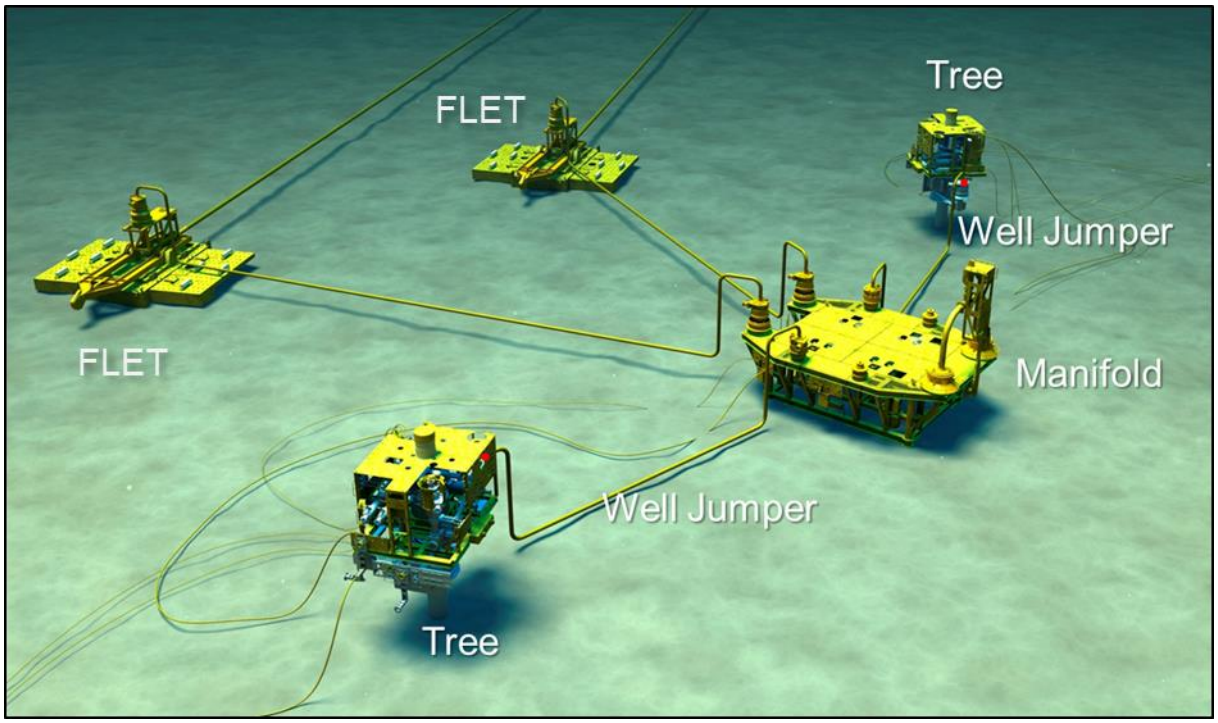


2.4.1 Well Flow Connections

Well flow connections between the subsea wells and the FPSO include several components. Each subsea development well is capped by a subsea tree, which include several isolation valves and a choke valve to control production and water and gas injection. For a given set of wells tied to the same manifold, the subsea trees are connected by well jumpers to the subsea manifold, which is then connected by flowline jumpers to flowline end terminations (FLETs) located towards the drill center end of the flowline.

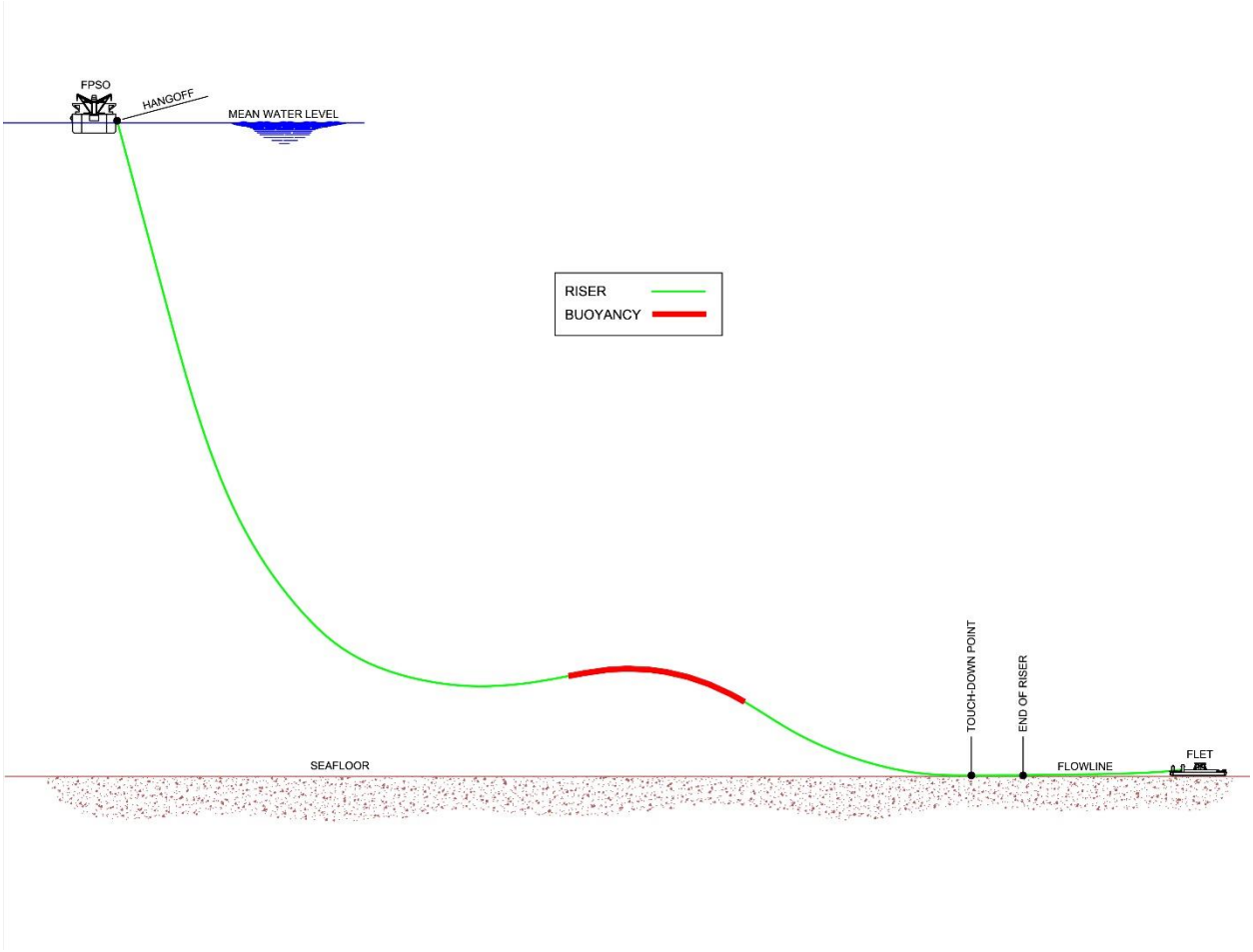
A typical configuration of the subsea trees, FLETs, flowlines, and manifolds expected at a drill center for the Project is indicated on Figure 2-9.

Figure 2-9 Representative Subsea Trees, FLETs, Jumpers, and Manifold



From the drill center, the rigid flowlines travel on the seabed to the vicinity of the FPSO and transition to vertical risers, where they connect to the FPSO at the surface. The risers carry fluids up to the FPSO at the surface, as shown on Figure 2-10. In the case of injection streams (i.e., for gas and water injection), the same configuration is used, but flow is from the FPSO downward through the risers to the water or gas injection manifolds.

Figure 2-10 Representation of Riser Connected to FPSO



2.4.2 FPSO Topside Subsea Control System

The FPSO will provide power, utilities, cabling, and tubing tie-ins to subsea control equipment installed on its topsides to control the subsea equipment. The FPSO will be configured with back-up power, in the event primary power is lost.

The subsea trees and manifolds will be monitored and controlled through the subsea control system on the FPSO via a dynamic and static steel tube umbilical. Subsea control system will accommodate typical monitoring requirements such as pressure and temperature measurement.

2.4.3 Risers, Flowlines, Umbilicals, and Manifolds

2.4.3.1 Risers and Flowlines

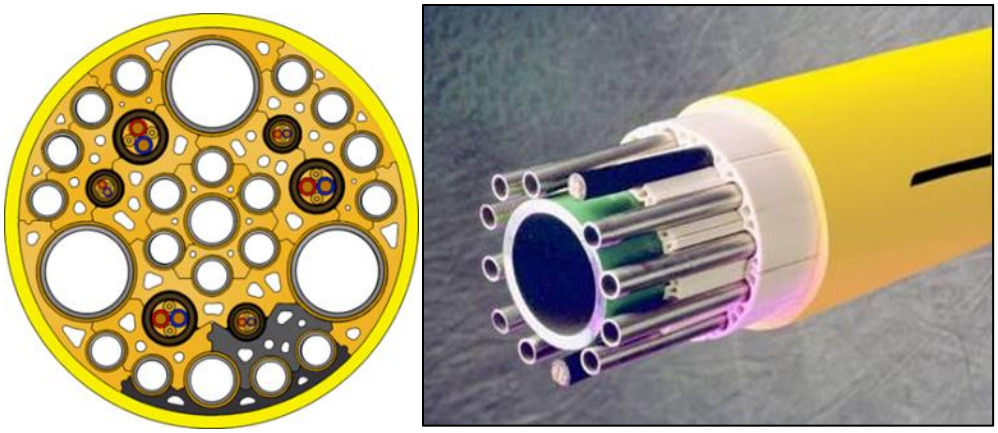
The Project will incorporate production, water, and gas injection flowlines and risers, as shown on Figure 2-3. Flowline and umbilical lengths will range from approximately 3.2 to 6.4 km (~2 mi to 4 mi), excluding risers, in water depths of approximately 1500 to 1900 m. The current

design lengths are based on preliminary shallow hazard surveys and current field layout, which may be adjusted during detailed design.

2.4.3.2 *Umbilical*

The umbilical (Figure 2-11) will be designed as an integrated bundle of tubes and cables to transport hydraulic fluid, injection chemicals, and electrical power/communication. A single dynamic umbilical, which will be connected to the FPSO at the surface and end at production Drill Center 1 (DC-1P), will service the Liza field during Phase 1. In-field umbilicals will be used to further distribute these services to the other subsea equipment.

Figure 2-11 Representative Integrated Dynamic Umbilical Cross Section



2.4.3.3 *Manifolds*

Manifolds are gathering points, or central connections made up of valves, hubs, piping, sensors, and control modules. Manifolds include a protective structural framework that rests on a seabed foundation where multiple trees, jumpers, and flowlines gather to consolidate flows before they are either transported to the FPSO on the surface as part of production or back down for injection of water and gas into the reservoir (Figure 2-12).

Figure 2-12 Representative Subsea Manifold



2.4.3.4 Gas Lift System

The FPSO riser support system will be designed for gas lift capability. The gas lift system is not required for initial startup, and it will be installed at some time during the Project production operations stage based on the production characteristics of the Liza reservoirs. This system will include a riser and flowline to DC-1P with connections to the production flowlines.

2.5 Floating Production, Storage, and Offloading Vessel

2.5.1 General Description

The FPSO vessel to be utilized for the Project will be a VLCC tanker, which utilizes a spread moored configuration to maintain station continuously for at least 20 years. The FPSO will be designed to receive the full production wellstream from the development wells and will process crude oil at a design rate of 100,000 barrels of oil per day (BOPD), with potential to safely operate at sustained peaks of up to approximately 120,000 BOPD. For the purposes of this EIA, potential impacts generated by the Project will be based on the highest potential oil production volume, which is conservatively based on 144,000 BOPD[10]. The FPSO hull will be capable of storing a minimum of 1.6 million barrels of stabilized crude oil. The FPSO will be able to offload approximately 1 million barrels to a tanker in a period of approximately 28 hours.

[10] 144,000 BOPD is 20% over the sustained peak volume of 120,000 BOPD.

The FPSO will also have the capability to process, dehydrate, compress, and re-inject the gas produced from the reservoir. The FPSO will be configured to treat seawater used for facility cooling purposes for injection into the reservoir, and to treat produced water for disposal overboard into the sea. Living quarters and associated utilities will be provided in order to support the operations on the FPSO.

Table 2-1 provides an estimate of the design rates for the FPSO facility. Although the Project nameplate oil production capacity is 100,000 barrels per day (bpd), the Project facilities will have the potential to safely operate at sustained peaks above the design rate. For purposes of this EIA, potential impacts generated by the Project (e.g., air emissions) were based on a potential peak production volume of 144,000 bpd to be conservative in the analysis.

Table 2-1 FPSO Key Design Rates

Service	**Design Rate[(1)] [(2)]**
Oil Production (bpd)	100,000
Produced Water (bpd)	100,000
Total Liquids (bpd)	150,000
Produced Gas (Mscfd)	180
Gas Injection (Mscfd)	160 (assumes 20 Mscfd of produced gas will be used as fuel gas for the FPSO)
Water Injection (bpd)	190,000

Notes:
bpd = barrels per day
Mscfd = million standard cubic feet per day
[1] All design rates are presented as the peak annual average.
[2] The facilities will have the potential to safely operate at sustained peaks of oil production up to approximately 120,000 bpd. For the purposes of the EIA, 144,000 bpd has been used as the basis to analyze potential impacts from the Project.

Key FPSO design features include the following:

- The FPSO will be designed to remain moored for at least 20 years without dry-docking and will include facilities to support in-water hull/structural surveys and repair and maintenance.
- The FPSO will be designed to operate in extreme (100-year return period) environmental conditions (associated wind, waves, and current).
- The FPSO will be designed to re-inject the produced gas back into the reservoir, except during times of injection system unavailability, which will require temporary, non-routine flaring.

A computer simulated picture of the planned FPSO and a general schematic of a converted FPSO topsides and hull are provided on Figures 2-13 and 2-14, respectively.

Figure 2-13 Computer Simulated Picture of Planned Liza Phase 1 FPSO

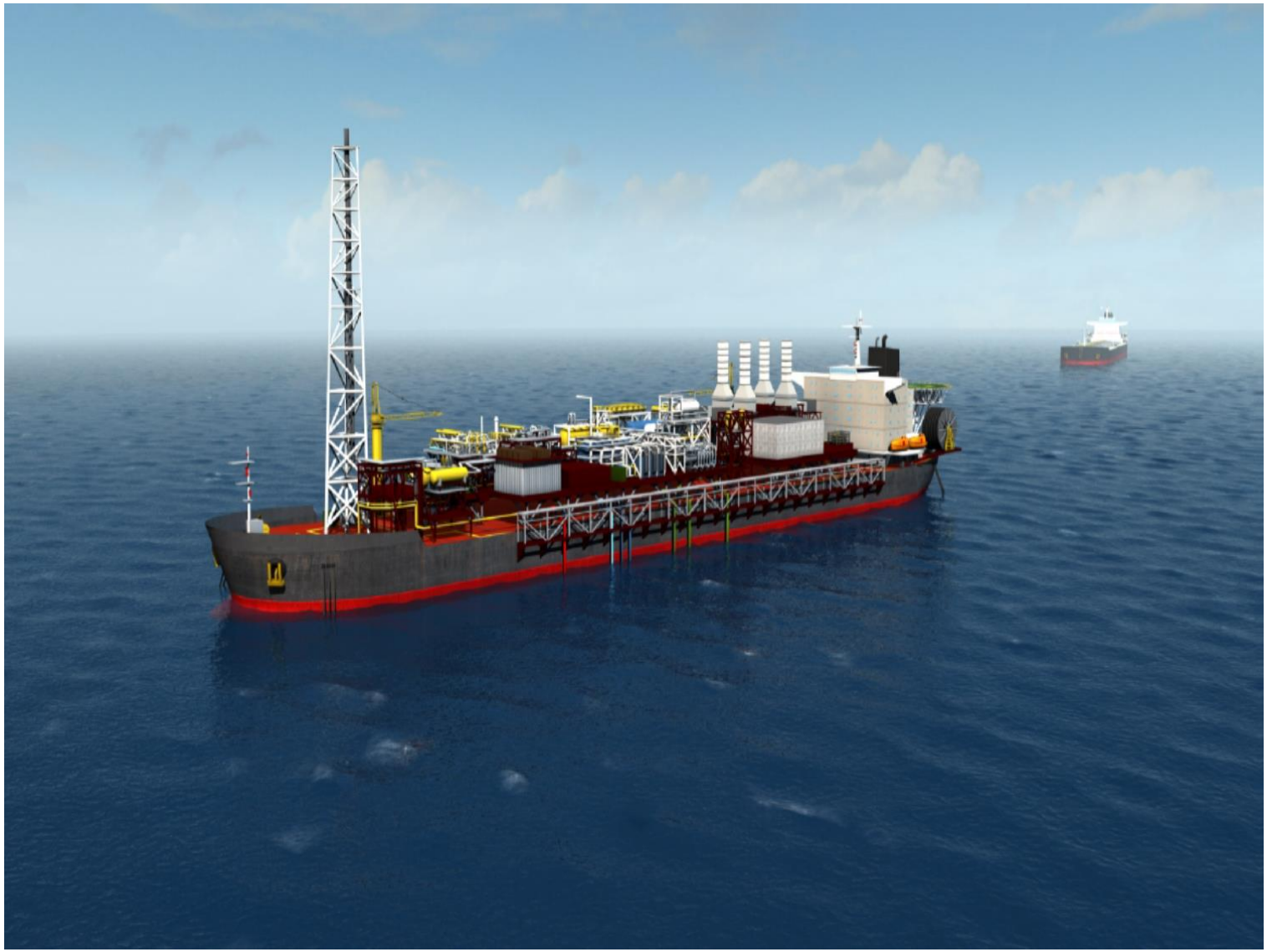
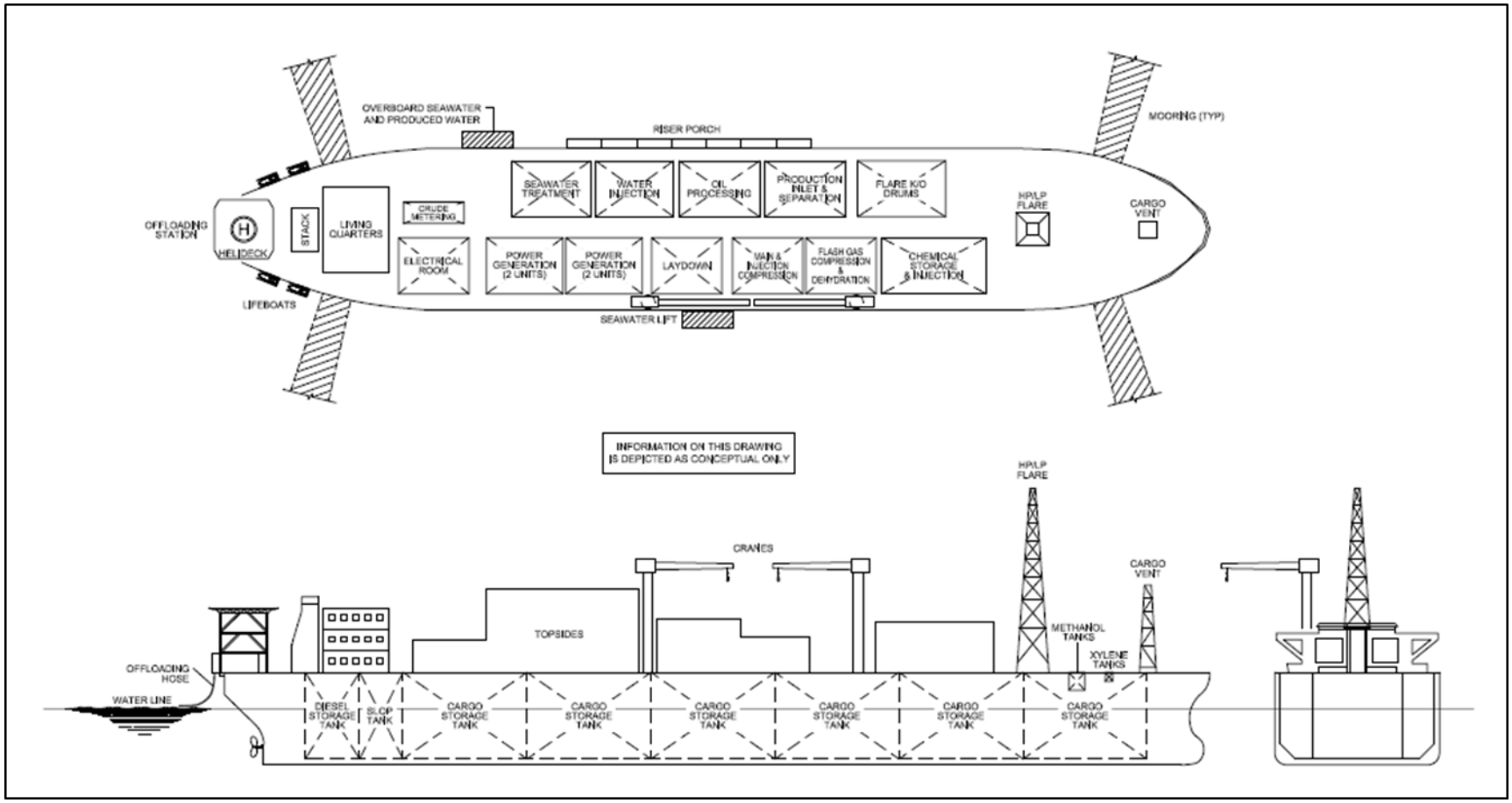


Figure 2-14 General Schematic of a Converted FPSO Topsides and Hull



2.5.2 FPSO Topsides

The FPSO's topsides design employs an interconnected module concept where process equipment is packaged in modules. The design concept maximizes pre-commissioning and functional testing of the modules prior to arrival offshore Guyana. The FPSO will arrive for installation, hook-up, and commissioning in the Stabroek Block fully fabricated, pre-assembled and most facilities, modules, components and systems pre-tested.

The principal functions of the topsides process facilities will be:

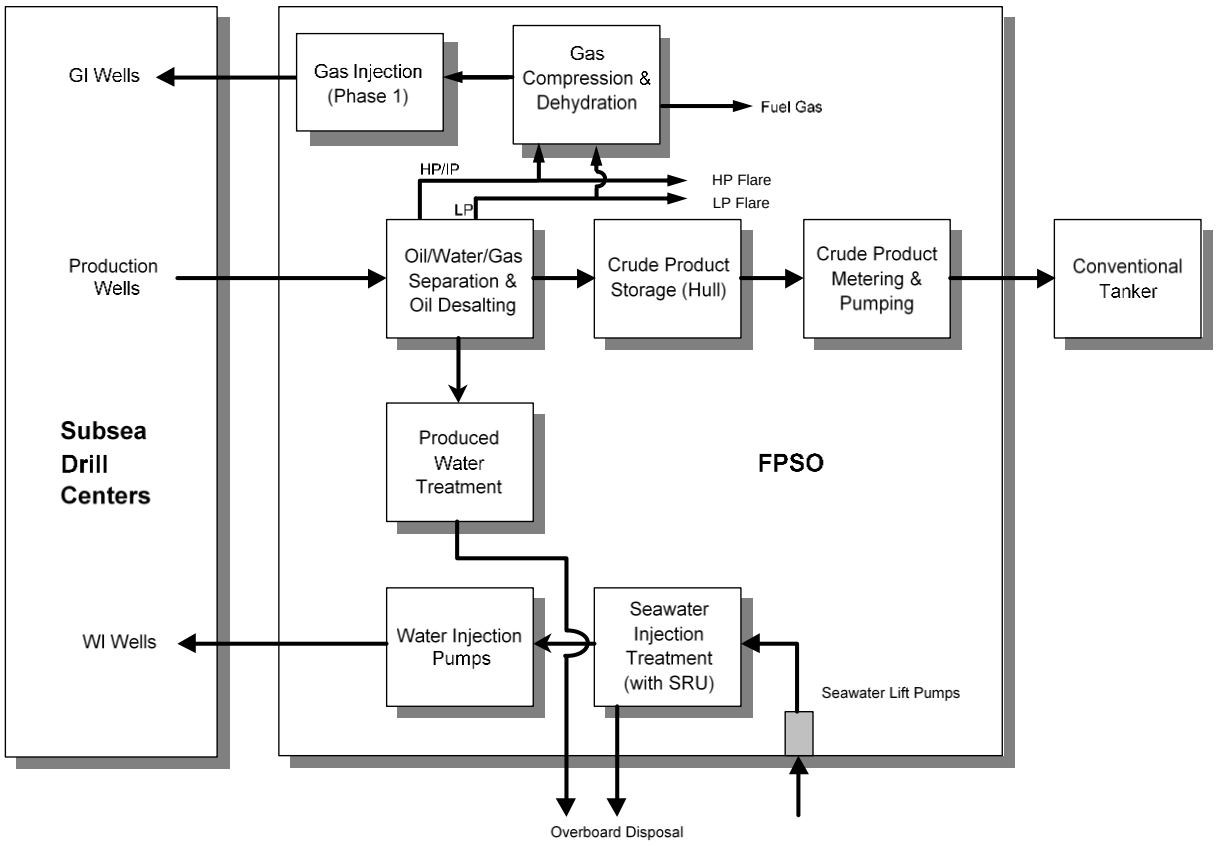
- To receive, separate, and process the produced reservoir fluids to provide:
    - a crude oil product for offloading onto conventional tankers,
    - produced water from the reservoir to be of sufficient quality for environmentally acceptable discharge to the sea, and
    - produced gas to meet requirements for FPSO turbine generator fuel gas and for re-injection into the reservoir;
- To treat seawater to provide a suitable supply of injection water to support the reservoir depletion plans; and
- To provide support systems for the safe accommodation of approximately 80-120 personnel involved in the operation of the production facilities and, on occasion, personnel involved with the drilling program.

Temporary accommodations may also be utilized during key activities including hook-up, commissioning and maintenance operations to increase accommodations capacity up to approximately 140 personnel.

2.5.3 FPSO Process Systems

The process facilities on the FPSO topsides are shown schematically on Figure 2-15 and are described in the subsequent sections.

Figure 2-15 Process Flow Diagram



Notes:
GI = Gas re-injection
WI = Water injection
HP = High pressure
IP = Intermediate pressure
LP = Low pressure
SRU = Sulfate Removal Unit

2.5.3.1 *Oil / Water / Gas Separation and Oil Desalting*

An inlet manifold will receive full wellstream fluids (consisting of oil, gas, and water) from the production flowlines and will route the fluids to the FPSO processing facilities. The wellstream fluids will be separated into oil, water, and gas phases in a single train of separation. The separation train consists of three stages (high, intermediate, and low pressure) of flash separation to produce a stabilized crude product. Fresh water will then be added to the stabilized crude product to remove dissolved salts as part of oil desalting. The final crude oil product from the flash separation / stabilization process will be treated to meet the specifications for sale prior to being sent to the crude product storage tanks in the FPSO hull. Further processing of the water and gas streams from the separation process and the process for treating seawater for injection are described below.

2.5.3.2 *Gas Processing*

For Phase 1, the Project will re-inject produced gas (that will not be consumed as fuel gas on the FPSO) back into the reservoir. The purpose of the FPSO gas processing system is to condition the associated produced gas (which is not consumed as FPSO fuel gas) to the appropriate specification prior to re-injection into the reservoir. It comprises systems to compress gas, dehydrate gas, and direct gas to be re-injected.

During equipment maintenance and process upsets, including startup and shutdown scenarios, part or all of the off-gas from the separation/stabilization process will be sent to the High Pressure (HP) or Low Pressure (LP) Flare Systems. Flaring will be temporary and non-routine. Flaring is discussed in more detail in Section 2.5.4.3 below.

2.5.3.3 *Produced Water Treatment*

The produced water treating system will be designed to collect produced water from the FPSO processing facilities and treat the water for discharge overboard per standard industry practice. The system will consist of primary and secondary treatment. Primary treatment will consist of either a skim vessel or hydrocyclones for removal of large oil droplets from the produced water. Secondary treatment will consist of a gas flotation for removal of small oil droplets in order to meet the discharge specification. Produced water that does not meet the overboard discharge specification will be routed to an appropriate tank in the hull for further treatment.

2.5.3.4 *Seawater Treatment and Water Injection System*

Water injection will be used for reservoir pressure maintenance to enhance oil production. Seawater used for injection water will be treated prior to injection into the producing reservoirs, per standard industry practice. The seawater treatment system will include sea lift pumping, filtration, deaeration, and sulfate removal. Seawater lift pumps on the FPSO will be used to pump seawater from depths up to 100 meters below the surface in order to access colder seawater than what is available from the ocean surface. The filtration system will consist of both coarse filtration (strainers) and fine filtration (multi-media filtration) for removal of particulate from the incoming seawater. Following filtration, seawater will be vacuum deaerated for removal of oxygen. The deaerated seawater will then be pumped through a membrane system for removal of sulfate ions from the seawater as the final treatment step. The treated seawater will then be pumped to the necessary pressure for injection into the producing reservoir.

A portion of the treated seawater will be further treated through a reverse osmosis system to make fresh water. Fresh water is required for removal of salt from the crude product as part of oil desalting, as described in Section 2.5.3.1.

2.5.4 FPSO Utility Systems

This section discusses the utility system requirements for the FPSO. For the most part, the utility systems designed to support the process facilities will be located above deck. Marine utility systems may be used to support topside systems where appropriate.

2.5.4.1 Process Cooling

Cooling of process streams via a closed loop, water-based cooling medium system is required to dissipate heat generated by the oil and water treating systems, the compression systems, and miscellaneous utility systems.

The seawater lifting system described in Section 2.5.3.4 will also supply the required seawater for cooling. Process hydrocarbon fluids do not come into contact with this seawater. Treated seawater will be disposed of overboard at a suitable temperature so as not to significantly impact marine life.

2.5.4.2 Process Heating

A process heating system is required as part of the crude oil treatment process to achieve the required crude oil product specifications. A closed loop, water-based heating medium system will be used to add heat to the incoming production. Waste heat from the power generation system will be used as the source of heat.

2.5.4.3 Flaring System

EEPGL intends to re-inject all operationally produced gas under routine conditions, except that which will be utilized for FPSO operations (e.g., fuel gas). A flare system will be provided for the collection and safe disposition of produced hydrocarbon gases resulting from unplanned, non-routine relief and blowdown events. Relief events occur to prevent overpressure scenarios in the process equipment. Blowdown events occur to depressure the facilities in a controlled manner as a result of emergency shutdown events. In addition, temporary, non-routine flaring will occur during equipment maintenance, process upsets, and start-up. The flare system will include both an HP and LP flare sharing a common flare tower, as shown on Figure 2-15. The flare tower has elevated flare tips for both high and low pressure flares, which provides for the safe ignition of hydrocarbon gases. Both flares will support high-efficiency combustion and will utilize pilots that have minimal emissions.

2.5.4.4 Topsides and Subsea Chemical Injection

The FPSO will have storage and injection facilities to inject the required amounts of chemicals and methanol into the production fluids to support production operations, both for subsea chemical injection requirements and for topsides chemical injection requirements. These chemicals are further described in Section 2.10. Table 2-6 provides a summary of the key effluent characteristics for planned discharges to water.

2.5.4.5 Air

An air compression system will be provided to supply FPSO hull and topsides equipment. Compressed air is primarily required for the operation of control valves and other process instrumentation requirements.

2.5.4.6 Nitrogen

Instrument air will feed the nitrogen generation system. Nitrogen will be provided as required for purging (i.e., removing residual amounts of products), inerting (i.e., introducing non-flammable gas to prevent ignition), blanketing (i.e., filling vapor space in tanks with non-flammable gas to prevent ignition), and as required for miscellaneous utilities.

2.5.4.7 Drains

The FPSO topsides shall be equipped with the following drain systems:

- Non-hydrocarbon open drain. Used to collect drain fluids (e.g., rainwater) from non-hydrocarbon areas and to route them to the slop tank in the FPSO hull or direct overboard.
- Hydrocarbon open drain. Used to collect drain fluids (e.g., oil contaminated water) from hydrocarbon areas and to route them to the slop tank in the FPSO hull.

2.5.4.8 Other

Two deck cranes will be provided for supply boat offloading and materials handling and to support general maintenance activities. Workshops, a laboratory capable of checking the properties of the produced and injection fluids as well as select discharges for compliance, medical facility, and storage facility for supplies and spare parts will also be provided. Heating, Ventilation, and Air Conditioning (HVAC) systems will be provided for buildings and enclosures.

2.5.5 Power Generation System

The required power for the FPSO will be generated by three systems as follows:

- The main power generation system will be gas turbine driven generator sets with spares available in the case of unplanned downtime. All generator sets will be dual fuel (diesel, produced gas) capable to allow for restoring power to the facility (i.e., black start).
- The essential services power generation system will be a diesel driven generator set. Essential services include systems required for facility restart and for flow assurance hydrate mitigation activities after an unplanned shutdown.
- The vessel emergency power generator set will be diesel driven and will provide power to both the hull and topsides emergency systems (e.g., safety systems including emergency lighting, telecommunication).

Additionally, for back-up power during emergency situations, the uninterruptible power supply (UPS) system will be provided to power equipment such as the Integrated Control and Safety System (ICSS) and subsea controls, among others.

2.5.6 Integrated Control and Safety System (ICSS)

Monitoring and control of the FPSO production operations will be performed by an ICSS. Located in the main control room of the FPSO, the ICSS will include process shutdown, emergency shutdown, and fire and gas systems to protect the facilities and personnel. These systems will interface to a public address and general alarm system (PA/GA) to provide distinct audible and visual alarm notification.

The ICSS includes the Process Control System (PCS), Safety Instrumented System (SIS), the Fire and Gas (F&G) system, the Alarm Management System (AMS), the Operator graphics / consoles; and the third-party interfaces to packaged systems (such as compressors, subsea, and marine, among others).

2.5.7 Communication Systems

Telecommunications equipment will be installed on the FPSO to enable safe operation of the facilities in normal and emergency conditions. This equipment will allow communication with the shorebase, support vessels, helicopters, and tankers as well as communication on the FPSO.

2.5.8 Additional Vessel Systems

2.5.8.1 FPSO Cargo Systems

The main purpose of the FPSO cargo system will be:

- To receive, distribute, and store on-specification crude oil from the process facilities into the FPSO cargo tanks;
- To receive and store off-specification crude oil from the process facilities into a designated FPSO cargo tank; and
- To offload the crude oil stored in the FPSO cargo tanks into a conventional tanker at regular intervals.

In addition to the FPSO cargo tanks, there will be a slop tank to receive stripping water from the cargo tanks and discharge from the topsides non-hazardous and hazardous drain system. The oil and water will be gravity-separated by a minimum residence and retention time. Once separated, the oil will be skimmed off the top and sent to the cargo tanks, and the water will be discharged overboard to specification.

The FPSO cargo tanks will be blanketed with inert gas. As depicted on Figure 2-15, a tank vent system will be provided to release vapor and inert gas from the cargo tanks to a safe location, toward the bow of the FPSO, to prevent an overpressure event in the tanks.

The marine cargo system supports the following routine activities:

- Flushing of the crude oil offloading export hose;
- Emergency and temporary ballasting of FPSO cargo tanks with seawater; and
- Inspection and maintenance of FPSO cargo tanks and piping systems between offloading operations.

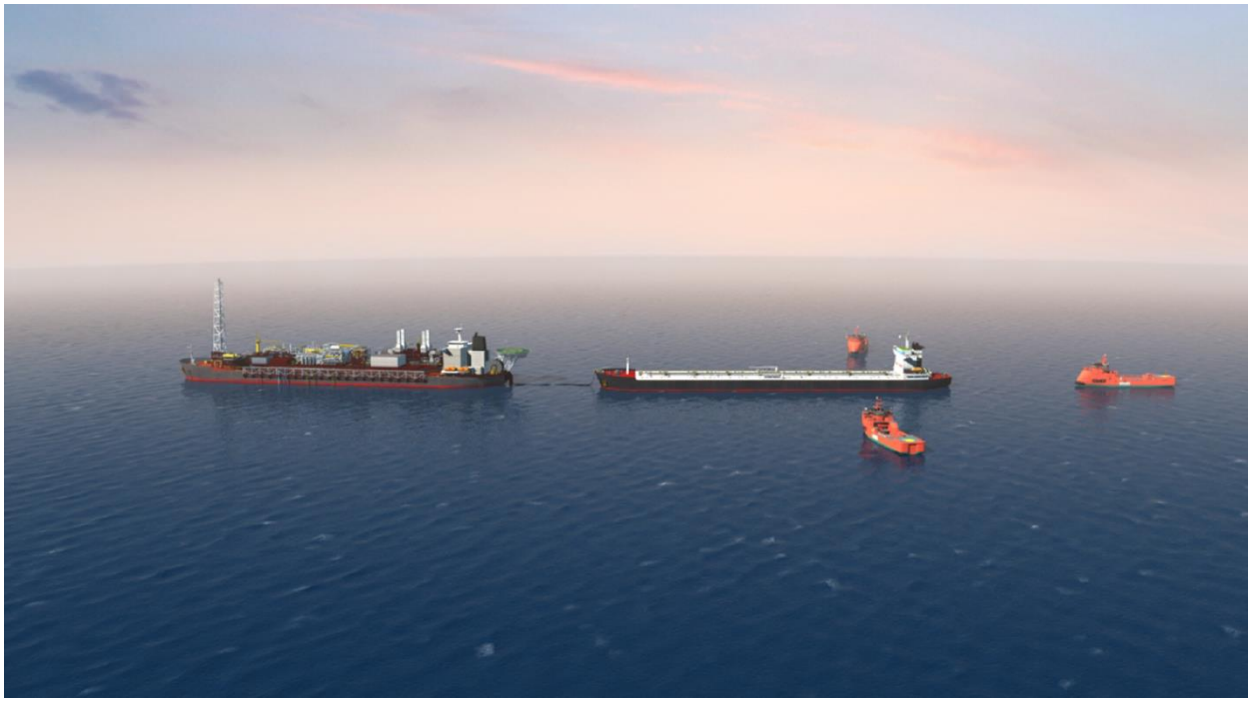
2.5.8.2 Custody Transfer Meter

For offloading, crude will be pumped from the FPSO hull storage tanks through a custody transfer metering package on the topsides and into the offloading system at a rate sufficient to achieve transfer of approximately 1 million barrels of oil in up to 28 hours up to a VLCC class tanker size.

2.5.8.3 Crude Oil Offloading

Export of the crude oil from the FPSO will be via a floating hose to the midship manifold of a conventional tanker. The FPSO will be configured for tandem offloading to a conventional tanker which will be owned/operated by others. The separation distance between the stern of the FPSO and the conventional tanker will be approximately 120 m (390 ft). The maximum conventional tanker size envisioned is a VLCC class. During offloading operations, the conventional tanker will maneuver and hold station relative to the FPSO with the aid of up to three assistance tugs, as shown on Figure 2-16. Crude will be transported to buyers' final location by the conventional tankers after each offloading operation.

Figure 2-16 General Offloading Configuration



2.5.8.4 Ballast System

Ballast water will be required during the transit from the shipyard to the site. Once on site, the unneeded ballast water from the FPSO may be discharged overboard.

2.5.8.5 Spread Mooring System

The FPSO will be permanently moored by fixed, spread mooring with up to a 20 point mooring line system each connected to their respective anchor pile embedded into the seafloor. The anchor piles will be either suction piles or driven piles. The mooring system will be designed to maintain the FPSO on station for a 100-year environmental condition.

2.5.9 Safety and Personnel Protection Systems

FPSO safety systems will include:

- Firewater System – The firewater system will have one pump each located at the fore and aft ends of the FPSO, with one pump serving as a redundant backup.
- Fire and Gas Detection Systems – Fire and smoke detectors will be located throughout the topsides and living quarters and will be wired centrally with alarms sounding in the central control room (CCR), which will activate the general alarm system on the FPSO. Gas detectors will be placed in areas where gas might be released or could accumulate.
- Blanket Gas Generation – To prevent fires, the cargo tanks will be operated with an inert gas blanket at all times except during tank entry. The inert gas for cargo tanks will be supplied by an inert gas system utilizing flue gas from the marine boilers. To provide gas blanketing for other spaces, including the methanol and xylene tanks, inert gas will be provided by routing compressed air through the nitrogen membrane package.
- Lifeboats and Life Rafts – The FPSO will be provided with lifeboats on either side of the accommodation, having a capacity on each side for 100 percent of the personnel on board (POB). A fast rescue boat will also be provided, complete with a davit launching and retrieving system.

2.6 Installation, Hook-up, and Commissioning

The sequence and duration of each FPSO and SURF installation, hook-up, and commissioning activity will be further defined as part of ongoing Project planning and development. The final sequence and durations of activities will depend on a number of factors, including, but not limited to, final Project design, marine vessel and equipment availability, mobilization times, and weather, among other factors. Key installation, hook-up, and commissioning activities will include:

- FPSO Mooring Installation – Installation of the FPSO's anchor piles and mooring lines. Following installation, the mooring lines will be staged on the seafloor until arrival of the FPSO.

- Flowline/Riser Installation – Installation of the production, water injection, and gas injection flowlines and risers. These components will be cleaned and tested to verify and ensure integrity after installation, and then staged on the seafloor until arrival of the FPSO.
- FPSO Positioning and Mooring Connection – Positioning of the FPSO using support tugs followed by retrieval of the FPSO mooring lines from the seafloor and hook-up of the FPSO to its mooring system.
- Manifold/Drill Center Installation – Installation of the manifolds, manifold foundation piles, jumpers, Subsea Distribution Units, and flying leads at the drill centers followed by integrity testing and verification.
- Umbilical Installation – Installation of the umbilical and umbilical termination unit.
- Riser Connection – Retrieval from the seafloor, pull-in, and connection of the risers to the FPSO.
- Testing and Commissioning – Testing and commissioning of the connected, integrated FPSO and SURF production systems, including testing and de-watering / displacing flowlines and umbilicals with commissioning fluids, which are further discussed in Section 2.10, and testing SURF control and shutdown systems. Some of these commissioning fluids may be discharged to the sea per standard industry practice, as shown in Section 2.10.2, Table 2-6. Any unused or used and recovered commissioning fluids and products will be re-used, recycled, or disposed of in accordance with applicable regulations and best practices.

The above activities will be executed in an optimal sequence with activities completed in parallel where possible.

During the FPSO/SURF installation stage, a remotely operated vehicle (ROV) may be periodically utilized to support the above mentioned activities (e.g., underwater observations, connections, and sampling, among others).

2.7 Production Operations

The Project will include a leased FPSO, owned and operated by the FPSO contractor, and a subsea development, owned by EEPGL and operated by the FPSO contractor under the direction of EEPGL. Throughout production operations, EEPGL's personnel will perform oversight and monitoring of the FPSO contractor to ensure that management systems pertinent to safety, the environment, and operations integrity are properly implemented. To accomplish this, EEPGL plans to utilize an onboard representative (OBR) supported by operational and technical specialists to monitor, and direct as necessary, operation of the FPSO and SURF facilities.

Operating processes will include flowing the hydrocarbon well stream from the reservoir to the FPSO, where further fluid separation, stabilization, storage, and management will occur prior to offloading the crude oil to the conventional tankers. General maintenance of the FPSO and SURF components will also be performed offshore during production operations. Some industry standard chemicals will be required as part of the processing and handling of the oil and associated gas on the FPSO, as well as treating produced water prior to discharge. Both the FPSO and SURF facilities will also require the use of industry standard additives to provide

flow assurance and prevent corrosion, scale, hydrate, and asphaltene formation as previously noted in Section 2.5.4.4 and described in Section 2.7.1. These subsea and topsides chemicals will separate into the oil, water or gas phases of the process stream, depending on their solubilities and applications. Therefore, residual quantities of these chemicals may be contained in the processed crude oil, discharged with produced water, or emitted to the atmosphere with vented and fugitive gases.

The final chemical requirements and quantities will be determined as part of the ongoing FPSO and SURF facilities design work, and a preliminary list is provided in Table 2-2. Any unused or used and re-captured production chemicals will be re-used, recycled, or disposed of in accordance with applicable regulations and best practices.

The objective of the following sections is to provide a general overview of the flow assurance challenges and strategies.

2.7.1 Common Flow Assurance Additives

2.7.1.1 Hydrates

Ambient seafloor temperatures in the Liza area are sufficiently cold that hydrates could form in the FPSO and SURF equipment. To prevent the formation of hydrates, a combination of inhibitor (methanol), thermal insulation, and operating practices will be utilized.

2.7.1.2 Paraffin and Asphaltenes

The insulation needed for hydrate mitigation is sufficient to prevent Paraffin (wax) deposition in the subsea production system. Paraffin inhibitor can be injected along with downhole asphaltene inhibitor downhole if needed. Asphaltene precipitation and/or deposition are expected at near wellbore and in production wells. Asphaltene deposition will be mitigated with continuous asphaltene inhibitor downhole. In case asphaltene deposition cannot be mitigated by asphaltene inhibitors, production wells will be soaked with xylene as remediation. Pigging operations with or without xylene may also be used for remediating any asphaltene deposition in the production flowline and riser.

2.7.1.3 Scale Control

Scale formation will be managed using scale inhibitor downhole and by sulfate reduction with Sulfate Removal Unit (SRU) at topsides.

2.7.1.4 Corrosion Control

Internal corrosion of the subsea facilities shall be managed by a combination of material selection and injection of inhibitor. Components in the production path upstream of the flowlines will be fabricated from corrosion-resistant alloys suitable for the intended service. The carbon steel flowlines and risers will be protected by the injection of corrosion inhibitor at the subsea production manifold headers.

2.7.2 Hydrogen Sulfide (H_2S) Management

The concentration of H_2S will be extremely low for the initial stage (i.e., 5-10 years) of FPSO/SURF production operations. There may be potential for the reservoir to sour over time, which influences material selection and corrosion inhibition for certain FPSO, SURF, and drilling systems. In the unlikely event that concentrations of H_2S increase to a level that could represent potential health or safety concerns for the Project's offshore workforce, additional management measures will be implemented as appropriate (e.g., training programs, personal protective equipment, response planning, and equipment for leak detection and alarms).

2.7.3 Marine Safety

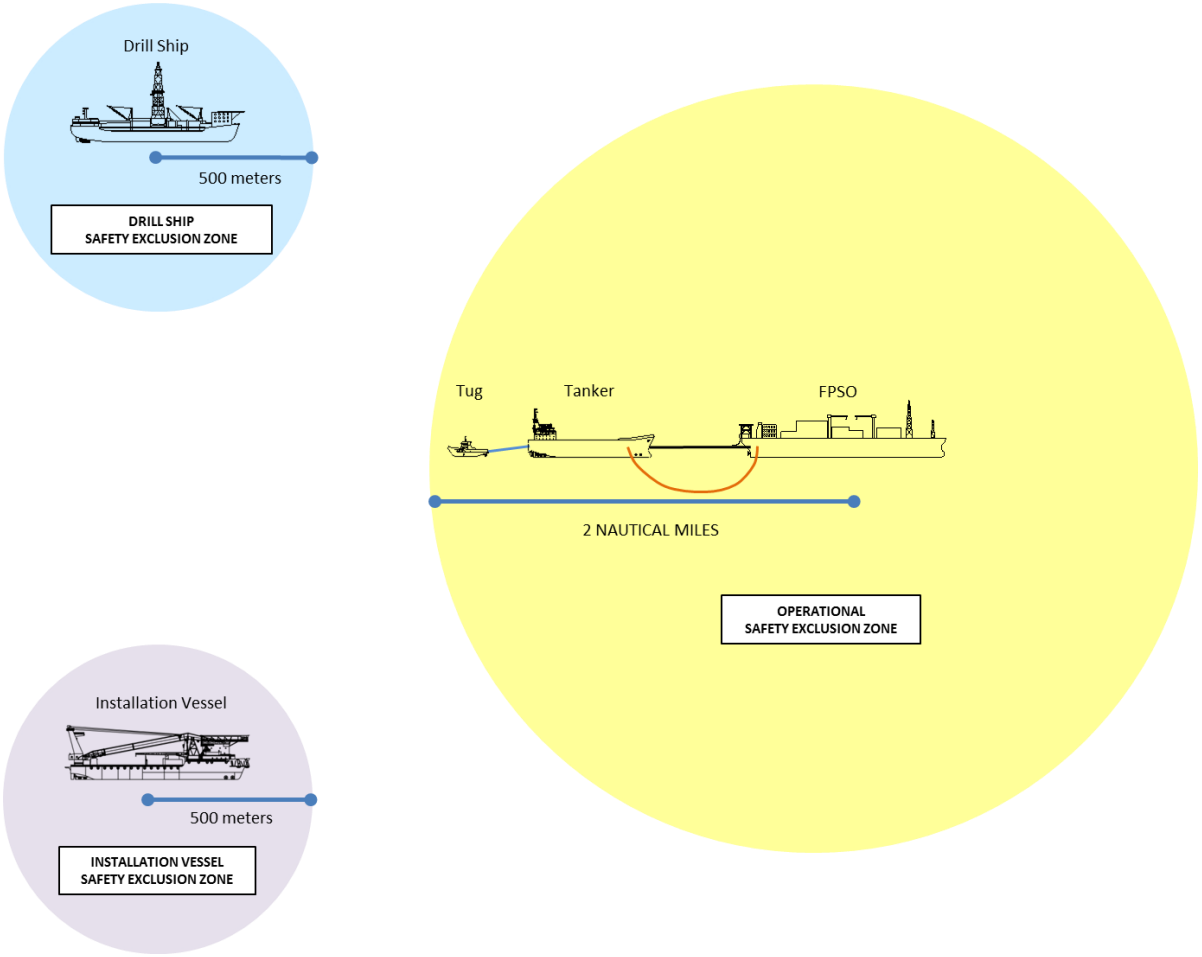
The Maritime Administration (MARAD) of the Ministry of Public Infrastructure is responsible for issuing notices to mariners concerning safety at sea.

MARAD will be advised of the location of drill ships during the drilling of the development wells and the performance of well workovers in the PDA, and of the location of installation vessels during major installation activities so that mariners are aware of these activities. Safety exclusion zones with a 500 m (~ 1640 ft) radius will be established around drill ships during drilling operations and around drill centers during well workovers, as well as around major installation vessels in accordance with industry standards and practices, as represented on Figure 2-17.

Authorizations for in-water activities will be obtained from MARAD and notices to mariners will be issued for all marine vessels including the FPSO, supply and support vessels, tugs, and those vessels employed during the FPSO/SURF installation, hook-up, and commissioning stage. The Project will also communicate major vessel movements to commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and where possible communicate Project activities to those individuals to aid them in avoiding Project vessels through the stakeholder engagement process.

As also shown on Figure 2-17, during the production operations stage, the FPSO will have a 2 nautical mile (nm) radius encircling the vessel where marine support and tanker off-loading will occur. No unauthorized vessels will be allowed to enter this approximately 4,000 ha operational marine safety exclusion zone. EEPGL will use radar and visual surveillance of the marine safety exclusion zones to monitor vessel traffic. Any vessels that may inadvertently enter the marine safety exclusion zone without authorization will be contacted via radio and instructed to leave the area. If EEPGL is unable to contact the vessel by radio, a Project supply vessel will approach the encroaching vessel and notify them that they have entered a marine safety exclusion zone. If the encroaching vessel ignores these instructions, EEPGL will contact the Guyana Coast Guard for support.

Figure 2-17 Preliminary Safety Exclusion Zones during Drilling, Installation, and Offloading Operations



2.7.4 Offloading Tankers

Conventional tankers supporting offloading operations typically arrive anywhere from one day to several hours ahead of the scheduled loading time, as a function of weather and ocean conditions. When the conventional tanker is ready to approach, a Mooring Master will board the vessel approximately 2 km (~1 mi) from the FPSO, in order to guide it to the FPSO for offloading. The conventional tankers will export the crude oil to the buyer's final location after offloading operations have been completed.

2.8 Onshore, Marine, and Aviation Support

2.8.1 Onshore Supply and Support Activities

Shorebase(s), laydown areas, pipe yards, warehouses, fuel supply, heliport, and waste management facilities in Guyana will be utilized to support development drilling, FPSO/SURF installation, production operations, and ultimately decommissioning. These onshore facilities will be owned/operated by others and will not be dedicated to the Project. The specific shorebase(s) and onshore support facilities (e.g., warehouses, laydown yards) to be utilized in Guyana have not yet been identified by EEPGL. A preliminary footprint estimate for onshore staging and storage in Guyana is approximately 30,000-50,000 m^2. However, the final area required will be determined as the Project development plan progresses. Accordingly, ERM has performed the impact assessment on the basis that the Project will utilize existing shorebase(s) located in Georgetown that meet this minimum requirement. Should any new or expanded shorebase(s) or onshore support facilities be utilized, the construction/expansion and any required dredging, as well as the associated permitting, of such facilities would be the responsibility of the owner/operator and such work scope would not be included in the scope of the EIA.

A typical shorebase quay is shown in Figure 2-18, and a typical laydown yard is shown in Figure 2-19. Where existing Guyana shorebase(s) do not have the technical and/or capacity requirements to support Project activities, EEPGL will potentially consider the use of other onshore support facilities and services in Guyana, as identified and deemed necessary. Additional logistical support may be provided by other regional suppliers outside of Guyana, as informed by inputs from EEPGL contractors after contract award, to address Project needs (e.g., deepwater port access in Trinidad).

Onshore support facilities will include pier/port/quayside space with sufficient draft for receipt of cargo vessels bringing materials to and from the shorebase(s). Marine support vessels will service the offshore activities and operations. A marine berth and secure warehousing space for indoor and outdoor storage of materials and goods, trucking, stevedoring, freight forwarding, customs logistics, receiving, inspection, and associated container handling and storage operations will also be utilized.

Daily activities and operations to be performed at the shorebase(s) will generally include:

- Storage of pipe, equipment and spares;
- Loading and unloading cargo from trucks and marine vessels;
- Use of cranes and other lifting equipment;
- Bulk storage of chemicals, fuels, and industrial consumables;
- Potential operation of a cement and drilling and completion fluids plant to support offshore drilling operations; and
- Secure handling and storage of wastes pending final recycling, treatment, or disposal.

Most of the major SURF equipment will be shipped preassembled and pre-tested directly to the offshore Project site from their points of origin. Other minor equipment, supplies, and materials may be temporarily staged at the shorebase(s) and associated laydown yards and warehouses until transferred offshore for installation or use. The owners/operators of these contracted facilities will be required to seek environmental authorization for any changes to current operations (e.g., bulk storage of chemicals and fuels or facility expansions).

Figure 2-18 Typical Shorebase Quay

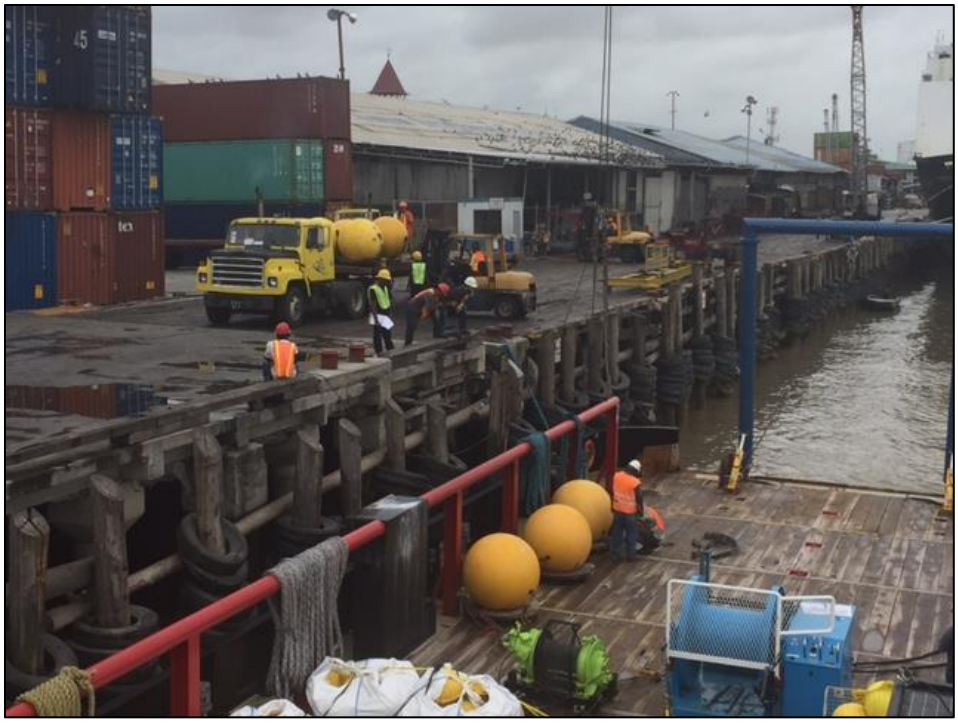


Figure 2-19 Typical Laydown Yard



Support and supply vessels will require sufficient water depths to transit between the Liza field and the shorebase(s). There is potential for some initial and periodic maintenance dredging to be performed by the shorebase owner/operator(s), with any required permitting being the responsibility of the shorebase owners/operators.

2.8.2 Logistical Support

An average of 10 round-trip helicopter flights is currently being made per week to support ongoing exploration drilling activities. It is estimated that during development drilling and FPSO/SURF installation, an incremental 20 to 25 helicopter flights per week will be added, for a total of 30 to 35 round-trip flights per week. During FPSO/SURF production operations, an estimated 20 to 25 round-trip helicopter flights per week will be necessary to support FPSO/SURF production operations and development drilling activities.

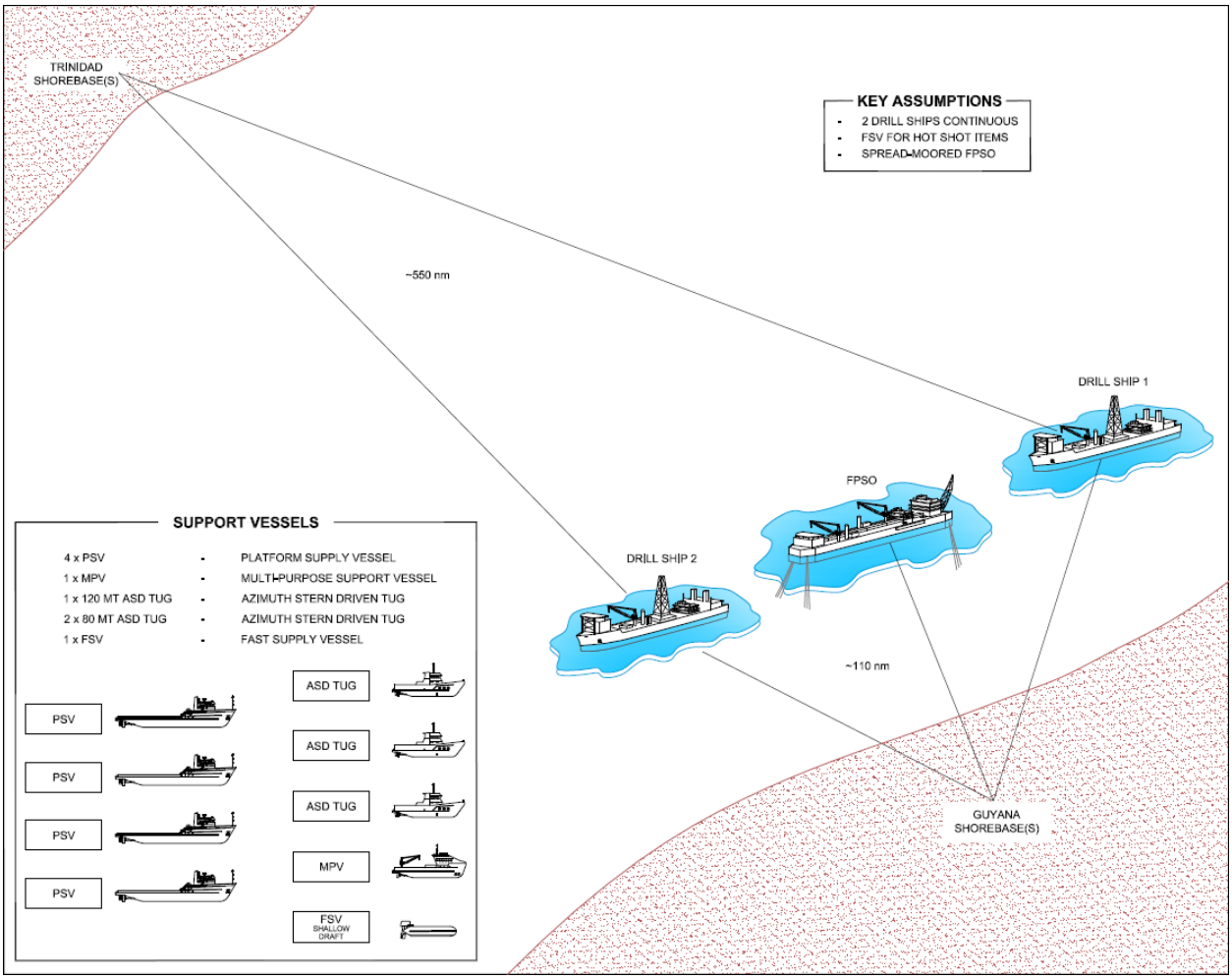
There will be a variety of marine and aviation support equipment supporting the FPSO, installation vessels, and drill ships, as shown on Figure 2-20. The support vessels will consist of Platform Supply Vessels (PSVs) conducting re-supply trips to the FPSO and drill ships, Tug Vessels (TVs) supporting tanker offloading activities, and Multi-Purpose Vessels (MPVs) supporting subsea installation and maintenance activities. Based on current drilling activities and past experience with similar developments, it is estimated that during development drilling and FPSO/SURF installation, an average of 12 vessel trips per week may be made to the PDA. During FPSO/SURF production operations, it is estimated that this number will be reduced to approximately 7 vessel trips per week. The vessels are planned to be loaded and offloaded at shorebase facilities in Guyana and/or Trinidad. Figure 2-21 depicts a conceptual diagram and

estimated number and types of logistical support equipment that will be utilized to support the Project.

Figure 2-20 Typical Logistics Support Vessels



Figure 2-21 Potential Drilling and Operations Stage Peak Fleet Profile



2.9 End of Operations (Decommissioning)

In advance of the completion of the Phase 1 production operations stage, EEPGL will prepare a decommissioning plan for the facility in compliance with the laws and regulations in effect at that time, while also considering the most appropriate technology available at that time. The decommissioning plan and strategy will be based on a notice of the intent for decommissioning the production facilities and plugging and abandonment of the development wells, which will be provided to the GGMC and EPA to obtain approval in accordance with the requirements of the Guyana Petroleum (Exploration and Production) Act (1998) and EP Act (Cap. 20:05).

EEPGL will perform inspections, surveys, and testing to assess, and report to the EPA the conditions that will provide the basis and required information to prepare a plan for decommissioning. All risers, pipelines, umbilicals, subsea equipment, and topside equipment will be safely and properly isolated, de-energized, and cleaned to remove hydrocarbons and other hazardous materials to a suitable level prior to being taken out of service.

Near the time of decommissioning, EEPGL will work with the EPA and the GGMC to select the final decommissioning strategy based on a comparative assessment, which is designed to evaluate the potential safety, environmental, technical, and economic impacts and associated mitigation measures in order to finalize the decommissioning plan.

Wells will be permanently plugged and abandoned (P&A) by restoring suitable cap rock to prevent escape of hydrocarbons to the environment. P&A barriers will be installed in the wellbore, of adequate length to contain reservoir fluids and deep enough to resist being bypassed by fracturing. The number of barriers required will depend on the distribution of hydrocarbon-bearing permeable zones within the wellbore.

It is expected that the risers, pipelines, umbilicals, subsea equipment, FPSO mooring lines and anchor piles will be disconnected and abandoned in place on the seafloor, unless an alternative strategy is selected based on the results of the comparative assessments.

The FPSO will be disconnected from its mooring system, removed from the production location, and towed to a new location for re-use or decommissioning.

Selected waste streams associated with decommissioning activities, including hazardous and non-hazardous wastes, will be managed and disposed of in accordance with standard industry practice and applicable regulations. Methods may include injection downhole into the reservoir, separation and incineration offshore, or transport to onshore waste management facilities for management and disposal.

2.10 Materials, Emissions, Discharges, and Wastes

This section describes the materials (i.e., primarily chemicals) used across the various stages of the Project, as well as the Project's planned emissions, discharges, and wastes.

The Project may potentially produce small amounts of Naturally Occurring Radioactive Material (NORM) from the reservoir over the life of the production operations stage. The Project may also utilize radiography periodically to support installation and maintenance activities

(e.g., non-destructive examination of materials for quality control purposes). The Project will follow standard industry practices to manage any workforce exposure to NORM or radiography. Any equipment containing such sources will be registered, strictly tracked, controlled, and returned to the vendor at the end of their use or if they must be replaced at any time.

The Project will not generate any meaningful vibration which could impact resources/receptors. EEPGL will manage airborne sound through engineering controls, through administrative controls, and by providing appropriate Personal Protection Equipment (PPE) to its Project workforce as described in Section 7.1.2. Underwater sound is discussed as part of the Marine Mammal impact evaluation (see Section 7.2.5). The Project generates heat, primarily in the form of a cooling water discharge to the sea, which is discussed as part of the Marine Water Quality impact evaluation (see Section 7.1.4). The Project generates light, which is discussed as part of the Seabird and Marine Turtle impact evaluations (see Sections 7.2.4 and 7.2.6, respectively).

2.10.1 Materials Inventory

Offshore oil development is primarily an extractive process (e.g., producing oil from the Liza field). This extractive process will, however, require the use of various equipment described in this chapter (e.g., drill ships, pipes, flowlines, FPSO), as well as some chemicals used to facilitate well drilling, oil recovery, water/waste treatment, pipeline maintenance, and other purposes, which have been described in prior sections of this chapter. The required volumes of these chemicals are yet to be determined.

Table 2-2 below provides preliminary inventories of the primary chemicals that would be used as part of the Project's drilling, installation/commissioning and production operation stages, respectively. Residual quantities of drilling and production chemicals may be discharged to the sea as components of drilling fluid or produced water, injected into the reservoir, or emitted to the atmosphere, as described in prior sections of this chapter. Unused or used and recovered chemicals will be re-used, recycled, or disposed of in accordance with applicable regulations and best practices.

All chemicals will be stored, either at the shorebase(s) or on the drill ship or FPSO, in appropriate storage containers (e.g., ATM standard) with either secondary containment or appropriate drainage control.

Table 2-2 Project Materials and Chemicals

Project Phase	Primary Chemical Materials / Products	
Drilling	Water-based drilling fluid (WBDF) • Water, seawater, or inorganic salts • Barite • Clays • Water-soluble biopolymers and modified biopolymers • Thinners • Shale Inhibitors • Calcium Carbonate • Lost circulation material • Caustic Soda • Soda Ash	Non-aqueous drilling fluid (NADF) • Base Oil (IOGP Group III) • Barite • Calcium chloride brine • Organophilic clay • Emulsifier • Wetting Agent • Viscosity modifiers • Fluid loss modifiers • Lime • Calcium Carbonate
	Completion & Treatment Fluids • Brines • Barite • Water Soluble Polymers • Inorganic and Organic Acids • Calcium Carbonate • Caustic Soda • Surfactants • Hydrate Inhibitor • Oxygen Scavenger • Corrosion Inhibitor	Cement • Cement class "G" • Extender • Accelerator • Defoamer • Retarder • Surfactant • Dye
SURF Equipment Commissioning	• Low-toxicity, water soluble hydraulic fluid • Nitrogen • Hydrate inhibitor (e.g., methanol, ethylene glycol)	• Marine gas oil • Biocide • Oxygen scavenger • Corrosion inhibitor
Production Operations	• Corrosion inhibitor • Scale inhibitor • Asphaltene inhibitor • Xylene • Methanol • Deumulsifier • Defoamer	• Polyelectrolyte • Triethylene glycol • Hydrogen sulfide scavenger • Oxygen scavenger • Biocide • Clarifier/coagulant • Hydraulic fluid

2.10.2 Emissions

The Project will include several sources of atmospheric emissions. The principal sources of atmospheric emissions from the Project operations can be divided into four main categories:

- Combustion Emissions: generated from combustion of liquid fuel or natural gas during aviation and marine support and installation activities, operation of the FPSO and drill ships, waste incineration, and non-routine flaring of gas that is not re-injected into the reservoir;
- Venting Emissions: consisting of emissions related to tank storage operations (flashing emissions, standing/working/breathing losses – dominated by FPSO product storage tanks, but also including other tank storage);
- Vessel loading emissions: dominated by emissions released during the transfer of crude oil from FPSO to tankers, but also including fuel transfer operations; and
- Fugitive Emissions: leakage through process equipment components (e.g., valves, flanges), and potential unplanned CFC releases from the HVAC and refrigeration systems.

Table 2-3 provides estimated maximum annual Project atmospheric emissions in three distinct periods, selected to account for differing activity levels over the Project life. Primary activities in each of these periods to which the corresponding emissions can be attributed are as follows:

- 2018 – 2019: Drilling, SURF installation and commissioning, and operation of related support vessels
- 2020 – 2021: Drilling, FPSO startup and associated temporary, non-routine flaring, beginning of production operations, tanker loading
- 2022 – 2040: Production operations following cessation of drilling, including temporary non-routine flaring, operation of related support vessels, and tanker loading.

Table 2-3 Annual Air Emissions Summary

Pollutant	Source Category	Annual Emissions (Tonnes unless otherwise specified)		
		2018-2019	2020-2021	2022-2040
Nitrogen Oxides (NO_x)				
	FPSO	0	1,635	1,545
	FPSO Flaring (temporary, non-routine)	0	375	175
	Tanker Loading	0	135	140
	Area Sources[11]	2,385	1,125	1,125
	Drill ship	1,255	1,670	0
	Total	3,640	4,945	2,975
Sulfur Dioxide (SO_2)				
	FPSO	0	45	50
	FPSO Flaring (temporary, non-routine)	0	0	5
	Tanker Loading	0	110	115
	Area Sources	85	40	40
	Drill Ship	45	60	0
	Total	130	250	205
Particulate Matter (PM)				
	FPSO	0	45	35
	FPSO Flaring (temporary, non-routine)	0	15	5
	Tanker Loading	0	10	10
	Area Sources	170	80	80
	Drill Ship	90	120	0
	Total	260	210	130
Carbon Monoxide (CO)				
	FPSO	0	425	405
	FPSO Flaring (temporary, non-routine)	0	2,030	940
	Tanker Loading	0	30	30
	Area Sources	500	235	235
	Drill ship	265	350	0
	Total	765	3,070	1,610
Other Pollutants				
Hydrogen Sulfide (H_2S)	FPSO Flaring (temporary, non-routine)	n/a	< 1	< 1
Volatile Organic Compounds (VOCs)	All Sources	95	10,250	10,720
Greenhouse Gases (GHGs [kilotonnes CO_2-equivalents])	All Sources	195	1,510	980

Note: The annual estimated totals currently reflect the preliminary Project schedule, which could change.

[11] Area Sources are mobile equipment such as aviation and marine support vessels (besides the FPSO and drill ships) used during drilling, installation, production operations, and decommissioning.

2.10.3 Discharges

The Project will have several planned discharges to water related to the operations and maintenance of the drill ships, FPSO, installation and commissioning activities. These planned discharges, based on the preliminary design information, are listed in Table 2-4. Potential discharges include drill cuttings and fluids, well completion and treatment fluids, produced water, cooling water, sulfate removal and potable water processing brines, topsides drainage, hydrostatic test water, ballast water, BOP testing fluids, and sanitary and domestic wastewater, as described below. All Project vessels will be equipped to comply with the water pollution control standards required by the International Maritime Organization (IMO) International Convention for the Prevention of Pollution by Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78).

Drill Cuttings and Fluids: WBDF, as listed in Table 2-2, and associated cuttings will be discharged to the sea without treatment per standard industry practice. The process for treating and discharging cuttings with residual NABF, as listed in Table 2-2, is described in Section 2.3.3.

Cement: Cement slurry returns are only expected during the cementing of the first casing string for each development well. The excess spacer and lead slurry will be discharged directly to the seafloor immediately around the well. Excess/unused cement will be discharged to the sea.

Well Completion and Treatment Fluids: Well completion and treatment fluids will be treated and discharged to the sea or shipped to shore for appropriate treatment/disposal per standard industry practice.

Produced Water: The produced water treating system will collect produced water from process facilities and treat the water prior to discharge overboard, as described in Section 2.5.3.3.

Cooling Water: Seawater is used to dissipate heat generated by the oil and water treating systems, the compression systems, and miscellaneous utility systems. Process hydrocarbon fluids do not come into contact with this seawater. Cooling water will be disposed of overboard at a suitable temperature so as not to significantly impact marine life.

Sulfate Removal & Potable Water Processing Brines: These brine disposal streams are byproducts of the membrane processes used offshore to generate sulfate-free water for injection and to generate fresh water for crude desalting and for living quarters requirements. No treatment of these streams (essentially seawater) is required prior to discharge.

Topsides Drainage: The topsides will have a non-hydrocarbon and hydrocarbon drain system. The hydrocarbon drain system will direct drainage to a slop tank, where oil and water will be gravity separated. Once separated, the oil will be skimmed off the top and sent to the cargo tanks, and the water will be discharged overboard in accordance with treatment specifications. The non-hydrocarbon drain system (e.g., rainwater) will route the drain fluids to the slop tank in the FPSO hull or directly overboard.

Hydrostatic Test Water: Seawater treated with chemicals (e.g., biocides) will be injected in the flowlines and risers to ensure the lines are sealed properly during installation, prior to the flow

of hydrocarbons. The treated seawater used for hydrostatic testing of the water and gas injection lines will be discharged near the seafloor per standard industry practice. The treated seawater used for hydrostatic testing of the production lines will be round-trip pigged to the FPSO and will be treated and discharged overboard with produced water.

Commissioning Fluids: A hydrate inhibiting substance (e.g., methanol or ethylene glycol) will be used to prevent formation of hydrates during commissioning of the production and gas injection lines. The fluid used for the gas injection line will be discharged at the seafloor, and the fluid used for the production lines will be returned to the FPSO, treated, and discharged from the overboard water line.

Ballast Water: Discharges of ballast water will be required for initial FPSO installation and recurring tanker offloading.

BOP Testing Fluids: During periodic testing (approximately every two weeks) of the BOP system, approximately 30 barrels of low-toxicity power fluid (i.e., fluid used to hydraulically move the preventers) will be discharged near the seafloor. The typical composition of this fluid is ~97 percent water with ~3 percent biocide/lubrication/corrosion protection chemicals.

Gray Water/Black Water/Food Preparation Wastes: The Project will provide wastewater treatment for sanitary wastes (black water/sewage) and food preparation wastes in accordance with MARPOL requirements. Gray water will be discharged overboard.

Table 2-4 summarizes drilling-related discharges and Table 2-5 summarizes commissioning and production-related discharges.

Table 2-4 Summary of Drilling and Completion-Related Discharges

Fluid Type	Estimated Discharge Per Well (bbl) [a]
Drill Cuttings Discharges	6,000
Water-Based Drilling Fluid (WBDF) Discharges	13,000
Non-Aqueous Base Fluid (NABF) retained on cuttings	400
Cement Returns	3,800
Completion and Treatment Fluids	6,000

[a] Values based on deepest well

Table 2-5 Summary of Commissioning and Production-Related Discharges

Type of Discharge and Effluent Characteristics	Expected Discharge Volume/Rate	Discharge Criteria	Treatment Required to Meet Criteria?
SURF & FPSO Installation / Commissioning Discharges			
Ballast Water (FPSO initial deballasting)	≤ 500,000 bbl total	1) Perform discharge in accordance with IMO requirements 2) No visible oil sheen on receiving water	No
Hydrostatic Test Water • Biocide: ≤ 500 ppm • Oxygen scavenger ≤ 100 ppm • Corrosion inhibitor ≤ 100 ppm	25,000 bbl (total volume for all flowlines and risers, occurring throughout SURF commissioning phase)	No visible oil sheen on receiving water	No
Gas Injection Line Commissioning Fluids • Hydrate inhibitor (e.g., methanol or ethylene glycol)	400 bbl total	None	N/A
Production Discharges			
Produced Water • Oil & Grease • Residual production and water treatment chemicals	≤ 100,000 bpd	Oil in water content: 29 mg/L (monthly average); 42 mg/L (daily maximum)	Yes
Cooling Water • Hypochlorite: ≤ 5 ppm	≤ 700,000 bpd	No visible oil sheen on receiving water Temperature rise <3°C at 100 m from discharge	No
Sulfate Removal & Potable Water Processing Brines • Hypochlorite: ≤ 1 ppm • Electrolyte: ≤ 1 ppm • Biocide: ≤ 5 ppm • Oxygen Scavenger: ≤ 10 ppm • Scale Inhibitor: ≤ 5 ppm	≤ 100,000 bpd	None	N/A
Subsea Hydraulic Fluid Discharge • Water soluble, low-toxicity	≤ 5 bpd	None	N/A
FPSO Bilge Water	1,800 bpd	Oil in water content: <15 mg/L	Yes
Inert Gas Generator Cooling Water	Negligible	None	N/A

Type of Discharge and Effluent Characteristics	Expected Discharge Volume/Rate	Discharge Criteria	Treatment Required to Meet Criteria?
FPSO Slop Tank Water	Negligible	Oil in water content: 29 mg/L (monthly average); 42 mg/L (daily maximum)	Yes
Miscellaneous Discharges including Boiler Blowdown, Desalinization Blowdown, Lab Sink Drainage	<10 bpd	None	N/A
Tanker Ballast Water	1,100,000 bbl total (at each tanker crude loading)	1) Perform in accordance with IMO requirements 2) No visible oil sheen on receiving water	No
BOP System Testing Water-Soluble Low-Toxicity Hydraulic Fluid	30 bbl every two weeks	None	N/A
Rain Water/Deck Drainage/Wash Down Water	Rainfall dependent	No visible oil sheen on receiving water	N/A
Gray Water	5,000 bpd	None	N/A
Black Water (sewage)	4,000 bpd	Total residual chlorine as low as practical but not less than 1 ppm	Yes
Food Preparation Wastes	<30 bpd	Macerated to <25 mm diameter	Yes

Notes:
bbl = barrels
bpd = barrels per day

2.10.4 Waste Management

The Project will generate a variety of solid wastes including both hazardous and non-hazardous wastes, which vary over time by Project stage. As Table 2-6 indicates, waste will begin to be generated when drilling commences, as early as 2018 per the current project schedule. Waste volumes generated will increase as drilling activity increases in 2019 and 2020. Additional waste will be generated from SURF installation and FPSO commissioning and hookup activities in the 2019-2020 timeframe. Waste volumes will then begin to decrease as drilling activity declines in 2021 and significantly decrease during the production operations stage once drilling activity is complete (2022 to 2039). When production operations cease, some waste will be generated from decommissioning activities.

Table 2-6 Summary of Estimated Annual Project Waste Generation and Management Methods

	Representative Waste Streams	Estimated Annual Waste Generation (metric tonnes)[1]					
		2018	2019	2020	2021	2022-2039	2040
Totals by Classification							
Non-hazardous wastes[2]	Plastic, glass, paper, scrap metal	1850	4220	5870	2480	400	330
Hazardous wastes	Used oil, paint waste, oil-contaminated cement	1770	4050	5470	2170	190	210
Totals by Management Method							
Offshore Incineration	Wood, paper, cardboard	250	600	830	360	80	110
Onshore Treatment / Incineration	Used NADF, oil sludge, unused chemicals	1670	3820	5140	2014	140	140
Onshore Landfill (all non-hazardous)[2]	General trash, incinerator ash,	1610	3630	5030	2080	280	230
Recycle into Process	Used oil, oily water	0	0	20	30	30	20
Recycle (all non-hazardous)	Plastic, glass, scrap metal	90	220	320	170	70	60

(1) The annual totals reflect the current preliminary Project schedule (see Section 2.14), which could change.

(2) Non-hazardous volumes include estimated quantities of residue from treatment of hazardous waste

Solid waste generated offshore will be reduced, recycled, treated, and disposed offshore (i.e., incinerated and accounted for in Table 2-4 under FPSO source) where practicable, with the remainder directed for onshore treatment, recycling, reuse, or disposal. For the exploration drilling program, EEPGL is currently utilizing a regional supplier who is operating an existing onshore waste treatment/incineration facility at a local shorebase in Georgetown, Guyana (see Figures 2-22 and 2-23). The Project is planning to utilize similar facilities in Guyana or the region during the development drilling, FPSO/SURF production operations, and decommissioning stages. To the extent that solid wastes are being disposed of by a Guyanese licensed onshore disposal facility (i.e., landfill, incinerator) in accordance with their permit, then impacts from the proper disposal of these wastes are not further discussed in this EIA. All Project waste streams will be managed in accordance with the Waste Management Plan that will be part of the Project Environmental and Socioeconomic Management Plan (ESMP).

Figure 2-22 Typical Waste Management Facilities at a Local Shorebase



Figure 2-23 Vertical Infrared Unit with Wet Scrubber and Oxidizer at Typical Waste Management Facilities



2.11 Embedded Controls

EEPGL has incorporated the embedded controls[12] provided in Table 2-7 into the Project:

Table 2-7 List of Embedded Controls

Embedded Control Measures	Resources/Receptors Benefitted
Drilling and SURF/FPSO Installation and Commissioning	
• Utilize WBDF to the extent reasonably practicable and in other cases use low-toxicity IOGP Group 3 NABF.	Marine sediments, water quality, mammals, turtles, fish, and benthos
• When NADF is used, utilize a solids control and cuttings dryer system to treat drill cuttings prior to discharge such that end of well maximum weighted mass ratio averaged over all well sections drilled using non-aqueous fluids shall not exceed 6.9 percent wet weight base fluid retained on cuttings.	Marine sediments, water quality, mammals, turtles, fish, and benthos
• For VSP activities, commence such operations during daylight hours after a suitable pre-watch by Marine Mammal Observers (MMOs) is performed and begin with soft start procedures, which incrementally increase source sound levels in order to allow marine mammals and turtles time to move away from the activity before full sound source energy is utilized, in accordance with JNCC guidelines.	Marine mammals, marine turtles
• With respect to prevention of spills of hydrocarbons and chemicals during the drilling stage: o Change liquid hydrocarbon transfer hoses periodically o Utilize dry-break connections on liquid hydrocarbon bulk transfer hoses o Utilize a liquid hydrocarbon checklist before every bulk transfer o Perform required inspections and testing of all equipment prior to deployment/installation; o Utilize certified Blowout Prevention (BOP) equipment; o Regularly test certified BOP equipment and other spill prevention equipment; o Utilize overbalanced drilling fluids to control wells while drilling; o Perform operational training certification (including well control training) for drill ship supervisors and engineers; o Regularly audit field operations on the drill ships, FPSO, and shorebase(s) to ensure application of designed safeguards; and o Controls for mitigating a failure of the dynamic positioning system on the drill ships and maintain station keeping, which include:	Air quality, marine sediments, marine water quality, protected areas, sensitive species, coastal habitats, coastal wildlife and shorebirds, marine mammals, turtles, fish, benthos, ecology and ecosystems

[12] Embedded controls are engineering specifications, components, and/or operational procedures that are planned as part of the Project.

Embedded Control Measures	Resources/Receptors Benefitted
▪ Use of a Class 3 Dynamic Positioning (DP) system, which includes numerous redundancies; ▪ Rigorous personnel qualifications and training; ▪ Seatrials and acceptance criteria; ▪ Continuous DP proving trials; ▪ System Failure Mode and Effects Analysis; ▪ Continuous DP failure consequence analysis; and ▪ Establishment of well-specific operations guidelines.	
• During pile driving activities, gradually increase the intensity of hammer energy to allow sensitive species to vacate the area before injury occurs (i.e., soft starts).	Marine mammals
• Maintain marine safety exclusion zones with a 500 m (~1,640 ft) radius around drill ships and major installation vessels to prevent unauthorized vessels from entering potentially hazardous areas.	Marine use and transportation safety
Production Operations	
• Re-inject produced gas which is not utilized as fuel gas on the FPSO to avoid routine flaring. With respect to non-routine flaring, the following measures will be implemented: o Monitor flare performance to maximize efficiency of flaring operation; o Ensure flare equipment is appropriately inspected and function tested prior to production operations; and o Ensure flare equipment is appropriately maintained and monitored during production operations.	Air quality
• Treat produced water on the FPSO to limit oil and grease (O&G) content to 29 mg/L monthly average and 42 mg/L daily maximum.	Marine water quality, mammals, turtles, fish, and benthos, seabirds, ecology and ecosystems
• Design cooling water process to avoid increases in ambient water temperature of more than 3˚C at 100m (~328 ft) from the FPSO when discharging.	Marine water quality, mammals, turtles, fish, and benthos, seabirds, ecology and ecosystems
• Perform onboard waste incineration for certain categories of waste.	Land use
• Utilize a Mooring Master from the FPSO located onboard the offloading tanker to support safe tanker approach/departure and offloading operations.	Marine use and transportation safety
• Utilize support tugs to aid tankers in maintaining station during approach/departure from FPSO and during offloading operations.	Marine use and transportation safety
• Utilize a hawser with a quick release mechanism to moor the FPSO to the tanker at a safe separation distance during offloading operations.	Marine use and transportation safety
• FPSO offloading to tankers will occur within an environmental operating limit that is established to ensure safe operations. In the event that adverse weather occurs during offloading operations that is beyond	Marine sediments, water quality, mammals, turtles, fish, benthos, and

Embedded Control Measures	Resources/Receptors Benefitted
the environmental operating limit the tanker will cease the offloading operations, and may disconnect and safely maneuver away from the FPSO as appropriate.	seabirds
• Utilize a marine bonded, double-carcass floating hose system certified by Class or other certifying agency that complies with the recommendations of OCIMF Guide to Manufacturing and Purchasing Hoses for Offshore Moorings (GMPHOM) 2009 Edition or later.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Utilize breakaway couplers on offloading hose that would stop the flow of oil from FPSO during an emergency disconnect scenario.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Utilize a load monitoring system in the FPSO control room to support FPSO offloading.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Utilize leak detection controls during FPSO offloading which include: o Leak detection for breach of the floating hose that complies with the recommendations of OCIMF GMPHOM 2009 Edition or later; o Utilization of instrumentation/procedures to perform volumetric checks during offloading.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Provide trained medical personnel on board the FPSO and major installation vessels to minimize reliance on medical infrastructure and facilities in Guyana.	Community health and wellbeing
• Utilize marine safety exclusion zone of 2 nautical miles around the FPSO to prevent unauthorized vessels from entering potentially hazardous areas.	Marine use and transportation safety
• Tankers will conduct ballasting operations in accordance with IMO regulations.	Ecological Balance and Ecosystems
General Measures	
• Maintain equipment, marine vessels, and helicopters in good working order and operate in accordance with manufacturer's specifications in order to reduce atmospheric emissions and sound levels to the extent reasonably practicable.	Air quality, water quality, marine mammals, marine turtles
• Regularly inspect and service shorebase cranes and construction equipment in order to mitigate the potential for spills and to maintain air emissions at optimal levels.	Air quality
• Shut down (or throttle down) sources of combustion equipment in intermittent use where reasonably practicable in order to reduce air emissions.	Air quality
• Utilize secondary containment for bulk fuel storage, drilling fluids, and hazardous materials, where practical.	Water quality
• Regularly check pipes, storage tanks, and other equipment associated with storage or transfer of hydrocarbons/chemicals for leaks.	Water quality
• Perform regular audits of field operations on the drill ship, FPSO, and shorebase to ensure application of designed safeguards.	Air quality, water quality

Embedded Control Measures	Resources/Receptors Benefitted
• Treat sewage to applicable standards under MARPOL 73/78.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• For those wastes that cannot be reused, treated, or discharged/disposed on the drill ship or FPSO they will be manifested and safely transferred to appropriate onshore facilities for management. Waste management contractors will be vetted prior to utilization. If deficiencies in contractors' operations are noted, an action plan to address the identified deficiencies will be established.	Land use
• Utilize oil/water separators to limit oil in water content in bilge water to <15 parts per million (ppm; per MARPOL).	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Provide standing instruction to Project dedicated vessel masters to avoid marine mammals and turtles while underway and reduce speed or deviate from course, as needed, to reduce probability of collisions.	Marine mammals, marine turtles
• Provide standing instruction to Project dedicated vessel masters to avoid any identified rafting seabirds when transiting to and from PDA.	Seabirds
• Observe standard international and local navigation procedures in and around the Georgetown Harbour and Demerara River, as well as best ship-keeping and navigation practices while at sea.	Marine use and transportation safety
• Project workers will be subject to health screening procedures to minimize risks of communicable diseases.	Community health and wellbeing
• Utilize an established SSHE program to which all Project workers and contractors will be required to mitigate against risk of injury/illness to workers. • All workers and contractors will receive training on implementation and will be required to adhere to its principles.	Occupational and community health, safety, and wellbeing
• Maintain an OSRP to ensure an effective response to an oil spill, including maintaining the equipment and other resources specified in the OSRP and conducting periodic training and drills.	All resources and receptors
• Where practicable, direct lighting on FPSO and major vessels to required operational areas rather than at the sea surface or skyward.	Seabirds and marine turtles
• Provide screening on FPSO and drill ships for seawater intakes to minimize the entrainment of aquatic life, where practical.	Marine fish

2.12 Project Workforce

Preliminary workforce estimates are provided in Table 2-8. These estimates have been slightly revised since submittal of the Application for Environmental Authorisation.

Table 2-8 Workforce Estimates

Project Stage	Estimated Workforce
Development Drilling	Approximately 600 persons offshore at peak, when utilizing up to two drill ships concurrently (Dependent upon final drill ships and support vessels selected)
Installation, including FPSO and SURF Mobilization, and Hook-up/Commissioning	Approximately 600 persons offshore at peak (Dependent upon final installation and support vessels selected)
Production Operations, including FPSO and conventional tanker	Approximately 100 to 140 persons offshore at peak (an additional 25 to 30 persons would be onboard the tanker) (Dependent upon conventional tanker schedule)
Decommissioning	Approximately 60 persons offshore at peak

In addition to the offshore components, there will also be personnel providing shorebase and marine logistical support onshore (approximately 100-150 persons), some of whom will be Project-dedicated while others will be shared resources. The onshore logistical support staff will ramp up gradually through the installation stage until reaching a peak during the development drilling campaign and FPSO/SURF installation activities, and then will diminish during FPSO/SURF production operations. The logistical support onshore staff level is expected to increase again briefly during decommissioning.

2.13 Worker Health and Safety

EEPGL and its parent company, ExxonMobil, are committed to protecting the safety, security, and health of its employees, contractors, and the public, with a goal of *Nobody Gets Hurt*. It has a robust and effective management system to protect its Project workforce. EEPGL will implement its Operations Integrity Management System (OIMS) (see Section 2.2) during each Project stage. This program is designed to manage occupational risks to Project workers and, therefore, occupational health and safety are not discussed further in this EIA.

2.14 Project Schedule

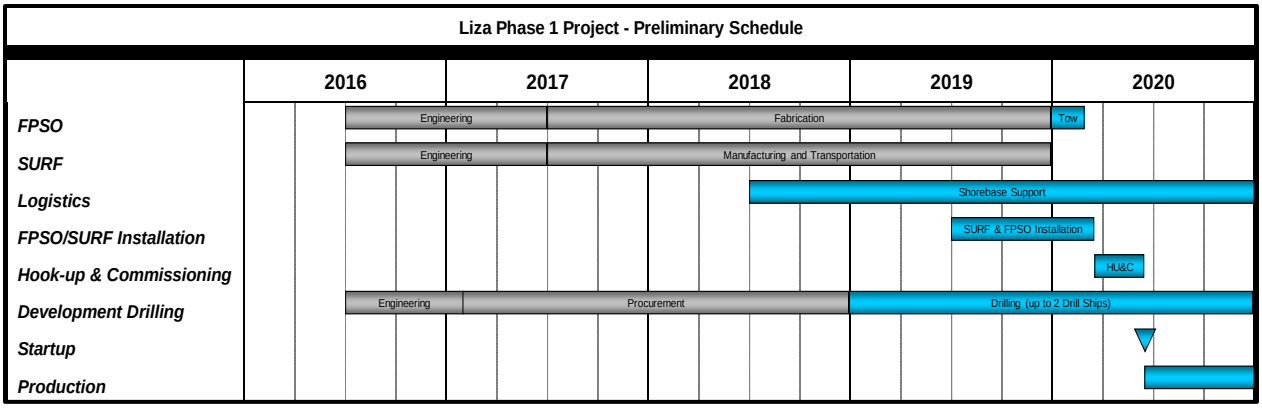
At this time, the proposed Project schedule is still being refined. The Project life cycle will include development drilling, installation, production operations, and decommissioning, as well as associated logistics and onshore support. The engineering stage will precede FPSO and SURF installation and development drilling operations, and will include front-end engineering and design (FEED) and detailed engineering. The execution stage will include procurement,

fabrication and construction, drilling, installation, hook-up, commissioning, and start-up. Operations and maintenance will follow start-up and will be the longest stage of the Project.

Figure 2-24 provides a preliminary schedule for the major Project components and activities. As depicted on Figure 2-24, oil production and export from the Project is planned for approximately mid-2020. To support this goal, development well drilling from up to two drill ships is planned to start in early 2019, with the potential for mobilization in 2018. The installation of the SURF components and the FPSO are planned to commence in 2019. Production will continue for at least 20 years. The milestones are still being refined and are subject to change.

This schedule provides for simultaneous development drilling and FPSO/SURF production operations, which will involve bringing the initial production wells online as subsequent development wells are being drilled.

Figure 2-24 Preliminary Project Schedule



2.15 Project Benefits

The Project will generate benefits for the citizens of Guyana in several ways:

- Through revenue sharing with the Government of Guyana, although the details of this revenue sharing is confidential. The type and extent of benefits associated with revenue sharing will depend on how decision makers in government decide to prioritize and allocate funding for future programs, which is unknown and outside the scope of the EIA;
- By procuring select Project goods and services from Guyanese businesses to the extent reasonably practicable; and
- By hiring Guyanese nationals where reasonably practicable, although the potential magnitude of hiring will be limited.

In addition to direct revenue sharing, expenditures, and employment, the Project would also likely generate induced economic benefits as other non-Project related businesses benefiting from direct Project purchases or worker spending will re-invest locally or expand spending in the area, thereby also generating more local value-added tax. These beneficial "multiplier" impacts will occur throughout the Project life.

2.16 Alternatives

This section describes the alternatives to the proposed Project that were considered:

- Location alternatives;
- Development concept alternatives;
- Technology and process alternatives; and
- No-go alternative.

2.16.1 Location Alternatives

The location of the Project, and the development wells in particular, is driven by the location of resource to be recovered. There are no meaningful location alternatives for the FPSO, SURF equipment, and drill centers within the PDA.

2.16.2 Development Concept Alternatives

Given the water depth and distance to shore of the Liza field, the development alternatives for Phase 1 are primarily limited to floating production systems (e.g., FPSO, semi-submersible, tension leg platforms). With the exception of the FPSO concept, the other deepwater production systems would necessitate the use of a separate Floating Storage and Offloading (FSO) vessel for oil storage and offloading in order to enable export of the oil to buyers. The use of an FSO would significantly increase the Project offshore infrastructure, which would increase Project impacts on air quality (e.g., increased air emissions), marine water quality (e.g., additional wastewater discharges), marine benthos (e.g., increased disturbance of the seafloor FSO for mooring system), marine use and transportation (e.g., expanded exclusion zones for other marine vessels). Therefore, the FPSO was chosen as the preferred concept for Phase 1 because it is a more efficient, stand-alone solution for deepwater oil processing and storage, and it also provides for fewer environmental impacts.

Three primary alternatives were considered for addressing associated gas produced during Phase 1 operations: gas re-injection, gas export, and continuous flaring. Gas re-injection was determined to be feasible for Phase 1, and it also provides benefits in reservoir management and reduced air emissions. As such, produced gas not used as fuel gas on the FPSO will be re-injected under normal operations. Continuous flaring of gas on a routine basis is not preferred, primarily due to the associated air emissions. Gas export alternatives for future development continue to be evaluated, particularly given challenges related to commercialization of associated gas. The FPSO has been designed to allow for future gas export should an export alternative be identified.

2.16.3 Technology Alternatives

EEPGL is using the most appropriate industry-proven technology in developing the Project in terms of well drilling, drilling fluids, equipment selection, development concepts, and environmental management. EEPGL's parent company Exxon Mobil and its contractors have extensive experience in delivering offshore deepwater development projects around the world,

particularly with FPSO and SURF components, and are applying that knowledge, experience, and technology in the development of the Project in Guyana.

2.16.4 No-go Alternative

The no-go alternative means that the proposed Project would not be executed. If this alternative is applied, the existing conditions described in Chapter 6 would remain unaffected by the Project and the potential positive and negative impacts assessed in Chapter 7 would not be realized. Therefore, evaluating the no-go alternative means evaluating the tradeoff between positive and negative impacts.

2.16.5 Summary of Alternatives

EEPGL considered a reasonable range of alternatives to the Project and their environmental impacts, and has selected the best action alternative, which is also the environmentally preferred alternative, for use during Phase 1. The FPSO and SURF production system is a proven development concept for deepwater oil developments and would leverage both operator and industry proven technologies and experiences.

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3.0 ADMINISTRATIVE FRAMEWORK

The Project must comply with applicable policies, guidelines, and legislation in Guyana (see Section 1.1, *Purpose of the EIA*). This chapter reviews the relevant legislations and policies in Guyana that are applicable to the Project and is divided into three sections:

- Section 3.1 describes Guyana's national legal framework, focusing on laws that apply to environmental issues in a general context such as the Constitution of Guyana, as well as specific national laws and regulations that focus on environmental issues such as the EP Act (Cap. 20:05) and the Environmental Protection (Authorisation) Regulations of 2000, and petroleum development issues. It also identifies several resource-specific environmental laws that are more narrowly focused and are directly or indirectly relevant to the Project.
- Section 3.2 describes the elements of the national policy framework that apply to the Project. These strategies and policies articulate the government's goals with respect to various environmental issues.
- Section 3.3 describes the various international and regional conventions and protocols to which Guyana is a signatory that are applicable to the Project.

In addition to these Guyana regulations, Section 3.4 discusses EEPGL's Operations Integrity Management System (OIMS), which establishes common expectations to address risks inherent in its business.

3.1 National Legal Framework

This section provides an overview of the key legislation currently in force in Guyana that pertains to resources that could be affected by the Project.

3.1.1 National Constitution of Guyana

Guyana is governed according to the Constitution of the Co-operative Republic of Guyana, as amended. The constitution took effect in 1980 and expressly provides for protection of the environment. Article 25 establishes "improvement of the environment" as a general duty of the citizenry.

3.1.2 National Constitution of Guyana

In 1996, the EP Act (Cap. 20:05) was ratified to implement the environmental provisions of the Constitution. The EP Act (Cap. 20:05) is Guyana's single most significant piece of environmental legislation because it articulates national policy on important environmental topics such as pollution control, the requirements for environmental review of projects that could potentially impact the environment, and the penalties for environmental infractions. It also provides for the establishment of an environmental trust fund. Most importantly, the EP Act (Cap. 20:05) authorized the formation of the EPA, and establishes the EPA as the lead agency on environmental matters in Guyana (FAO, 2013). The EPA is one of the agencies included within the Ministry of Natural Resources. The EP Act (Cap. 20:05) further mandates

the EPA to oversee the effective management, conservation, protection, and improvement of the environment (EPA, 2012). It also requires the EPA to take the necessary measures to ensure the prevention and control of pollution, assessment of the impact of economic development on the environment, and the sustainable use of natural resources.

The EPA has issued an official guidance document entitled "Environmental Impact Assessment Guidelines" which describes the general components and content of a typical EIA. This EIA has been prepared consistent with the recommendations in this document (see Table 1-2).

3.1.3 The Guyana Geology and Mines Commission Act

The Guyana Geology and Mines Commission Act was enacted in 1979 and authorized the government to establish the GGMC, which is within the Ministry of Natural Resources. The GGMC promotes and regulates the exploration and development of the country's mineral resources. The GGMC has a dedicated Petroleum Unit charged specifically with regulatory supervision of the oil and gas sector; however, petroleum-related activities also occur in other divisions, such as the Geological Services Division and the Environment Division.

3.1.4 The Petroleum Act

The Petroleum (Exploration and Production) Act was enacted in 1986 to regulate the prospecting for and production of petroleum in Guyana, including the territorial sea, continental shelf, and exclusive economic zone. This act identifies persons allowed to hold prospecting licenses, establishes the process for obtaining prospecting licenses, and specifies requirements for further resource development in the event petroleum resources are discovered.

The GGMC has a dedicated Petroleum Unit charged specifically with regulatory supervision of the oil and gas sector; however, petroleum-related activities also occur in other divisions, such as the Geological Services Division and the Environment Division. In 2012, the Commonwealth Secretariat was commissioned by the Government's then Ministry of Natural Resources and Environment, now the Ministry of Natural Resources, to prepare recommendations to reform Guyana's regulatory regime that governs the upstream petroleum sector. In September 2015, the Minister of Governance (via the GGMC's Petroleum Unit) announced plans to upgrade the country's upstream oil and gas policy, which was originally crafted in 2012 and finalized in 2014. In June 2016, the Ministry of Natural Resources completed a new national oil and gas policy and announced pending revisions to the Petroleum Act. These revisions were due for consideration by Guyana's National Assembly before the end of 2016 (Kaieteur News, 2016) but had not been presented for approval as of February 2017. In late January 2017, Guyana's Government Information Agency (GINA) announced the Ministry of Natural Resources' plan to conduct a national outreach program to provide information to the public and answer questions on the emerging oil and gas sector (GINA, 2017).

3.1.5 Other Resource-Specific National Environmental and Social Laws

Several additional Guyanese environmental laws with more narrowly defined scopes pertain to specific biological or physical natural resources. Other laws which primarily have a public health related focus are also indirectly related to the environment. Several of Guyana's environmental statutes were enacted prior to the 1980 Constitution and were subsequently incorporated into the newly formed national legal framework, but most were enacted after 1980. Table 3-1 identifies these laws and summarizes their relevance to the Project.

Table 3-1 Resource-Specific Environmental and Social Laws

Title	Objective	Relevance to the Project
Biological Resources		
Fisheries Act, 2002	Regulates fishing and related activities in Guyana territorial waters.	The Fisheries Act authorizes the prohibition and/or regulation of deposition or discharge of substances harmful to fish. Would primarily affect the contents of routine discharges from Project vessels and the FPSO.
Wild Birds Protection Act, 1987	Protects listed wild birds in Guyana.	Sections 3 and 6 prohibit knowingly wounding or killing wild birds listed in the First and Second Schedule of the Act and establishes penalties.
Species Protection Regulations, 1999	Provides for the establishment of a Management Authority and a Scientific Authority in compliance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	Provides for wildlife protection, conservation, and management.
Wildlife Management and Conservation Regulations, 2013 (recently supplemented by passing of Wildlife Conservation and Management Bill, 2016)	Provides for the establishment of a Management Authority and the management of the country's flora and fauna.	Provides a supportive mechanism cognizant of the national goals for wildlife protection, conservation, management and sustainable use.

Physical Resources		
Environmental Protection Water Quality Regulations, 2000	Focused on setting effluent standards, reporting requirements, penalties for violations of standards, and permitting requirements for discharges.	Regulates discharges of listed substances, which could include substances used during the Project. Would affect the concentrations of certain constituents (primarily metals, but including others such as nitrogenous compounds, fluoride, and sulfate) that could be discharged in the routine discharges from the Project.
Environmental Protection Air Quality Regulations, 2000	Sets ambient air quality standards, reporting requirements, penalties for violations of standards, and permitting requirements for stationary and mobile sources.	Regulates discharges that could be emitted during the Project, including smoke, particulates, and carbon monoxide (CO).
Environmental Protection Hazardous Waste Regulations, 2000	Establishes requirements for generating, handling, and disposing of hazardous waste as well as penalties for violations of these requirements.	Identifies wastes subject to regulation, including several types of waste that could be produced by the Project.
Toxic Chemicals Control Act No. 13 of 2000, as amended in 2007	Provides for the formation of a Pesticides and Toxic Chemicals Control Board. Establishes requirements for registration, licensure, and trade in pesticides and toxic chemicals. Amended in 2007 to provide rules for the exportation of pesticides and toxic chemicals.	Establishes regulations pertaining to the use of toxic chemicals and pesticides. Pesticides will not be required for this Project, but small amounts of chemicals may be used. The Act would regulate the importation, registration, and use of these chemicals.
Environmental Protection Noise Management Regulations, 2000	Establishes general provisions for noise avoidance and restrictions from multiple commercial and industrial sources including sound making devices, night clubs, equipment, tools, and construction activities.	Tools and equipment includes pile drivers, steam shovels, pneumatic hammers, pumps, vent or valve devices and any other similar equipment. A regulated facility includes any offshore installation and any other installation, whether floating or resting on the seabed.

Draft Guyana Standard, Requirements for Industrial Effluent Discharge into the Environment, 2015	Compulsory standard used for monitoring of effluents into freshwater, estuarine, and marine water resources.	Sets limits for key parameters in discharges of industrial effluent. Would affect the concentrations of many of the same constituents in routine discharges that would be regulated under the Environmental Protection Water Quality Regulations 2000. Would also dictate the general water chemistry parameters (e.g., temperature, biological oxygen demand, pH) of these discharges.
Public Health		
Occupational Safety and Health Act, 1997	Legally defines the responsibilities of workers and management with respect to keeping workplaces safe.	Would generally apply to workers and Project-related activities on the Project site(s).
Food & Drug Regulations (Food and Drug Act)	Regulates the sale, advertisement, preparation, and handling of food products. Regulates the manufacture, advertisement, trade, and administration of pharmaceuticals. Provides the Ministry of Health authority to inspect facilities to establish compliance with sanitation standards.	Governs the preparation of food and provision of medications at Project facilities.
Social / Cultural Resources		
National Trust Act	Stewardship of historic resources and places of cultural significance.	Governs the management of any building, structure, object, or other man-made or natural feature that is of historic or national cultural significance that could be impacted by the Project. Includes shipwrecks and other marine features. Would only apply to the Project in the event of a chance find, in which case the Act would require EEPGL to work cooperatively with the National Trust to manage any resources discovered.

Most recently, the Minister of Natural Resources, who functions as the sponsoring Minister for the Oil and Gas industry, announced plans in September 2015 to upgrade the country's upstream oil and gas policy, which was originally crafted in 2012 and finalized in 2014, indicating an evolving policy and regulatory framework surrounding the oil and gas industry in Guyana.

To date, there are 16 laws concerning oil and gas in Guyana. The majority of these laws are housed with the EPA, National Advisory Council on Occupational Safety and Health, Guyana Revenue Authority (GRA), GGMC, or Guyana National Bureau of Standards.

3.2 National Policy Framework

Guyana's government has articulated national policies on several environmental and social topics that are relevant to the Project. This section provides an overview of the key government policies applicable to the Project.

3.2.1 National Development Strategy

The National Development Strategy (NDS) recommends priorities for Guyana's economic and social development policies for the next decade. The draft document contains technical analysis of problems and future prospects in all sectors of the economy and in areas of social concern.

The NDS contains six volumes. Volumes 3 and 5 are the most relevant to the Project. Volume 3 of the NDS sets government policy with regard to the environment as well as social equality issues. It identifies 12 distinct "features" of Guyana's natural resources and environment, and sets policies governing the management of each feature. Relevant features to this Project covered under Volume 3 include the coastal zone, fisheries, waste management, pollution control, and environmental impacts of private-sector activities (NDS, 1997).

Volume 5 of the NDS relates in part to the energy sector. It describes the condition of the energy sector in Guyana, reviews past government policies related to the energy sector, identifies challenges facing the energy sector in Guyana, and describes the government's vision for development and regulation of the sector into the future (NDS, 1997).

3.2.2 National Environmental Action Plan

Guyana's National Environmental Action Plan (NEAP) articulates the national government's approach to managing the environment from the perspective of economic development. The NEAP considers the issues of environmental management, economic development, social justice, and public health to be inextricably linked. It identifies deforestation, pollution, and unregulated gold mining as historically minor but with growing environmental problems, and identifies private sector investment as one of the primary opportunities to generate the necessary capacity within Guyana to: 1) provide an appropriate level of public services to its citizens; 2) reduce and/or eliminate the avoidable environmental degradation that occurs when resource development occurs in a regulatory vacuum; and 3) reduce unsustainable uses of natural resources due to the socioeconomic pressures of widespread poverty.

The NEAP is directly relevant to the Project in several ways. It identifies the coastal zone, which will support Project activities, as an area in need of focused management due to the concentrated human population along the coast and the susceptibility of the coastal environment to both natural and human-induced degradation. It identifies private sector-led development projects as a mechanism to build capacity and ultimately support more

responsible environmental management. Finally, it identifies petroleum resources as a potential target for development.

3.2.3 Integrated Coastal Zone Management Action Plan

Guyana's Integrated Coastal Zone Management (ICZM) process is an ongoing initiative to: promote the wise use, development, and protection of coastal and marine resources; enhance collaboration among sectorial agencies; and promote economic development. In 2000, after two years of study, the ICZM Committee produced an ICZM Action Plan, which was approved by the Cabinet in 2001.

The ICZM Action Plan addresses policy development, analysis and planning, coordination, public awareness building and education, control and compliance, monitoring and measurement and information management (GLSC, 2006). Other coastal-zone related tasks currently being undertaken by the Government include: strengthening the institutional setup for ICZM; conducting a public awareness campaign to increase public understanding of the vulnerability of the coastal zone to sea level rise and climate change; and creating a database of coastal resources to facilitate improved ICZM. Currently, the EPA is mandated to coordinate the ICZM program and coordinate the development of the ICZM Action Plan through the ICZM Committee.

Under the Caribbean Planning for Adaptation to Climate Change project, Guyana has also conducted a socioeconomic assessment of sea-level rise as part of a wider vulnerability assessment and developed a Climate Change Adaptation Policy and Implementation Strategy for coastal and low-lying areas.

3.2.4 Protected Areas Act

The Protected Areas Act was enacted in 2011. It provides for protection and conservation of Guyana's natural heritage and natural capital through a national network of protected areas, and established a Protected Areas Commission to oversee the management of this network. It also highlights the importance of maintaining ecosystem services of national and global importance and public participation in protected areas and conservation, and it establishes a protected areas trust fund to ensure adequate financial support for maintenance of the network. Other functions of this Act include promoting national pride in and encouraging stewardship of Guyana's natural heritage, recognizing the conservation efforts and achievements of Amerindian Villages and Amerindian Communities, and promoting the recovery and rehabilitation of vulnerable, threatened, and endangered species.

3.2.5 Guyana's National Biodiversity Strategy and Action Plan (NBSAP)

Guyana's current National Biodiversity Strategy and Action Plan was formally adopted in 2015, and is the third iteration of the NBSAP. It establishes the national vision for biodiversity, which is to sustainably utilize, manage, and mainstream biodiversity by 2030, thereby contributing to the advancement of Guyana's bio-security, and socio-economic and low carbon development. It is intended to guide national policy with respect to biodiversity through 2020. It recognizes the

importance of biodiversity to the growing ecotourism industry and other economic sectors. It also simultaneously recognized the importance of the mining industry to the national economy and the potential for conflicts between the mining industry and ecotourism if land degradation is associated with mining activity is not appropriately managed. The NBSAP set forth nine strategic objectives intended to promote conservation and sustainability on a national scale, improve biodiversity monitoring, harmonize legal and policy-based mechanisms across all levels of government to support biodiversity conservation, and prioritize funding to meet these objectives.

3.2.6 Low Carbon Development Strategy and the Green Economy

In June 2009, the Government of Guyana announced the Low Carbon Development Strategy (LCDS). The LCDS aims to protect and maintain the forests in an effort to reduce global carbon emissions and at the same time attract payments from developed countries for the climate services that the forests provide. In 2013 the LCDS was updated to focus on two main goals: (1) transforming the national economy to deliver greater economic and social development by following a low carbon development path while simultaneously combating climate change (2) providing a model for the world of how climate change can be addressed through low carbon development in developing countries. The LCDS identifies Reducing Deforestation and Forest Degradation Plus as a primary mechanism for achieving the goals of the strategy.

Although there is no formal government plan for achieving a "green economy", the Government of Guyana has expressed interest in the concept. President David Granger has defined the "green economy" as consisting of the four "pillars" of energy, environmental security, ecological services, and enterprise and employment (Kaieteur News, 2016). The LCDS provides the conceptual framework for implementing the "green economy".

3.2.7 Guyana Energy Agency's Strategic Plan

The Guyana Energy Agency (GEA) was established by the Guyana Energy Agency Act of 1997 with a mandate to advise the Prime Minister on energy related issues, develop a national energy policy, improve energy efficiency, monitor the energy sector, and educate the public on energy efficiency and renewable energy (GEA, undated). The GEA's Strategic Plan for 2014-2018 specifically charges the Agency with monitoring "the production, importation, distribution, and utilization of petroleum and petroleum products."

3.3 International Conventions and Protocols

Guyana is signatory to a number of international agreements and conventions relating to environmental management and community rights, although not all of these agreements have been translated into national legislation. The key agreements relevant to the Project to which Guyana has acceded or is a signatory are listed in Table 3-2.

Guyana is a member state of two organizations that administer multiple international treaties and conventions: the International Labour Organization (ILO) and the International Maritime Organization (IMO). The ILO has established eight "fundamental" conventions which provide

certain general protections to workers in signatory states such as the right to organize, standards for remuneration, restrictions on child labor (including minimum ages to work), and protection from forced labor. In addition to these fundamental agreements, Guyana is signatory to several specific agreements that would govern certain specific aspects of the Project as they relate to labor.

The IMO is a similar organization whose member states have agreed to one or more conventions related to maritime activities. These include three "key" conventions (the International Convention for the Safety of Life at Sea, the International Convention for the Prevention of Pollution from Ships, and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers) as well as several other agreements concerning more specific aspects of maritime activity such as safety and security at sea, maritime pollution, and liability for maritime casualties. Guyana's Maritime Administration manages compliance with the requirements of the agreements Guyana is signatory to under the IMO, with technical assistance from the IMO's Regional Maritime Advisory Office in Port of Spain, Trinidad.

The agreements to which Guyana is party through its membership in the ILO and IMO are identified in bold in Table 3.2.

Table 3-2 International Agreements Relevant to Environmental and Socioeconomic Issues in Guyana

Agreement/ Convention	Objective	Status	Relevance to Project
Climate Change/Air Quality			
United Nations Framework Convention on Climate Change	Promote international cooperation to limit average temperature increases and resulting changes in climate. Promote international cooperation to adapt to these impacts.	Acceded and Ratified in 1994	Provides for controls on greenhouse gas emissions within Guyana's territory (maritime and land), and establishes national policy regarding adaptation to climate change.
Kyoto Protocol	Extends the UNFCCC and commits countries to reduce greenhouse gas emissions.	Acceded in 2003	Establishes national emission reduction targets.
Vienna Convention on the Protection of the Ozone Layer	Provides a framework for the protection of the ozone layer.	Acceded in 1993	Establishes measures for protecting the ozone layer.
Montreal Protocol on Substances that Deplete the Ozone Layer	Is a protocol to the Vienna Convention and is designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion.	Acceded in 1993	Prohibits the use of several groups of halogenated hydrocarbons that may deplete the ozone layer.

Pollution Prevention			
International Convention for the Prevention of Pollution from Ships	Regulates various forms of marine pollution, including oil and fuel, noxious liquid, hazardous substances, sewage, garbage, air emissions, and ballast water.	Acceded in 1997	Impacts the handling and disposition of controlled substances from the drill ships, FPSO, and support vessels.
International Convention for Safe Containers	Promote the safe transport and handling of containers through generally acceptable test procedures and related strength requirements, and facilitate the international transport of containers by providing uniform international safety regulations, equally applicable to all modes of surface transport.	Acceded in 1997	Regulates the manufacture, use, and integrity of containers used on board the drill ships, FPSO, and support vessels.
International Convention Relating to Intervention on the High Seas in Cases of Oil Pollution Casualties	Confirms the right of coastal member states to take specific actions when necessary to prevent pollution from oil following a maritime casualty	Acceded in 1997	Would protect Guyana's rights to respond to an oil spill if such an event were to occur.
International Convention on Civil Liability for Oil Pollution Damage	Establishes vessel owners' liability for damages caused by pollution from oil spills and provides for compensation would be available where oil pollution damage was caused by maritime casualties involving oil tankers	Acceded in 1997	Would not apply directly to EEPGL's activities, but would apply to potential spills from tankers that had received oil from the FPSO.
Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal	Reduce and control the movements of hazardous waste between nations and discourage transfer of hazardous waste from developed to less developed countries.	Acceded in 2001	Would apply to the Project only if hazardous waste generated in Guyana were disposed outside Guyana, or if hazardous waste was brought into Guyana from a foreign state for disposal during execution of the Project.
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	Provides a mechanism for formally obtaining and disseminating decisions of party nations as to whether they wish to receive future shipments of listed chemicals, and for ensuring compliance with these decisions by exporting party nations.	Acceded in 2007	Would apply to the Project only if chemicals and/or pesticides listed under the convention were shipped into or out of Guyana.

Stockholm Convention on Persistent Organic Pollutants (POPs), as amended	Requires party nations to take measures to eliminate or reduce the release of persistent organic pollutants.	Acceded in 2007	Would apply to the Project only if POPs were released to the environment during the course of Project-related activities in Guyana.
International Convention on Oil Pollution Preparedness, Response and Cooperation	Establishes measures for dealing with marine oil pollution incidents	Ratified in 1997	Requires ships to have a shipboard oil pollution emergency plan.
Ecological/Environmental Quality/Cultural Heritage			
The Cartagena Convention for the Protection and Development of the Marine Environment in the Wider Caribbean Region	Provide framework for international protection and development of the marine environment across the Caribbean region.	Acceded and Ratified in 2010	Sets general goals for protection for the marine environment, especially from pollution.
Protocol on Specially Protected Areas and Wildlife	Protocol supplementing and supporting the Cartagena Convention. Requires signatories to adopt an ecosystem approach to conservation. Provides mechanism for compliance with the Convention on Biological Diversity.	Acceded and Ratified in 2010	Elaborates on the wildlife goals established in the Cartagena Convention and Convention on Biological Diversity.
Convention on Biological Diversity	Promotes biological conservation within the framework of sustainable development and use of biological resources, and the fair and equitable sharing of benefits of genetic resources.	Signed in 1992, Ratified in 1994	Discourages activities that would negatively impact biodiversity.

United Nations Convention on the Law of the Seas	Defines nations' rights and responsibilities in terms of their use of oceans and provides guidance on environmental and natural resource management.	Concluded in 1982 and ratified in 1994	Defines legal status of subsea mineral resources as the "common heritage of humankind," encourages resource development to be done in a way that supports healthy global economic growth and trade balance, and mandates that states take measures to prevent, control, and reduce pollution of the oceans.
Convention on International Trade in Endangered Species of Wild Flora and Fauna	Protects endangered plants and animals from international trade.	Acceded in 1977	Restricts collection and trade of endangered species.
UNESCO Convention on the Protection of the Underwater Cultural Heritage	Protects "all traces of human existence having a cultural, historical, or archaeological character" that have been under water for over 100 years.	Ratified in 2014	Applies to shipwrecks.
Labor/Health/Safety			
International Convention for the Safety of Life at Sea	Specifies minimum standards for the construction, equipment and operation of vessels, compatible with their safety. Allows governments of participating states to inspect vessels flagged in other participating states to ensure compliance.	Acceded in 1997	Affects construction, operation, and equipment on board the drill ships, FPSO, installation vessels, and support vessels.
Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation	Promotes safety at sea by criminalizing actions that would endanger a vessel or its cargo, or contributing to activities that would do so.	Acceded in 2003	Would apply to any activity intended to endanger vessels while at sea conducting permitted activities related the Project.
Dock Work Convention	Regulates activities associated with the loading and unloading of cargo onto/from oceangoing vessels when at port.	Acceded 1983	Would apply to loading and offloading activities at the shorebase.

Repatriation of Seafarers Convention (Revised)	Requires vessel owners/operators to repatriate (at the operator's expense) seafarers that have successfully concluded a minimum period of service onboard a vessel (minimum time to qualify for this benefit to be determined by the member state but not to exceed 12 months)	Acceded 1996	Would apply to workers onboard both EEPGL owned/operated vessels, their contractors, and tankers receiving oil from the FPSO.
Seafarer's Identify Documents Convention	Requires signatory states to issue identity cards to seafarers and for other signatory states to allow holders of these cards entry to their territories for the purposes of shore leave, joining a crew, or repatriation after completing a voyage.	Acceded 1966	Would apply to seafarers entering or egressing Guyana prior to or following employment on vessels operated by EEPGL or its contractors, and to seafarers on shore leave while employed by EEPGL or its contractors.
Convention on the International Regulations for Preventing Collisions at Sea	Officially recognizes the importance of traffic separation in the marine environment and codifies basic measures to accommodate traffic separation, including safe speed, signaling conventions, and general vessel conduct.	Acceded in 1997	Governs operation of drill ships, FPSO, installation vessels, and support vessels.
International Convention on Standards of Training, Certification and Watchkeeping	Obligates crews operating vessels flagged in signatory states to adhere to minimum standards relating to training, certification and watch keeping. Requires signatory states to submit detailed information to the International Maritime Organization concerning administrative measures taken to ensure compliance with the convention.	Acceded in 1997	Impacts required capabilities of crew on board the drill ships, FPSO, installation vessels, and support vessels, and provides for inspection by authorities to ensure compliance.
Convention on Facilitation of International Maritime Traffic	Prevent unnecessary delays in maritime traffic arising from burdensome documentation requirements, and establish uniform formalities and other procedures to permit transboundary maritime commerce and travel.	Acceded in 1998	Facilitates entry of drill ships, FPSO, installation vessels, and support vessels into Guyana.

Guyana also belongs to other international organizations such as the Organization of American States, the International Monetary Fund, and the Caribbean Community.

To highlight Guyana's adherence to international standards and guidelines relevant to the oil and gas sector, in May 2010 the country announced its commitment to the implementation of

the Extractive Industries Transparency Initiative, and in September 2015, the country recommitted its support to the ILO.

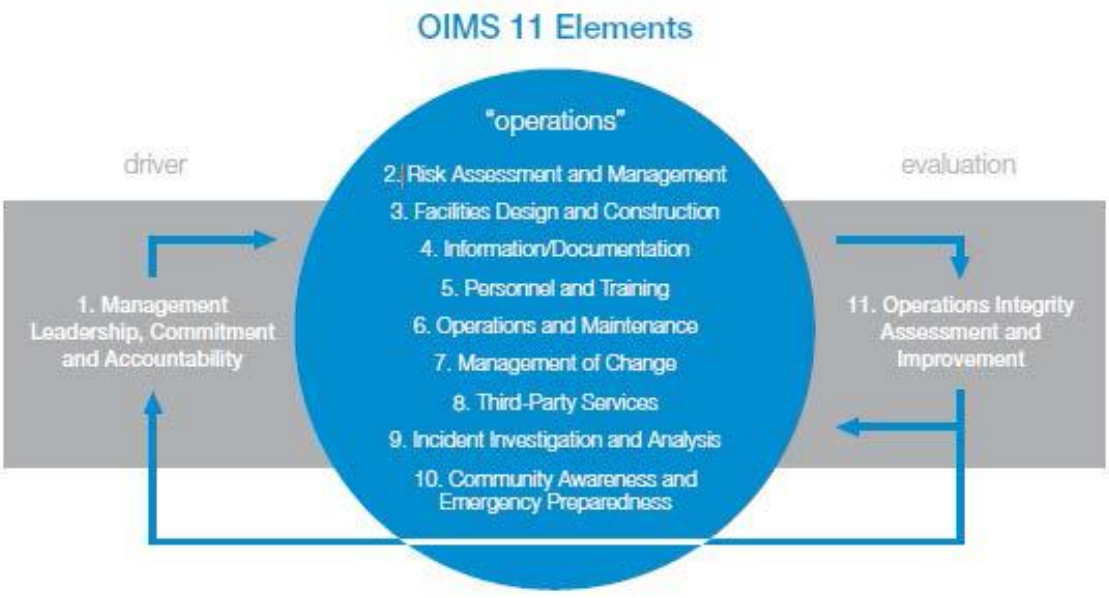
3.4 EEPGL's Operations Integrity Management System

The Company and its affiliates (including EEPGL) are committed to conducting business in a manner that is compatible with the environmental and economic needs of the communities in which it operates, and that protects the safety, security, and health of its employees, those involved with its operations, its customers, and the public. These commitments are documented in its Safety, Security, Health, Environmental, and Product Safety policies. These policies are put into practice through a disciplined management framework called OIMS.

EEPGL's OIMS Framework[13] establishes common expectations used by Company affiliates worldwide for addressing risks inherent in its business. The term Operations Integrity (OI) is used to address all aspects of its business that can impact personnel and process safety, security, health, and environmental performance.

Application of the OIMS Framework is required across all Company affiliates, with particular emphasis on design, construction, and operations. Management is responsible for ensuring that management systems that satisfy the OIMS Framework are in place. Implementation will be consistent with the risks associated with the business activities being planned and performed. Figure 3-1 provides a high level description of the OIMS Framework and its 11 essential Elements.

Figure 3-1 Operations Integrity Management System



[13] http://corporate.exxonmobil.com/company/about-us/safety-and-health/operations-integrity-management-system

4.0 METHODOLOGY FOR PREPARING THE ENVIRONMENTAL IMPACT ASSESSMENT

The purpose of this EIA is to assess the potential physical, biological, and socioeconomic (including social, economic, community health, and cultural) impacts of the Project. This chapter provides a summary of the approach and methodology used to assess the potential impacts associated with the Project. The EIA has been undertaken in a manner consistent with the Guyana Environmental Impact Assessment Guidelines – Volumes 1 and 2 (2000 and 2004, respectively).

This chapter also describes the process used to conduct the EIA. The EIA was prepared to provide an independent, science-based evaluation of the potential impacts associated with the development drilling, installation, production operations, and decommissioning stages of the Project. The EIA is also intended to share those findings with stakeholders and decision-makers so they can make informed decisions regarding the potential benefits and impacts of the Project, as well as the measures proposed to enhance these benefits and mitigate these impacts.

This EIA has been undertaken following a systematic process that evaluates the potential impacts that the Project could have on physical, biological, and socioeconomic resources/receptors, and that identifies measures that EEPGL will take to avoid, reduce, and remedy adverse impacts. For the purposes of the EIA, an "impact" is defined as any alteration of existing conditions (adverse or beneficial) caused directly or indirectly by the Project. The EP Act (Cap. 20:05) defines an "adverse" impact as meaning one or more of the following:

- Impairment of the quality of the natural environment or any use that can be made of it;
- Injury or damage to property or to plant or animal life;
- Harm or material discomfort to any person;
- An adverse effect on the health of any person;
- Impairment of the safety of any person;
- Rendering any property or plant or animal life unfit for use by human or unfit for its role in the ecosystem;
- Loss of enjoyment of normal use of property; and
- Interference with the normal conduct of business.

Information on potential impacts, including potential cumulative impacts related to the Project, was obtained by ERM from various primary and secondary sources, including: consultation and key informant interviews with the EPA, GGMC, and other stakeholders; environmental impact assessments for other similar projects worldwide; and scientific research and literature.

The key stages for this EIA approach are:

- Screening;
- Scoping and Terms of Reference;
- Assessing Existing Conditions;
- Project Description and Interaction with Design and Decision-Making Process;

- Stakeholder Engagement;
- Assessment of Impacts and Identification of Mitigation;
- Mitigation, Management, and Monitoring; and
- Disclosure and Reporting.

The methodologies for the key stages are described in the subsequent sections.

4.1 Screening

The first stage of the EIA process involved the EPA screening the Project to determine the appropriate level of analysis to support the Application for Environmental Authorisation (Application) submitted by EEPGL. The EPA screens projects based on the information provided in the Application and determines the depth of environmental assessment/type of document required to support the Application. Based on the results of its screening assessment, the EPA may determine that the information included in the application is sufficient to support a permitting decision, or it may require a Strategic Environmental Assessment, Environmental Management Plan, and/or an Environmental Impact Assessment. The EPA determined that the Project could result in potentially significant impacts, and, in accordance with the EP Act (Cap. 20:05), indicated on July 29, 2016 that the Project requires an Environmental Impact Assessment to inform a decision to approve or reject the Project.

4.2 Scoping and Terms of Reference

The key objectives of scoping are to:

- Identify key sensitivities and those actions having the potential to cause or contribute to significant impacts on physical, biological, and socioeconomic resources/receptors;
- Identify potential siting, layout, and technology alternatives for the Project;
- Obtain stakeholder views through consultation; and
- Help inform the Terms of Reference (ToR) for the EIA through consultation to ensure that the process and output are focused on the key issues. The ToR describes the scope, technical approach, and issues of importance to be considered in the EIA.

EPA issued a draft ToR for the Project on September 8, 2016, and its availability was advertised in the newspaper on September 9, 2016. Sector Agency Scoping Meetings were held on October 5 and 6, 2016, to receive government agency comments on the draft ToR. Public Scoping Meetings were held in each of the six coastal regions as follows to receive public comments on the draft ToR:

- Region 1: November 14, 2016
- Region 2: October 26, 2016
- Region 3: October 24, 2016
- Region 4: December 3, 2016
- Region 5: December 2, 2016
- Region 6: November 8, 2016.

Following the public scoping meetings, the EPA required the submittal of an updated Project Summary, which EEPGL submitted on January 13, 2017. The EPA issued a public notice for the updated Project Summary with an additional 28-day public comment period. EPA approved the Final ToR on February 17, 2017. The Final ToR was developed to guide the preparation of the EIA and outline the requirements of the same. The Final ToR incorporated the concerns, issues, and suggestions garnered during the 28-day Public Notification Period and the public and sector agency meetings described above.

4.3 Assessing Existing Conditions

The description of existing physical, environmental, and socioeconomic conditions provides information on resources/receptors identified during scoping that have the potential to be significantly impacted by the Project. The description of existing conditions is aimed at providing sufficient detail to meet the following objectives:

- Identify the key conditions and sensitivities in areas potentially impacted by the Project;
- Provide a basis for extrapolation of the current situation, taking into consideration natural variability, and development of future scenarios without the Project;
- Provide data to aid the prediction and evaluation of potential impacts of the Project;
- Understand stakeholder concerns, perceptions, and expectations regarding the Project;
- Inform development of appropriate mitigation measures; and
- Provide a benchmark to inform assessments of future changes and of the effectiveness of mitigation measures.

Field studies conducted to document existing conditions for the EIA are described in Chapter 6.

4.4 Interaction with Design and Decision-Making Process

The interaction between the EIA team and the design and decision-making process was one of the key areas in which the EIA influenced how the Project would be developed. It included involvement in defining the Project and identifying those activities with the potential to cause physical, biological, or socioeconomic impacts. Project planning, decision making, and refinement of the Project description continued throughout the assessment process in view of identified impacts and proposed mitigation measures. During the EIA process, there was extensive communication between the impact assessment team and the Project design team with regard to identifying alternatives, potential impacts, and mitigation measures.

4.5 Stakeholder Engagement

Stakeholder engagement has and is being conducted to support the development of the EIA and associated ESMP. The objectives of the Project's stakeholder engagement activities are to:

- Promote the development of respectful and open relationships between stakeholders and EEPGL during the Project life cycle;
- Identify Project stakeholders and understand their interests and concerns in relation to Project activities, and incorporate such interests and concerns into the EIA and ESMP development processes, and, if appropriate, the Project design;

- Provide stakeholders with timely information about the Project, in ways that are appropriate to their interests and needs, and also appropriate to the level of expected risks and potential adverse impacts;
- Satisfy regulatory and EEPGL expectations for stakeholder engagement; and
- Record feedback and resolve any grievances that may arise from Project-related activities through a formal feedback mechanism.

4.5.1 Stakeholder Engagement Plan

Project stakeholder engagement activities are guided by a Stakeholder Engagement Plan (SEP), which describes:

- Stakeholders identified for engagement;
- A program of engagement and communications activities, and their frequency throughout the Project life cycle;
- A dedicated phone line and email address through which stakeholders can contact EEPGL to voice concerns, provide information, or ask questions about the Project and its activities; and
- Mechanisms through which EEPGL will monitor and report on external engagement and communications.

The SEP is a document that is updated periodically as the Project progresses to reflect new information, changing conditions, and additional stakeholders.

4.5.2 Stakeholder Identification and Engagement Strategy

Project stakeholders have been identified through a combination of desktop research and in-country assessment and engagement. Stakeholder categories include, but are not limited to: government officials; communities (including indigenous peoples); interest groups; non-governmental organizations (NGOs); the private sector; media; academic and research institutions; and professional, business, and worker associations.

Building on the stakeholder identification and mapping analysis, EEPGL's stakeholder engagement strategy identifies mechanisms and tools to facilitate stakeholder communications and public information sharing. These tools are divided into two tiers that interact to facilitate informed engagement. The first tier is information sharing, in which EEPGL provides information about the Project to stakeholders to support their understanding of what is proposed to occur. The second tier is consultation, in which EEPGL seeks to support open dialogue and to receive stakeholder feedback, opinions, concerns, and knowledge regarding the way the Project may interact with the natural and social environment. The objective of the consultation is to ensure that EEPGL has identified key stakeholder issues and concerns.

EEPGL may disseminate information through print and online publications, media releases, as well as presentations and open houses. The intent of these types of activities is to provide information to a broad audience or group of stakeholders as efficiently as possible. Consultation or dialogue activities involving a two-way flow or exchange of information

between stakeholders and the Project may include one-on-one and small group meetings, public meetings including a question and answer session, and feedback mechanisms such as a dedicated email address (contact-EEPGL@exxonmobil.com) and phone line (+592 231 2866, extension 12400). The intention of these activities is to allow for not only a two-way exchange of information, but also a means for EEPGL to gather information concerning topics that are important to its stakeholders. These activities also help ensure stakeholders' comments and opinions are heard and legitimate concerns can be addressed.

4.5.3 Stakeholder Engagement Process

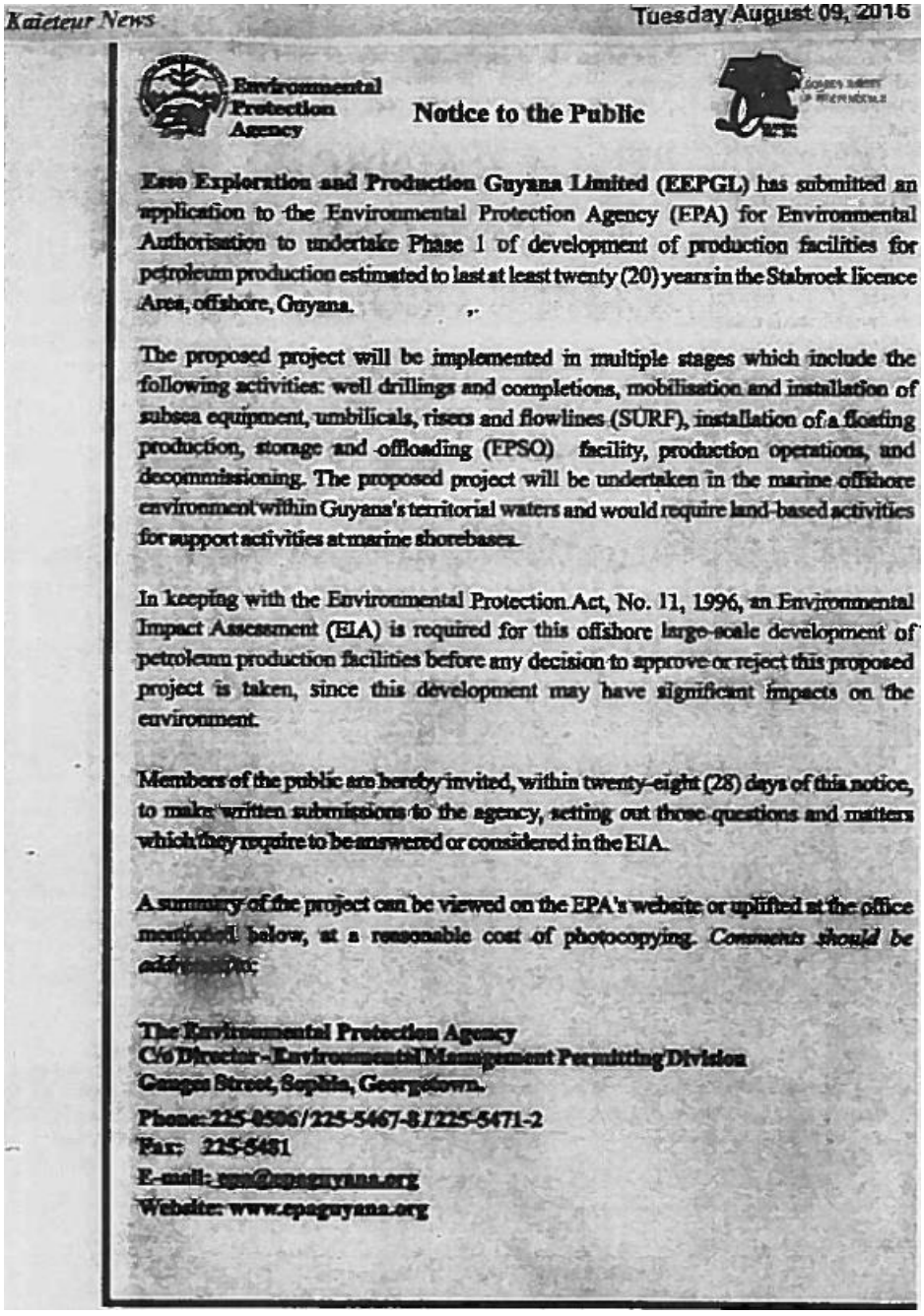
Stakeholder engagement activities are an integral part of the Project lifecycle: from the initial notification when the Project is proposed, to the scoping of potential impacts, to the EIA, and throughout the life of the Project.

EEPGL has conducted a robust public consultation program to both inform the public about the Project and understand community and stakeholder concerns so they could be incorporated into the EIA. The different stages of the Project each require stakeholder engagement that is tailored in terms of its objectives and intensity, as well as the forms of engagement used. The various engagements completed and/or planned specific to the EIA stage are summarized below.

- EEPGL has held many meetings and various workshops with the government and others on offshore oil and gas exploration and development.
- The submission of the Application was posted in the local newspaper on August 9, 2016, by EPA (Figure 4-1) and was subject to a 28-day public comment period. There were no comments received from the public in regards to the Application.
- EEPGL and/or ERM have held meetings or key informant interviews with over 30 Guyana government agencies/commissions, many elected officials and Regional Administrators, over 15 professional or business associations, international and domestic non-governmental organizations, several universities and research institutes, various religious and ethnic organizations, and the media to inform stakeholders about the Project and to collect information needed for the EIA. Although questionnaires were not used, these meetings are documented in the SEP and inputs from these engagements were incorporated into the existing conditions and impact assessment components of the EIA (Chapters 6 and 7, respectively).
- The Draft ToR was developed and published by the EPA on their website on September 8, 2016.
- Sector Agency Scoping Meetings were held with EEPGL, the EPA, and other government agencies on October 5 and 6, 2016, with over 150 attendees of which approximately 100 were members of the general public, to discuss the Draft ToR, scope potential impacts, and capture agency-level stakeholder feedback on the Draft ToR.
- Public Scoping Meetings for the purpose of scoping potential impacts and capturing stakeholder opinions from the general public on the Draft ToR were held in Regions 1 through 6 during October, November, and December 2016 with over 300 attendees, of which over 200 were public participants (Figure 4-2).

- Following the public scoping meetings, the EPA required the submittal of an updated Project Summary, which EEPGL submitted on January 13, 2017, that was followed by an additional 28-day public comment period. Once the Draft EIA is submitted to the EPA, the EPA administers a 60-day public comment period, during which the public is invited to submit comments to the EPA on the Draft EIA, after which EEPGL has 30 days to address comments and submit the Final EIA.

Figure 4-1 Environmental Application Invitation for Public Comment



Kaieteur News — Tuesday August 09, 2016

Environmental Protection Agency

Notice to the Public

Esso Exploration and Production Guyana Limited (EEPGL) has submitted an application to the Environmental Protection Agency (EPA) for Environmental Authorisation to undertake Phase 1 of development of production facilities for petroleum production estimated to last at least twenty (20) years in the Stabroek licence Area, offshore, Guyana.

The proposed project will be implemented in multiple stages which include the following activities: well drillings and completions, mobilisation and installation of subsea equipment, umbilicals, risers and flowlines (SURF), installation of a floating production, storage and offloading (FPSO) facility, production operations, and decommissioning. The proposed project will be undertaken in the marine offshore environment within Guyana's territorial waters and would require land-based activities for support activities at marine shorebases.

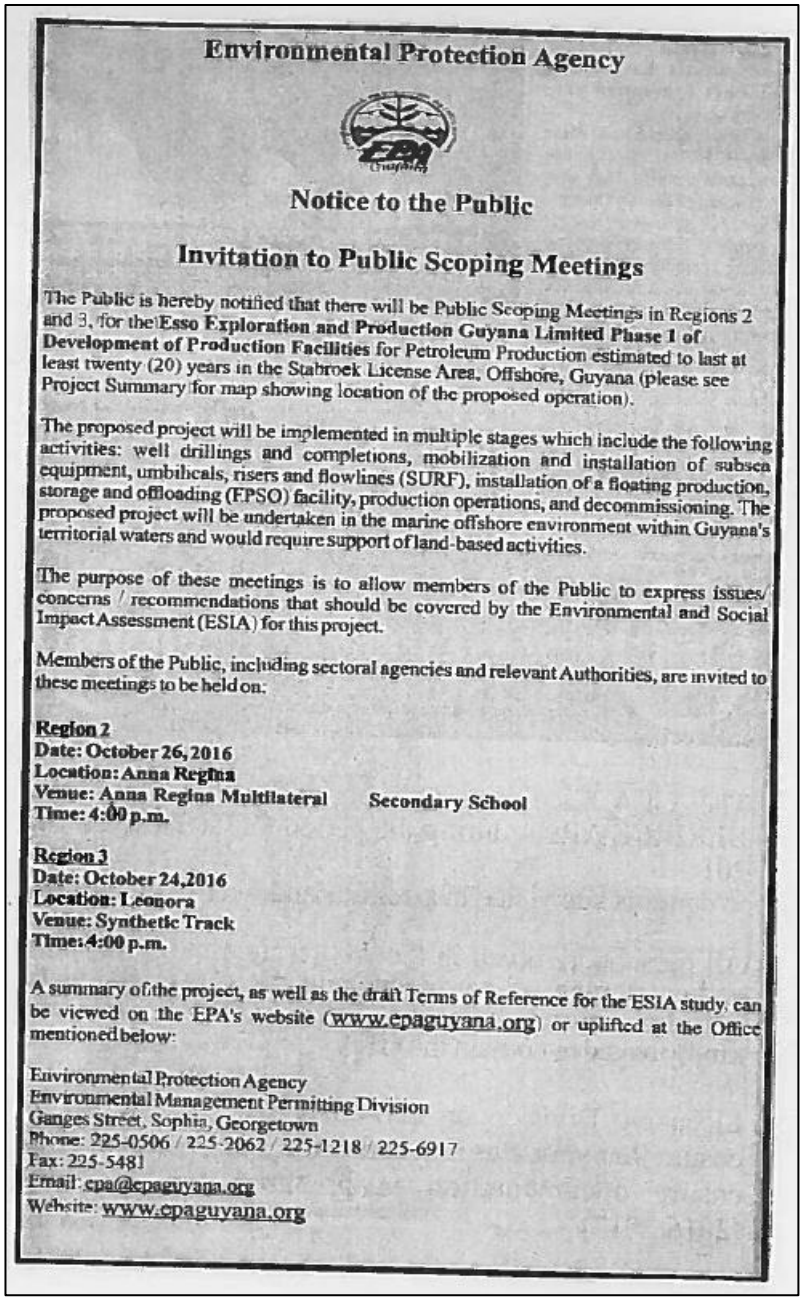
In keeping with the Environmental Protection Act, No. 11, 1996, an Environmental Impact Assessment (EIA) is required for this offshore large-scale development of petroleum production facilities before any decision to approve or reject this proposed project is taken, since this development may have significant impacts on the environment.

Members of the public are hereby invited, within twenty-eight (28) days of this notice, to make written submissions to the agency, setting out those questions and matters which they require to be answered or considered in the EIA.

A summary of the project can be viewed on the EPA's website or uplifted at the office mentioned below, at a reasonable cost of photocopying. *Comments should be addressed to:*

The Environmental Protection Agency
C/o Director - Environmental Management Permitting Division
Gaugen Street, Sophia, Georgetown.
Phone: 225-0506/225-5467-8/225-5471-2
Fax: 225-5481
E-mail: epa@epaguyana.org
Website: www.epaguyana.org

Figure 4-2 Sample Draft Terms of Reference Invitation for Public Comment - Regions 2 and 3



Environmental Protection Agency

Notice to the Public

Invitation to Public Scoping Meetings

The Public is hereby notified that there will be Public Scoping Meetings in Regions 2 and 3, for the **Esso Exploration and Production Guyana Limited Phase 1 of Development of Production Facilities** for Petroleum Production estimated to last at least twenty (20) years in the Stabroek License Area, Offshore, Guyana (please see Project Summary for map showing location of the proposed operation).

The proposed project will be implemented in multiple stages which include the following activities: well drillings and completions, mobilization and installation of subsea equipment, umbilicals, risers and flowlines (SURF), installation of a floating production, storage and offloading (FPSO) facility, production operations, and decommissioning. The proposed project will be undertaken in the marine offshore environment within Guyana's territorial waters and would require support of land-based activities.

The purpose of these meetings is to allow members of the Public to express issues/ concerns / recommendations that should be covered by the Environmental and Social Impact Assessment (ESIA) for this project.

Members of the Public, including sectoral agencies and relevant Authorities, are invited to these meetings to be held on:

Region 2
Date: October 26, 2016
Location: Anna Regina
Venue: Anna Regina Multilateral Secondary School
Time: 4:00 p.m.

Region 3
Date: October 24, 2016
Location: Leonora
Venue: Synthetic Track
Time: 4:00 p.m.

A summary of the project, as well as the draft Terms of Reference for the ESIA study, can be viewed on the EPA's website (www.epaguyana.org) or uplifted at the Office mentioned below:

Environmental Protection Agency
Environmental Management Permitting Division
Ganges Street, Sophia, Georgetown
Phone: 225-0506 / 225-2062 / 225-1218 / 225-6917
Fax: 225-5481
Email: epa@epaguyana.org
Website: www.epaguyana.org

Once the EIA process is complete, and assuming EEPGL obtains environmental authorization and other approvals from EPA, GGMC, and EAB, the Project will transition into execution. Plans for stakeholder engagement during Project execution are described in the SEP, and engagement activities will be adjusted to reflect evolving Project status and activity level, as well as stakeholder concerns over the life of the Project. During Project execution, the emphasis of engagement shifts from input gathering to disclosure about planned activities as well as consultation (including receipt of feedback) on ongoing and planned activities. EEPGL will

keep the public informed about the general progress of the Project (e.g., completion of Project stages such as well drilling) and will respond to any grievances (e.g., specific concerns) filed under the Project's Grievance Procedure, which is described in the SEP. The Grievance Procedure will be in place throughout the life of the Project.

4.5.4 Stakeholder Comments and Considerations

This section summarizes the key comments and suggestions received from stakeholders during the EIA consultation processes to date and how these comments have been considered and addressed in the EIA (Table 4-1).

During the Project's EIA scoping phase, the EPA led a series of eight scoping meetings (two meetings attended by agency representatives, and one public meeting each in Regions 1-6). These meetings served to inform stakeholders about, and receive feedback on, the EIA Terms of Reference (ToR) which were also made available on the EPA website throughout the scoping phase. The public was also made aware that comments could be submitted directly to the EPA during the 28-day public comment period of the scoping phase.

A total of 163 comments were received from public stakeholders over the course of the scoping phase. Some were raised in person at the scoping meetings, while others were submitted via comment boxes at the meetings, or by letter to the EPA. The largest number of comments (58) pertained to the EIA approach, process and/or methodology, including questions about the EIA timeline, the company conducting the EIA, delineation of the Area of Influence (AOI), data collected for the EIA, stakeholder engagement efforts over the course of the EIA process, and content of the ESMP. There were also numerous questions and comments (37) about potential impacts of the Project, including impacts to marine life and other biological resources, fishing livelihoods, air quality, indigenous lands, and potential for accidents. A total of 40 comments pertained to the Project Description, including the project location, life of the project, processes for waste management, use of produced gas, and measures to prevent and address oil spills. A total of 19 comments were received about possible socioeconomic benefits of the Project, including employment, government revenues, and local content. Seven comments were received regarding the EPA's role and capacity in the EIA process, and three questions were received about the administrative framework regulating oil and gas development in Guyana. Table 4-1 below summarizes key themes raised by stakeholders during the EIA scoping phase, and indicates how these have been considered in the EIA.

Table 4-1 Themes in Scoping Comments Received and Consideration in EIA

Key Theme	Consideration in EIA
Differences between Phase 1 and Phase 2, types of SURF and FPSO equipment and methods, gas re-injection	Phase 2 has not been defined. Any future phases would be addressed through a separate permitting process. A Project Description is provided in Chapter 2.
EIA methodology, hierarchy, data collection techniques, types of surveys and studies, limitations, predictive analysis, and considerations for mitigation	The methodology for the EIA including existing condition data collection, assessment, and mitigation analysis is discussed in Chapter 4.
Oil spill response (OSR) capabilities, protection measures, vessel information, response capacity (e.g., trained responders, equipment), notifications, liability	OSR planning is discussed in Chapter 7. Potential impacts as a result of an unplanned event, such as an oil spill, are assessed in Section 7.4. A separate Oil Spill Response Plan for the Project is being developed.
Area of Influence (AOI) determinations	The AOI for the Project is described in Chapter 5.
Timing for public comment period, cut-off dates, and how comments are incorporated into the EIA	Details related to the EIA process and the administrative frameworks are discussed in Chapter 3. Details related to the public comment period and how stakeholder feedback is incorporated into the EIA are discussed here in Section 4.5.
Credentials and experience of the company developing the EIA.	A brief description of ERM and its experience conducting EIAs for offshore oil and gas projects is presented in Section 1.0 of the EIA. Curriculum vitae for the key EIA team members are provided in Appendix B of the EIA.
Subcontractor management and monitoring, logistical support requirements, and onshore shorebases	Details related to subcontractors and logistical support are described in Chapter 2.
Decommissioning	Decommissioning information is presented in Chapter 2.
Alternatives analysis, particularly as it pertains to Air Quality	An alternatives analysis is included in Section 2. Further details pertaining to Air Quality, Climate Change, and the impact on receptors is discussed in Chapter 7.
Strategic Environmental Assessment (SEA) details, current and previous stakeholder engagement information	The SEA that was submitted to EPA in March 2014 and includes previous stakeholder information can be found on the EPA website.
Role of Marine Mammal Observers	Information pertaining to marine mammal data collection can be found in Chapter 6.
Potential socioeconomic benefits of the Project including employment and government revenue.	Socioeconomic benefits of the Project are discussed generally in Section 7.3.2 and Section 7.3.3 of the EIA. Opportunities for local employment and procurement are currently under study; details will be elaborated in a Project-specific local content plan.
Potential adverse impacts on livelihoods and economy, including fishing livelihoods.	Potential adverse impacts to employment, livelihoods and economy are discussed in Section 7.3.2, Section 7.3.3. and Section 7.4.4.

Key Theme	Consideration in EIA
Management and use of produced gas	A description of the gas production rate, and its management and use by the Project are described in Section 2.5 of the EIA.
Use and disposal of hazardous substances	A list of chemicals that the Project intends to use is provided in Section 2.10.1 of the EIA. Management of wastes including hazardous waste is provided in Section 2.10.4.
Emissions and their impacts	An estimated annual emissions summary is provided in Section 2.10.2 of the EIA, while assessments of Project emissions on ambient air quality and climate are provided in Section 7.1.1.
Waste streams and their management and discharge	Descriptions of the Project vessels' discharges, and management/disposal systems and practices are provided in Sections 2.10.3 and 2.10.4.
Possible effects on coastal resources including mangroves and artisanal fisheries	Assessment of impacts to coastal resources is provided in Section 7.2.1, Section 7.2.2, Section 7.2.3, Section 7.4.3 and Section 7.4.4 of the EIA.
Possible effects on marine life	An assessment of impacts to biological receptors, including marine wildlife, can be found in Section 7.2 and Section 7.4.3 of the EIA.
Possible effects on fishing livelihoods	Assessment of impacts to fishing livelihoods can be found in Section 7.3.3 and Section 7.4.4.
Impacts to indigenous people, lands and resources	A discussion of indigenous people and resources and their potential to be affected by the Project is provided in Section 7.3.10 and Section 7.4.4.8.
Oil spill potential impacts and impacted locations	Oil spill modeling results, and assessment of potential impacts of an oil spill are discussed in Section 7.4 of the EIA.
Potential for social changes such as trafficking, prostitution, drug trade etc.	Potential impacts to community safety are assessed in Section 7.3.4 of the EIA.
Principles and content of the Environmental and Social Management Plan (ESMP)	The guiding principles and an overview of general structure and content of the ESMP are discussed in Chapter 9 of the EIA.
Type of anchor mooring on offshore vessels	The type of anchor mooring or other positioning mechanism to be utilized by Project vessels is discussed in Section 2.

Some questions were raised during the scoping meetings that were outside the scope of an EIA (e.g., the potential for an oil refinery in Guyana) and/or are confidential, such as the details of EEPGL's agreement with the Government of Guyana, and are therefore not discussed in Table 4-1.

4.6 Assessment of Impacts and Identification of Mitigation

The primary purpose of an EIA is to predict the potential impacts resulting from a proposed Project and to identify and evaluate the efficacy of measures to avoid, reduce, or remedy these impacts. ERM uses a standard impact assessment methodology for evaluating the impacts and significance of projects around the world – the ERM Impact Assessment Standard. This methodology takes into consideration both the magnitude of an impact and the sensitivity/vulnerability/importance of the resource/receptor to determine the significance of the impact (see Table 4-2), which is described in more detail below.

Table 4-2 Evaluation of Impact Significance

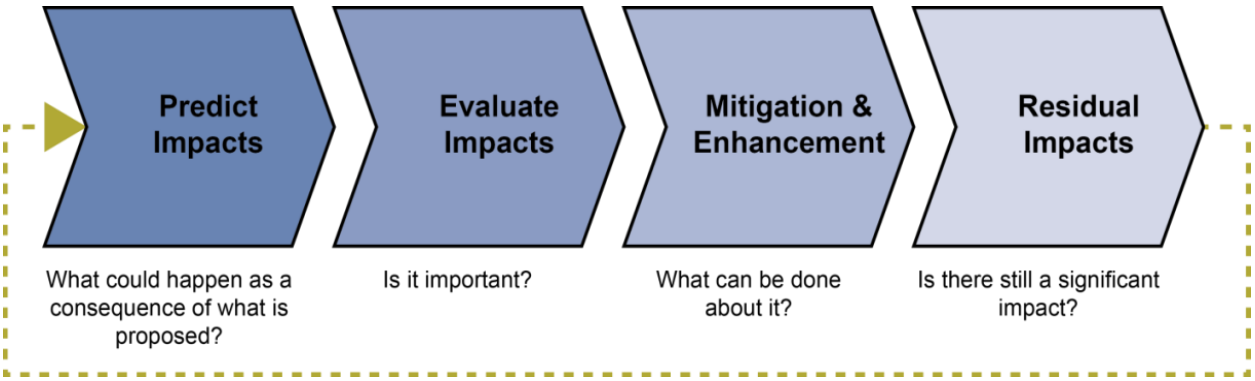
Impact Significance Matrix		**Sensitivity/Vulnerability/Importance of Resource/Receptor**		
		Low	**Medium**	**High**
Negative Impacts				
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major
Positive Impacts				
Magnitude of Impact	NA	Positive	Positive	Positive

Impacts can be "direct", "indirect", or "induced", as defined below:

- **Direct** – Impacts that result from a direct interaction between the Project and a resource/receptor (e.g., disturbance of a benthic community habitat on the seafloor);
- **Indirect** – Impacts that follow indirectly from the direct interactions between the Project and its environment as a result of subsequent interactions within the environment (e.g., impacts to marine fish who feed off a directly impacted benthic community); and
- **Induced** – Impacts that result from other activities (that are not part of the Project) that happen as a consequence of the Project (e.g., influx of job seekers).

The assessment of impacts proceeded through an iterative four-step process, as illustrated in Figure 4-3.

Figure 4-3 Impact Prediction and Evaluation Process



Step 1: Predict Impacts

The EIA evaluates potential Project impacts by predicting and quantifying to the extent possible the *magnitude* of those impacts on resources/receptors and the sensitivity/vulnerability/importance of the impacted resources/receptors.

"Magnitude" is a function of the following impact characteristics:

- Type of impact (i.e., direct, indirect, induced; avoidable or unavoidable)
- Nature of the change (what is impacted and how; positive or negative);
- Size, scale, or intensity;
- Geographical extent and distribution (e.g., local, regional, national, international);
- Duration and/or frequency (e.g., temporary, short term, long term, permanent); and
- Reversibility (reversible or irreversible).

Magnitude therefore describes the change that is predicted to occur in the resource / receptor (e.g., the area and duration over which air or groundwater may become polluted, the level of increase in concentration, the degree and probability of impact on the health or livelihood of a local community). The magnitude of impacts are predicted and evaluated using a variety of different methods appropriate to the resources/receptors potentially impacted by the Project. For example, models are used to evaluate potential impacts on physical resources (e.g., water quality, oil spill, air dispersion, and underwater sound models). Table 5-1 provides additional information on the analytical methods used in assessing impacts for resources/receptors.

The magnitude of an impact takes into account all the various dimensions of a particular impact in order to make a determination as to where the impact falls on the spectrum (in the case of adverse impacts) including *Negligible, Small, Medium,* and *Large*. Some impacts can result in changes to the environment that may be immeasurable, undetectable, or within the range of normal natural variation. Such changes can be regarded as essentially having little or no impact, and are thus characterized as having a *Negligible* magnitude. Other impacts may result in changes that are substantial and/or extremely widespread, and these are characterized as

having a *Large* magnitude. In the case of positive impacts, this EIA does not attempt to characterize magnitude. In determining the magnitude of impacts on resources / receptors, embedded controls are taken into consideration. For example, the assessed magnitude of impacts on seawater quality from proposed produced water discharge considers the efficacy of produced water treatment measures that are part of the Project design.

The "sensitivity/vulnerability/importance" of the impacted resource/receptor is characterized by considering the nature of the resource/receptor as well as other factors including legal protection, government policy, stakeholder views, and economic value. The definitions for *Low*, *Medium*, and *High* sensitivity/vulnerability/importance designations will vary on a resource/receptor basis.

Step 2: Evaluate Impacts

For routine aspects of the Project, the significance for each impact was assigned based on the evaluations of the magnitude of the impact and the sensitivity/vulnerability/importance of the resource/receptor using the matrix shown in Table 4-2 above. This matrix applies to all resources/receptors. The assignment of a significance rating enables decision-makers and stakeholders to understand key potential Project impacts.

The following considerations are provided to clarify what the various significance designations represent.

- An impact of *Negligible* significance is one where a resource/receptor will not be impacted by a particular activity, or the predicted impact is deemed to be imperceptible or is indistinguishable from natural background variations, or small magnitude impacts are predicted only to low sensitivity receptors.
- An impact of *Minor* significance is one where a resource/receptor will experience a noticeable impact, but the impact magnitude is *Small* or *Medium* and/or the resource/receptor is*, respectively,* of *Medium* or *Low* sensitivity/vulnerability/ importance.
- An impact of *Moderate* significance has an impact magnitude that falls somewhere in the range from a threshold above which the impact is *Minor*, up to a level that might be just short of being considered *Major*.
- An impact of *Major* significance is one where the impact magnitude is *Medium* or *Large* for a resource/receptor of *High* sensitivity/vulnerability/importance (or *Large* magnitude for a *Medium* sensitivity/vulnerability/importance resource/receptor).
- An impact of *Positive* significance is one that has been identified as having a positive impact on the receptor/resource. This EIA does not attempt to characterize magnitude for positive impacts.

The specific criteria used to evaluate significance of impacts for each resource/receptor are presented in Chapter 7.

Non-routine/unplanned events related to the Project (e.g., oil spills, traffic accidents, or other events with a low probability of occurrence do not lend themselves readily to the analysis described above. For these types of events, understanding the significance of the risk requires understanding of the:

- Consequence (potential) of the event if it were to occur; and
- Likelihood of the event occurring.

As such, for these unplanned events, a Risk Table (Table 4-3) based on event consequence and likelihood is used to assess the significance of impacts associated with the events.

Table 4-3 Evaluation of Risk

Risk Matrix		Consequence/Severity		
		Low	Medium	High
Likelihood	Unlikely	Minor	Minor	Moderate
	Possible	Minor	Moderate	Major
	Likely	Moderate	Major	Major

"Consequence/severity" takes into consideration the magnitude, as defined for Step 1, of the potential impact if the unplanned event were to occur.

"Likelihood" reflects the probability of occurrence and is defined as follows:

- **Unlikely**—considered a rare event, and there is a small likelihood that an event could occur;
- **Possible**—the event has a reasonable chance to occur at some time during normal operating conditions; and
- **Likely**—the event is expected to occur during the life of the facility.

Likelihood is estimated on the basis of experience and/or evidence that such an outcome has previously occurred. It is important to note that likelihood is a measure of the degree to which the unplanned event is expected to occur, not the degree to which an impact is expected to occur as a result of the unplanned event. The latter concept is referred to as uncertainty, and this is typically dealt with in a contextual discussion in the impact assessment, rather than in the impact significance assignment process.

Step 3: Mitigation and Enhancement

The next step in the process for this EIA is the identification of measures that can be taken to mitigate, as far as reasonably practicable, the identified potential impacts of the Project.

A mitigation hierarchy is used where preference is always given to avoid the impact before considering other types of mitigation. The preferred hierarchy of measures followed in this EIA is:

- **Avoid**—remove the source of the impact by employing alternative designs or operations to avoid risks related to environmental and socioeconomic impacts;
- **Reduce**—lessen the probability and/or consequence of impacts that cannot be avoided (e.g., reduce the size of the project footprint); and
- **Remedy**—if significant impacts cannot be avoided or reduced, then "repair" the consequences of the impact after it has occurred through rehabilitation, reclamation, restoration, compensation, and/or offsets.

Management measures are generally not developed for potential adverse impacts that are assessed as *Negligible*. Practicable measures, as available, are adopted for higher levels of impact significance.

Step 4: Determine and Manage Residual Impacts

The final step in the iterative impact evaluation process for this EIA is the determination of "residual impacts" (i.e., impacts that are predicted to remain after both embedded controls and committed mitigation measures have been taken into consideration). This typically involves pursuing elements of Step 1 and Step 2 to re-evaluate the magnitude and then the significance of the potential impact now considering the implementation of proposed mitigation measures. If significant residual impacts remain, efforts aligned with Step 3 are made to identify additional or alternative cost-effective and practicable mitigation measures.

- The management emphasis for *Moderate* and *Major* impacts is on reducing the impact to a level that is as low as reasonably practicable. This does not necessarily mean, for example, that impacts of *Moderate* significance have to be reduced to *Minor*, but rather that impacts are being managed effectively and efficiently.
- Although a goal of an impact assessment is to eliminate *Major* residual impacts through impact avoidance or other measures, for some resources/receptors, there may be *Major* residual impacts after all practicable mitigation options have been exhausted. Decision-makers must weigh such negative factors against the positive ones, such as employment, in reaching a decision on the Project.

4.7 Mitigation, Management, and Monitoring

In support of the EIA process, ERM and EEPGL developed a Project ESMP (as summarized in Chapter 9) that includes:

- Management measures identified in the impact assessment;
- Summary of how the measures will be implemented; and
- Monitoring strategy to evaluate the effectiveness of the management measures.

The management strategy uses an adaptive approach during the Project life cycle to ensure that recommended management measures are implemented as planned and produce the desired outcomes. This adaptive approach provides the Project, in consultation with the EPA and other stakeholders, the opportunity to:

- Address unanticipated adverse impacts that are encountered through the addition of new management measures (following the avoid/reduce/remedy hierarchy);
- Adjust or replace existing management measures when appropriate during the Project life cycle to address evolving impacts; and
- Retire existing management measures when no longer demonstrating value.

EEPGL recognizes that demonstrating capacity to manage non-routine, unplanned events, such as oil spills, is an important and integral component of the impact management process. As such, the ESMP includes an Oil Spill Response Plan (OSRP) to address the possibility of non-routine, unplanned events.

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5.0 SCOPE OF THE ENVIRONMENTAL IMPACT ASSESSMENT

The scope of the EIA includes all Phase 1 Project stages (i.e., development drilling, installation, hook-up/commissioning, production operations, and decommissioning) as described in Chapter 2 and planned activities listed in Section 5.2. The EIA also addresses non-routine, unplanned events (e.g., spills and releases). This EIA builds on the previous Strategic Environmental Assessment prepared for EEPGL's original Exploration Drilling in the Stabroek Petroleum Prospecting License Area (March 2014), and the Environmental Management Plan prepared for EEPGL's Liza Field Multiwell Exploration Program (February 2016). The collection of additional data and completion of further analyses, however, were required to evaluate the potential environmental and socioeconomic impacts of all stages of the Project, which are addressed in this EIA.

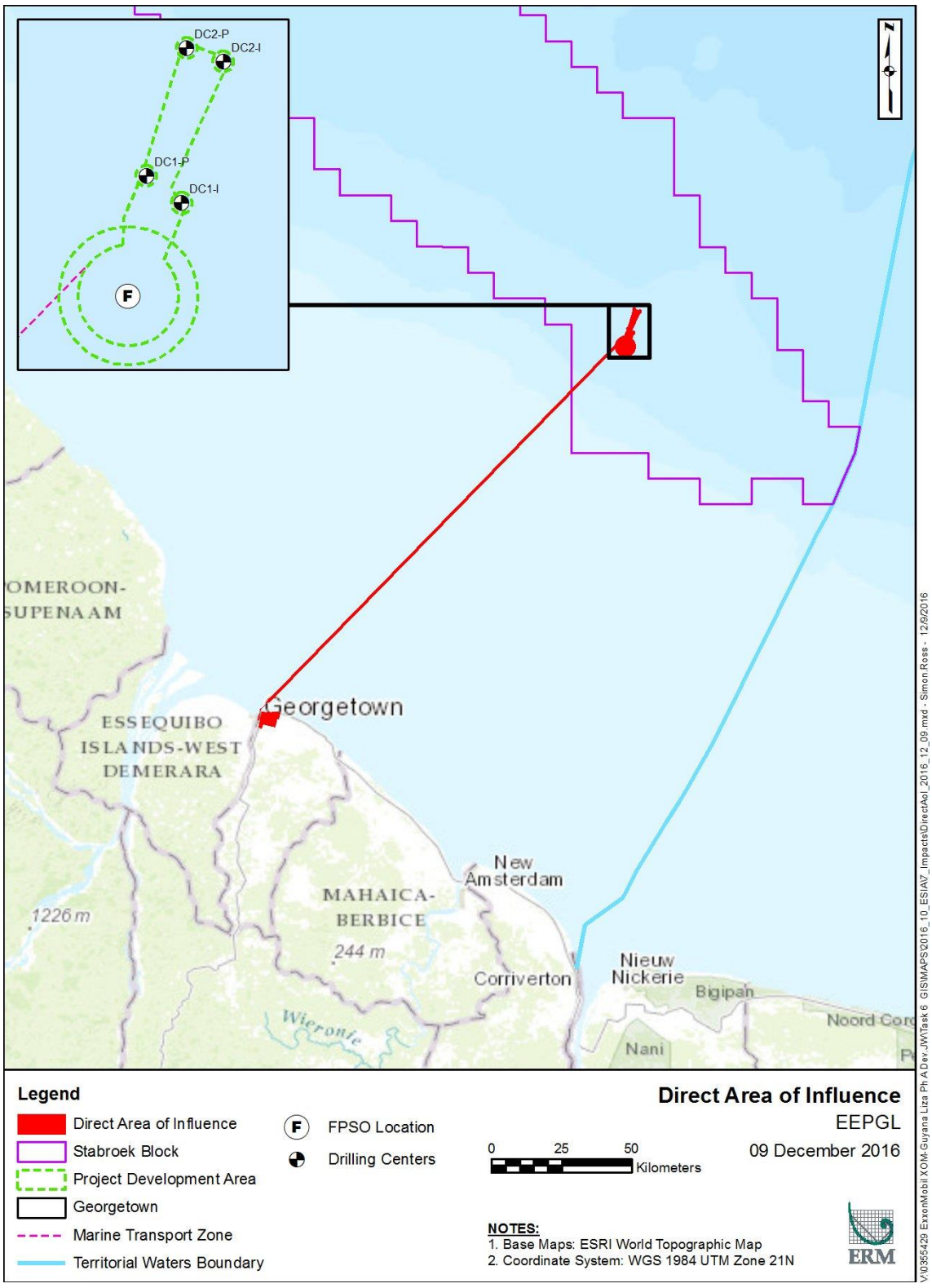
5.1 The Area of Influence

The area potentially impacted by a project is referred to as its Area of Influence (AOI). For purposes of this impact assessment, the Project AOI was divided into a direct and an indirect AOI, as described below:

- Direct AOI, within which the Project is expected to have direct impacts (Figure 5-1). This area includes: (1) the PDA (i.e., the Liza Phase 1 area including the subsea wells, SURF equipment, and the FPSO); (2) the marine transit corridors between the PDA and shore-based activity centers in Guyana and Trinidad; and (3) the city of Georgetown; and
- Indirect AOI, within which the Project is expected to have indirect impacts (Figure 5-2). This area includes: (1) coastal areas and marine waters within the territorial boundary of Guyana that could potentially be impacted by an unplanned event (i.e., an oil spill; see Section 7.4 for more details on oil spill modeling) and (2) coastal Regions 1 to 6 who could be impacted to a greater extent by the Project than the other regions because of their subsistence and commercial marine fisheries (e.g., potential impacts on fish and marine transport) and increased exposure to Project socioeconomic impacts. Although all 10 regions of Guyana would potentially benefit from the shared government revenue stream from the Project, the Indirect AOI does not include the entire country because the extent to which any specific region could benefit from the revenues is dependent on the government's policies rather than on EEPGL's activities as assessed in this EIA.

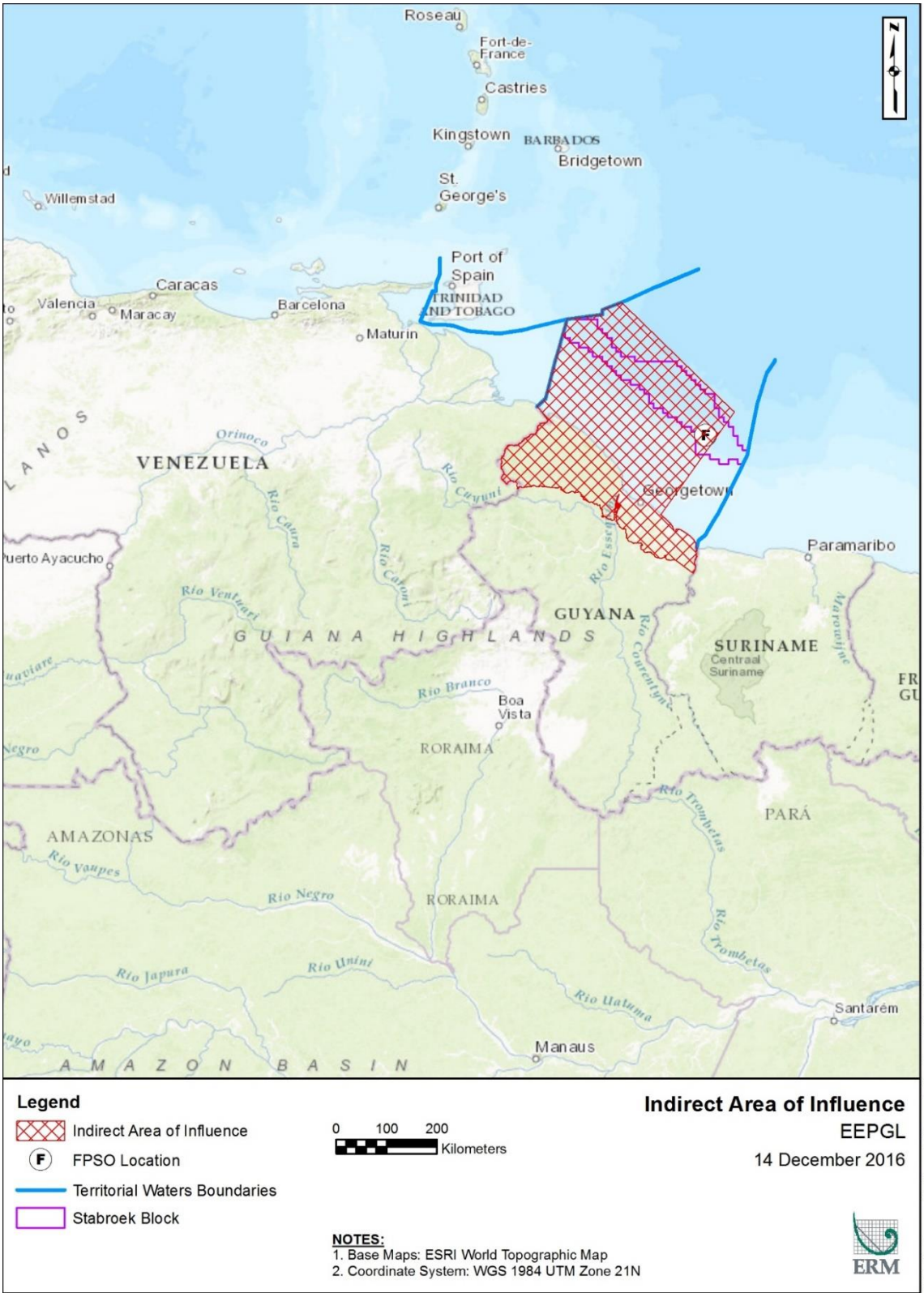
As described in Section 8, cumulative impacts on environmental and socioeconomic resources could potentially result from incremental impacts of the Project, when combined with other past, present, and reasonably foreseeable future projects/developments within the AOI. The geographic area of concern for the cumulative impacts analysis is generally consistent with the Project AOI.

Figure 5-1 Direct Area of Influence



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

Figure 5-2 Indirect Area of Influence



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

5.2 Project Interactions with Environmental and Socioeconomic Receptors

In order to define the scope of the environmental and socioeconomic impact analysis, it is necessary to identify the potential interactions between the Project and the resources/receptors within the AOI. These interactions are the mechanisms that could trigger Project-related impacts on resources/receptors.

Each of the Project activities and potential unplanned events listed below has the potential to interact with existing resources/receptors in the AOI, which could potentially create environmental or socioeconomic impacts.

- Development Drilling Stage:
  - Drill ship and drilling operations
    - Power generation
    - Drill cuttings discharges
    - Drilling fluids discharges
    - Wastewater discharges
    - Offshore waste treatment and disposal including incineration
  - VSP
  - ROV operations
  - Onshore waste management, recycling, treatment, and disposal

- Installation of FPSO/SURF Components Stage:
  - Marine installation vessels and FPSO
    - Power generation
    - Install mooring system (e.g., driven or suction piles for FPSO and select SURF equipment)
    - Discharge of hydrostatic test water, hydrate inhibitor, ballast water
    - Wastewater discharges
    - Limited waste incineration
  - ROV operations and installation of SURF equipment
  - Hook-up and commissioning of FPSO and SURF equipment
  - Onshore waste management, recycling, treatment, and disposal

- Production Operations Stage:
  - FPSO Vessel Operations
    - Power and heat generation
    - Non-routine, temporary flaring
    - Produced water discharges
    - Brine discharges from sulfate removal and potable water processing
    - Sanitary wastewater discharges
    - Ballast water discharge (one time at mobilization)
    - Non-hydrocarbon contact cooling water discharges
    - Gas re-injection into reservoir
    - Seawater intake

  - Seawater injection into reservoir
  - Chemical use (topsides, subsea, downhole)
- Oil Offloading to Conventional Tankers
  - Tanker power generation
  - Venting of cargo tanks during oil loading
  - Seawater intake for ballast operations
  - Tanker ballast water discharge on arrival
  - Tanker domestic wastewater discharge
- Offshore waste treatment and disposal including waste incineration
- Onshore waste management, recycling, treatment, and disposal

- Decommissioning Stage:
  - Marine decommissioning vessels and FPSO
    - Power generation
    - Disconnection of mooring system and SURF equipment
    - Wastewater discharges
    - Limited waste incineration
  - Onshore waste management, recycling, treatment, and disposal

- Logistical Support (across all Project stages):
  - Supply and support vessel/aircraft operations
  - Onshore fuel transfers from suppliers
  - Utilization of shorebases, including pipe yards and warehouses
  - Onshore waste management, recycling, treatment, and disposal

- Non-routine, Unplanned Events:
  - Oil spill or release – FPSO/SURF production operations
  - Oil spill or release – Well control event
  - Other oil spills or releases
  - Other unplanned events

5.3 Resources/Receptors Assessed in the EIA

One of the purposes of the scoping process is to identify which resources/receptors could potentially be significantly impacted by the Project, and which resources/receptors would not have the potential to be significantly impacted by the Project. Based on the Project Description and understanding of existing conditions at the time of scoping, Table 5-1 lists those resources/receptors that were identified as having the potential to be impacted by the Project, subject to further assessment. These resources/receptors were retained for further consideration in the EIA.

Table 5-2 lists those resources/receptors that have been identified as unlikely to have the potential to be impacted by the Project and the rationale for this determination. These resources/receptors are excluded from further consideration in the EIA.

Table 5-1 Summary of Resources/Receptors Retained for Further Consideration in EIA and Corresponding Potential Impacts, Primary Sources of Potential Impacts, and Analytical Approach

Resource or Receptor	Potential Impacts	Primary Sources of Potential Impacts	Analytical Approach
Physical Resources			
Air Quality and Climate	Air emissions resulting from the Project have the potential to change ambient air quality in the Project AOI on a localized basis. Air quality is important for health of humans and wildlife. Potential impact of greenhouse gas emissions from the Project on climate change.	• Power generation • Other combustion sources • Non-routine, temporary flaring • Fugitive emissions from storage and loading • Waste incineration • Helicopter and aviation emissions	To describe actual air quality conditions in the vicinity of the Project, ambient air quality data were collected at the proposed Project site approximately 190 km (120 mi) offshore of Guyana, including measurements of particulate matter (PM_{10}), carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), and volatile organic compounds (VOC). Measurements were taken onboard a research vessel. Air emission inventories were prepared for these pollutants and a screening level analysis was conducted to identify potential air quality impacts associated with Project activities. Dispersion modeling was conducted to assess potential impacts to ambient air quality. Potential impacts were described. Estimated greenhouse gas (GHG) emissions for the Project were calculated.
Sound	Auditory impacts on Project workers.	• Equipment/machinery operating onboard the FPSO or drill ships •	Managing occupational-related risks through appropriate PPE.
Marine Geology and Sediments	The Project will disturb marine geology and sediments on a localized basis in the PDA and could impact sediment quality from non-aqueous base fluid (NABF) on drill cuttings discharges.	• Drilling of development wells • Installation of FPSO and SURF components	A fate and transport model (GIFT) was used to evaluate cuttings and drilling fluid deposition surrounding the development wells. The physical differences between the native seafloor and the accumulated drill cuttings, as well as the distribution of residual NABF on drill cuttings, were described based on the results of the modeling analysis.
Marine Water Quality	The Project could have localized impacts to marine water quality in the PDA from discharge of drill cuttings and from routine operational and hydrotesting discharges. The Project could potentially impact marine water quality in the Project AOI as a result of non-routine, unplanned events.	• Drilling of development wells (cuttings and fluid discharge) • Cooling water discharges • Installation of FPSO and SURF components • Wastewater discharges • Produced water discharges • Hydrotesting discharges • Non-routine, unplanned event (e.g., spill or release)	A fate and transport model (GIFT) was used to evaluate total suspended solids (TSS) concentrations resulting from discharge of drilling fluid and cuttings based on global ocean currents data. USEPA's CORMIX model was used to simulate the mixing zone around the drill ships and FPSO, and to support an analysis of impacts on marine water quality from routine production operations discharges and one-time hydrotesting discharges. Oil spill modeling was used to estimate concentrations of dissolved hydrocarbons that might result from different unplanned event scenarios
Biological Resources			
Protected Areas and Special Status Species	The Project is not expected to impact Protected Areas during routine, planned operations and activities in the Project AOI. The Project could potentially impact Protected Areas in the Project AOI as a result of non-routine, unplanned events. The Project could potentially impact some special status species (e.g., endangered or listed species) in a localized manner in the PDA as a result of underwater sound, light, seawater withdrawal, and changes in marine water quality. The Project could potentially impact special status species in the Project AOI as a result of non-routine, unplanned events.	• Non-routine, unplanned event (e.g., spill or release) • Underwater sound generated by marine component operations and activities • Lighting on offshore facilities (e.g., FPSO, drill ships) • Seawater intake by FPSO • Wastewater discharges • Drilling of development wells (cuttings and fluid discharge) • Cooling water discharges • Produced water discharges • Hydrotesting discharges • Vessel movements	Oil spill modeling was used to simulate the trajectory of an oil spill and assess the risk of oiling impacting any designated Protected Areas. Consistent with the approach taken for marine mammals, turtles, and fish without special status designation, the scientific literature was reviewed for information on the impacts of planned offshore activities on special status species, including marine turtles, fish, and marine mammals. Oil spill modeling was used to assess potential spill-related impacts. Underwater sound was modeled to assess potential auditory impacts associated with marine activities. USEPA's CORMIX model was used to simulate the mixing zone around the drill ships and FPSO, and to support an analysis of impacts on marine water quality from routine operational discharges and one-time hydrotesting discharges. The GIFT model was used to evaluate TSS concentrations resulting from discharge of drilling fluid and cuttings based on global ocean currents.

Resource or Receptor	Potential Impacts	Primary Sources of Potential Impacts	Analytical Approach
Coastal Habitats	The Project is not expected to impact beaches, mangroves, or wetlands in the Project AOI during routine, planned operations and activities. The Project could potentially impact beaches, mangroves, and wetland habitats in the Project AOI as a result of non-routine, unplanned events.	• Non-routine, unplanned event (e.g., spill or release)	Oil spill modeling was used to simulate the trajectory of an oil spill and assess the risk of oiling beaches, mangroves, or wetlands.
Coastal Wildlife and Shorebirds	The Project is not expected to impact coastal wildlife or shorebirds during routine, planned operations and activities in the Project AOI. The Project could potentially impact coastal wildlife and shorebirds in the Project AOI as a result of non-routine, unplanned events.	• Non-routine, unplanned event (e.g., spill or release)	Oil spill modeling was used to simulate the trajectory of an oil spill and assess the risk of impacting coastal wildlife and shorebirds.
Seabirds	The Project could potentially impact seabirds in a localized manner in the PDA as a result of light (i.e., disorientation). The Project could potentially impact seabirds in the Project AOI as a result of non-routine, unplanned events.	• Drill ship, FPSO, and support vessel operations • Lighting on offshore facilities (e.g., FPSO, drill ships) • Non-routine, temporary flaring • Waste incineration • Non-routine, unplanned event (e.g., spill or release)	The scientific literature was reviewed for information on the impacts of lighting from planned offshore activities on seabirds. Oil spill modeling was used to assess potential spill-related impacts on seabirds.
Marine Mammals	The Project could potentially impact some marine mammals in a localized manner in the Project AOI as a result of underwater sound and ship strikes. The Project could potentially impact marine mammals in the Project AOI as a result of non-routine, unplanned events.	• Underwater sound generated by marine component operations and activities • Ship strikes • Changes in forage availability • Lighting on offshore facilities (e.g., FPSO, drill ships) • Seawater intake by FPSO • Wastewater discharges • Drilling of development wells (cuttings and fluid discharge) • Cooling water discharges • Produced water discharges • Hydrotesting discharges • Non-routine, unplanned event (e.g., spill or release)	The scientific literature was reviewed for information on the impacts of planned offshore activities on marine mammals, turtles and fish. Analyses were performed based on expected marine mammal and turtle presence and Project vessel transits to assess likelihood of vessel strikes. Oil spill modeling was used to assess potential spill-related impacts. Underwater sound was modeled to assess potential auditory impacts associated with marine activities. USEPA's CORMIX model was used to simulate the mixing zone around the drill ships and FPSO, and to support an analysis of impacts on marine water quality from routine operational discharges and one-time hydrotesting discharges. A fate and transport model (GIFT) was used to evaluate total suspended solids (TSS) concentrations resulting from discharge of drilling fluid and cuttings based on global ocean currents. Oil spill modeling will be used to assess potential spill-related impacts on marine mammals, turtles, and fish.
Marine Turtles	The Project could potentially impact some marine turtles in a localized manner in the Project AOI as a result of underwater sound, ship strikes, and light. The Project could potentially impact marine turtles in the Project AOI as a result of non-routine, unplanned events.		
Marine Fish	The Project could potentially impact some marine fish as a result of underwater sound, light, seawater withdrawal, and changes in marine water quality in the PDA. The Project could potentially impact marine fish in the Project AOI as a result of non-routine, unplanned events.		
Marine Benthos	The Project could potentially disturb some benthic habitat and organisms in a localized manner in the PDA.	• Drilling of development wells (cuttings discharge and deposition) • Installation of FPSO (mooring structures) and SURF components • Non-routine, unplanned event (e.g., spill or release)	Fate and transport model (GIFT) was used to predict the extent and thickness of cuttings discharged on the seafloor surrounding the development wells. The physical differences between the native seafloor and the accumulated drill cuttings, as well as the distribution of NABF containing cuttings and potential for toxicity impacts, were described based on the results of the modeling analysis. Impacts from planned activities were evaluated in terms of the percentage of benthic habitat impacted by disturbance.

Resource or Receptor	Potential Impacts	Primary Sources of Potential Impacts	Analytical Approach
Ecological Balance and Ecosystems	The Project could have indirect impacts on ecological functions in the Project AOI, particularly if special status species or trophic relationships are disturbed.	• Underwater sound generated by marine component operations and activities • Lighting on offshore facilities (e.g., FPSO, drill ships) • Seawater intake by FPSO • Installation of FPSO and SURF components • Installation-related disturbances to seafloor • Wastewater discharges • Ballast water discharges • Waste incineration • Non-routine, unplanned event (e.g., spill or release)	The scientific literature was reviewed to determine the ecological relationships between major marine taxonomic groups. Oil spill modeling was used to assess potential spill-related impacts on marine organisms.
Socioeconomic Resources			
Economic Conditions	The Project is generally anticipated to have a positive impact on the economy of Guyana as a result of government revenue sharing from the Project, as well as employment and local procurement opportunities. Potential adverse impacts may include potential shorter term increases in the cost of living as a result of increased demand for specific goods and services. Potential adverse impacts to income from agriculture and fisheries could also occur as a result of non-routine, unplanned events.	• Government revenue sharing from Project • Local Project purchases of select materials, goods, and services • Limited local Project employment (direct and indirect) • Increased spending on select materials, goods, and services (indirect multiplier impacts for local/regional population)	Government reports were reviewed and key informant interviews were conducted to identify key economic drivers in the national, regional, and local economies and determine the likely Project-related impacts on these economic factors. A particular emphasis was placed on industrial sectors that are important to coastal communities.

Employment and Livelihoods	The Project is expected to build capacity in the local labor force, increase demand for skilled labor, and increase demand for service industries (beneficial impact). There is also the potential for limited adverse impacts to fishing activities as a result of marine safety exclusion zones or marine traffic, and non-routine, unplanned events.	• Local employment for:
		  ○ Drill ships
		  ○ Installation vessels
		  ○ FPSO topside equipment and operations
		  ○ Marine support and supply vessels
		  ○ Tankers
		  ○ Tugs and support vessels
		  ○ Aviation operations
		• Marine safety exclusion zones
		• Project-related marine traffic
		• Drilling; FPSO/SURF installation, hookup and commissioning; and FPSO and support vessel operations (aspects relating to occupational health and safety for Project workforce)
		• Non-routine, unplanned event (e.g., spill or release)
			Project workforce projections and types of labor requirements were assessed against data obtained through key informant interviews on the existing service industry within Guyana. The potential for adverse impacts to fishing activities was assessed by taking into consideration the distance from shore at which different fishery types typically operate, in comparison to the locations and durations of Project-related marine activity and marine safety exclusion zones. Potential occupational hazards to Project workforce working onshore and offshore were assessed.

Community Health and Wellbeing	Most Project activities will be located offshore in the PDA and would have no direct impacts on communities in Guyana. Introduction of limited levels of foreign labor could potentially have health and socioeconomic impacts. The Project could potentially impact community health and wellbeing in the Project AOI due to onshore traffic, social interaction, or as a result of non-routine, unplanned events.	• Increased traffic as a result of Project activities at the Guyana shorebase locations • Social interaction between Project workers and residents • Pressure on wages from introduction of foreign workers and increased competition for skilled labor • Noise and light near shore by Project marine and aviation operations • Non-routine, unplanned event (e.g., spill or release)	Potential risks to safety and health of local communities posed by shorebase operations were assessed. Key informant interviews were conducted to characterize existing road, marine, and air traffic safety conditions, as well as coastal agriculture, aquaculture, and offshore/coastal fishing activities. Oil spill modeling was used to simulate the trajectory of an oil spill and to assess potential spill-related impacts on community health and wellbeing.
Marine Use and Transportation	The Project may result in increased marine shipping and general marine-related traffic, which could potentially contribute to marine vessel congestion in port areas.	• Marine vessel operations	Key informant interviews were conducted to characterize communities dependent on marine transportation for livelihoods (e.g., speedboat operators and fisherpersons), and to characterize existing marine vessel and safety conditions in the Project's AOI.

Resource or Receptor	Potential Impacts	Primary Sources of Potential Impacts	Analytical Approach
Social Infrastructure and Services	The Project will use public infrastructure and services and thus could potentially compete with other existing businesses and consumers across a range of services (e.g., roads, medical and emergency response, accommodation, and utilities). The Project may result in increased vehicular traffic in Georgetown, which could potentially contribute to vehicular congestion in certain areas.	• Project demand requirements for selected infrastructure and services which could overburden existing capacity and supply • Shorebase operations • Ground transportation operations	Key informant interviews and review of government reports were conducted to assess existing demand on public infrastructure, transportation networks, vehicular traffic, and public services and to determine the impact (access and safety) that any additional demand on these resources would have on impacted communities.
Cultural Heritage	The Project has the potential to adversely impact cultural heritage through localized disturbance of archaeological or historical sites related to Project development. These resources have conservation, cultural, and other values to stakeholders. The Project could potentially impact cultural heritage in the Project AOI as a result of non-routine, unplanned events.	• Drilling of development wells • Installation of FPSO and SURF components • Non-routine, unplanned event (e.g., spill or release)	AUV and other geophysical surveys were conducted to map seabed objects in the PDA. Oil spill modeling was used to simulate the trajectory of an oil spill and to assess the potential for a release from an unplanned event to contact terrestrial archaeological sites.
Land Use	No new Project-dedicated land disturbance is planned. There is the potential that third-party onshore facilities may elect to expand or impact adjacent land as a result of supporting Project-related needs; however, these impacts are outside the scope of this EIA.	• Shorebase operations • Pipe yards • Warehouses • Bulk fuel storage and transfer facilities • Onshore waste recycling, treatment and disposal facilities	Land use in the area surrounding onshore facilities planned for Project use was reviewed and assessed with respect to the potential for significance of land use changes as a result of the Project.
Ecosystem Services	Project-related impacts on natural resources could lead to shorter term direct or indirect impacts on the services and/or values derived from natural resources and ecosystems in the AOI.	• Direct or indirect impacts derived from one or more of the impacts on physical, biological, or socioeconomic resources described above	The use of natural resources by local communities, including indigenous communities, was examined to identify specific dependencies on resources that could be impacted by the Project. Where dependencies on natural resources that would be impacted were identified, the direct and indirect impacts of Project activities on local communities' access to and use of impacted resources was assessed.
Indigenous Peoples	The Project is not expected to directly cause any changes to population and demographics in indigenous communities. The Project could potentially impact indigenous peoples in the Project AOI as a result of non-routine, unplanned events.	• Non-routine, unplanned event (e.g., spill or release)	Coastal communities, including indigenous communities, in the Project AOI were mapped. Key informant interviews were conducted to characterize socioeconomic conditions in communities, and their reliance on natural resources. Oil spill modeling was used to simulate the trajectory of an oil spill and to assess the potential for oil to contact lands and natural resources of coastal communities.

Table 5-2 Resources and Receptors Excluded from Further Consideration in the EIA

Resource/Receptor	Rationale for Excluding
Coastal (Onshore) Resources	
Onshore geology/soils	The Project will not result in any onshore disturbance to geology and soils.
Topography/Landscape	The Project will not require any excavation, fill, or other land-based activities that could change topography or landscapes.
Groundwater quality	The Project will not require any changes in land use that could impact ground water quantity or quality.
Terrestrial vegetation	The Project will not require any clearing or disturbance of terrestrial vegetation. Even in the case of an unplanned event such as a spill, only estuarine vegetation (e.g., mangroves) would be expected to be potentially impacted. Terrestrial vegetation should be unaffected by a spill event.
Freshwater habitats	The Project is offshore with no new onshore disturbance, so will not have any impact on freshwater habitats.
Marine Resources	
Aquatic plants	The marine aspects of the Project will occur in an area that is too deep to support vascular marine plants.
Physical Resources	
Natural hazards	The Project is not located within an area that is known to have a high level of seismic activity or susceptibility to other natural hazard with the potential to affect Project facilities.
Vibration and radiation	The Project will not generate any vibration or radiation that would be expected to impact resources/receptors. See Section 2.10

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6.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

6.1 Physical Resources

6.1.1 Air Quality and Climate

This section describes the existing air quality conditions and climate in the Project AOI. Air quality in a geographic area is determined by the presence of background concentrations due to natural and distant sources, the type and amount of pollutants emitted locally into the atmosphere, the topography of the area, and the weather and climate conditions. The levels of pollutants and pollutant concentrations in the atmosphere are typically expressed in units of ppm, parts per billion (ppb), or micrograms per cubic meter ($\mu g/m^3$), averaged over various periods of time.

6.1.1.1 Methodology

Climate: Information on meteorological conditions in coastal Guyana was obtained from publicly available sources and technical literature. Parameters discussed include rainfall, offshore wind direction, air temperature, and relative humidity.

To develop more specific information regarding the conditions in the PDA, EEPGL and ERM have deployed oceanographic moorings in the PDA to collect information on existing oceanographic and meteorological conditions in the area to support design development. The meteorological moorings are equipped with a Datawell Direction Wavescan Buoy, which measures wave and atmospheric conditions. With respect to atmospheric conditions, the instrument measures and logs:

- wind direction/speed (two anemometers record 10-minute average wind speeds and gusts),
- air temperature,
- atmospheric pressure,
- solar radiation,
- precipitation, and
- relative humidity.

Air Quality: Since the PDA is located approximately 190 km (~120 miles) offshore in the Atlantic Ocean and far removed from any anthropogenic sources of emissions other than intermittent marine traffic, ambient air quality is determined primarily by regional influences rather than by local emission sources or topographic influences. ERM has conducted offshore air monitoring, including the collection of air samples, to analyze existing ambient concentrations of relevant air quality pollutants in the PDA; the samples were collected from onboard a research vessel within the Stabroek Block and PDA. The pollutants collected include inhalable particulate matter (i.e., that fraction with aerodynamic diameter of less than 10 micrometers,"PM_{10}"), carbon monoxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), and volatile organic compounds (VOC).

6.1.1.1 Regional or National Setting/Context

Climate: Guyana has a wet tropical climate characterized by two pronounced wet seasons and year-round warm temperatures.

The bimodal wet/dry regime is caused by the annual migration of the Inter-Tropical Convergence Zone (ITCZ), which changes latitude based on the Earth's position and angle in relation to the sun. Northward movement of the ITCZ occurs as energy from the sun is strongest in the Northern Hemisphere during the Northern Hemisphere's summer, thereby increasing solar heating in that hemisphere. The relative changes in solar heating slightly shift the atmosphere primary circulation cells, which cause the area of trade wind convergence closest to the Equator to migrate seasonally. In the areas closest to the ITCZ, one can expect increased thunderstorm activity and heavy rainfall between mid-April and the end of July, with peak rainfall in June. This period is known in Guyana as the primary wet season. The secondary wet season occurs during the southward migration of the ITCZ from mid-November to the end of January, with peak rainfall in December. The intervening periods (January to April and mid-August to mid-November) are relatively dry, but rain can occur at any time of the year. Average annual rainfall totals range between 70 inches and 110 inches (~180 cm to ~280 cm, Hydromet, 2014). During El Niño years, Guyana's long dry season is often drier and warmer than normal, and La Niña years bring wetter and cooler conditions than normal during the long wet season (McSweeney et al., 2010).

Although the ITCZ moves seasonally, it is generally located between 5 degrees (°) North and 5° South latitude. North and south of the ITCZ, atmospheric circulation and the Coriolis effect create global wind patterns including the Northern Hemisphere's trade winds and westerlies (NOAA, 2008). Guyana's coastal zone is located approximately between 6° and 8° latitude, and the Stabroek Block is located between 7° and 8° latitude, both within the southern portion of the area impacted by the trade winds. The influence of the trade winds produces a strongly dominant northeast wind offshore of Guyana, which gives rise to the afternoon "sea breeze" that usually blows inland across coastal Guyana from the ocean.

Annual average temperatures in coastal Guyana are relatively constant, with an annual average daytime maximum temperature of 29.6 degrees Celsius (°C) (85.3 degrees Fahrenheit [°F]) and an annual average night time minimum temperature of 24.0 °C (75.2°F). The average daily temperature is approximately 27 °C (81°F). Relative humidity is high at 80 percent or more year round in the coastal zone.

Air Quality: For purposes of this EIA, relevant literature was used to identify appropriate ranges of concentrations to represent existing conditions. Based on the estimated Project emissions profile, the principal relevant air pollutants of interest are $PM_{2.5}$ and NO_2. Yale University (2016) published a report that ranked Guyana 6th (from the best) out of 180 countries in air quality. As part of this study, Yale University (2015) published an online mapping tool, which estimates that the average concentration of $PM_{2.5}$ in onshore Guyana is 2.5 $\mu g/m^3$. No values were found in the literature for onshore air quality existing conditions for NO_2.

6.1.1.2 Existing Conditions in Area of Influence

Climate: In general, climate conditions within the Project AOI should be similar to those described above for Guyana. The results of the ERM's effort to further characterize climate conditions within the PDA will be incorporated into the Final EIA.

Air Quality: The PDA is well offshore and far removed from any existing stationary anthropogenic sources of airborne pollution. In addition, the prevalent wind direction is from the northeast (open ocean); therefore, ambient air quality within the PDA is expected to be good. This assumption was confirmed by the results of a 20-day ambient air quality measurement program conducted aboard the Research Vessel Proteus. Those measurements found that air pollutant levels were generally below detection levels, with the exception of PM_{10}. Chemical analysis of particulate matter samples found that the most of the collected mass was composed of sodium chloride—the most likely source of which is sea salt.

6.1.2 Sound

This section includes a summary of the desktop review of existing underwater sound conditions in the Project AOI. It also describes the different metrics commonly used to represent underwater acoustic fields. A description of the modeling study used to predict underwater sound levels associated with Project activities in the PDA is discussed in Section 7.2.5, Marine Mammals.

This analysis is limited to underwater sound because the Project is located approximately 190 km (~120 mi) offshore from Georgetown, so airborne sound and ground-borne vibration from offshore Project activities will not impact onshore community or public receptors in Guyana. Offshore, the principal airborne sound receptors of potential concern will be the Project workforce on the Project vessels, who will be provided with appropriate Personal Protective Equipment (PPE), including ear protection (when engineered controls must be augmented to manage sound exposure). The Project will not measurably impact any airborne sound or ground-borne vibration at the onshore shorebase, pipe yards, and warehouse locations. Therefore, airborne sound and ground-borne vibration are not discussed further in this section.

6.1.2.1 Underwater Acoustic Metrics

Underwater sound amplitude is measured in decibels (dB) relative to a fixed reference pressure (p_0 = 1 micro Pascal (µPa)) or reference energy level (1 $\mu Pa^2 \cdot s$). Three common descriptors are the:

- peak Sound Pressure Level (peak SPL, measured in dB re: 1 µPa),
- Root Mean Square SPL (RMS SPL, measured in dB re: 1 µPa), and
- Sound Exposure Level (SEL, measured in dB re: 1 $\mu Pa^2 \cdot s$).

The peak SPL metric is the maximum instantaneous SPL in a stated frequency band attained by an acoustic event. The peak metric is commonly quoted for impulsive sounds, but does not account for the duration or bandwidth of the sound. At higher intensities, the peak SPL can be a

valid criterion for assessing whether a sound is potentially injurious or may cause behavioral implications to a marine receptor.

The RMS SPL is a measure of the average pressure or the effective pressure over the duration of an acoustic event, such as the emission of one acoustic pulse from a seismic source (e.g., vertical seismic profiler). This level is the root mean square pressure level of the pulse.

The SEL is a measure of the total acoustic energy contained in one or more acoustic events and is often used as an indication of the energy dose over a specific event or time. The SEL metric measures the sound energy to which an organism at that location would be exposed.

Sound loudness is a subjective term describing the strength of the ear's perception of a sound. It is a complex interaction between the sound pressure level and the hearing ability of an individual receptor for that sound (how well the sound can be detected). Because the loudness of impulsive sound is not generally proportional to the instantaneous acoustic pressure, the peak SPL is a poor indicator of perceived loudness. As such, several other sound level metrics such as RMS SPL and SEL are commonly used to evaluate the loudness of impulsive sound and its impacts on marine life.

More information on the underwater acoustic metrics described above, including the analytical formulation of these metrics, is provided in the document *Underwater Sound Associated with Liza Phase 1 Project Activities*, prepared by JASCO Applied Sciences in December 2016 (JASCO, 2016).

6.1.2.2 Methodology

Ambient underwater sound levels were based on literature values for coastal Guyana. Research has indicated that with the exception of localized or short term events that may cause acute exposure (e.g., passage of a single ship, intense rain events, or whale vocalizations) underwater sound levels do not vary much in the open ocean. Human activities are minimal in the PDA (principally related to commercial fishing and other ocean going vessels). Therefore, the use of literature values from coastal Guyana should be a reasonable representation of underwater sound conditions in the PDA.

6.1.2.3 Regional or National Setting/Context

Ambient underwater sound levels can serve as existing conditions from which to measure potential disturbance impacts associated with Project activities. Sound in the ocean is the result of both natural and anthropogenic sources. Examples of notable sound levels produced by natural sources include snapping shrimp (peak SPL of individual snaps vary from 183 to 189 dB re 1 µPa at 1 m, with a typical peak spectrum between 2 and 5 kHz and energy extending to 200 kHz), waves breaking at 50 Hz due to sea surface agitation (61 to 76 dB re 1 µPa/$\sqrt{Hz}$ depending on the sea state), and waves breaking at 25 kHz due to sea surface agitation (32 to 47 dB re 1 µPa/$\sqrt{Hz}$ depending on the sea state) (Hildebrand 2009). Examples of notable sound levels produced by human or mechanical sources include cargo vessels at 16 knots (173 m length; 192 dB RMS re 1 µPa at 1 m with typical spectrum between 40 and 100 Hz), small boat outboard engine at 20 knots (160 dB RMS re 1 µPa at 1 m with typical spectrum between 1000

and 5000 Hz), seismic array (260 dB RMS re 1 µPa at 1 m with typical spectrum between 5 and 300 Hz), and sub-bottom profiler (230 dB RMS re 1 µPa at 1 m with typical spectrum between 3000 and 7000 Hz) (Hildebrand 2009).

6.1.2.4 Existing Conditions in Project Development Area

Guyana's entire continental shelf and slope, including the Stabroek Block, are influenced by the Guiana Current, which transports warm, turbid water north from the mouth of the Amazon River across the coast of northern South America. There are currently no notable sources of mechanical or human-generated background sound in the PDA, other than sporadic instances of commercial vessels and other ocean going vessels. Considering the natural sources such as the Guiana Current and other features of the PDA (e.g., depth, distance from shoreline), existing underwater sounds in the PDA are not expected to exceed 120 dB_{rms}.

6.1.3 Marine Geology and Sediments

6.1.3.1 Coastal Geology

Guyana's continental shelf occupies an area of 18,790 mi^2. The average width of the continental shelf is approximately 113 km (~70 mi) (NDS, 1997). The shelf is widest near the borders of Suriname and Venezuela, and slightly narrower near the center. Guyana's coastline is approximately 431 km (~268 mi) long (NDS, 1997). The Guyana Coast is a sedimentary plain that has formed from successive deposits of sediment with a series of coastal ridges crossing the coast from east to west. These ridges are connected with submarine features that move across the shallow continental shelf in a northward direction driven by the nearshore current.

6.1.3.2 Marine Stratigraphy

The Guyana basin has been described as a passive margin basin associated with the rifting and opening of the Equatorial Atlantic Ocean. Part of the Guyana Basin is onshore, but most of it occurs offshore. Table 6-1 summarizes the age and composition of the major geologic formations (listed in descending order from ground surface) that comprise the Guyana Basin (Workman, 2000; CGX, 2009).

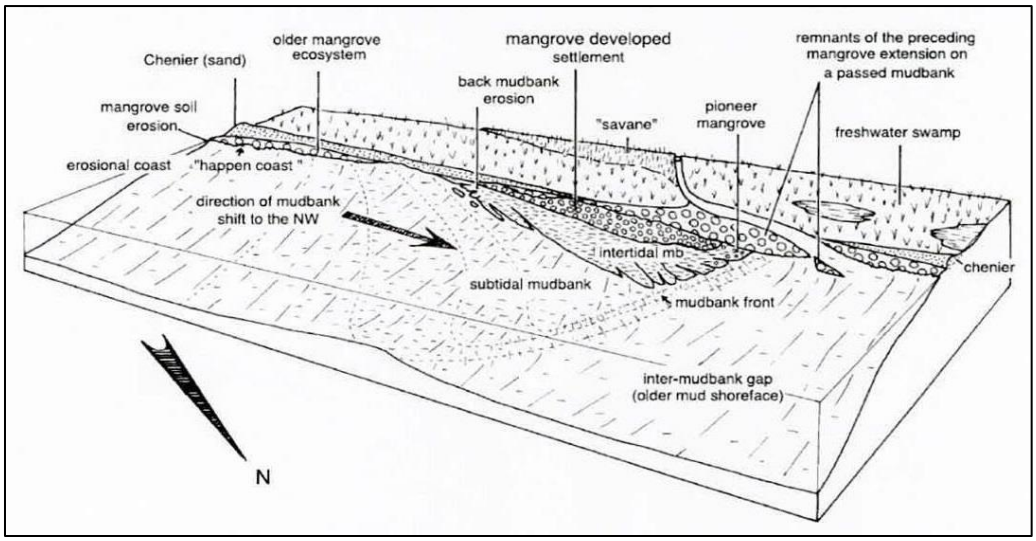
Table 6-1 Major Geologic Formations of the Guyana Basin

Formation	Age	Composition
Corentyne	Pleistocene-Pliocene	Sandstone and shale
Pomeroon	Miocene-Eocene	Carbonate sandstone and shale
Georgetown	Maastrichtian	Sandstone, shale and carbonate
New Amsterdam	Lower Tertiary to Maastrichtian	Sandstone and shale
Canje	Santonian to Turonian	Organic shale, non-organic shale, and sandstone
Potoco Formation	Aptian	Carbonates
Stabroek Formation	Cretaceous–Barremian	Basal shales and sandstones of continental origin
Precambrian Basement	Proterozoic-Hadean	Metamorphic rock

6.1.3.3 Marine Sedimentology

Fine clay and mud sediment are transported from the mouth of the Amazon River and are deposited approximately 21 to 60 km (13 to 37 mi) offshore to an average thickness of approximately 20 m (~65 ft) along Guyana's continental shelf (CGX Resources, 2009). Moving further out to sea (i.e., toward the edge of the continental shelf), sand gradually becomes the dominant sediment layer. The bathymetric profile of the continental shelf forms a generally smooth, gradual slope from nearshore to shelf edge, but a series of low mud ridges or mudbanks are located approximately 21 to 60 km (13 to 37 mi) offshore (Figure 6-1).

Figure 6-1 Typical Distribution of Mudbanks and Mangroves on Guyana's Coast



Source: Institutional Capacity Building Activities on Guyana Sea Defenses, 2005.

Although the Essequibo and several other smaller rivers (e.g., the Demerara, Corentyne, and Berbice Rivers) discharge large quantities of fine sediment, which are subsequently transported seaward and westward across the continental shelf, analysis of the humic content, nutrient composition, and ratio of surface area to mass of Guyanese marine sediments indicates that they are nearly identical to Amazonian sediments and unlike continental Guyanese sediments (Eisma and van der Marel, 1971). This evidence strongly indicates that from a sedimentary perspective, the Guyanese continental shelf functions as a marine extension of the Amazonian delta system. At greater depths, calcarenite (coral fragment) substrates become more prevalent (Strømme and Sætersdal, 1989). The Stabroek Block occupies the transition area between the Amazonian-influenced zone and the older, deeper calcarenite zones.

In the PDA, the foundation zone of the seabed sediments comprises a hemipelagic drape of very soft to soft clay irregularly interbedded with interpreted coarse-grain-prone turbidites. The mud content of the sediments averaged 60.8 percent and the sand content averaged 39.1 percent across the 2016 survey area. The surficial layer is underlain by a regional Mass Transport Complex (MTC) consisting of a heterogeneous clay-prone matrix material with intact blocks. The thickness of the surficial soft clay varies across the PDA from approximately 4.5 m (~ 15 ft) to 41 m (135 ft). These features could influence the design or siting of certain subsea

components that will rest on the seafloor, although they do not present structural or operational hazards to the Project (Fugro 2016).

6.1.3.4 Sediment Quality

Sediment samples were collected from the Stabroek Block offshore Guyana as part of two environmental baseline surveys (EBS). The surveys were conducted prior to EEPGL exploration drilling activities in April and May of 2014 (Maxon Consulting, Inc. and TDI Brooks International, Inc., 2014) and during later EEPGL exploration drilling activities in March of 2016 (FUGRO EMU Limited, 2016). Sediment samples were collected from 10 sampling stations as part of the 2014 survey and from 25 sampling stations as part of the 2016 survey (these locations are collective referred to as the Study Area in this section); the stations include locations within the PDA as well as locations outside the PDA, but within the southeastern portion of the Stabroek Block. A discussion of the results from both surveys is provided below. Summaries of the results for metals and hydrocarbon concentrations in the sampled sediments are presented in Table 6-2 and Table 6-3, respectively.

Table 6-2 Summary Results for Sediment Metals, Reported in µg g^{-1} dry weight

Parameter	Mean	Minimum	Maximum	Mean Background[1]	Effects Range Low[2]	Effects Range Median[3]
2014 Liza EBS (n=10)						
Aluminum	11,495	8,100	15,000	77,440	--	--
Arsenic	6.1	4.5	11.4	2	8.2	70
Barium	98.9	57.4	159	668	--	--
Cadmium	0.125	0.102	0.165	0.102	1.2	9.6
Chromium	14.9	8.6	21.1	35	81	370
Copper	13.1	9.9	16.5	14.3	34	270
Iron	19,130	13,500	25,300	30,890	--	--
Lead	11.6	8.3	15.6	17	46.7	218
Mercury	0.042	0.026	0.062	0.056	0.15	0.71
Nickel	21.4	14.1	32.3	18.6	20.9	51.6
Vanadium	23.5	18.1	28.3	53	--	--
Zinc	45.5	26.9	63.7	52	150	410
2016 Liza EBS (n=25)						
Aluminum	43,432	13,900	66,600	77,440	--	--
Arsenic	11.6	6.1	97.1	2	8.2	70
Barium	175	44	272	668	--	--
Cadmium	0.120	0.073	0.255	0.102	1.2	9.6
Chromium	36.1	14.5	53.4	35	81	370
Copper	20.2	6.9	30.5	14.3	34	270
Iron	30,364	12,100	98,100	30,890	--	--

Parameter	Mean	Minimum	Maximum	Mean Background[1]	Effects Range Low[2]	Effects Range Median[3]
Mercury	0.029	0.016	0.042	0.056	0.15	0.71
Selenium	0.22	0.05	0.75	0.083	--	--
Lead	15.5	9.9	27.5	17	46.7	218
Nickel	27.0	10.8	51.5	18.6	20.9	51.6
Zinc	69.7	32.5	101.0	52	150	410

N/A – Not applicable (background level not available)
Note: One half of the detection limit was used for non-detect results in all statistical calculations
1 Mean concentration in upper continental crust (Wedepohl, 1995).
2 NOAA Effects Range Low (Ecotox, 1996)
3 NOAA Effects Range Median (Ecotox, 1996)

Table 6-3 Summary Results for Sediment Hydrocarbons

Parameter		Mean	Minimum	Maximum	Background[1]
2014 Liza EBS (n=10)					
Total Saturated Hydrocarbon (SHC) (µg g^{-1})		10.64	8	14	N/A
Total Unresolved SHC (µg g^{-1})		6.97	3	12	N/A
Total Resolved SHC (µg g^{-1})		3.68	2	8.9	N/A
CPI (Carbon Preference Index)		1.97	1.47	3.27	N/A
Pristane (µg g^{-1})		0.007	0.004	0.012	N/A
Phytane (µg g^{-1})		0.005	0.003	0.010	N/A
Pristane/Phytane Ratio		1.34	0.67	1.8	N/A
$nC_{16}/(nC_{15}+nC_{17})$		0.40	0.24	0.51	N/A
Total PAH (µg g^{-1})		0.03861	0.02458	0.05336	N/A
Petrogenic/Pyrogenic		3.36	2.14	4.65	N/A
2016 Liza EBS (n=25)					
THC (µg g^{-1})		2.8	1.5	4.8	0.2-5
Unresolved Complex MixtureCM (µg g^{-1})		1.8	0.9	2.8	N/A
n-alkanes	nC_{12-20} (µg g^{-1})	0.06	0.02	0.13	N/A
	nC_{21-36} (µg g^{-1})	0.21	0.1	0.38	N/A
	nC_{12-36} (µg g^{-1})	0.27	0.12	0.5	N/A
CPI	nC_{12-20}	1.29	1.1	2.41	N/A
	nC_{21-36}	2.62	2.09	2.99	N/A
	nC_{12-36}	2.22	1.83	2.7	N/A
Pristane (µg g^{-1})		0.002	0.001	0.013	N/A
Phytane (µg g^{-1})		0.003	0.001	0.012	N/A
Pristane/Phytane Ratio		1.28	0.13	2.27	N/A
Total PAH (Sum of 2-6 Rings) (µg g^{-1})		0.048	0.016	0.239	N/A
Sum of 2-3 Rings (NPD) (µg g^{-1})		0.016	0.006	0.082	N/A
Sum of 4-6 Rings (µg g^{-1})		0.032	0.010	0.157	N/A
NPD/4-6 Ring		0.54	0.35	0.82	N/A

PAH - Polycyclic aromatic hydrocarbons; NPD – Naphthalene, phenanthrene, anthracene, and dibenzothiophene (2-ring and 3-ring PAHs); SHC - Saturated and aliphatic hydrocarbons; THC - Total hydrocarbons; UCM - Unresolved complex mixture; CPI - Carbon preference index (the ratio of odd number carbon chain n-alkanes to even numbered chain n-alkanes); Pr/Ph - Ratio of pristane to phytane
Petrogenic/Pyrogenic – Ratio of the sum of combustion-related PAHs (fluoranthene, pyrene, chrysene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene divided by the sum of petrogenic PAHs (naphthalene, acenaphthene, acenaphthalene, fluorene, phenanthrene, dibenzothiophenes, chrysenes, and fluoranthenes/pyrenes.
2-6 Ring PAH - Total 2 to 6 ring polycyclic aromatic hydrocarbons
nC12-20 – Alkanes ranging from carbon numbers 12 to 20
nC21-36 – Alkanes ranging from carbon numbers 21 to 36
nC12-36 – Alkanes ranging from carbon numbers 12 to 36
N/A – Not applicable (background level not available)
[1] Typical THC levels (i.e. 'background') in sediments remote from anthropogenic activities (North Sea Task Force, 1993).

6.1.3.5 2014 EBS Results (TDI Brooks International, Inc., 2014)

During the 2014 EBS, sediment samples were analyzed for the following parameters:

- Total organic carbon (TOC)
- Metals
- Hydrocarbons

Total Organic Carbon

Concentrations of TOC were less than 1 percent at all survey stations. Higher concentrations of TOC were found in the southwest portion of the survey area, which is closer to shore.

Metals

Twelve metals were measured to assess general patterns of distribution across the Study Area, which was defined as the Liza Area of Interest for the purpose of the study, and what is now considered the PDA. Of the 12 metals analyzed, 10 metals (i.e., arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, vanadium, and zinc) were used as indicators of anthropogenic sources; 2 metals (i.e., aluminum and iron) were used to provide geological source information. All of the ten anthropogenic-indicator metals had concentrations similar to those reported for the upper continental crust (Wedepohl, 1995), with the exception of arsenic, which was slightly elevated (average of 4.51 $\mu g\ g^{-1}$ compared to an upper continental crust mean background concentration of 2 $\mu g\ g^{-1}$). However, all average concentrations were at or below the NOAA Effect Range Low (ERL) values.

Hydrocarbons

Hydrocarbons are divided into two classes of compounds: aliphatic compounds and aromatic compounds. The hydrocarbon analysis consisted of the analysis of saturated and other aliphatic hydrocarbons (SHC), including selected isoprenoids and polycyclic aromatic hydrocarbons (PAHs).

Aliphatic Compounds: Aliphatic compounds can be "saturated" (alkanes with carbon atoms joined by single bonds), or "unsaturated" (alkenes with carbons joined by double bonds). The study measured concentrations of saturated hydrocarbons that encompass light and heavy fractions of petroleum (i.e., alkanes nC_9-nC_{40}) and selected isoprenoids (branched chain unsaturated hydrocarbons), including pristine and phytane. Concentrations of total SHC ranged from 8 $\mu g\ g^{-1}$ to 14 $\mu g\ g^{-1}$. The unresolved portion of the SHC analysis (i.e., SHCs that cannot be identified through the use of standard analytical methods) ranged from 3 $\mu g\ g^{-1}$ to 12 $\mu g\ g^{-1}$, with an average of 7.0 $\mu g\ g^{-1}$, which makes up approximately 66 percent of the average SHC concentration.

Several SHC-based parameters and ratios were used to distinguish between biogenic and petroleum-derived sources. These parameters and ratios are listed below, along with a general discussion of their relevance in determining the source of the hydrocarbons.

- Carbon Preference Index (CPI): The total odd-chain hydrocarbons divided by the total even-chain hydrocarbons. A value of 2 to 4 indicates input from plants. As petroleum is added, the value decreases, approaching 1.
- Pristane/Phytane Ratio: The source of phytane is mainly petroleum, whereas pristane is derived from both biological matter and petroleum. In environmental samples with no petroleum contribution, this ratio is greater than 1 and it decreases as petroleum is added.
- Hexadecane (nC16)/(Pentadecane [nC15] + Heptadecane [nC17]) ratio: At "background" levels, hydrocarbons nC15 and nC17 can be used as indicators of plankton hydrocarbon inputs. As plankton productivity increases, this ratio decreases. If the ratio were to increase over time or within the data set, the rationale would be that it is related to anthropogenic sources. Hexadecane (nC16) is rarely found in biolipids (Thompson and Eglinton 1978); paraffins of nC15, nC17, or nC19 have been found to be predominant in benthic algae (Clark and Blumer 1967, Youngblood et al. 1971).

The results of the sediment samples exhibited a predominance of odd-carbon-number over even-carbon-number n-alkanes, with an average CPI value of approximately 2, indicating primarily biogenic sources of hydrocarbons. This could be expected given the volume of land runoff from the Essequibo and Demerara rivers.

The average pristane/phytane ratio of 1.34 reflects a predominance of pristane over phytane in the sediments, indicating a predominantly biogenic source of hydrocarbons.

The low ratio (less than 1) of nC_{16} over the sum of nC_{15} + nC_{17} for all samples indicates relatively higher concentrations of plankton-related hydrocarbons, as compared to hydrocarbons from anthropogenic sources.

PAHs: PAHs are composed of aromatic rings. PAHs analyzed included 20 parent (i.e., unalkylated) compounds and 23 alkylated homologues, consisting of two- to six-ring PAH compounds. Concentrations of total PAHs (all 43 analytes) ranged from 0.02458 $\mu g\ g^{-1}$ to 0.05336 $\mu g\ g^{-1}$.

The sample distribution of individual PAHs provided information for a range of hydrocarbon sources. The Petrogenic/Pyrogenic distribution ratio listed below is useful to distinguish between petroleum-derived hydrocarbons and those derived from combustion of fossil fuels. The ratio increases as inputs from petroleum increase.

- Petrogenic/Pyrogenic Ratio – The ratio of the sum of petrogenic PAHs divided by the sum of pyrogenic (i.e., combustion-related) PAHs, where:
  - petrogenic PAHs include naphthalene, acenaphthene, acenaphthalene, fluorene, phenanthrenes, and dibenzothiophenes, as well as the daughter compounds of the chrysenes, and fluoranthenes/pyrenes, and
  - pyrogenic PAHs include the parent compounds of fluoranthene, pyrene, and chrysene, as well as benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

In general, sample distributions of PAHs were dominated by the low molecular weight PAHs - naphthalenes and anthracene-phenanthrenes. The petrogenic/pyrogenic ratios of greater than 1 indicate hydrocarbons are from biogenic or natural material (potentially including petroleum-derived) rather than combustion-related compounds. High concentrations of perylene relative to other PAHs were also observed. Perylene is a biogenic compound linked to plant pigments from terrestrial runoff and is not indicative of either petrogenic or pyrogenic sources (Fugro, 2016). Both total PAHs and total SHC exhibited strong positive correlations with TOC, further supporting biogenic origins of the trace hydrocarbons.

Overall, the 2014 sediment hydrocarbon results indicate that biogenic or natural materials are the primary source of the low-level hydrocarbons measured in the survey area. Biogenic hydrocarbon sources most likely consist of terrestrial plant and humic material transported to the survey area via river inputs.

6.1.3.6 2016 EBS Results (Fugro, 2016)

During the 2016 EBS, sediment samples were analyzed for the following parameters:

- TOC
- Metals
- Hydrocarbons

TOC

Similar to the 2014 results, concentrations of TOC ranged from below the reporting limit to 1.1 percent. TOC concentrations were found to be higher at sampling locations with a greater proportion of fine sediments, indicating a negative correlation between grain size and organic content (logical given that smaller grain sizes have a greater surface area and thus more ability to adsorb organic matter).

Metals

Twelve metals were measured to determine general patterns of distribution across the survey area (i.e., Stabroek Block). Of the 12 metals analyzed, 10 metals (i.e., arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, vanadium, and zinc) were used as indicators of anthropogenic sources and 2 metals (i.e., aluminum and iron) were used to provide geological source information. The maximum concentrations of the individual metals measured during the 2016 survey were consistently higher than those from the 2014 survey; this is possibly a result of the different acids used by the 2014 and 2016 laboratories for extraction, or of greater variability in the data set due to the significantly larger sample area covered by the 2016 investigation compared to the 2014 investigation. Average concentrations of anthropogenic-indicator metals arsenic and nickel exceeded the NOAA ERL values. While this may reflect the composition of source material, there may be some contribution from terrestrial runoff contaminated from mining or other industries, as carried to the Guyana basin via riverine inputs from Brazil and the Guiana Shield.

Hydrocarbons

The hydrocarbon analyses include measurements of total hydrocarbons (THC) and PAHs.

THC concentrations ranged from 1.5 µg g^{-1} to 4.8 µg g^{-1}. THC showed positive correlations with metals concentrations, with the exception of copper and arsenic, as well as with TOC concentrations. The unresolved complex mixture (UCM, i.e., fraction of THC that cannot be resolved/identified) concentrations ranged from 0.9 µg g^{-1} to 2.8 µg g^{-1}, and the average was 1.8 µg g^{-1}, which makes up 64 percent of the average THC concentration. Concentrations of alkanes (nC_{12-36}) ranged from 0.12 µg g^{-1} to 0.50 µg g^{-1}. Levels of short chain alkanes (nC_{12-20}) were consistently lower than those of the long chain alkanes (nC_{21-36}).

Several THC-based parameters and ratios were used to distinguish between biogenic and petroleum-derived sources. The values of CPI for the total range of alkanes (nC_{12-36}) ranged from 1.83 µg g^{-1} to 2.27 µg g^{-1}. These results display a predominance of odd-carbon-number over even-carbon-number n-alkanes, with an average CPI value greater than 2, indicating primarily biogenic sources of hydrocarbons. The average pristane/phytane ratio was 1.28, meaning a predominance of pristane over phytane exists in the sediments, indicating the primary source of the hydrocarbons is likely biological.

PAHs, a subset of total hydrocarbons, were analyzed. Concentrations of total PAHs ranged from 0.016 µg g^{-1} to 0.239 µg g^{-1}. The sample distribution of individual PAHs provided information for a range of hydrocarbon sources. A distribution ratio is listed below as well as a general discussion of its relevance in determining the source of the hydrocarbons.

- Naphthalene, Phenanthrene, Anthracene, and Dibenzothiophene (NPD)/4 to 6 Ring Ratio – The ratio of the sum of naphthalene, phenanthrene, anthracene, and dibenzothiophene (petrogenic indicators) divided by the sum of 4 to 6-ring PAHs (pyrogenic indicators). This ratio is useful to determine the relative contributions of pyrogenic and petrogenic hydrocarbons in differentiating sources. The ratio increases as inputs from petroleum increase.

In general, samples showed a predominance of 4 to 6 ring PAHs (i.e., NPD/4 to 6 ring ratios of less than 1), indicating predominantly pyrogenic sources of hydrocarbons, as opposed to petrogenic sources. However, high concentrations of perylene (a biogenic compound linked to plant pigments from terrestrial runoff and not indicative of either petrogenic or pyrogenic sources) relative to other PAHs were also observed.

Overall, the 2016 sediment hydrocarbon results indicate that the low levels of hydrocarbons measured in the Study Area could have derived from biogenic or natural materials as well as combustion-related compounds. Biogenic hydrocarbon sources most likely consist of terrestrial plant and humic material transported to the survey area via river inputs, while combustion-related emissions could arise from multiple natural or anthropogenic sources.

6.1.4 Oceanographic Conditions/Marine Water Quality

6.1.4.1 Oceanographic Conditions

Guyana's marine environment is bounded, and heavily influenced, by the Orinoco and Amazon rivers in Venezuela and Brazil, respectively. During the rainy season, Guyana's coastal marine waters receive large volumes of freshwater discharges from these major rivers, as well as from Guyana's own Essequibo, Demerara, and Berbice rivers (FAO, 2005).

Guyana's surficial marine waters are crossed by the Guiana Current, which is part of the northern limb of the North Atlantic Meridional Overturning Circulation (MOC). The North Atlantic MOC circulates water between the subtropics and polar region. The Guiana Current derives from the North Brazil Current (NBC) flowing north along the northeastern coast of South America from northern Brazil toward the southeastern Caribbean Sea. As it reaches French Guiana, part of the NBC separates from the coast to join the North Equatorial Counter Current (NECC), while the rest continues flowing northwest to form the Guiana Current. Figure 6-2 illustrates the proximity of the Guiana Current, NBC, and North Equatorial Counter Current to the Stabroek Block.

Several times a year, the NBC turns back on itself to create closed circulation and form regions of strong eddies (circular currents). These eddies can separate the NBC and NECC. These eddies can travel northwest along the South American coast. The current magnitude within these eddies can vary with depths significantly. These eddies may range from approximately 145 km to 400 km (~90 to 250 mi) in diameter.

During springtime, the Guiana Current can extend as far as 300 nautical miles offshore to cover Guyana's entire continental shelf. Its highest velocities tend to occur along the edge of the continental shelf (i.e., in Guyana just shoreward of the Stabroek Block). Fluctuations in the ITCZ and the trade winds lead to significant variation in the strength of the Guiana Current and the extent of its influence offshore, but maximum speeds generally occur in April to May, while minimum speeds commonly occur in September (Gyory et al., 2013).

The Guiana Current primarily travels near the water surface while the deeper portion of the water column in the Stabroek Block is strongly influenced by the North Atlantic Deep Western Boundary Current, which is the southward limb of the North Atlantic MOC which returns colder, denser water from polar regions to the subtropics at intermediate and deep levels.

In May 2014, EEPGL commissioned a Lowered Acoustic Doppler Current Profiler (LADCP) survey of four stations along a transect located in the central portion of the Stabroek Block to support design development. The profilers were placed at depths ranging from approximately 970 m to 1100 m. The survey indicated the presence of both the Guiana Current and the Deep Western Boundary Current. Figure 6-3 shows vector stick plots from the four stations along the LADCP transect. Figure 6-4 shows the locations of these LADCPs relative to the planned FPSO location and the southern boundary of the Stabroek Block. The three deepest stations (1, 2, and 3) showed similar vertical current structure (i.e., a north-westward surface flow influenced by the Guiana Current and a south-eastward deep flow due to the Deep Western Boundary

Current). The shallowest station (Station 4) showed a similar layered structure, but the speed of the north-westward surface current, however, was significantly greater at this station than at the others (TDI-Brooks International, Inc., 2014).

Figure 6-2 Marine Currents in the Vicinity of the Project Development Area

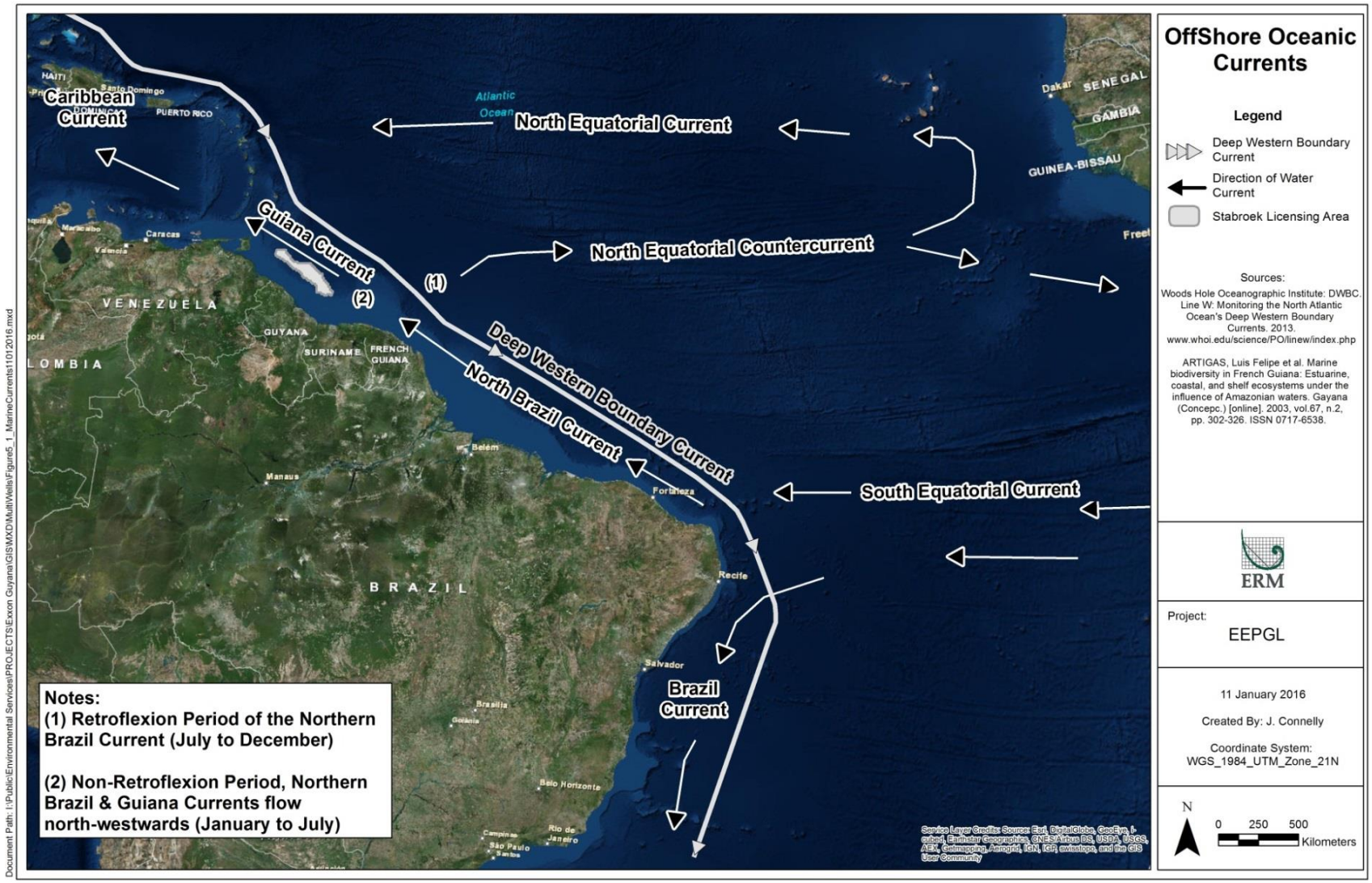
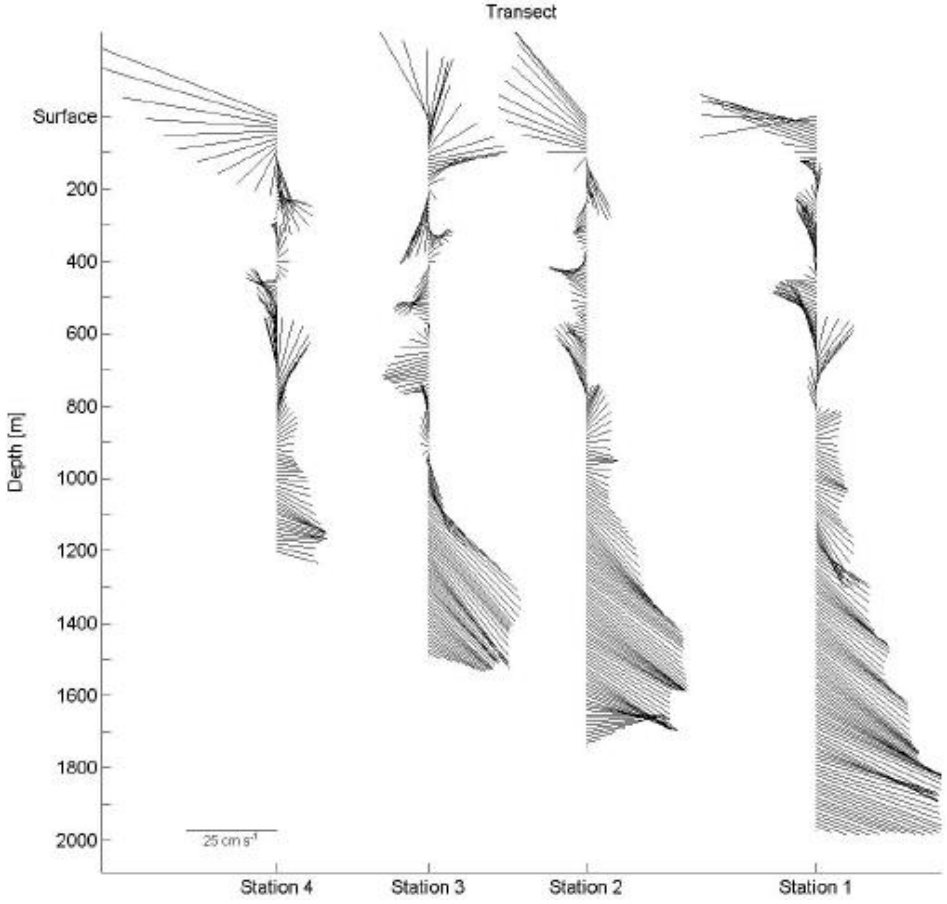


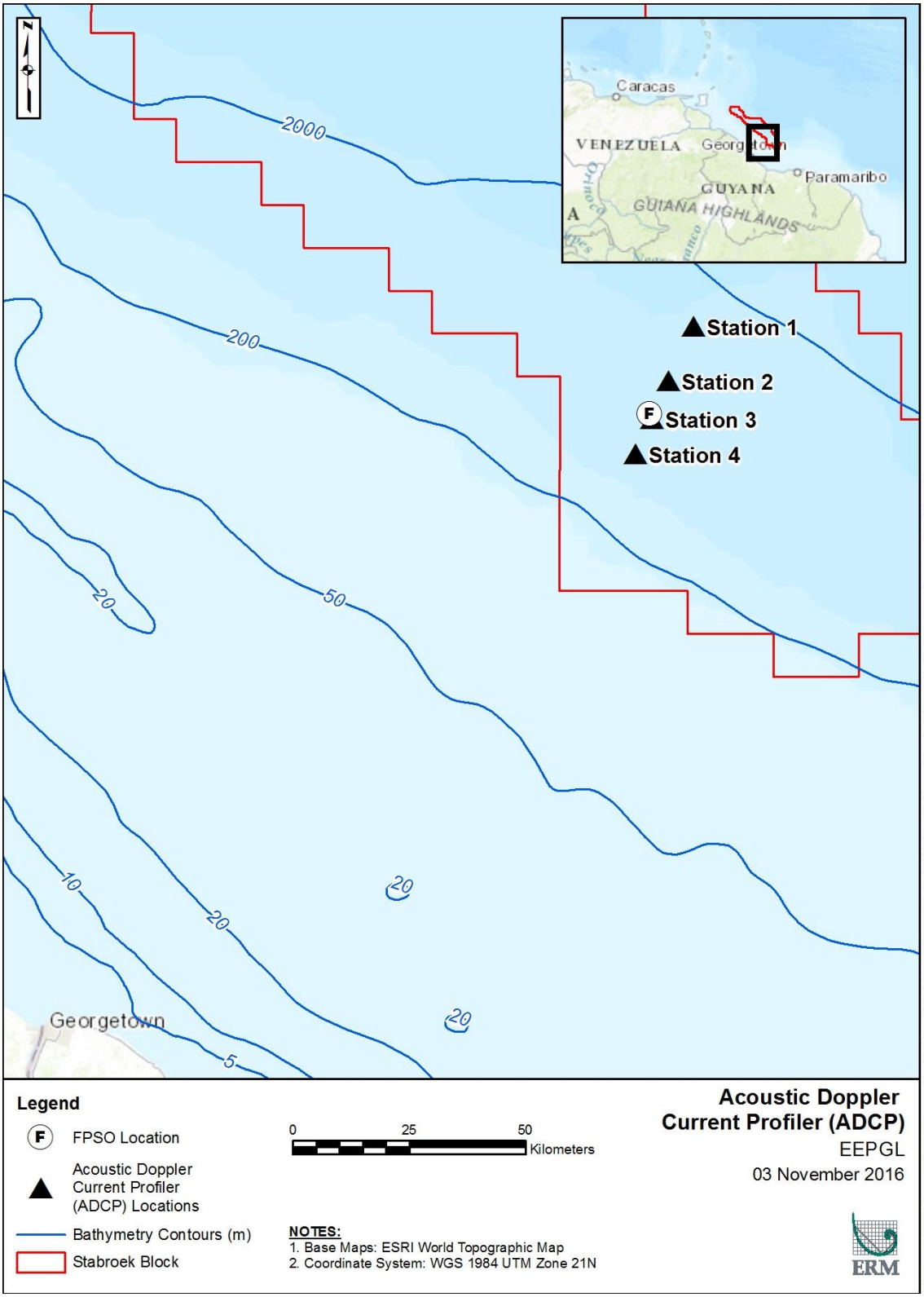
Figure 6-3 Vector Stick Plot for Stations on the Stabroek LADCP Transect



Each "stick" (also called a vector) describes the direction, speed, and depth of a discrete measurement. The length of the vector is directly proportional to its speed (a scale is provided at the bottom of the plot). The depth of each measurement is provided on the y-axis. The direction of the vector points in the compass direction of the current flow (north corresponding to "up" on the plot). The horizontal distance between stations on the x-axis is to scale.

Source: TDI-Brooks, 2014

Figure 6-4 LADCP Locations



6.1.4.2 Marine Water Quality

The hydrographic and isohaline conditions in Guyana's coastal marine waters are greatly impacted by the outflow of the coastal rivers in the region, as described in Section 6.1.4.1. The large amount of freshwater discharge impacts ocean salinity and temperature. Oceanic water is relatively heavy, cold, and saline compared to the lighter, warm, and fresher water of the Amazon and Orinoco plumes, which converge offshore of Guyana. These convergences form oceanic fronts offshore of Guyana. Freshwater lenses generated by the Amazon and Orinoco rivers are transported across Guyana's continental shelf to points north and west. These lenses persist for months and have been detected as far away as Barbados and Trinidad (Sherman and Hempel, 2009).

Of the several coastal rivers that impact the marine environment offshore Guyana, the Amazon River, with its average discharge of 180,000 m^3/sec (Nittrouer and De Master, 1987), is the most prominent factor in marine water quality in the region. Analysis of the Amazonian plume has shown there is little seasonal variation in the plume's nutrient content (e.g., silicates of 144 $\mu mol.kg^{-1}$, phosphates of 0.7 $\mu mol.kg^{-1}$, and nitrates of 16 $\mu mol.kg^{-1}$) (De Master and Pope, 1996). It has been estimated that 40 to 50 percent of the annual Amazon run-off transits along the coast of the Guyanas.

The entire region offshore of Guyana is considered part of the North Brazil Shelf Large Marine Ecosystem (LME). The ocean temperature in the North Brazil Shelf LME has alternately warmed and cooled over the last few decades. A period of cooling lasted from the mid-1970s through the mid-1990s, but since the mid-1990s the LME has consistently warmed (Sherman and Hempel, 2009). Although the ocean temperature has alternately warmed and cooled in recent decades, the net change in LME water temperature since 1957 equates to an average increase of +0.22 ˚C over 50 years (Sherman and Hempel, 2009).

Water quality samples were collected from the Stabroek Block offshore Guyana as part of two environmental survey efforts in 2014 and 2016. The 2014 samples were collected in April and May of 2014 prior to exploration drilling activities (Maxon Consulting, Inc. and TDI Brooks International, Inc., 2014).

The 2016 survey provided an additional detailed integrated site investigation covering 247 mi^2 (~64,000 ha) of the offshore PDA (FUGRO EMU, 2016). This study enables ERM to have a multi-year database of water quality in the Stabroek Block, as well as the ability to analyze a greater number of locations to further characterize the block. Sampling locations were chosen based on current and future exploration and potential development activities.

In the 2016 study, water quality samples were collected at top, middle, and bottom depths and analyses of the collected samples covered a range of physicochemical parameters. In addition, conductivity, temperature, and depth (CTD) profiles (including dissolved oxygen, pH, and turbidity measurements) were acquired and assessed through in situ monitoring of water column profiles at 15 locations.

Results from the 2016 vertical profiles show a stratified water column in terms of temperature, salinity, and dissolved oxygen. The depths of the thermocline, halocline, and oxygen boundary layer were observed to increase with the total depth of water. Dissolved oxygen concentrations reach near saturation levels near the surface, but decrease with depth. The mean sea surface temperature was 27.8 ^{o}C, while bottom temperatures ranged between 2.7 ^{o}C (deepest station) and 11.2 ^{o}C (shallowest station). Salinity ranged between 37.05 parts per trillion (ppt) to 36.60 ppt near the surface. In depths below the halocline, the salinity ranged between 33.63 ppt and 35.50 ppt. Mean pH values ranged between 8.18 and 8.47, increasing slightly with depth. Low turbidity was measured throughout the water column, with values less than or equal to 2.9 formazine turbidity units (FTU).

The presence of organic carbon content in the water column was analyzed by measuring TOC in discrete water samples. TOC decreased slightly with depth. TOC ranged between 0.9 mg/l and 3.9 mg/l at the surface and between 0.9 mg/l and 2.4 mg/l in the bottom depths.

Total suspended solids (TSS) concentrations were generally higher near the surface than at depth. In the 2016 survey, values ranged from 2.4 mg/l to 18.3 mg/l near the surface and from below the detection limit to 7.7 mg/l at the bottom depths.

In the 2014 survey, measured hydrocarbon concentrations were mostly below detection limits (total SHC less than 13 µg/l to less than 13.5 µg/l). In the 2016 survey, whose protocols allowed for lower detection limits, THC were detected at concentrations ranging from 8.3 µg/l to 35.9 µg/l in the bottom depths and 10.0 µg/l to 33.1 µg/l near the surface. Individual n-aliphatics were also measured, from 12 carbons (n-dodecane) to 36 carbons (n-hexatriacontane). The sum of all measured aliphatics in the 2016 survey ranged from 0.55 µg/l to 4.22 µg/l at the surface and from 0.37 µg/l to 16.3 µg/l in the bottom depths.

In the 2014 survey, PAHs were reported to be below detection limits with the exception of naphthalene as well as the C1 and C2 alkylated homologues of naphthalene, fluorene, and phenanthrene, all of which are ubiquitous trace-level laboratory contaminants. In the 2016 survey, the sum of the PAHs with two to six benzene rings ranged from 0.051 µg/l to 0.109 µg/l at the surface and 0.059 µg/l to 0.133 µg/l at the bottom depths. The sum of the 16 PAHs from U.S. Environmental Protection Agency's (USEPA's) priority pollutant list ranged from 0.006 µg/l to 0.021 µg/l.

Pristane to phytane ratios, indicative of the possible origin of hydrocarbons present, were close to 1.0, suggesting an oxidizing depositional environment with the compounds likely derived from chlorophyll (Moustafa and Morsi, 2012). Ratios below 1.0 would suggest the presence of petroleum-based hydrocarbons.

In both the 2014 and 2016 surveys, measured metal concentrations in the collected water samples were below USEPA Saltwater Quality Standards (USEPA, 2015). Table 6-4 provides the minimum, mean, and maximum values for metals measured in 2014 and 2016, along with USEPA's criterion maximum concentrations (CMCs) and criterion continuous concentrations (CCCs) for comparison. The CMCs and CCCs are the USEPA's recommended highest concentrations in saltwater that are not expected to pose a significant risk for acute and chronic

impacts, respectively, to the majority of species in a given environment (USEPA, 2016). All samples had concentrations within the natural range of the ocean water (Morel et al., 2006), well below the CMCs and CCCs.

Table 6-4 EBS Water Column Heavy Metals Concentrations

	Heavy Metals Concentrations (µg/l)							
	Arsenic	**Barium**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Mercury**	**Zinc**
Min	1.02	6.4	0.03	0.523	0.211	0.041	<0.0002	<4
Mean	1.43	7.5	0.043	0.656	0.385 - 1.68	0.144	0.000104	2.44 - 6.42
Max	1.77	9.2	0.064	0.778	3.68	0.625	0.000254	26.4
USEPA CMC	40	40	4.8	210	90	1.8	1.8	69
USEPA CCC	8.8	8.8	3.1	8.1	81	0.94	0.94	36

Source: Maxon Consulting, Inc. and TDI Brooks International, Inc., 2014; Fugro, 2016
Note: One half of the detection limit was used for non-detect results in all statistical calculations.

6.2 Biological Resources

6.2.1 Protected Areas and Special Status Species

Formerly, the EPA was Guyana's focal point for the Convention of Biological Diversity, and the agency coordinated the National Protected Areas System (EPA, Undated), which included five protected areas.

In 2011, Guyana enacted Protected Areas legislation that established a Protected Areas Commission to oversee and manage protected areas. This legislation established a list of prohibited activities, including unlawfully entering or remaining within a protected area; disturbing or destroying the vegetation (common or endangered); removing or exterminating wildlife species (common or endangered); damaging archeological finds or sites; and mining. If any prohibited activities occur, fines range from $50,000 to $500,000 (Guyanese dollars [GYD]) (Protected Areas Act, 2011). Guyana's National Biodiversity Strategy and Action Plan (2015) states the overall importance of biodiversity's role within the country:

> *Guyana's biodiversity provides an important basis for climate regulation, poverty reduction, provisioning of fresh water and hydropower, economic growth and development in areas such as agriculture, forestry and fisheries, payment for forest climate services, community based economies, particularly in hinterland communities and biodiversity-related education, scientific research and recreation. Loss of biodiversity and any disruption in the provision of ecosystem services would impact negatively on the economy and more particularly on the quality of life in the hinterland and indigenous communities.* (GNBSAAP, 2015)

The 2011 legislation also established Shell Beach and the Kanuku Mountains as Guyana's newest nationally Protected Areas. This increased the total number of Protected Areas in Guyana to seven and increased the total land area protected to approximately 1.8 million hectares or about nine percent of Guyana's land area, as summarized in Table 6-5. Figure 6-5 illustrates the locations of Guyana's Protected Areas. There are currently no designated marine Protected Areas in Guyana.

Table 6-5 Protected Areas in Guyana

Protected Area	Km²
Kaieteur National Park	630
Iwokrama Forest	3,710
Kanashen (Community Owned Conservation Area)	6,250
Kanuku Mountains	6,110
Shell Beach Nature Reserve	2,000
Moraballi Forest Reserve	110
Mabura Hill Forest Reserve	20

Source: IUCN and UNEP-WCMC (2016)

Of the seven Protected Areas, Shell Beach Protected Area (SBPA) is the only one located on Guyana's coast, and so it is most pertinent to the impacts analysis of the Project. The SBPA includes Guyana's coastline but does not extend into the Atlantic Ocean; however, the ecology of the coastal zone and Shell Beach are inextricably connected to the coastal marine ecosystem.

Figure 6-6 provides a detailed map of SBPA, the beaches it incorporates, and the surrounding area. It is located in northwestern Guyana and extends for almost 140 km (~87 mi) between the Waini, Baramani, and Moruka rivers, and the Atlantic Ocean. The PDA is located approximately 300 km (187 mi) northeast of the southernmost (closest) point of Shell Beach.

Shell Beach, which derived its name from the fact that its entire stretch of coastline is comprised mainly of mainly pulverized shells from crustaceans (RBAPSBPA, 2004), is a dynamic area. Its landscape constantly changes due to the competing impacts of erosion and accretion along the shoreline. The area is 70 percent forested; the rest is made up of mostly swamp (<30 percent) and sandy beaches (<1 percent) (Kandaswamy, 2014). Shell Beach supports numerous plant species, including coconut, papaya, and palm trees (GMTCS, 2011; Bovell, 2011).

The vegetative community has changed little in recent history apart from limited clearing to accommodate a few dispersed encampments and farmsteads. The rivers bordering the Protected Area discharge nutrients through the Protected Area's mudflats and mangroves. These high nutrient levels contribute to the productivity of the marine ecosystem. Fish, prawns, and crabs from the nearshore marine area use the mangrove covered coastlines as nursery habitat.

Figure 6-5 Protected Areas of Guyana

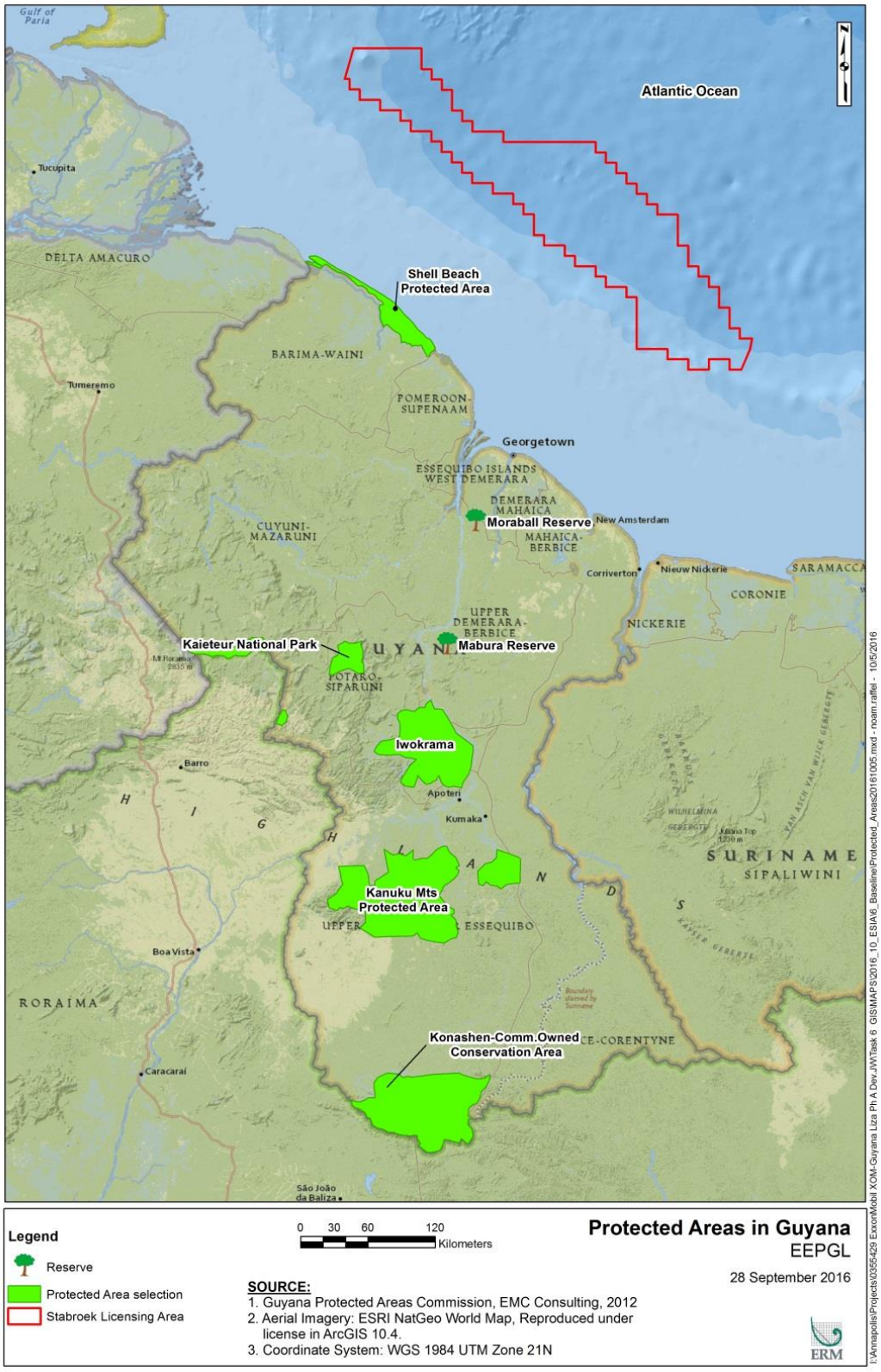
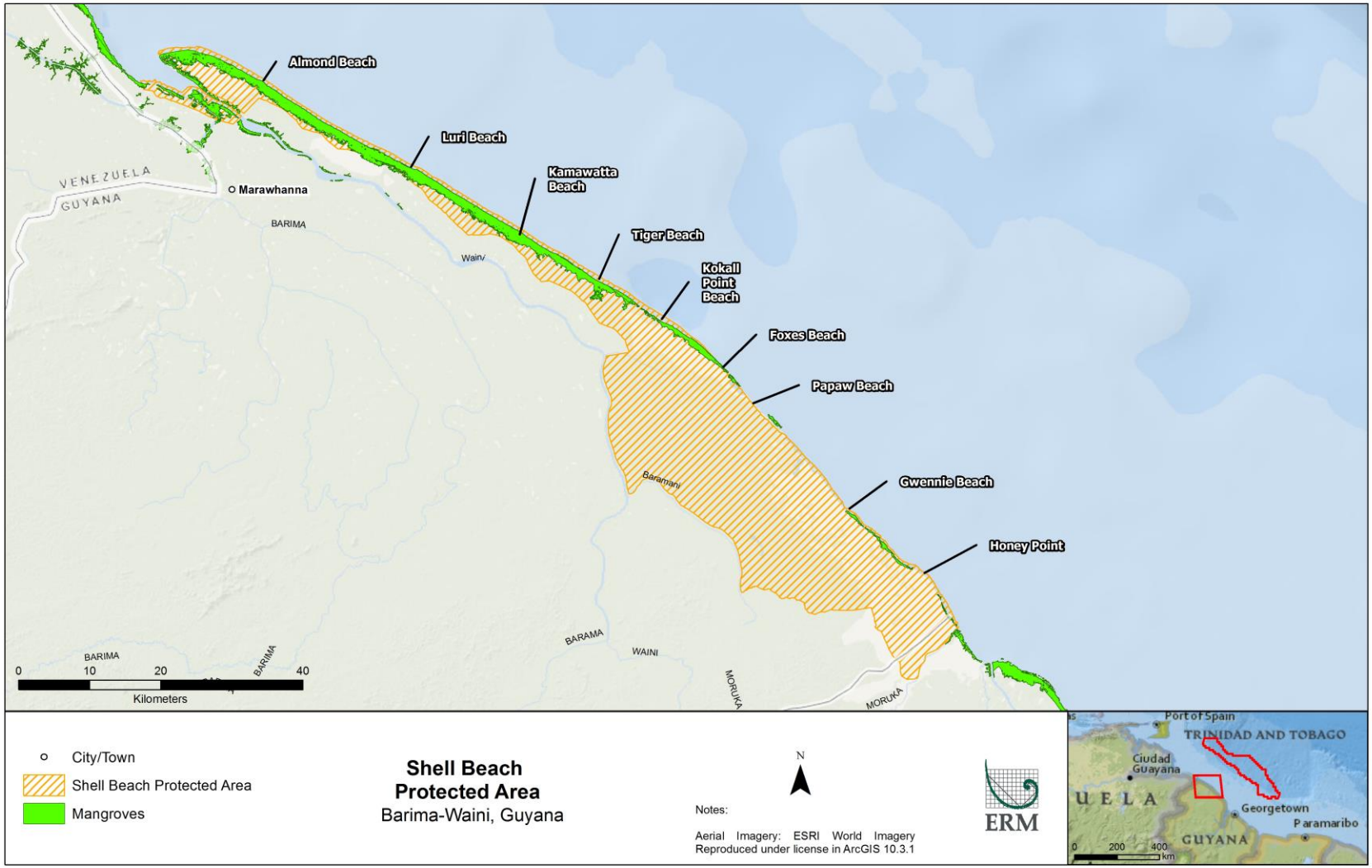


Figure 6-6 Shell Beach Protected Area



Shell Beach is best known as a sea turtle nesting site. The composition of the substrate at Shell Beach, its geographical location, and the low anthropogenic activity makes it an ideal nesting site for sea turtles. Most nesting beaches in Guyana are used by only one or two species of sea turtles, but four species of sea turtles (Leatherback, Hawksbill, Olive Ridley, and Green Turtle) nest at Shell Beach (Pritchard, 2001). In addition to sea turtles, there are also at least four other species of turtles present within the Protected Area, including yellow-foot tortoise (*Geochelone denticulate*), scorpion mud turtle (*Kinosternon scorpioides*), giant river turtle (*Podocnemis expansa*), and mata mata (*Chelus fimbriata*).

The SPBA also supports rich bird, herpetofauna (reptiles and amphibians), and mammal communities. The 2004 Rapid Biodiversity Assessment documented 170 species of birds, 20 species of mammals, and 31 species of herpetofauna. The 170 species of birds represent one of the richest populations in Guyana and include well known species such as scarlet ibis (*Eudocimus ruber*), roseate spoonbill (*Platalea ajaja*), and Caribbean Flamingo (*Phoenicopterus ruber*), orange-winged Amazon parrots (*Amazona amazonica)* and several species of macaws.

Sixteen herpetofauna species (other than turtles) are known to inhabit the Shell Beach area. These include the Ameiva lizard (*Ameiva ameiva*), whiptail lizard (*Cnemidorphous lemniscatus*), water labaria (*Helicops angulatus)*, cane toad (*Bufo Marinus*), paradoxical frog (*Pseudis paradoxa*), and numerous tree frogs (*Hyla* spp.) (RBAPSBPA, 2004).

Twenty species of mammals, including howler monkeys (*Alouatta* spp.), jaguars (*Panthera* spp.), and manatees (*Trichechus* sp.), are known to inhabit the Shell Beach area and surrounding coastal region (Prince et al., 2004; Kalamandeen et al., 2005). Appendix G – Flora and Fauna Diversity of Shell Beach, provides an extensive list of species within the area.

Resources within Protected Areas are a key factor in supporting local communities (see Chapter 7 for additional information). Areas within and near Shell Beach have been inhabited for 10,000 years by Amerindian groups from the Warao, Carib, and Arawak tribes (Charles et al., 2004). Most of the current indigenous residents of the Shell Beach area are concentrated in a community known as Almond Beach, near the northern end of the Protected Area. Other communities included within the boundary of the Protected Area, as delineated in 2011, include Father's Beach and Assakata. The remainder of the Protected Area is sparsely populated, if at all.

Indigenous communities have historically used the Shell Beach area for subsistence fishing, crabbing, trapping, farming, logging, and palm harvesting. The important crab species that are utilized by the locals include blue sheriga (*Callinectes bocourti*), sheriga (*Portunas spinimamus*), bunderi (*Cardiosoma guanhumi*), and buck-crab (*Ucides cordatus*) (RBAPSBPA, 2004). They have also historically engaged in sea turtle trapping and harvesting of sea turtle eggs. While these activities have declined in recent years as emphasis on conservation and sustainability has increased, illegal catching of turtles may still occur (Charles et al., 2004).

Increasing human activity in proximity to Shell Beach has led to increasing exploitation of natural resources and has the potential to lead to additional ecological harm. In 1997, a fire caused by human activity extensively damaged an area of mangroves (Pritchard, 2001).

Throughout the past few decades, there have also been various industrial proposals for Shell Beach. These include proposals to extract shell material from the beaches as feedstock for fertilizer production and to develop a luxury tourist outpost (Charles et al., 2004). Amerindian communities in the area have also expressed interest in developing ecotourism in the area (Charles et al., 2004).

6.2.1.1 Special Status Species

The International Union for Conservation of Nature (IUCN) maintains a Red List, which provides taxonomic, conservation status, and distribution information on plants and animals that have been globally evaluated to determine their relative risk of extinction (IUCN, 2014). The IUCN categorizes species according to their risk at six status levels ranging from "Extinct" to "Least Concern," as defined in Table 6-7.

Table 6-7 Definitions of IUCN Red List Threatened Categories

IUCN Red List Status	Definition
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), and throughout its historical range have failed to record an individual.
Critically Endangered (CR)	A taxon is Critically Endangered when the best available evidence (severe population decline, very small population, very small geographic area occupied, or a probability of extinction in the next 10 years of >50%) indicates that it is facing an extremely high risk of extinction in the wild.
Endangered (EN)	A taxon is Endangered when the best available evidence (large population decline, small population, small geographic area occupied, or a probability of extinction in the next 20 years of >20%) indicates that it is facing a very high risk of extinction in the wild.
Vulnerable (VU)	A taxon is Vulnerable when the best available evidence (substantial population decline, small population, fairly small geographic area occupied, or a probability of extinction in the next 100 years is >10%) indicates that it is considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered, or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.
Least Concern (LC)	A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Taxa that are widespread and abundant are included in this category.
Data Deficient	A taxon is Data Deficient when there is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

Source: IUCN 2001

Species categorized as CR, EN, and VU are collectively considered to be internationally "threatened," while NT species are close to qualifying as "threatened" and LC species are considered internationally widespread and abundant. There are 296 species known to occur in the coastal and marine habitats in Guyana on the IUCN Red List. Sixty-two of these marine and coastal species have been ranked NT or higher. These species are listed in Appendix H. According to the IUCN's classification scheme, these species currently face a credible threat of extinction.

Most of the threatened (CR, EN or VU) or NT species that could be impacted by the Project are fish. They include highly migratory species such as species of tunas and sharks, bentho-pelagic species including certain groupers, and demersal species including species of skates and rays. As noted in Section 6.3.3.2, many of these fish species are also targeted by the Guyanese commercial fishing industry. The remaining threatened or NT marine and coastal species in Appendix H include sea turtles, marine mammals, and crustaceans.

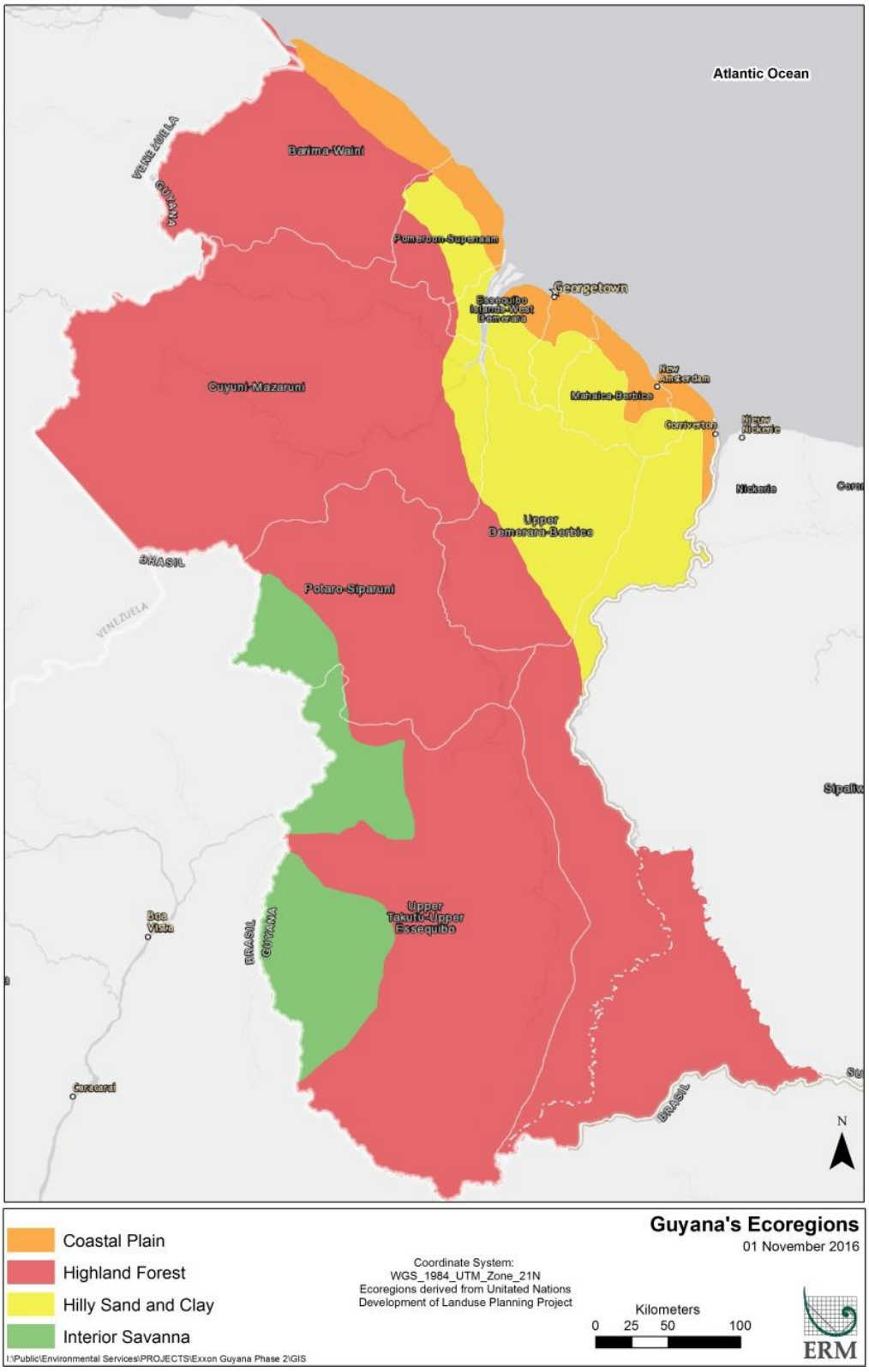
6.2.2 Coastal Habitats

There are four ecoregions in Guyana (Figure 6-7): coastal plain, interior savannas, hilly sand and clay, and forested highlands (GNBSAAP, 2015). The Project will have no impact on the interior savannas, hilly sand and clay, and forested highlands, so this section focuses on habitats of the coastal plain (note that the only potential impacts on the coastal plain are those associated with unplanned events [i.e., oil spill]).

Guyana's coastal plain occupies approximately 7 percent of the country's total area and extends along the entire approximately 400 km (~250 mi) of the Atlantic coast, varying in width from approximately 16 km to 64 km (10 mi to 40 mi) (Kalamandeen and Da Silva, 2002) and in elevation from sea level to approximately 3 m (~10 ft) (GNBSAAP, 2015). The coastal plain is a narrow belt of sediments with riverine and marine clays and silts stretching along Guyana's coastline. The coastal zone is a highly productive and sensitive environment that is subjected to marine and terrestrial influences. Guyana's coastal ecoregion is a network of plains and low hills, including mangroves, salt to brackish lagoons, brackish herbaceous swamps, swamp woods, and swamp forests. The coastal zone contains some of the world's most productive ecosystems, with rich biological diversity (Kalamandeen and Da Silva, 2002). The swamps are an important source of freshwater to mangroves and other flora and fauna (WWF, 2016).

Along the Guyana shoreline, the portion of the coastal plain with the most potential to be impacted by an unplanned event associated with the Project, the principal habitats are mangroves, beaches, and mudbanks, which are described below.

Figure 6-7 Guyana's Ecoregions



6.2.2.1 Mangroves

Mangroves are regarded as one of the most important ecosystems for the security of the biodiversity of the entire Guyana coast, as they protect coastlines from wave action and shoreline erosion (see Section 6.1.3). Figure 6-8 shows the general distribution of mangrove resources along coastal Guyana; Figure 6-9 provides photographs of mangroves in Guyana. It is difficult to ascertain the exact location and extent of mangrove forests in the country because the mangroves are subject to erosion and other factors that can lead to rapid and dramatic changes in distribution.

A 2008 Smithsonian report stated that mangroves occupied over 81,000 hectares of Guyana's coast in six of Guyana's 10 geopolitical regions (Smithsonian, 2008). The Guyana Mangrove Restoration Project estimates 75 percent of the country's mangroves are concentrated in Regions 1 and 2 (GMRP Fact Sheet, 2010), which are located along the northwestern coast and include SBPA.

Coastal mangroves have been identified by numerous national and international stakeholders as vital to Guyana's biodiversity, physical security, and economy (WWF, 2016; GMRP, 2010; Ilieva, undated). In 2014, ERM conducted a coastal zone sensitivity analysis as part of the Oil Spill Response (OSR) planning for the Liza-1 drilling program. The analysis included detailed mapping of mangroves along Guyana's coast from Georgetown west to the Venezuelan border. Figure 6-8 is a composite of 10 individual map tiles showing the identified distribution of mangroves (red-shading) across this portion of Guyana's coastline as of 2013.

There are currently three species of mangrove in Guyana: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*) and white mangrove (*Laguncularia racemosa*). Mangroves in Guyana have a unique distribution pattern that is different from the norm in most other countries. RGME (2014) noted that in Guyana black mangroves typically colonize the coastal shorelines, and red mangroves establish themselves further inland along the rivers. There is some overlap in the typical distribution of these species elsewhere, but in general the pattern in other countries is for red mangroves to establish along the shoreline, black mangroves to establish farther inland, and white mangroves to establish the farthest inland. Mangrove ecosystems are known to be among the most productive ecosystems in the world (Mann, 1982), serving major habitats while providing shelter and feeding sites for many faunal species (Mestre, Krul and Moraes, 2007). Many invertebrate inhabitants of mangrove ecosystems in Guyana live either on or in close proximity to mangrove roots and substrates and include snails, barnacles, tunicates, mollusks, polychaete worms, oligochaete worms, shrimp, crabs, sponges, jellyfish, amphipods, and isopods. These small organisms provide forage for birds, mammals, reptiles, amphibians, and fish. Herons, egrets, and ibises are the most conspicuous group of bird species found in mangroves due to the abundant food sources in a relatively safe habitat (Da Silva, 2014).

Figure 6-8 Guyana's Mangrove Distribution (Georgetown west to Venezuelan Border)

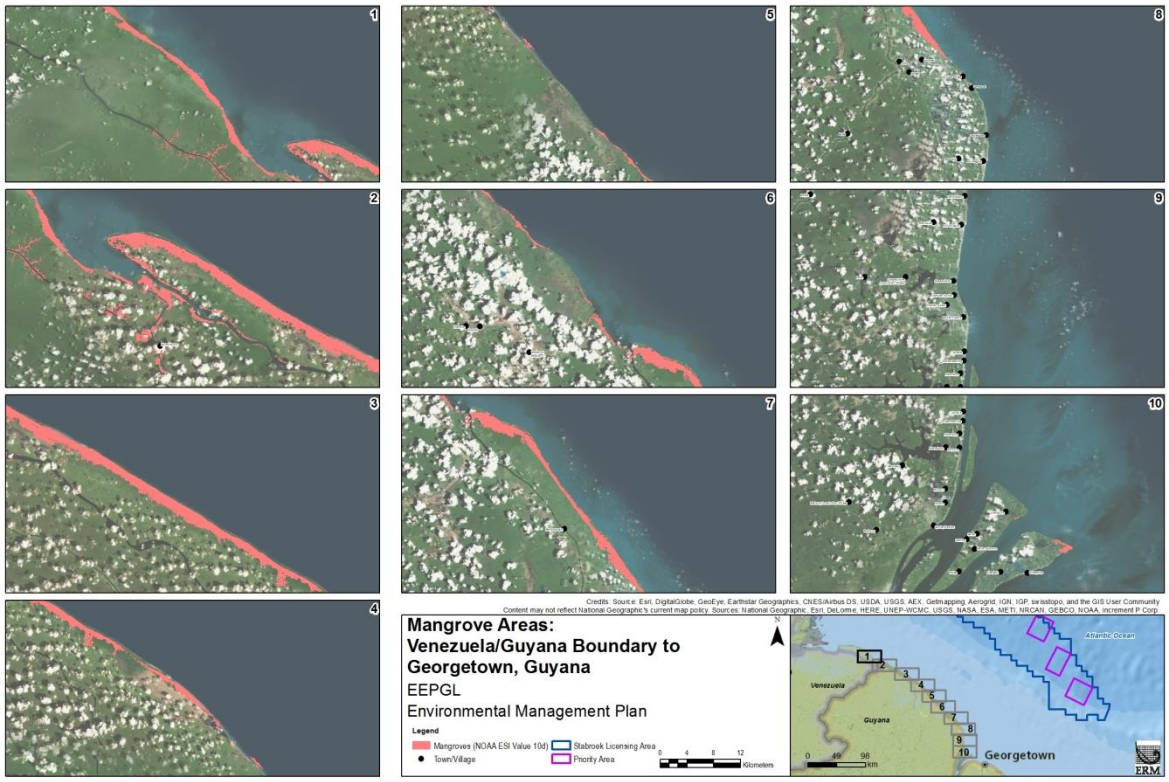


Figure 6-9 Mangrove Photographs



Coastal Mangroves



Red Mangrove Forest

Source: ERM, 2016; Rapid Biodiversity Assessment of Shell Beach, 2004

6.2.2.2 Beaches

Guyana has relatively few beaches, but the beaches that do occur are critically important nesting habitats for sea turtles and providing habitat used by a variety of avian, herpetofauna, and mammalian species (see Figure 6-6, for the locations of beaches in the SBPA).

6.2.2.3 Mudbanks

See Section 6.1.3 for the description of the physical attributes and location of Guyana's mudbanks, which generally refer to the submerged mud features below the low tide line (as distinct from the intertidal mud "flats". There has been no targeted biological surveys of Guyana' mud banks conducted to date, but coastal mud habitats typically support burrowing invertebrates such as marine worms, mollusks, crustaceans, amphipods, and copepods. This invertebrate community provides important forage for bottom-feeding fishes such as grunts, catfishes, and snappers (particularly during their early life stages).

6.2.3 Coastal Wildlife and Shorebirds

Guyana occupies the west-central portion of the Guianan mangrove ecoregion, which extends from southeastern Venezuela southeast to French Guiana between the Orinoco River Deltas and the Oyapok River Delta in French Guiana. The ecoregion is a bio-geographical rather than geopolitical region, and was designated as a distinct ecoregion by the World Wildlife Fund as part of their Terrestrial Ecosystems of the World project (Olsen et al. 2001). Despite supporting over 90% of the country's human population, Guyana's coastal region supports a diverse fauna. This section briefly describes bird, mammal, reptile, and amphibian species that are representative of Guyana's coastal region.

6.2.3.1 Coastal Wildlife

Numerous mammal, reptile, and amphibian species occur in Guyana's mangroves, agricultural areas, and coastal forests. There are over 50 species of mammals present including opossums; bats; primates such as capuchin monkeys (*Cebus apell*a), squirrel monkeys (Saimira sciureus), howler monkey (*Alouatta seniculus*) and Guianan saki (*Pithecia pithecia*); giant ant-eater (*Myrmecophaga triactyla*); several species of cats including pumas (*Panthera onca*), puma (*Puma concolor*), and ocelot (*Leopardus pardalis*); ungulates and rodents including the capybara (*Hydrochaeris hydrochaeris*), paca (*Agouti paca)* red rumped agouti (*Dasyprocta leporina*); red and grey brocket deer (*Mazama* sp.); and the giant river otter (*Pteronura brasiliensis*), which is a freshwater species, and the neotropical otter (*Lontra longicaudi*s), which is found in both freshwater and estuarine habitats (WWF, undated). Other reptiles that frequent this ecoregion are the green iguana (*Iguana iguana*), spectacled caiman (*Caiman crocodilus)* and anaconda (*Eunectes murinus*). Amphibians are generally less common along the coast than in the interior especially due to saline influence in the mangroves, but two species that are found along the coast are the paradoxal frog (*Pseudis paradoxa*) and the pipa frog (*Pipa pipa*).

6.2.3.2 Shorebirds

Guyana has a high species richness and diversity of flora and fauna. The coastal bird community is rich in Guyana, with over 200 species of coastal birds recorded, including a variety of parrots and macaws, numerous waterbirds and shorebirds, and raptors including the rare Harpy Eagle (*Harpia harpyja*) (GNBSAAP, 2015). A coastal bird survey conducted along the coast in the Georgetown region by Bayney and Da Silva (2005) documented 32 coastal bird species, 20 of which are migrants. The most abundant species documented in the survey were shorebirds including Least Sandpiper (*Calidris minutilla*), Spotted Sandpiper (*Actitis malcularia*), Ruddy Turnstone (*Arenaria interpres*), and Semipalmated Plover (*Charadrius semipalmatus*). Waterbird species including Snowy Egret (*Egretta thula*) and Cattle Egret (*Bulbulcis ibis*) were also abundant. In 2007, Braun et al. developed a comprehensive checklist of the 814 bird species within 11 habitats documented in Guyana (Braun et al., 2007). The coastal habitats surveyed include mangrove forests and mudflats and the checklist includes 47 species within 18 families for the mangroves and 38 species within 8 families for the mudflat habitats (Braun et al., 2007) (Appendix I). A more recent bird survey within coastal mangrove habitats in southeast Guyana identified 37 species within 14 families (Da Silva 2014). In this 2014 survey, the most abundant species recorded were the Rufous Crab-hawk (*Buteogallus aequinoctialis*), Great Egret (*Ardea alba*), Greater Kiskadee (*Pitangus sulphuratus*), Scarlet Ibis (*Eudocimus ruber*) and the Pied Water Tyrant (*Fluvicola pica*) (Appendix I).

As discussed in Section 6.2.2, Shell Beach is the only coastal Protected Area in Guyana. Two biodiversity surveys have been undertaken within and around Shell Beach over roughly the past decade (Mendonca et al. 2006; GEPA et al.; 2004). Each of these surveys documented over 200 bird species in the Shell Beach area, including many forest interior species that occur in the inland habitats of Shell Beach. Many of the over 200 species documented are migrants, traveling from United States and Canada to spend the winter season in Guyana, primarily following the Atlantic and Central Flyways to South America. The most abundant coastal species recorded at and around Shell Beach during the two surveys included Laughing Gull (*Larus atricilla*), Scarlet Ibis (*Eudocimus ruber*), Yellow-billed Tern (*Sterna superciliaris*), Least Tern (*Sterna antillarum*), Spotted Sandpiper (*Actitis macularia*), *Lesser* Yellowlegs (*Tringa flavipes*), and Blackbellied Whistling-duck (*Dendrocyna autumnalis*) (Mendonca et al. 2006; GEPA et al.: 2004).

BirdLife International (2016a) has designated several Important Bird Areas (IBAs) in the neighboring countries of Suriname, Trinidad and Tobago, and Venezuela. These IBAs provide foraging, breeding, and nesting habitats similar to those found along Guyana's coastline. However, no IBAs have been designated in Guyana.

6.2.4 Seabirds

Seabirds are birds that spend their time in nearshore and/or offshore marine environments away from land, except when they are nesting. Types or groups of seabirds more prevalent in this region include albatrosses, petrels, shearwaters, storm-petrels, skuas, jaegers, tropicbirds, and terns. Twenty-two species of seabirds breed in the Caribbean and dozens more occur as migrants through the region. Seabird data that is specific to Guyana is almost non-existent and

no comprehensive survey of seabirds has ever been conducted in Guyana (BirdLife International, 2016).

Birdlife International lists 21 species of seabirds for Guyana (BirdLife International, 2016). Other current data sources, such as eBird, and seabird observations recorded in the Stabroek Block during the EEPGL seismic surveys conducted in 2015 and 2016, increase the total number of documented seabird species in Guyana to 30 (eBird, 2016; RPS, 2016). This number is consistent with that of other countries in the region. For example, 32 and 29 species of seabirds are documented in Trinidad and Tobago and Venezuela, respectively (BirdLife International, 2016). Table 6-8 lists the seabird species documented in Guyana based on the BirdLife data, eBird records, and EEPGL observations. Any of these species could occur in the PDA at some time during the year (specific timing of occurrence is dependent on the species and environmental conditions). All of the 30 species of seabirds known to occur in Guyana are currently listed on the IUCN Red List as LC, which means that the population status of the species does not meet the IUCN criteria for a threatened or NT designation (IUCN, 2016).

Of the species observed in the Stabroek Block during the EEPGL seismic surveys, the most commonly observed species (in descending order of number of sightings (i.e.; frequency of occurrence) were the Masked Booby (*Sula dactylatra*), Magnificent Frigatebird (*Fregata magnificens*), and Brown Booby *(Sula leucogaster*) (RPS, 2016).

Seabirds feed on fish and other marine organisms that concentrate on or near the surface of the water, either by surface feeding (from flight or swimming) or by diving. As such, the presence and availability of seabird prey in a given area, which is strongly influenced by the ocean's currents, are a major determinant in the occurrence of seabirds. Further, water clarity can impact a seabird's foraging success and some studies have suggested that seabirds in the Caribbean prefer areas with clear water where they can more easily see their prey (Schreiber, 2001).

Seabirds in the PDA area are likely to be transients, moving opportunistically with schools of fish and other prey. The marine environment within the PDA is heavily influenced by the Guiana Current, which is a strong surface current that directs surface flows northwestward. No slower moving or circular currents or areas of upwelling that could concentrate marine biota are known to occur in the PDA. Further, no islands or near-surface submarine ridges that would be an attractant to foraging seabirds occur in the PDA. While a variety of fish occur in the PDA, including schooling fish such as tuna and mahi-mahi, no evidence suggests that large concentrations of fish consistently occur in the PDA to the extent that they would promote regular use by foraging seabirds. The turbid conditions in the Stabroek Block further reduce the likelihood that the area has significant importance for foraging seabirds.

Since 2010, BirdLife International has focused its efforts on identifying Marine IBAs with specific significance to seabirds. The types of sites that qualify as Marine IBAs include seabird breeding colonies, foraging areas around breeding colonies, non-breeding (usually coastal) concentrations, migratory bottlenecks, and feeding areas for pelagic species (Birdlife International, 2016b). No Marine IBAs have been identified in Guyana, but three Marine IBAs of

global or regional importance to seabirds have been designated in neighboring countries: St. Giles Islands and Little Tobago, both located off the northeastern tip of Tobago, and Isla de Aves in Venezuela (Lentino and Esclasans, 2009; Birdlife International 2016b; Devenish et al., 2009). Figure 6-10 depicts the location of these IBAs relative to the Stabroek Block.

Table 6-8 Seabird Species Known to Occur in Guyana

Common Name [a, b, c]	**Scientific Name**
Magnificent Frigatebird [a, b, c]	*Fregata magnificens*
Brown Booby [a, b, c]	*Sula leucogaster*
Masked Booby [a, b]	*Sula dactylatra*
Red-footed Booby [b]	*Sula sula*
White-tailed Tropicbird [a, b]	*Phaethon lepturus*
Leach's Storm-petrel [a, c]	*Oceanodroma leucorhoa*
Audubon's Shearwater [a, b, c]	*Puffinus lherminieri*
Wilson's Storm-petrel [b, c]	*Oceanites oceanicus*
Cory's Shearwater [a, b]	*Calonectris diomedea*
Barolo Shearwater [b]	*Puffinus baroli*
Great Shearwater [a, c]	*Ardenna gravis*
Arctic Jaeger [c]	*Stercorarius parasiticus*
Pomarine Jaeger [a, b, c]	*Stercorarius pomarinus*
Parasitic Jaeger [b]	*Stercorarius parasiticus*
South Polar Skua [b]	*Stercorarius maccormicki*
Great Skua [c]	*Catharacta skua*
Least Tern [b, c]	*Sternula antillarum*
Royal Tern [b, c]	*Sterna maxima*
Black Tern [b, c]	*Chlidonias niger*
Common Tern [a, b, c]	*Sterna hirundo*
Bridled Tern [b, c]	*Onychoprion anaethetus*
Sooty Tern [c]	*Onychoprion fuscatus*
Sandwich Tern [b, c]	*Thalasseus sandvicensis*
Roseate Tern [b]	*Sterna dougalli*
Brown Noddy [b, c]	*Anous stolidus*
Gull Billed-tern [b, c]	*Gelochelidon nilotica*
Northern Gannet [b]	*Morus bassanus*
Laughing Gull [b, c]	*Larus atricilla*
Brown Pelican [b, c]	*Pelecanus occidentalis*
Neotropic Cormorant [b, c]	*Phalacrocorax brasilianus*

[a] Species observed in in the Stabroek Block during the EEPGL seismic surveys conducted in 2015 and 2016 (RPS, 2016)
[b] eBird record (eBird Caribbean, 2016)
[c] BirdLife International record (BirdLife International, 2016)

St. Giles Islands IBA includes one main island and several surrounding rock outcrops that support globally important numbers of breeding Red-billed Tropicbird (*Phaethon aethereus*) and regionally important numbers of breeding Audubon's Shearwater (*Puffinus lherminieri*), Magnificent Frigatebird (*Fregata magnificens*), Masked Booby (*Sula dactylatra*), and Red-footed Booby (*S. sula*). Other seabirds such as Brown Booby (*S. leucogaster*) and Brown Noddy (*Anous stolidus*) also breed there (White, 2008; Devenish et al., 2009).

Little Tobago IBA supports globally important breeding populations of Red-billed Tropicbird and Laughing Gull (*Larus atricilla*), and regionally important breeding populations of Audubon's Shearwater, Brown Booby, Red-footed Booby, and Bridled Tern (White, 2008; Devenish et al., 2009).

Field surveys conducted as part of the coastal mapping of Trinidad and Tobago documented large colonies of seabirds at both St. Giles Island and Little Tobago, as well as along the northeastern cliffs of Tobago, from Corvo Point to Pedro Point (ERM, 2016).

The Isla de Aves IBA in Venezuela supports the largest breeding colony of Brown Noddy known from the Caribbean (5,509 pairs), as well as the principal breeding colony of Sooty Tern (*Sterna fuscata*) in Venezuela (12,182 pairs) (Lentino and Esclasans, 2009).

Figure 6-10 Location of IBAs with Importance to Seabirds Relative to Stabroek Block



6.2.5 Marine Mammals

Although there have been no comprehensive studies in the PDA, a basic understanding of the existing composition and distribution of the marine mammal community in the vicinity of the PDA is provided by regional compilations (Ward, 2001; Ward and Moscrop, 1999), marine mammal observation (MMO) data collected during EEPGL exploration activities from 2014 to 2016 (RPS PSO database), studies on cetaceans in offshore waters of neighboring countries such as Suriname and Venezuela (de Boer, 2015; IWC/SC 2006), and incidental reports associated with strandings and bycatch (Project GLOBAL, 2007). Information from these reports and other studies provides the foundation for this discussion of existing conditions, which is focused on cetaceans. One sirenian, the West Indian manatee, and two pinniped groups (seals and sea lions), have been documented in the region, but are either now considered to be locally extinct or extremely rare and would not be expected to be encountered in coastal waters adjacent to the PDA (Ward, 2001). However, the manatee may be encountered in nearshore and riverine settings.

6.2.5.1 Regional Setting

The equatorial waters of Guyana are located within sub-region VI of the Wider Caribbean Region (WCR). This sub-region includes the countries of Guyana, Suriname, and French Guiana (Ward and Moscrop, 1999). Many cetacean species are known to occur either seasonally or year-round in the waters of the WCR, but there are minimal data concerning the life history and behavior of the majority of these species. The cetacean community is also under-recorded in waters off of French Guiana and Guyana (de Boer, 2015; Mannocci et al., 2013). In contrast, more detailed records exist for Venezuela in the southern Caribbean region. The scarcity of cetacean records for sub-region VI can be attributed to a lack of survey effort rather than an absence of marine mammals (de Boer, 2015).

6.2.5.2 Marine Mammal Data from the Project Development Area

The 2007 Global Bycatch Assessment of Long-lived Species (Project GloBAL) Country Profile of Guyana provides a list of marine mammals whose distributions overlap with Guyana's Exclusive Economic Zone (EEZ). The cetacean species documented in this report are listed in Table 6-9.

Table 6-9 Marine Mammals with Ranges that include Waters Offshore Guyana

Common Name	Scientific Name	IUCN Status	Notes
Sei whale	*Balaenoptera borealis*	EN	The sei whale is a baleen whale and is the third-largest after the blue whale and the fin whale. It inhabits most oceans and adjoining seas, and prefers deep offshore waters.
Bryde's whale	*Balaenoptera brydei*	Data Deficient	Bryde's whales are moderately sized and closely resemble their relative, the sei whale.

Common Name	Scientific Name	IUCN Status	Notes
Blue whale	*Balaenoptera musculus*	EN	Blue whales are the largest mammals on earth. Their diet consists almost entirely of krill. Blue whales were hunted nearly to extinction.
Fin whale	*Balaenoptera physalus*	EN	Fin whales are the second largest mammal after blue whales; they are found worldwide and their food consists of small fish, squid, copepods and krill.
Short beaked common dolphin	*Delphinus delphis*	LC	These dolphins occur throughout warm temperate and tropical oceans. Short-beaked common dolphins can occur in aggregations of hundreds or even thousands of dolphins. They sometimes associate with other dolphin species, such as pilot whales.
Long beaked common dolphin	*Delphinus capensis*	Data Deficient	The range of this dolphin is more restricted than that of the short beaked common dolphin. It has a varied diet. One of the main threats to this dolphin is fisheries.
Minke whale	*Balaenoptera acutorostrata*	LC	Minke whales are the second smallest baleen whale.
North Atlantic right whale	*Eubalaena glacialis*	EN	This is a baleen whale that was once a preferred target for whalers. They feed mostly on copepods and krill.
Pygmy killer whale	*Feresa attenuate*	Data Deficient	This is a poorly known and rarely seen dolphin that avoids human contact. They are often caught in drift gill nets.
Short-finned pilot whale	*Globicephala macrorhynchus*	Data Deficient	Short-finned pilot whales are very sociable and are rarely seen alone. They are found in groups of 10 to 30, though some pods are as large as 50. The species primarily feeds on squid, but will also feed on certain species of fish and octopus. They feed nearly 300 m deep or more, and spend great lengths of time at depth. A pod may spread out up to 800 m (~2,640 ft) to cover more area to find food.
Risso's dolphin	*Grampus griseus*	LC	These are found worldwide in temperate and tropical waters, just off the continental shelf on steep banks. Risso's dolphins feed almost exclusively on neritic and oceanic squid, mostly nocturnally.
Pygmy sperm whale	*Kogia breviceps*	Data Deficient	The pygmy sperm whale is not much larger than many dolphins. Pygmy sperm whales are normally either solitary, or found in pairs. They feed mainly on cephalopods.
Dwarf sperm whale	*Kogia simus*	Data Deficient	The dwarf sperm whale is the smallest species commonly known as a whale. Dwarf sperm whales feed mainly on squid and crab. Its preferred habitat appears to be just off the continental shelf.

Common Name	Scientific Name	IUCN Status	Notes
Fraser's dolphin	*Lagenodelphis hosei*	LC	This dolphin is normally sighted in deep tropical waters. Fraser's dolphins swim quickly in large tightly packed groups of about 100 to 1000 in number.
Humpback whale	*Megaptera novaeangliae*	LC	Found in oceans and seas around the world, humpback whales typically migrate up to 25,000 km each year. Humpbacks feed only in summer, in polar waters, and migrate to tropical or subtropical waters to breed and give birth in the winter. Once hunted to the brink of extinction, its population fell by an estimated 90% before a 1966 moratorium. Since this time, stocks have partially recovered.
Blainville's beaked whale	*Mesoplodon densirostris*	Data Deficient	This species of beaked whale is found in tropical and warm waters in all oceans, and has been known to range into very high latitudes. The whales are seen in groups of three to seven individuals. Dives have been measured as long as 22 minutes.
Gervais' beaked whale	*Mesoplodon europaeus*	Data Deficient	These whales occur in small groups. They most likely feed on squid. Although this species frequently strands, until 1998, no one had made a confirmed sighting of the species at sea.
True's beaked whale	*Mesoplodon mirus*	Data Deficient	These have been seen in small groups, and are believed to be squid eaters. Little else is known.
Melon-headed whale	*Peponocephala electra*	LC	Closely related to the pygmy killer whale and pilot whale, collectively this dolphin species is known by the common name blackfish. It is also related to the false killer whale. The melon-headed whale is widespread throughout the world's tropical waters, although not often seen by humans because it prefers deep water.
Sperm whale	*Physeter macrocephalus*	VU	The largest of the toothed whales that can be found anywhere in the open ocean, females and young males live together in groups while mature males live solitary lives outside of the mating season. Females give birth every four to twenty years, and care for the calves for more than a decade. A mature sperm whale has few natural predators. They feed on squid and fish and usually dive between 300 to 800 m (984 to 2,625 ft) to forage.
False killer whale	*Pseudorca crassidens*	Data Deficient	This species lives in temperate and tropical waters throughout the world. As its name implies, the false killer whale shares characteristics, such as appearance, with the more widely known killer whale. Like the killer whale, the false killer whale attacks and kills other cetaceans.

Common Name	Scientific Name	IUCN Status	Notes
Pantropical spotted dolphin	*Stenella attenuata*	LC	Found in all the world's temperate and tropical oceans, this species was threatened due to the killing of millions of individuals in tuna purse seines. In the 1980s, the rise of "dolphin-friendly" tuna capture methods benefitted the species and it is now one of the most abundant dolphin species in the world.
Clymene dolphin	*Stenella clymene*	Data Deficient	Clymene dolphins spend most of their lives in waters over 100 m (330 ft) in depth, but occasionally move into shallower, coastal regions. They feed on squid and small schooling fish, hunting either at night, or in mesopelagic waters where there is only limited light.
Striped dolphin	*Stenella coeruleoalba*	LC	The striped dolphin inhabits temperate or tropical, offshore waters. It moves in large groups — usually up to thousands of individuals in number. The adult striped dolphin eats fish, squid, octopus, krill, and other crustaceans.
Spinner dolphin	*Stenella longerostris*	Data Deficient	The spinner dolphin is a small dolphin found in offshore tropical waters around the world. The species primarily inhabits coastal waters, islands, or banks.
Rough-toothed dolphin	*Steno bredanensis*	LC	These dolphins can be found in deep warm and tropical waters around the world and are typically social animals. An average group has between 10 and 20 members. They have also been reported to school together with other species of dolphin, and with pilot whales, false killer whales, and humpback whales.

Source: Global, 2007; De Boer, 2015; IUCN 3.1; Minasian et al., 1984

A recent peer-reviewed study was conducted in Suriname and adjacent waters in 2012 (De Boer 2015). The data from this study were collected at similar depths and distances offshore as the PDA. De Boer (2015) documented the presence of 10 identifiable species in dedicated, effort-related surveys. These are shown in bold in Table 5-A of de Boer (2015). In addition, during transit to the survey area (Trinidad to Suriname), De Boer also documented incidental sightings of common bottlenose dolphins (*Tursiops truncatus*) off of Trinidad, other dolphins (*Stenella sp*.) off of Guyana, and Guiana dolphin (*Sotalia guianensis*) at the entrance of the Suriname River. These species may be encountered closer to shore where Project-related marine support vessel transits will be occurring.

The survey data from De Boer (2015) show that the cetacean community in the Suriname area is primarily composed of odontocetes (toothed whales, including sperm whales, beaked whales, killer whales, and dolphins). These are more common offshore of Suriname than the baleen whales (including Bryde's and sei whales). The occurrence of baleen whales is likely seasonal, with Bryde's/sei whales recorded only during June and July. Additional opportunistic records

cited in De Boer (2015) show that large baleen whales have been observed in early October. Both shelf waters and offshore waters are important for the dolphin community.

De Boer (2015) notes that the most abundant species documented offshore Suriname were the sperm whale and melon-headed whale. Spinner and pantropical spotted dolphins were also frequently encountered in large groups. The relative abundance index for all cetaceans was relatively low, as expected for the offshore survey location (approximately 1,190 m to 3,350 m [3,900 ft to 11,000 ft] water depths). Based on these data when viewed together with other systematic surveys in tropical regions in the eastern Atlantic and western Africa, estimated densities were found to be much higher in areas that spanned both deep and shallow waters versus the deep water-only area surveyed offshore Suriname. (De Boer, 2010). For example, tropical shallow shelf waters off of the Maldives in the Indian Ocean generally hold a much more diverse and abundant cetacean community (Clark et al., 2012).

Other older reports provide additional information for context. For example, the International Whaling Commission (IWC) Scientific Committee's (SC's) Draft Report on Small Cetaceans of the Wider Caribbean (IWC/SC, 2006) cites information from French Guiana and Venezuela and provides secondary information on Guyana's marine mammals. Bottlenose dolphins are incidentally captured in both gillnet and trawl fisheries in these countries. Tucuxi or grey dolphin (*Sotalia fluviatilis*) are known to suffer incidental capture in gillnets and seines throughout their range, which includes the Guianas (French Guiana, Suriname and Guyana).

Marine mammal observations during recent seismic surveys conducted between December 2015 and March 2016 (RPS, 2016) noted that dolphins were detected (either visually or acoustically) on 20 occasions and included four species: pantropical and bottlenose dolphins, short-finned pilot whales, and melon headed whales. Two sperm whale detections and two Bryde's whale detections were also recorded, along with one unidentified baleen whale. Visual monitoring was conducted over a period of about 85 days for a total of 1007.5 hours. Data from this winter study were combined with other observations in the Stabroek and Canje Blocks to develop the list of confirmed species sighted depicted in Table 6-10.

Table 6-10 Marine Mammal Species Visually Observed during EEPGL Activities Since 2014

Common Name	Scientific Name
Bryde's whale	*Balaenoptera brydei*
Fraser's dolphin	*Lagenodelphis hosei*
Melon headed whale	*Peponocephala electra*
Pantropical spotted dolphin	*Stenella attenuate*
Risso's dolphin	*Grampus griseus*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sperm whale	*Physeter microcephalus*
Spinner dolphin	*Stenella longirostris*

Source: RPS, 2016

Table 6-11 summarizes the data for acoustic and visual observations of marine mammals in the vicinity of the PDA, month-by-month, over the period June 1, 2014 to September 1, 2016. The locations of whales sighted or identified from acoustic observations during this period are depicted on Figure 6-11.

Table 6-11 Data Compiled from PSO Observations June 2014 to September 2016

	Number of Observations											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sperm Whale	3	2	2	1	0	1	4	6	2	4	0	0
Dolphin	56	28	3	8	6	7	14	34	52	42	52	42
Baleen Whale	7	3	6	4	0	2	3	0	0	0	1	3
Beaked Whale	0	0	0	0	1	0	1	0	0	0	0	0

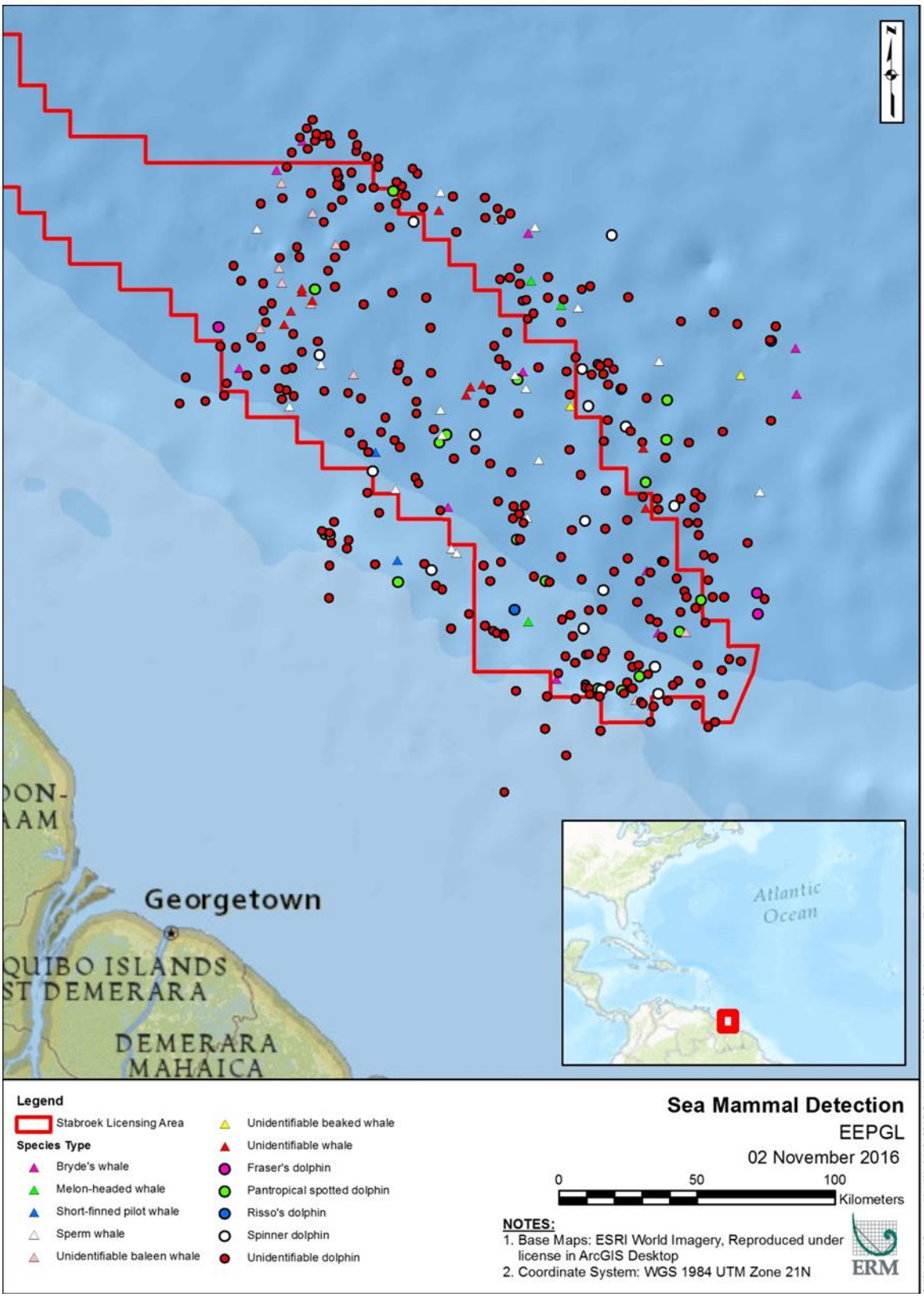
Source: RPS PSOMAP database search from June 1, 2014, to Sept 1, 2016. Includes visual and acoustic detections. Data indicates number of detections rather than abundance.

These observations off of Guyana correspond with those documented by De Boer (2015) off of Suriname. Based on these recent sightings and data compilations, toothed whales (including dolphins) are detected most frequently in the PDA, but baleen whales may also be encountered.

A survey of nearshore waters conducted by Charles et al. (2004) of 125 Guyanese captains of trawl, drift seine, and red snapper fishing vessels found that these vessels usually encountered boto (*Inia geoffrensis*), spotted dolphin (*Stenella spp*.), longmouth or common dolphin (*Delphinus delphi*), tucuxi (*Sotalia fluviatilis*), spinner dolphin (*Stenella longirostrus*), and bottlenose dolphin (*Tursiops truncatus*). Individuals of these species may be encountered by marine support vessel operations and tankers in these waters.

Nearshore Project activities in or near the Demerara River could encounter West Indian manatees. A subspecies of the West Indian manatee is sometimes referred to as the Antillean manatee (*Trichechus manatus manatus*). Antillean manatees are sparsely distributed throughout the Caribbean and the Northwestern Atlantic Ocean, from Mexico, east to the Greater Antilles, and south to Brazil. They are found in French Guiana, Suriname, Guyana, Trinidad (though there has been a lack of recent sightings there), and Venezuela. Historically, Antillean manatees were hunted by local natives and sold to European explorers for food. Today, they are threatened by loss of habitat, poaching, entanglement with fishing gear, and increased boating activity.

Figure 6-11 Locations of Marine Mammal Sightings Relative to the Stabroek Block



6.2.6 Marine Turtles

According to the *Regional Sea Turtle Conservation Program and Action Plan for the Guianas* (2003), sea turtles are an important natural resource shared by the countries of the "Guiana Shield region", which encompasses the nations of Venezuela, Guyana, Suriname, French Guiana, and Brazil. Data from this action plan along with more recent compilations from Project Global (2007), The Center for Rural Empowerment and the Environment ([CREE], 2014), and observations collected during exploration activities from 2014 to 2016 represent the main sources of data for turtles in the Project Area. In addition, information on the interaction between sea turtles and trawl fisheries on the Guianas shelf since the 1970s was reviewed (Pritchard 1973, 1991).

6.2.6.1 Regional Setting and Species Descriptions

Five sea turtle species are found in the region, all of which occur in Guyanese waters. Four of these species: green turtle (*Chelonia mydas*), leatherback turtle (*Dermochelys coriacea*), hawksbill turtle (*Eretmochelys imbricata*), and Olive Ridley turtle (*Lepidochelys olivacea*) nest on Guyana's beaches. Loggerhead turtles (*Caretta caretta*) also occur offshore Guyana, but rarely come ashore. In addition to sandy beaches for egg-laying, as a group sea turtles require healthy coral reef, seagrass, and hard-bottom habitats for food and refuge, although the relative importance of these habitats varies by species. Based on each species' known habitat requirements some green sea turtles likely remain in Guyana waters as juveniles to feed in the sargassum mats while the other species largely move to clearer waters and coral reefs to the north after hatching (Piniak and Eckert, 2011).

Green turtles are generally found in tropical and subtropical waters along coastlines and continental islands between the latitudes of 30° North and 30° South. They are distributed worldwide, nesting in more than 80 countries and inhabiting the coastal waters of more than 140 countries (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2007). Green turtles are listed as endangered by the IUCN and are protected from exploitation in most countries. Adult green turtles are benthic herbivores (Bjorndal et al., 1997); they play an important role in seagrass ecosystems by pruning them, increasing the nutrient cycle and preventing the creation of sediment (Bjorndal and Jackson, 2003; Jackson et al., 2001). Their migrations have two phases: they travel rapidly to the open ocean in a straight line and then move more slowly toward the migration coasts (Troëng et al., 2005b).

Leatherback turtles are the largest of all sea turtle species and do not have a hard shell like other sea turtles; instead, their shell is made of leathery tissue. Leatherbacks are found in pelagic tropical and temperate marine waters, where they spend most of the time feeding on jellyfish, salps, and siphonophores (DOE, 2014); however, they are also known to forage along coastlines. Leatherbacks make extensive seasonal migrations between different feeding areas and nest at the same location every year (NWF, 2014b). Leatherback turtles nest from March to mid-July along the Caribbean coast (Troëng et al., 2004). Young leatherback turtles can remain in tropical latitudes until the length of their shell reaches approximately 40 inches (Eckert 1999). The largest nesting colony in the Caribbean region is located in Yalimapo, French Guiana (Eckert

and Grobois 2001). A moderate number of nests can also be found in Guyana, Venezuela, Trinidad, and Colombia. This species is listed by the IUCN as Vulnerable.

The hawksbill turtle is a small- to medium-sized sea turtle that has an elongated head that tapers to a point with a beaklike mouth, giving its name (NOAA, 2014e). These turtles are circumtropical and can be found in waters from latitudes of 30° North to 30° South in the Atlantic, Pacific, and Indian oceans and use a wide range of broadly separated localities and habitats during their lifetimes (Mortimer and Donnelly, 2008). However, individuals located within the Atlantic Ocean primarily feed on sponges and are found within lagoons, ledges, and caves associated with coral reef environments (NOAA, 2014e). These types of habitats are generally found northwest of the PDA in the Caribbean Sea. This species is listed as Critically Endangered by the IUCN.

The loggerhead turtle is an oceanic turtle distributed throughout the world. The loggerhead turtle is found in the Atlantic, Pacific, and Indian oceans, as well as the Mediterranean Sea. It spends most of its life in saltwater and estuarine habitats, with females briefly coming ashore to lay eggs. The loggerhead sea turtle has a low reproductive rate; females lay an average of four egg clutches and then become quiescent, producing no eggs for two to three years. The loggerhead turtle is omnivorous, feeding mainly on bottom-dwelling invertebrates. Its large and powerful jaws serve as an effective tool for dismantling its prey. Young loggerheads are exploited by numerous predators; the eggs are especially vulnerable to terrestrial organisms. This species is classified by the IUCN as Endangered with high risk of extinction.

The olive ridley turtle is a small circumtropical sea turtle that is classified as vulnerable by the IUCN. While olive ridley turtle populations have declined in prior decades, their populations have remained stable in more recent years. Olive ridley turtles are best known for their behavior of synchronized nesting in mass numbers, termed *arribadas*. Females return to the same beach at which they first hatched to lay their eggs. The olive ridley is predominantly carnivorous, especially in immature stages of the life cycle. Animal prey consists of protochordates or invertebrates, which can be caught in shallow marine waters or estuarine habitats. Common prey items include jellyfish, tunicates, sea urchins, bryozoans, bivalves, snails, shrimp, crabs, rock lobsters, and sipunculid worms.

Large nesting aggregations of green and leatherback turtles are located in the Guianas (Suriname and French Guiana), while smaller nesting areas are located from northwestern Guyana (Shell Beach) to Venezuela and some Caribbean islands (which includes the Leeward, Lesser, and Greater Antilles); the Gulf of Mexico (Central America); and Atlantic Ocean (the Bahamas; and the southern coast of the United States) (Piniak, 2011). The hawksbill turtle's range is primarily in the Caribbean Sea, with small nesting areas in the Guianas and in eastern Brazil. The olive ridley turtle primarily nests along the French Guiana coast with small nesting areas along the northeastern coast of Venezuela to Suriname and in eastern Brazil (Piniak, 2011).

The primary nesting site for all these species in Guyana is Shell Beach, located on the northwestern coast of Guyana. The exact locations of secondary nesting sites change due to coastal erosion, which creates and destroys nesting areas continuously, but they are generally distributed along the northwest coast between the Pomeroon River and the Waini River

estuaries. Leatherback turtles are the most common species on Guyana's nesting beaches, while nesting green and hawksbill turtles are less common. According to CREE, the primary nesting season for the leatherback, green, hawksbill, and olive ridley turtles in Guyana (Shell Beach) occurs at night from March to August (CREE, 2014).

The primary threats to sea turtles are poaching of eggs and adults, intentional and accidental fishing, and habitat disturbance and degradation due to marine pollution, coastal zone development, shore erosion, lighting, and debris. Population monitoring and conservation activities are limited, primarily due to the logistical challenges associated with the remoteness of primary nesting sites.

Although leatherback and olive ridley turtles occur at higher densities and thus show a corresponding higher frequency in shrimp trawls, juvenile greens and loggerheads are also taken as bycatch (see Project Global, 2007). Tambiah (1994) estimated that trawl nets in the Guianas caught 1,300 turtles annually, with mortality rates of 60 percent. Tambiah (1994) also reported that gillnet fisheries in Guyana and Suriname are an even bigger threat than trawl fisheries, incidentally capturing 21,600 sea turtles per year. However, the report documents the highest incidences of olive ridley bycatch occurring during the period prior to the nesting arribadas in Suriname (January to March), coinciding with the peak period for shrimp fisheries (February to May).

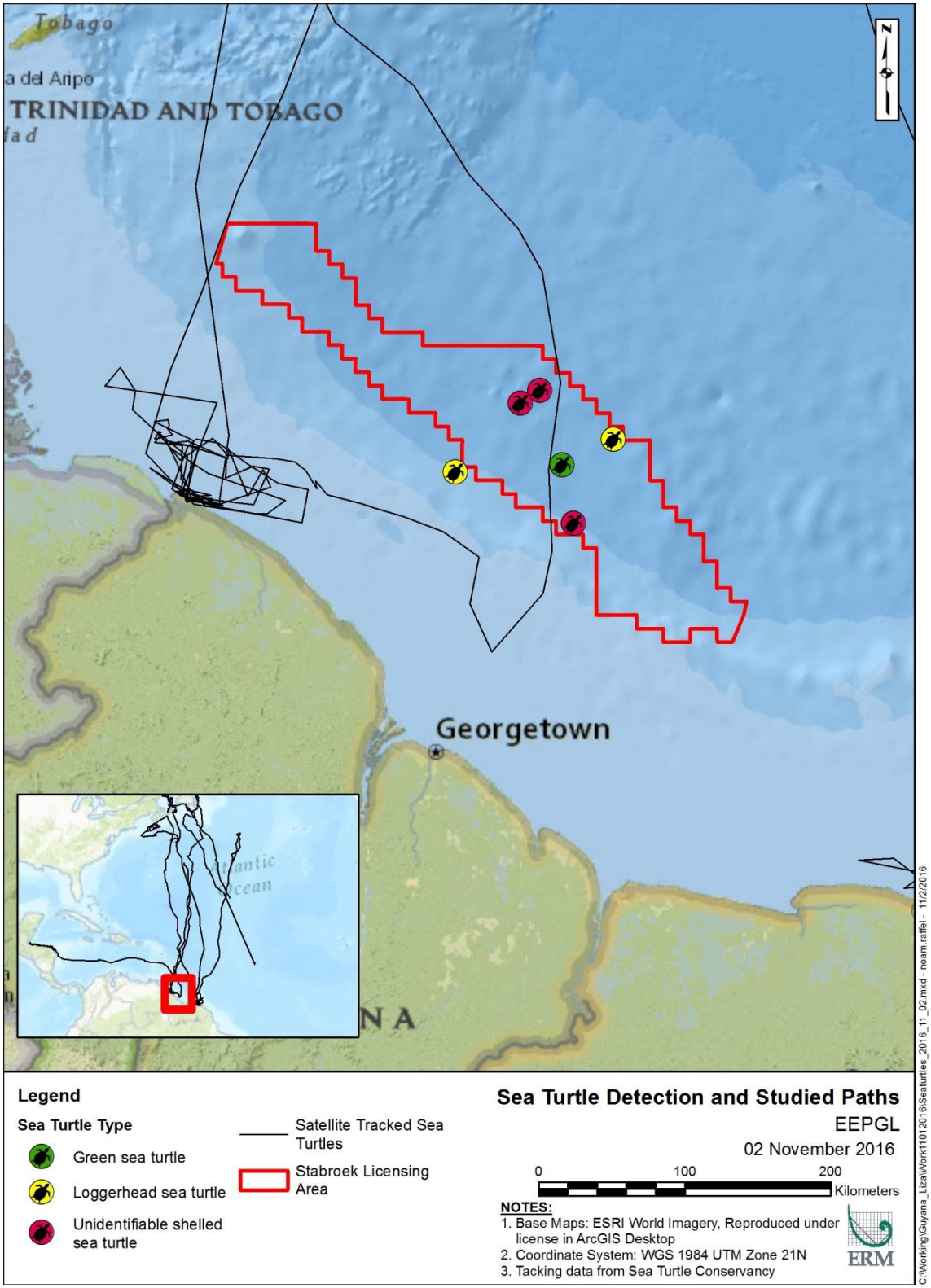
6.2.6.2 Marine Turtle Data for the Project Development Area

MMO observations conducting during seismic surveys between July 2015 and August 2016 detected six sea turtles: one green turtle, two loggerhead turtles and three unidentified turtles. The locations of the sightings are indicated on Figure 6-11.

Based on these recent sightings and data compilations, it is possible that any of the five above-referenced sea turtle species could be encountered in the PDA.

The Sea Turtle Conservation Society actively maps sea turtle movements, by placing satellite transmitter tags on individual turtles after they finish nesting (see www.conserveturtles.org). Starting on May 21, 2012, the Society mapped movements of three leatherback turtles from their nesting place at Shell Beach (Figure 6.-12). Each remained offshore of Shell Beach and in Guyana's equatorial waters for several weeks. By the second to third week of June, two had moved farther offshore in transit to waters off the coast of Nova Scotia, while one remained in Guyanese waters until the third week of July and eventually transited to Honduran waters. One passed through the Stabroek Block before moving northward. These movements are consistent with Piniak and Eckert's (2011) assertion that most species of marine turtles likely move out of Guyanese waters as juveniles.

Figure 6-12 Location of Sea Turtle Sightings and Satellite Tracks Relative to the Stabroek Block



6.2.7 Marine Fish

Scientific data on marine fish in the PDA are sparse. Much of what is known about marine fishes offshore Guyana is known from study of commercial landings. The inshore fish community is dominated by drums, croakers, and marine catfishes, and includes other species such as snooks and tarpon. Further offshore near the interface of the turbid North Brazil Current with oceanic water, the fish community is more complex, consisting of pelagic, highly migratory species such as tunas, jacks, and mackerels in the upper water column and snappers and groupers in the demersal zone (lowest section of the water column, near the seafloor) (MOA, 2013). Sharks are found inshore and offshore.

Guyana's marine fish community exemplifies the ecological connectivity among the mangroves, estuaries, and offshore zones, because many fish species are dependent on different habitats at specific life stages or occur in more than one habitat type. Several species that occur in the inshore and offshore zones as adults are dependent on coastal mangroves as juveniles, particularly drums, croakers, and snappers. Catfishes occur in the mangroves, estuaries, and oceanic waters as adults. Some other species, including snooks and tarpon, may occur occasionally in the ocean, but are specifically adapted to completing their entire life cycles in mangrove-lined estuaries (MOA, 2013).

6.2.7.1 Historical Data on Demersal Coastal Species

The most complete data on marine fish in Guyana's territorial waters come from a two-year trawl survey conducted in 1958 and 1959. The survey consisted of 35 cruises lasting 4 to 11 days each, and included data from 1,070 stations comprising 2,246 fishing hours (McConnell, 1962). Although the study report does not contain a map of the individual stations, the map of the study area indicates that they extended seaward to the edge of the continental shelf. Although the study did capture some pelagic species, it was designed as a trawl survey and was therefore more oriented toward demersal species. The study documented the presence of 213 species of fish, comprised primarily of drums, croakers, catfishes, jacks, grunts, and snappers. McConnell noted a spatial pattern in the distribution of fishes across the shelf, and separated the shelf into four biogeographic zones:

- Zone 1: described as the "brown fish" zone, water depths from 0 to 10 fathoms (0-18 m). The fish community in this zone was dominated by drums, catfishes, rays, and various toadfishes (Batrachoididae).
- Zone 2: described as the "golden fish" zone, water depths from 10 up to 30 fathoms (18-55 m). The fish community in this zone was dominated by catfishes, jacks, and grunts.
- Zone 3: described as the "silver fish" zone. This zone was associated with less turbid oceanic waters and the location of this zone was more dependent on water quality than depth, but the fish typical of this zone were particularly abundant in water 20 to 40 fathoms (37-75 m).
- Zone 4: described as the "red fish" zone, ranging from water depths of about 20 fathoms near Suriname and 30 to 40 fathoms (55-75m) closer to Georgetown seaward to the edge of the continental shelf. Snappers and various demersal species comprised the bulk of the catch in this zone.

Approximately 80 species of fish occurred in Zone 4 in the McConnell study. These species are listed in Appendix K. Although the PDA is located slightly north of the seaward limit of McConnell's study area (and in deeper water), the catches from Zone 4 contain species that are also found at much deeper depths, and are therefore considered indicative of the types of fish that are likely to occur in the PDA, especially near the seafloor.

The data from Zone 4 in the McConnell study include several species that are commonly associated with coral reefs, including butterflyfishes, angelfishes, wrasses, and parrotfishes (MConnell, 1962). McConnell notes that coral fragments appeared in the trawl, but that the coral retrieved in the net was dead. It seems likely that the coral-associated fishes in the McConnell study were likely present on scattered fragments of dead coral or possibly small dead patches of coral rather than on living reefs.

Based on comparisons with species lists from nearby countries, McConnell determined that about 50 percent of Guyana's marine fish species were widely distributed coastal species, about 10 percent were clear-water associated species more typical of the Caribbean Islands, about 5 percent were more southerly species typical of the Brazilian coast, and the balance were habitat generalists with no defined regional habitat associations. McConnell also noted that the North Atlantic Continental Shelf is continuous from the Gulf of Mexico to Brazil and that there were no major barriers to migration through this area, so Guyana's marine fish community would be expected to have many species in common with other countries in the region. This likely explains the presence of so many widespread species in the dataset.

The Guyana Fisheries Department (a division of the Guyana Ministry of Agriculture) does not monitor non-commercial marine fisheries, but bycatch data from the nearshore shrimp trawl fishery provided by the Guyana Fisheries Department (summarized in Table 6-12) are consistent with the McConnell study with respect to marketable species in McConnell's "brown" fish zones. Recent bycatch data collected since 2012 from shrimp trawlers identify seven species of fish. Four of these species (Bangamary, Bashaw, Croaker, Sea Trout) are in the family Scianidae, which McConnell identified as characteristic of Zone 1 (McConnell et al., 1962); Bangamary, Bashaw, and Sea Trout represent 65-75 percent of the total bycatch by weight each year from 2012 to 2015.

Table 6-12 Fish Bycatch from the Nearshore Shrimp Trawling Fishery 2012-2015 (mt)

Species	2012	2013	2014	2015
Bangamary	757	921	1,380	1,151
Butterfish	559	665	6622	485
Bashaw	111	189	1799	168
Croaker	0	0	0	0
Sea Trout	303	292	4711	303
Grey Snapper	3	2	22	0.1
Snook	0	0	0	42
Total	**1,733**	**2,069**	**2,692**	**2,148**

Source: ERM Personal Communication 16

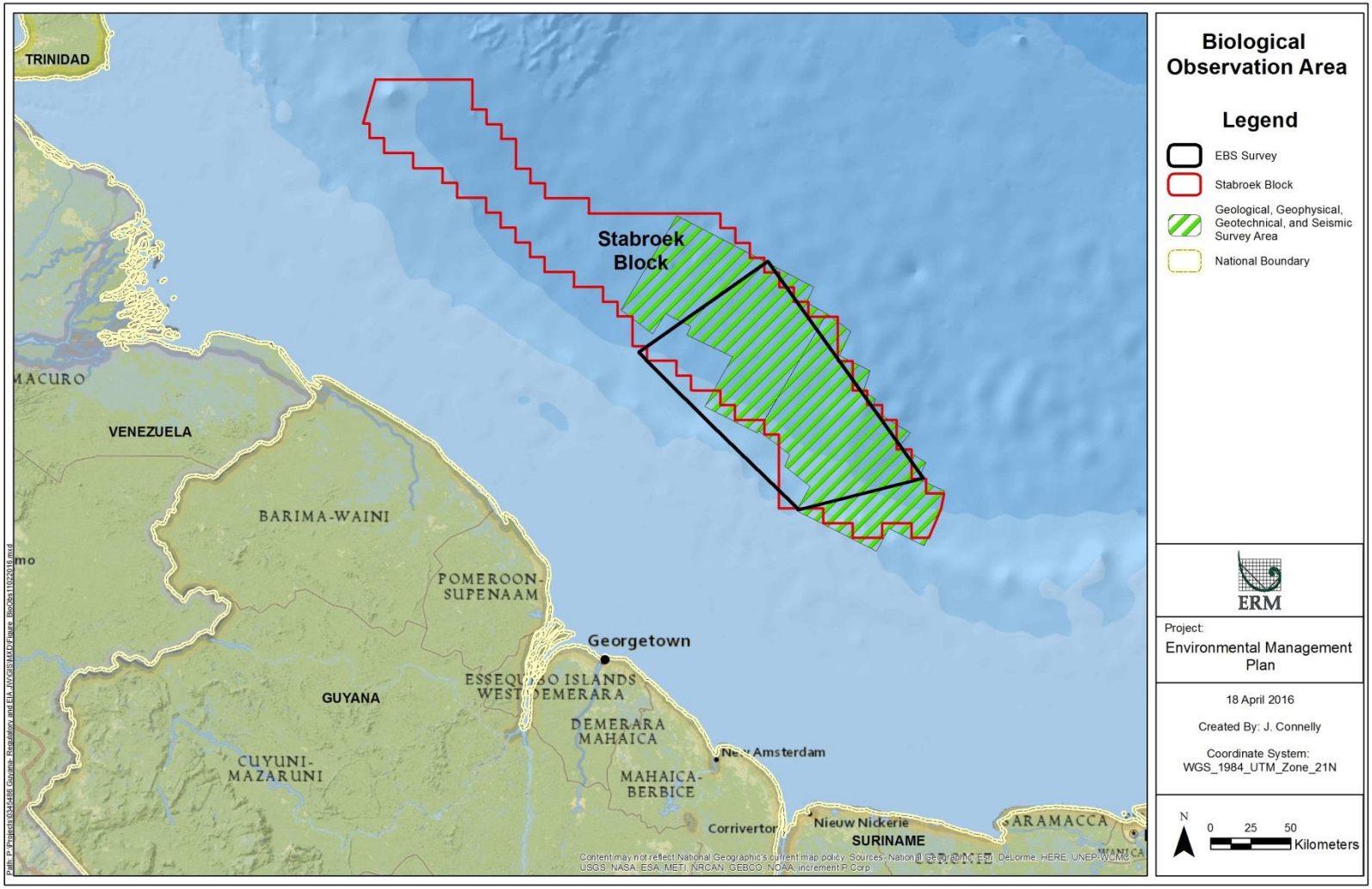
6.2.7.2 *Observations from EEPGL's Offshore Activities*

Project-specific information on fish species from the PDA is available from observations made during EEPGL's various activities in the southeastern half of the Stabroek Block since 2014 (Figure 6-13). Fish observed in this area (Figure 6-13) include 17 species, as listed in Table 6-13. None of these species were documented in the McConnell study, but the data from EEPGL's activities were acquired from surface observations and are comprised of species that are characteristic of the upper water column, so would not be expected in McConnell's trawl survey.

Table 6-13 Fish Species Observed in the Stabroek Block during EEPGL Activities Since 2014

Common Name	Scientific Name
Mahi-mahi	*Coryphaena hippurus*
Jack	*Seriola sp.*
Atlantic tripletail	*Lobotes surinamensis*
Atlantic flying fish	*Chellopogon melanurus*
Little tunny	*Euthynnus alletteratus*
Manta ray	*Manta sp.*
Ocean sunfish	*Mola mola*
Planehead filefish	*Stephanolepis hispidus*
Sailfish	*Istiophrous albicans*
Skipjack tuna	*Katsuwonus pelamis*
Blackfin tuna	*Thunnus atlanticus*
Yellowfin tuna	*Thunnus albacares*
Clearwing flying fish	*Cypselurus comatus*
Blue marlin	*Makaira nigricans*
Bar jack	*Caranx ruber*
Crevalle jack	*Caranx hippos*
Rainbow runner	*Elagatis bipinnulata*

Figure 6-13 Approximate Locations of Biological Observations Made Since 2014



In the summer of 2011, several islands in the eastern Caribbean (e.g., Anguilla, Antigua & Barbuda, Barbados, British Virgin Islands, Guadeloupe, Martinique, St. Lucia, St. Maarten / St. Martin) experienced large amounts of sargassum washing ashore. In 2012 and 2014, Barbados, Guadeloupe, Dominica, Antigua & Barbuda, St. Croix, and Puerto Rico reported moderate episodes of the phenomenon. The sargassum consisted of two species: Common Gulfweed (*Sargassum natans*) and Broad-toothed Gulfweed (*Sargassum fluitans*) (CRFM, undated). A large amount of sargassum was also documented in the Stabroek Block in 2015. Quantities were sufficiently large in the block to clog intake hoses for vessel propulsion systems and foul acquisition equipment being used to collect seismic data in the block at the time. Subsequent analysis of satellite imagery revealed that although sargassum densities were unusually high offshore Guyana in 2015, sargassum concentrations fluctuate annually and have a seasonal peak between April and September (Palandro, 2016).

The presence of such large amounts of sargassum is significant from a fish biodiversity perspective because sargassum has several important ecological roles related to marine fishes, including:

- concentrating forage fish that are preyed upon by large pelagic fishes (including juvenile swordfish, dolphinfish, filefishes, jacks, flying fishes, triggerfishes, and various tunas);
- spawning habitat for flying fish (*Exocoetidae*); and
- habitat for unique fishes and other organisms that spend most or all of their lives in floating mats of sargassum, including the sargassum fish (*Histrio histrio*).

6.2.7.3 Special Status Fish Species

Thirty marine and coastal fishes in Guyana have been ranked by the IUCN as threatened (CR, EN, or VU) with another 21 ranked as NT. According to the IUCN's classification scheme, these species currently face a credible threat of extinction, and are expected to face such risks soon. An additional 17 are considered Data Deficient and cannot be objectively assessed with the currently available data. Most of the threatened or NT species that could be impacted by the Project are fish. These species are listed in Appendix H. They include highly migratory species (e.g., some tunas and sharks), bentho-pelagic species (e.g., some groupers), and demersal species (e.g., some skates and rays). As noted in Section 6.3.3.2, many of these fish species are also targeted by the Guyanese commercial fishing industry.

All of the CR species are coastal species and would not be expected to occur in the vicinity of the PDA. Several of the EN species, including Atlantic bluefin tuna, whale shark, squat-headed hammerhead shark, and scalloped hammerhead shark, are open water pelagic species and could occur in the PDA intermittently, but would not be expected to be residents in the area. The two remaining EN species (golden tilefish and Nassau grouper) are bottom-dwelling species and do not move large distances as adults, but they are most often associated with uneven bottoms containing rocky outcrops, shipwrecks, or other structural habitats. The continental slope in the vicinity of the PDA lacks any known structure that would be expected to attract or aggregate these species.

The VU, NT, and Data Deficient categories all contain a mix of pelagic species (e.g., sharks and tunas) and demersal marine species (such as grouper, skate, and ray species), and in some cases species that are important targets of fishery activities (e.g., gillbacker).

6.2.8 Marine Benthos

The benthic communities inhabiting the Guyana Basin are influenced by the dominant environmental conditions that characterize the area, including sediment composition, water turbidity, and nutrient loads. This section describes the marine benthic habitat within the Project AOI.

6.2.8.1 Methodology

This section draws on information provided in the scientific literature, maps, Automated Underwater Vehicle (AUV) photographs, as well as field data collected by box coring and sediment profile imaging during the 2014 and 2016 environmental surveys.

6.2.8.2 Regional Setting

Marine benthic biological resources offshore of Guyana are poorly studied, but do not include the matrix of shallow coral reefs and seagrass meadows that are characteristic of coastal tropical Atlantic environments elsewhere. This is due to the highly turbid conditions offshore of Guyana, which do not permit the growth of warm water corals, since they rely on symbiotic photosynthetic algae for nourishment.

Two cold-water coral species (*Madrepora oculata* and *Solenosmilia variabilis*) are known to occur offshore of Guyana. Both species occur in a wide range of depths, *M. oculata* from 55 to 1,950 m and *S. variabilis* from approximately 219 m to 2,165 m. The locations and the extent of deepwater corals offshore of Guyana have not been published (Freiwald et al., 2004). Many cold water corals construct reefs that support highly diverse invertebrate and fish fauna (NOAA, 2014). Both *M. oculata* and *S. variabilis* are technically considered reef-building corals, but *M. oculata* is particularly fragile and does not often form deepwater reefs. It more frequently occurs as a commensal species living within or on reefs that were originally constructed by more robust species such as *S. variabilis*.

Several species of bentho-pelagic shrimp occur in Guyanese waters, including shallow water species such as the Atlantic Seabob (*Xiphopenaeus kroyeri*), the Southern Brown Shrimp (*Penaeus subtilis*), and the Southern White Shrimp (*Penaeus schmitti*). The Red-spotted Shrimp (*Penaeus brasiliensis*) and the Southern Pink Shrimp (*P. notialis*) are found in deeper waters (USEPA, 2010). While these species are free swimming, they are often found at or near the bottom.

In addition to shrimp, there are other species of crustaceans found in the deepwater areas of the Caribbean Sea. These include several species of isopods (such as *Leptanthura guianae* and *Malacanthura truncata*) (Poore and Schotte, 2009 and 2015) and amphipods (including *Ampelisca mississippiana*, and *Thaumastasoma* species). There are also numerous species of annelids,

including the polychaetes *Tharyx marioni*, *Aricidea suecia*, *Levinsenia uncinata*, and *Paraonella monilaris*, as well as bivalves, such as *Vesicomya vesical* and *Heterodonta* sp. (Wei et al., 2010).

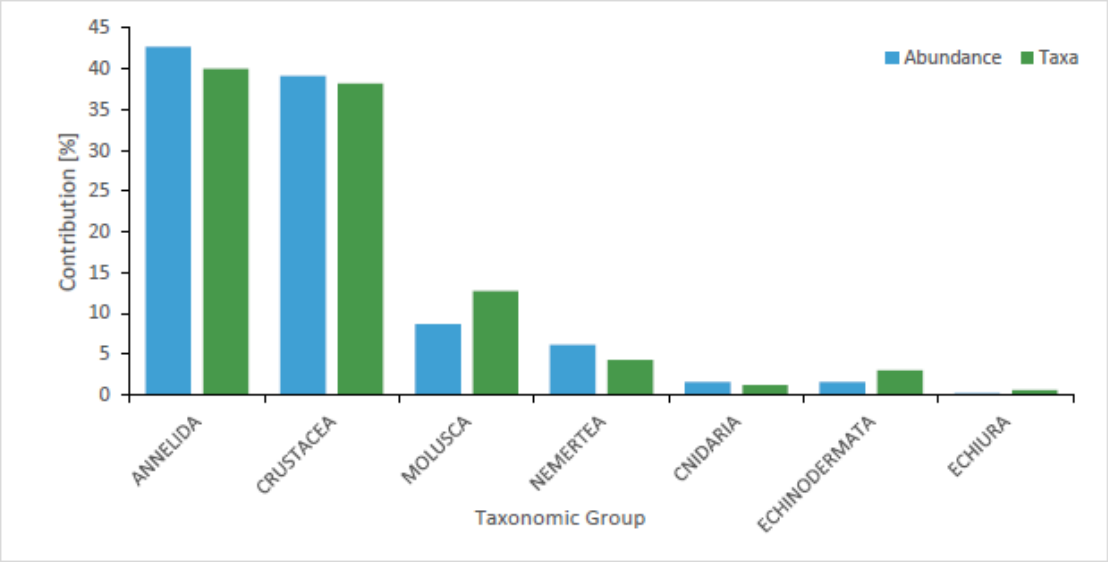
6.2.8.3 Existing Conditions in the Project Development Area

Results of the 2014 environmental survey revealed that the total abundance of benthic infauna in the PDA was low, averaging 116 organisms per m^2. This organism density is below the range of typical abundances reported from other continental slopes (Rowe et al., 1982; Flach et al., 1999). The most abundant major taxonomic groups were polychaete worms, crustaceans, and mollusks. The overall prevalence of these three groups is typical for marine sediments. Polychaetes were the numerically dominant group identified (avg. density 47 per m^2, representing 41 percent of the total groups). Polychaetes typically comprise about half of all species and a third of macrofaunal species from deep-water marine habitats worldwide. Aside from polychaetes, no other individual major taxa were abundant, with each of the other taxa groups individually representing less than 14 percent of total abundance. The observed paucity of macrofauna is likely ascribed to limited organic food sources, indicated by the low organic carbon content in the sediment. No deepwater coral growth was detected in either the 2014 or 2016 environmental surveys or the AUV surveys of the seafloor in the vicinity of the Liza-1 well (Maxon Consulting, Inc. and TDI Brooks International, Inc., 2014; FUGRO EMU Limited, 2016).

A total of 50 distinct families were identified during the 2014 environmental survey, with approximately half represented by either one or two individuals. This is a relatively high level of diversity considering the low abundance of macrofauna. Dominant families were typical cosmopolitan inhabitants of shelf and slope sediments worldwide. These included spionid, cirratulid, paraonid polychaetes, phoxocephalid amphipods, and thyasirid and nuculanid (bivalve) mollusks.

Similar to the 2014 data, the 2016 environmental study showed an overall prevalence of annelids (including polychaetes), crustaceans, and mollusks typical for marine sediments as well as low macrofaunal densities. The 2016 samples averaged 20 organisms per 0.1 m^2, which can be extrapolated to 200 organisms per 1 m^2 for the purposes of comparison to the 2014 data. While the 2014 survey did not categorize the macrofauna organisms beyond the family level, the 2016 survey further classified the macrofauna to the order and species level and covered a larger sampling area. Results from the 2016 sampling showed macrofaunal communities within the survey area to be diverse. In 2016, a total of 165 taxa were identified in 7 phyla and 27 families, with 36 identified to species level (including 15 species of polychaetes, 10 crustaceans, 8 mollusks, and 3 sipunculid worms). Annelida were the numerically dominant group (phylum), in terms of species composition (40 percent) and abundance (42.7 percent). Crustaceans accounted for the second highest species composition (38.2 percent) and abundance (39.1 percent), followed by mollusks (12.7 percent and 8.7 percent, respectively) and other taxa (collectively 9.1 percent and 9.5 percent, respectively) (Figure 6-14).

Figure 6-14 Abundance of Major Taxonomic Groups Identified in 2016 EBS



Source: FUGRO EMU Limited, 2016

Table 6-14 identifies the common macrofauna families identified in the 2014 and 2016 studies. As the 2014 survey did not categorize the macrofauna organisms beyond the family level, the commonalities between the 2014 and 2016 surveys were identified based on equivalent families. Both surveys characterized the surveyed area to have a diverse macrofauna community, with polychaete worms as the most abundant major taxonomic group. The 2014 survey additionally recognized that overall macrofaunal abundance within the surveyed area is at the lower end of the macrofaunal densities reported for continental slope sediments around the world (Rowe et al. 1982; Flach et al., 1999). The 2016 survey similarly reported that numbers identified in all taxonomic groups were low.

Table 6-14 List of Common Macrofauna Families between the 2014 and 2016 Environmental Survey Reports

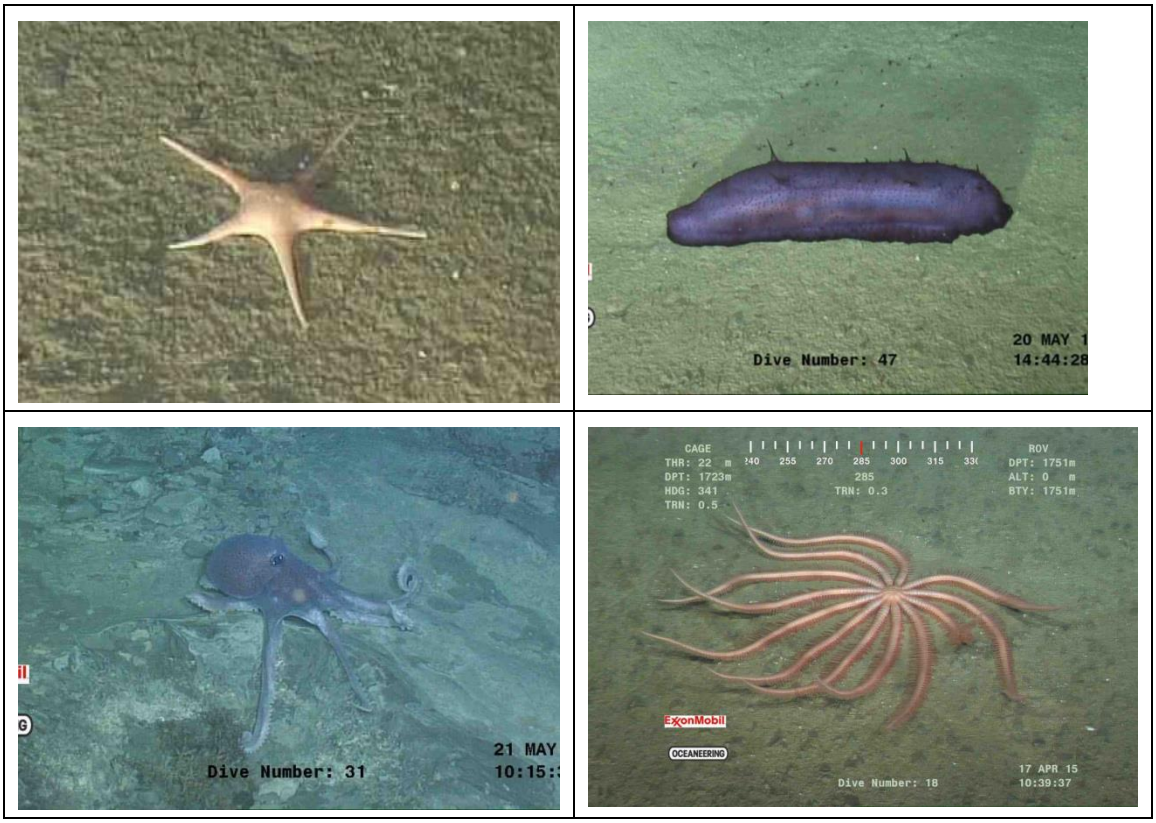
Phylum	Class	Order	Family
Annelida	Polychaeta	Sabellida	Oweniidae
Annelida	Polychaeta	Spionida	Spionidae
Annelida	Polychaeta	Spionida	Magelonidae
Annelida	Polychaeta	Terebellida	Cirratulidae
Annelida	Polychaeta	Terebellida	Ampharetidae
Annelida	Polychaeta	Not assigned	Orbiniidae
Annelida	Polychaeta	Not assigned	Paraonidae
Annelida	Polychaeta	Not assigned	Capitellidae
Annelida	Polychaeta	Not assigned	Maldanidae
Annelida	Polychaeta	Not assigned	Opheliidae
Annelida	Polychaeta	Phyllodocida	Phyllodocidae
Annelida	Polychaeta	Not assigned	Orbiniidae

Phylum	Class	Order	Family
Annelida	Polychaeta	Eunicida	Lumbrineridae
Annelida	Polychaeta	Eunicida	Onuphidae
Arthropoda	Malacostraca	Cumacea	Unidentified
Arthropoda	Malacostraca	Tanaidacea	Apseudidae
Mollusca	Scaphopoda	Dentaliida	Dentaliidae
Nematoda	Unidentified	Unidentified	Unidentified
Sipuncula	Sipunculidea	Golfingiiformes	Unidentified
Sipuncula	Sipunculidea	Golfingiiformes	Golfingiidae
Sipuncula	Sipunculidea	Golfingiiformes	Phascolionidae

Notes: The term "not assigned" references that the scientific community has not specifically classified the organism to a given categorization. The term "unidentified" refers to the surveyor's inability to further identity the categorization of an organism.

Figure 6-15 depicts some of the benthic fauna detected during the 2014 environmental survey.

Figure 6-15 Benthos Photographed in the Vicinity of the Liza-1 Well



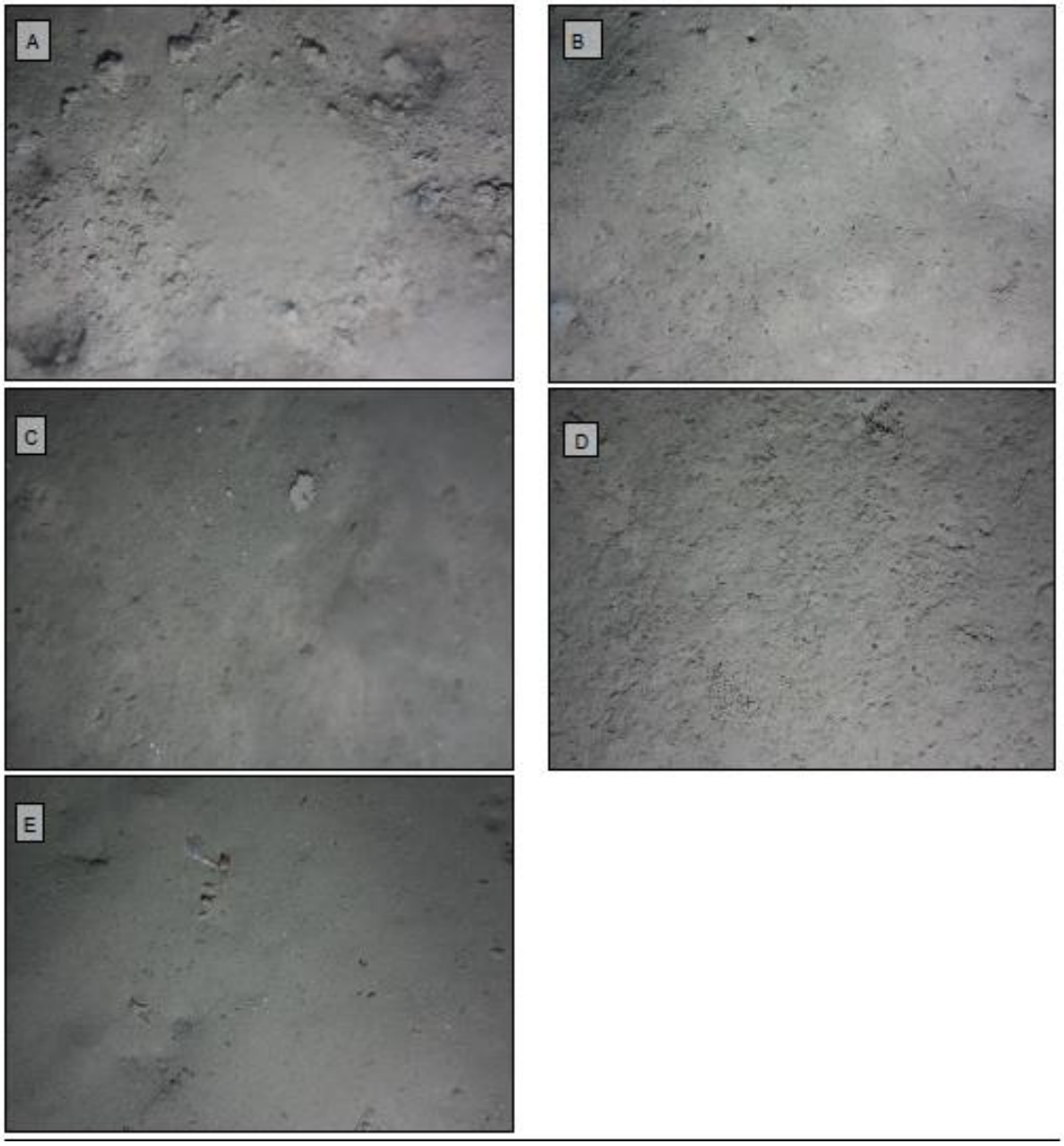
Source: Maxon Consulting, Inc. and TDI Brooks International, Inc., 2014

Both surveys reported that there was not a strong correlation between macrofaunal communities or number of species and any single parameter such as sediment characteristics or water depth.

The results of the seabed photography sediment and faunal data review showed the survey area primarily consists of one broad benthic habitat type: sublittoral sediment (EUNIS[14] code A5). This marine benthic habitat can encompass a wide range of sediments from boulders and cobbles, through pebbles and shingles, coarse sands, sands, fine sands, muds, and mixed sediments (Davies et al., 2004). Each sediment type hosts characteristic biological communities, which together define biotopes. Within the sublittoral sediment habitat, one biotope was identified: circa-littoral sandy mud (A5.35) with aspects of deep sea mud. Benthic epifauna were scarcely observed in the photographs taken. Figure 6-16 provides representative photographs of the circa-littoral sandy mud biotope taken from five of the 2016 sample stations. Epifauna were sparse in the photographs taken, but evidence of habitation by tube building polychaetes (possibly Sabellidae and Terebellidae), burrowing shrimp, and foraminifera can be observed in all of the images of the seafloor. Mud shrimp burrows were evident in most photographs, and some photographs showed other taxa including tusk shells, gastropods, and hydroids.

[14] The European Nature Information System (EUNIS) is a habitat classification system developed by the European Environment Agency (EEA) in collaboration with international experts. The EUNIS includes all types of natural and artificial habitats, both aquatic and terrestrial.

Figure 6-16 Representative Photographs of the Circa-Littoral Sandy Mud Biotope Photographed in the Vicinity of the Liza-1 Well



Source: FUGRO EMU Limited, 2016

Photo A: Station NC21_BCE002; Mud, tube building polychaetes and amphipods, mud shrimp burrows, Scaphopoda (tusk shells), gastropods, foraminiferans
Photo B: Station NC21_BCE004; Sandy Mud, tube building polychaetes and amphipods, mud shrimp burrows, foraminiferans. Unidentified hydroid
Photo C: Station NC21_BCE005 Sandy Mud, tube building polychaetes and amphipods, foraminiferans, Scaphopoda
Photo D: Station NC21_BCE024 Sandy Mud, tube building polychaetes and amphipods, foraminiferans
Photo E: Station NC21_BCE025; Muddy Sand, Sabellids and other tube building polychaetes, mud shrimp burrows, foraminiferans

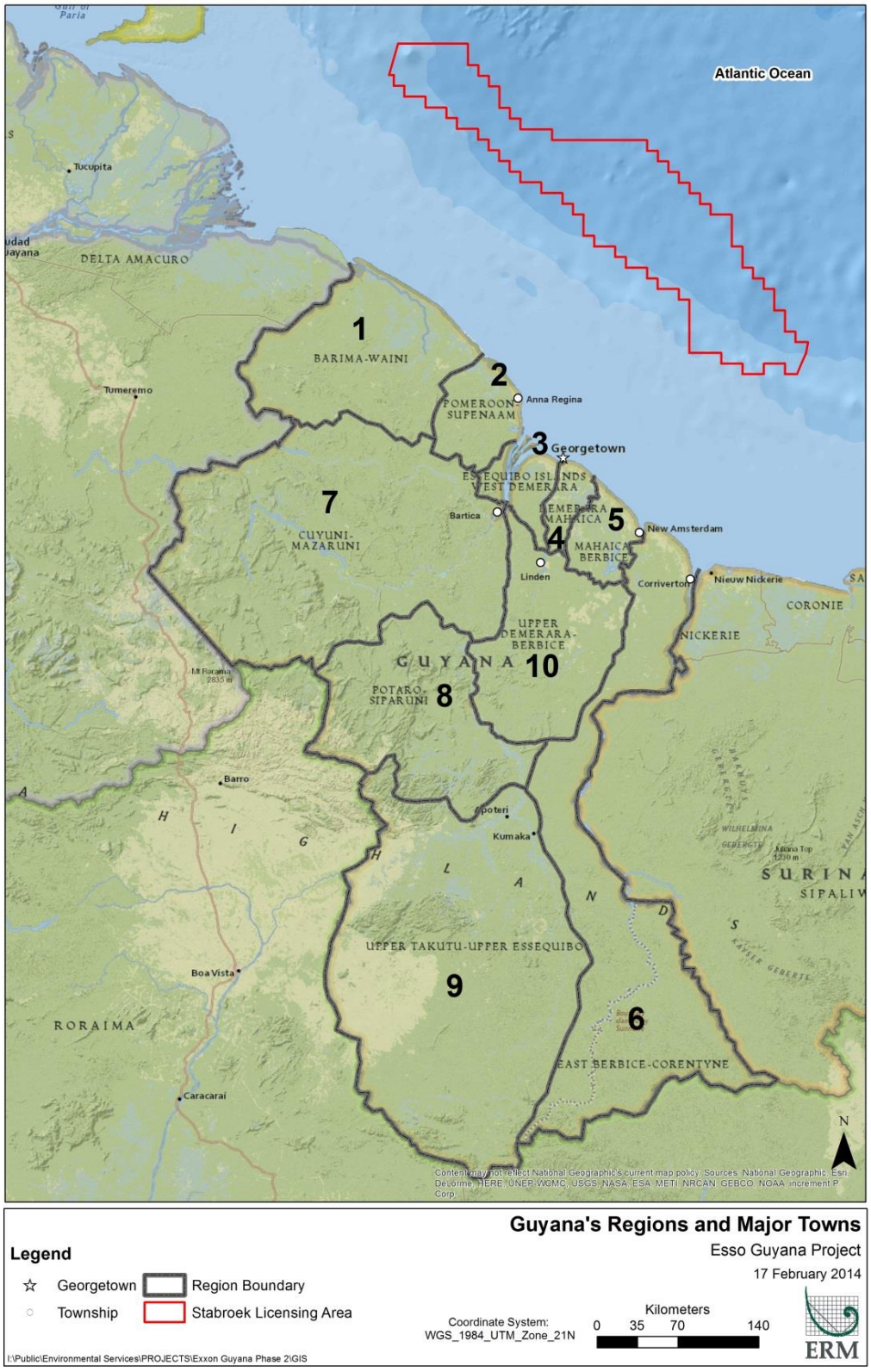
6.3 Socioeconomic Resources

This section describes the existing socioeconomic characteristics of the Project AOI. It was developed based on secondary information contained in Project-related materials; socio-economic reports and data obtained through government entities and other stakeholders; and other relevant data received from public sources. It is also based on information obtained directly from key informant interviews with members of national, regional, and local governments; civil societies and non-governmental organizations (NGOs); local community members; and other Project stakeholders. Specific stakeholder engagement information can be found in Section 4.5.

6.3.1 Administrative Divisions in Guyana

Guyana is divided administratively into 10 regions, pictured on Figure 6-17. These regions are further subdivided into Neighborhood Democratic Councils (NDCs), of which there are 65 in total. Within the NDCs are villages, the smallest administrative unit. In addition, there is one city that serves as the capital (Georgetown) and nine townships. Four of these townships were designated as new townships by the Ministry of Communities in 2015 as part of an administrative decentralization effort. Each of the nine townships has its own mayor and council, and is intended to serve as an administrative hub for government services, such as passports and driver's licenses, as well as providing utilities and public services, such as water and sanitation, as well as other services such as banking.

Figure 6-17 Guyana's Administrative Regions and Townships



6.3.2 Population Distribution

Most of Guyana's population is located in the six coastal regions, and, according to the 2012 national census, nearly half of the country's population lives in Region 4 (Demerara-Mahaica), which includes the capital city of Georgetown. Table 6-15 summarizes the distribution of population within the 10 regions in 2012, the last year for which complete census data are available.

Table 6-15 Regional Population Distribution in Guyana

Region		Population 2002	Population 2012	Population change since 2002	Percent of Guyana's Total Population
1	Barima-Waini	24,275	27,643	+13.9%	3.7%
2	Pomeroon – Supenaam	49,253	46,810	-5.0%	6.3%
3	Essequibo Islands - West Demerara	103,061	107,785	+4.6%	14.4%
4	Demerara-Mahaica	310,320	311,563	+0.4%	41.7%
5	Mahaica – Berbice	52,428	49,820	-5.0%	6.7%
6	East Berbice – Corentyne	123,695	109,652	-11.4%	14.7%
7	Cuyuni-Mazaruni	17,597	18,375	+4.4%	2.5%
8	Potaro – Siparuni	10,095	11,077	+9.7%	1.5%
9	Upper Takutu - Upper Essequibo	19,387	24,238	+25.0%	3.2%
10	Upper Demerara – Berbice	41,112	39,992	-2.7%	5.3%
	Guyana	748,084	746,955	-0.6%	100.0%

Source: Bureau of Statistics Guyana, 2012; Bureau of Statistics Guyana, 2002.

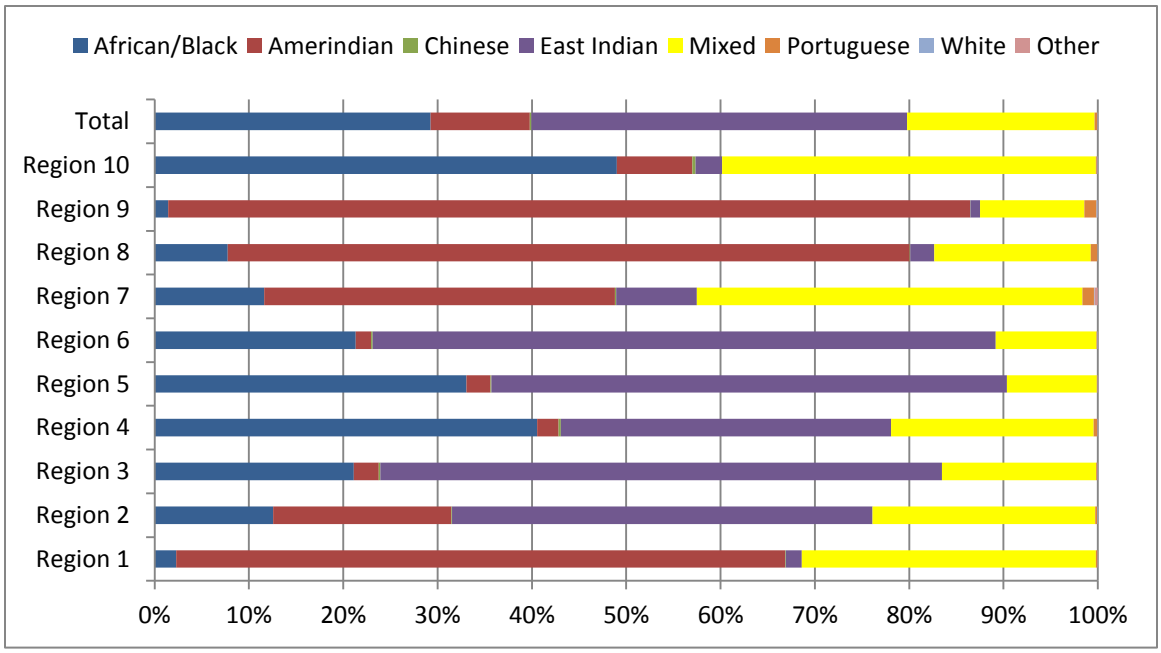
Note: Each region's change in population should be weighted based on that region's percent of the total population, so the sum of population changes in each region do not add up to the total national population change.

6.3.2.1 Ethnic Composition

Data from the 2012 census indicate that the majority of the country's population are representatives of two ethnic groups, those of East Indian descent (39.8 percent) and those of African descent (29.3 percent). These are followed by populations of mixed ethnicity (19.9 percent) and indigenous peoples who, in Guyana, are referred to as Amerindians (10.5 percent). Other ethnicities, including Chinese, White, and Portuguese, collectively make up less than one percent of the population.

Figure 6-18 shows the ethnic composition of each region and indicates notable differences between interior and coastal regions and between regions that are highly rural versus more urban. The more populated and urban Regions 3, 4, 5, and 6 are dominated by populations of East Indian and African descent, followed by populations of mixed ethnicity. Amerindian population numbers in these regions are low. However, the majority of population residing in the more remote and rural Regions 1, 8, and 9 is of Amerindian ethnicity.

Figure 6-18 Regional Distribution of Ethnicity, 2012



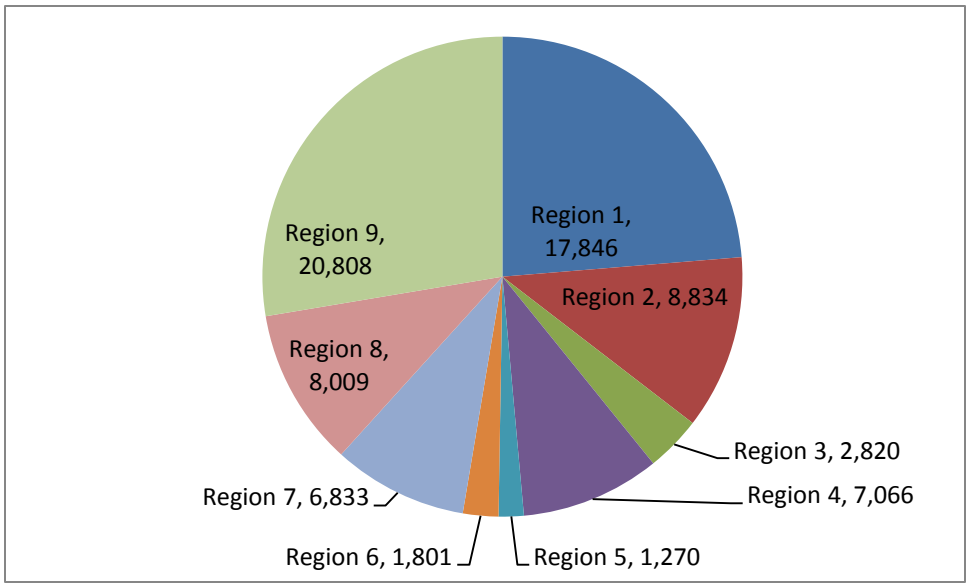
Source: Bureau of Statistics Guyana, 2012

6.3.2.2 *Indigenous Peoples*

Amerindians in Guyana numbered 78,492 as of the 2012 census, and their population is on the rise, with growth of 12.8 percent seen in the period 2002-2012.

According to Minority Rights Group International (2008), there are nine main Amerindian groups in Guyana, of which three are coastal: the Carib, Warao, and Arawak tribes. Other groups tend to inhabit the country's hinterland regions. Many of the Amerindians in Guyana, particularly in the coastal area, have undergone cultural integration with the general population and share much of the same culture as the Afro- and Indo-Guyanese population. However, as a whole, the standard of living for the Amerindian population in Guyana is lower than for the general population, particularly for those in remote areas where provision of infrastructure and services is a challenge. The distribution of Amerindian population among the regions is shown on Figure 6-19.

Figure 6-19 Amerindian Population by Region, 2012



Source: Bureau of Statistics Guyana, 2012

The coastal plain of Region 1 and part of Region 2 are not accessible by road and therefore Amerindian communities in these areas are remote and are generally underserved by public infrastructure and services. These populations make use of a range of coastal resources for subsistence and livelihoods. Communities that are directly adjacent to the coast are the titled community of Three Brothers along the Waini River, directly inland from Shell Beach, and the non-titled communities within the SBPA (Almond Beach, Father's Beach and Unity Grant). Titled indigenous communities located 5-10 km inland from the coast in Regions 1 and 2 are Santa Rosa, Waramuri, Manawurin, Assakata and Wakapau. In the SBPA, fishing and crabbing activity is particularly active at the westernmost end of Shell Beach, at the mouth of the Waini River. At the eastern end of Shell Beach in the community of Father's Beach, there are coconut plantations used for manufacturing oil, and just northwest of this is a forested area where hunting, trapping, fishing, crabbing, crabwood seed harvesting, and lumbering occurs (Protected Areas Commission, 2015).

In Regions 3 and 4, titled indigenous communities are located inland and not within the coastal plain.

6.3.3 Education

The education system in Guyana is similar to that of other Caribbean countries, with school being compulsory from ages of 5 to 16 through pre-primary, primary, and secondary schools. The federal Ministry of Education controls education budgets, policies, and standards and administers these by region. In 2012, the government spent 3.2 percent of GDP on the education sector (CIA World Factbook, 2016). Between the years of 2008 and 2012, the youth (15-24 years) literacy rate was 93.7 percent and 92.4 percent for females and males, respectively. Pre-primary and primary school gross enrollment averaged from 83.7 percent to 88.7 percent depending

upon grade and gender, with male youth averaging a few percentage points lower than female youth. Secondary school net enrollment was 80.6 percent and 71.2 percent for female and male youth, respectively (UNICEF, 2016).

At the time of writing, the 2012 census compendium on social indicators had yet to be released. Therefore, the only reliable data on educational attainment at the regional level are from the 2002 census compendium, which shows that Region 1 had the highest percentages of male youth (10.9 percent) and female youth (15.3 percent) with either no schooling or Kindergarten level only, with Regions 8 and 9 only a few percentage points higher. In Regions 2 and 3, the percentage of all youth with either no schooling or Kindergarten level only ranged between 2 percent and 4 percent. Region 4 and Region 10 had the highest level of enrollment across all levels (Guyana Bureau of Statistics, 2002).

The levels of primary education for the indigenous population are typically lower than non-indigenous groups of the population. In the Amerindian communities, the attendance rate at primary schools has been reported to be 50 percent lower than average. This is partly attributable to a shortage of teachers, and standardized teaching methods and curriculum which limits appreciation for indigenous culture and values. While access to education in Amerindian communities continues to be limited, the stated government policy is to provide indigenous children with the same educational opportunities available to the rest of the population (Minority Rights International, 2008).

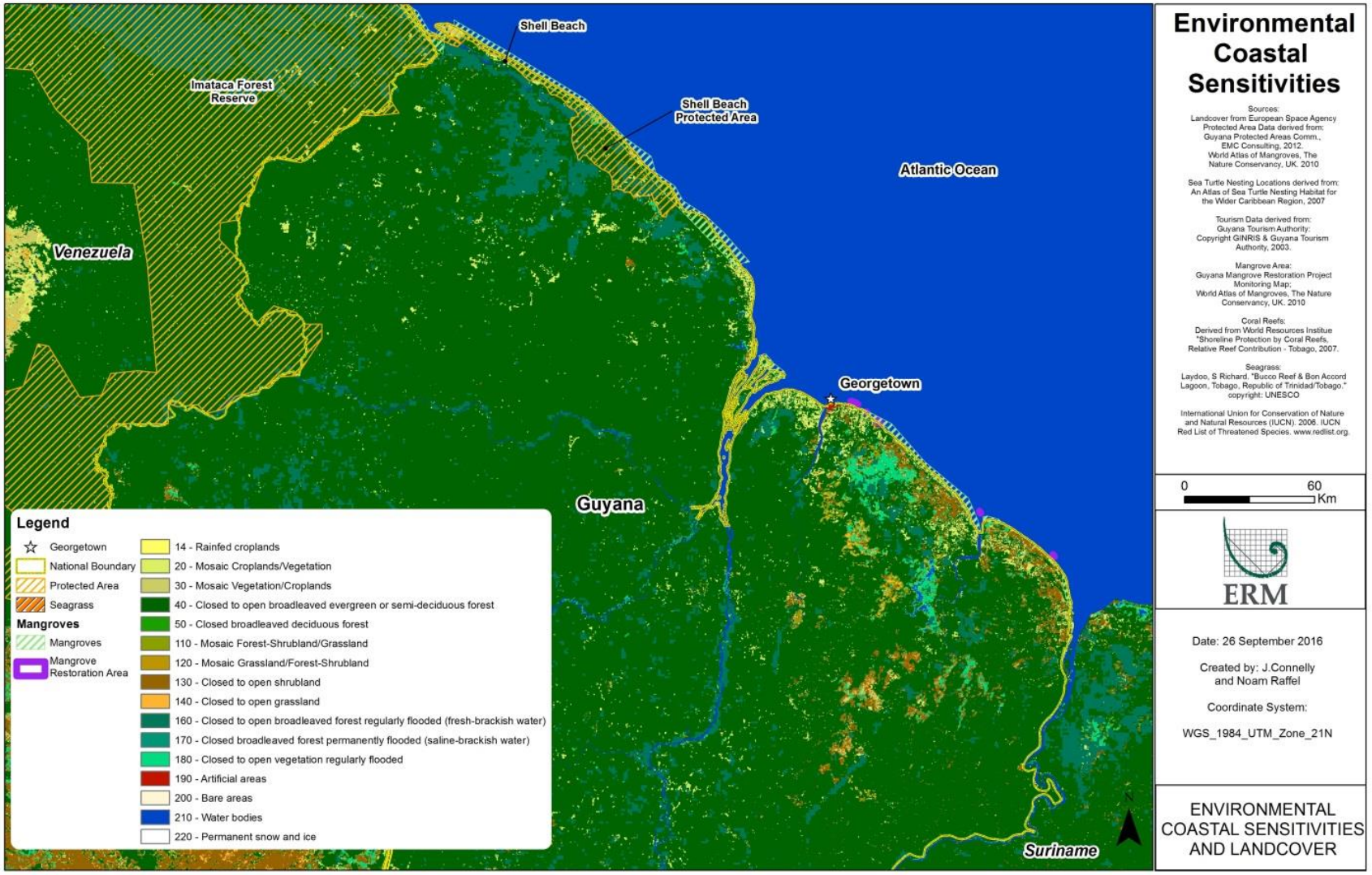
6.3.4 Land Use

Guyana is divided into the following three main geographic zones:

- The low-lying coastal plain occupying about 5 percent of the country's land area, which ranges from approximately 5 km to 6.5 km (~3 to 4 mi) wide along the coast;
- The "white sand belt", a largely vegetated zone dominated by white sandy soils lying inland from the coastal zone, ranging from approximately 150 km to 250 km (~93 mi to 155 mi) wide and containing most of the country's mineral deposits; and
- The interior highlands that extend from the white sand belt to the country's southern borders and makes up the largest land area in the country.

As described above, Guyana is a sparsely populated country, with the majority of the population concentrated in the coastal plain region. In 2012, the cultivated area in Guyana was estimated at 1,107,000 acres. Cultivated land is also concentrated in the coastal plain, where the majority of the population resides (FAO, 2015). Figure 6-20 shows land cover in the coastal and white sand belt areas. In the coastal plain areas, cultivated areas are evident in Regions 2, 3, and 4 (southeast of SBPA) and occur to a lesser extent in Region 1 (including SBPA). The landscape in these areas is dominated by sugar, rice, and coconut plantations, interspersed with smaller scale establishments of non-traditional crops and livestock.

Figure 6-20 Land Cover in Coastal Guyana



Source: ERM, 2014 and CCI, 2012

The SBPA is a notable feature in the coastal area. It was designated a Protected Area with the passage of the Protected Areas Act of 2011, and is the only Protected Area on Guyana's coast. More information on the SBPA is provided in Section 6.2.2.

6.3.4.1 Land Ownership

The pattern of land ownership in Guyana today is approximately 85% government-owned, approximately 14 percent Amerindian-owned, and one to two percent privately owned. There are two land markets: one consisting of freehold properties and one consisting of the lease of state-owned land. Amerindian lands are owned collectively and are not subject to transfer or sale. Approximately half of the farms in the coastal area are freehold properties and these tend to be small properties of 5-15 acres each (Government of Guyana, 1997). Leases of government-owned lands are issued by the Guyana Lands and Surveys Commission (GLSC).

According to a study of the land registration system in Guyana conducted by the Inter-American Development Bank (IDB), the country's dual property registration system (title registration and deed registration) has regulations that overlap and conflict, and is considered complex and bureaucratic. The systems are also considered ineffective in managing and enforcing rights. As a result, a large number of land owners do not register their properties or do not keep their ownership rights up to date (IDB, 2010).

6.3.5 Economy

Guyana's nominal GDP in 2015 was $653.8 billion GYD, or approximately $3.2 billion U.S. dollars (USD). The per capita GDP in 2015 was $761,000 GYD, or approximately $3,700 USD (BSG, 2016), and it was reclassified by the World Bank from a lower middle income to an upper middle income country in 2016 (World Bank, 2016). Guyana's main sectors by contribution to GDP are summarized in Table 6-16.

Table 6-16 Economic Sectors and Contribution to GDP, 2015

Sector	Percent of GDP
Agriculture, Fishing and Forestry	19.2%
Wholesale and Retail Trade	12.3%
Transportation and Storage	11.2%
Mining and Quarrying	10.9%
Construction	9.8%
Manufacturing	7.4%
Public Administration	7.2%
Information and Communication	7.0%
Financial and Insurance Activities	5.0%
Education	4.5%
Other Services	3.9%
Health and Social Services	2.0%
Real Estate	1.2%

Source: PSC, 2015

Note: Percentages add to more than 100 due to rounding.

Guyana relies heavily on trade, with exports totaling $238.3 billion GYD ($1.15 billion USD) in 2015, up from $183.3 billion GYD ($884.9 million USD) in 2010 (Guyana Bureau of Statistics, 2015). The main export products for the country are sugar, rice, bauxite, gold, forest products, and fish (FAO, 2015). Sectors that are uniquely tied to the coastal environment in Guyana, as well as the mining sector, are described in further detail below.

6.3.5.1 Agriculture

According to the Private Sector Commission, Guyana has a relatively strong agricultural sector and is the only net exporter of food in the Caribbean. In 2015, agriculture, fishing and forestry accounted for 19.2 percent of the country's GDP, or $73.9 billion GYD (approximately $356.7 million USD).

Rice

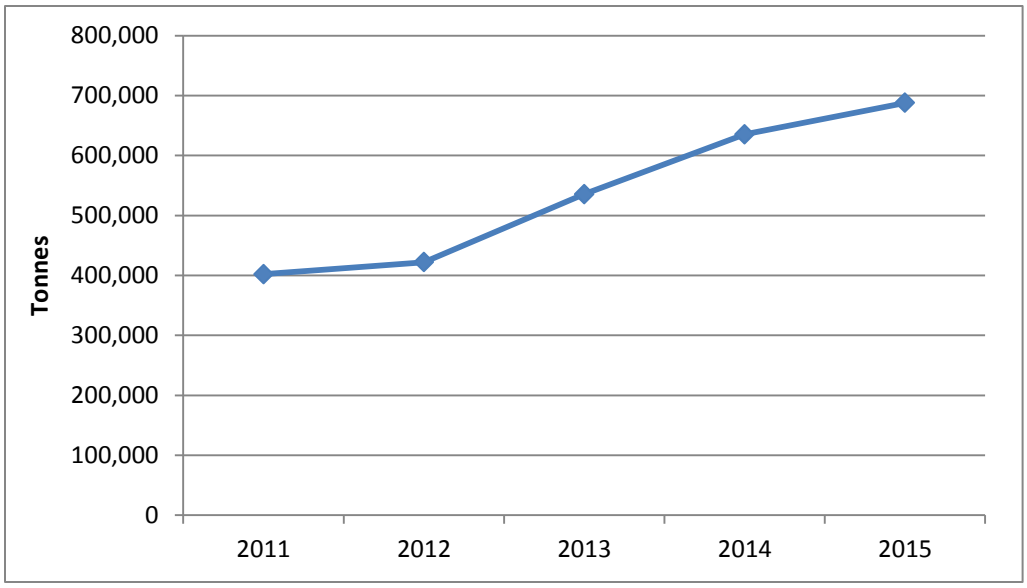
Rice farming is the predominant agricultural activity in the coastal areas of Regions 2 and 3, accounting for an estimated 85 percent of the overall economy in Region 2, and 55 to 60 percent of the economy in Region 3 (ERM Personal Communication 1). Rice fields dominate the landscape in many coastal areas in these regions (Figure 6-21).

Figure 6-21 Rice Field in Region 2 Pomeroon-Supenaam



The rice sector yield grew by 8.3 percent in 2015 (see Figure 6-22). However, the first half of 2016 has seen a decline in yields attributed to El Niño-related dry weather, as well as an early arrival of the rainy season (Ministry of Finance, 2016).

Figure 6-22 Annual Rice Production, 2011-2015



Source: Private Sector Commission 2015

According to the president of the Guyana Rice Producers' Association, industrial rice production requires the ability to precisely control water levels in the rice fields. The rice growers in coastal Guyana achieve this by operating two separate systems of canals, one dedicated to irrigation and another dedicated to drainage. The irrigation canals convey fresh water from water conservancies via gravity to the rice fields. The rice fields are contained within a dike system that has separate gates for irrigation and drainage systems. The fields drain to a separate network of canals that were constructed to provide general drainage to the surrounding coastal landscape (ERM Personal Communication 1). These canals drain to the Atlantic Ocean via manually-operated mechanical sluice gates (locally called *kokers*; see Figure 6-23). The drainage canals are generally constructed at or very near sea level to achieve the gradient necessary for drainage of the surrounding landscape and can therefore be tidally influenced, but the kokers control inflow from the sea. This system ensures that the rice fields remain upgradient of tidally influenced water in the drainage canals and prevents salt water from intruding into the fields (ERM Personal Communication 1).

Figure 6-23 Sluice Gate (Koker) in Charity (Region 2) at High Tide



Note: Seawater seeping into drainage canal from ocean through closed gate.

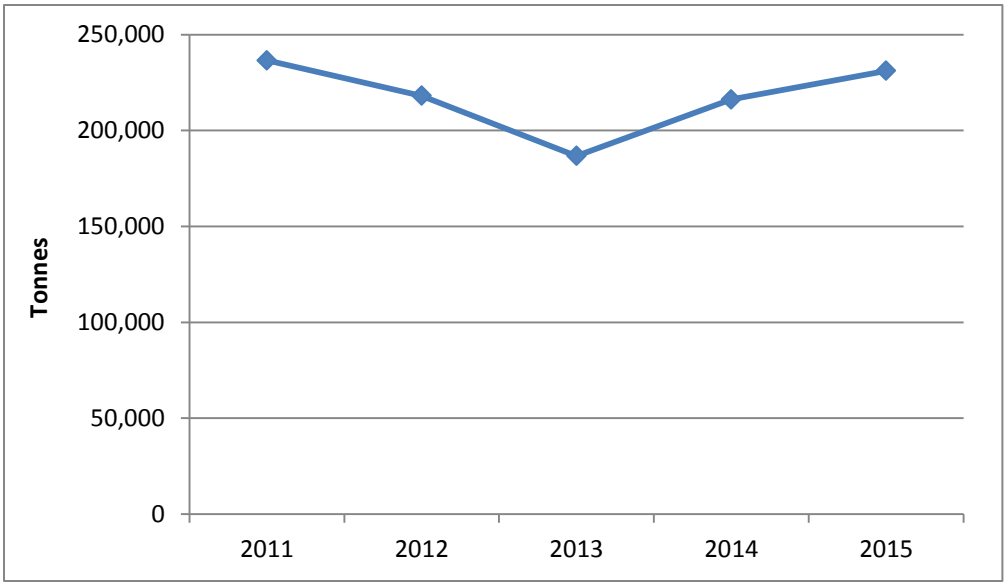
Sugar

Figure 6-24 shows an aerial view of sugar plantations in Region 2. Sugar production increased in 2014 and 2015 after being in decline in previous years (Figure 6-25). According to Guyana Sugar Corporation (GuySuCo), the national sugar company, sugar production employs 18,000 people in Guyana and accounts for 40 percent of the country's agricultural production. GuySuCo's Demerara sugar is exported to markets in the European Union, the U.S., and CARICOM countries.

Figure 6-24 Aerial View of Sugar Plantations in Region 2



Figure 6-25 Annual Sugar Production, 2011-2015

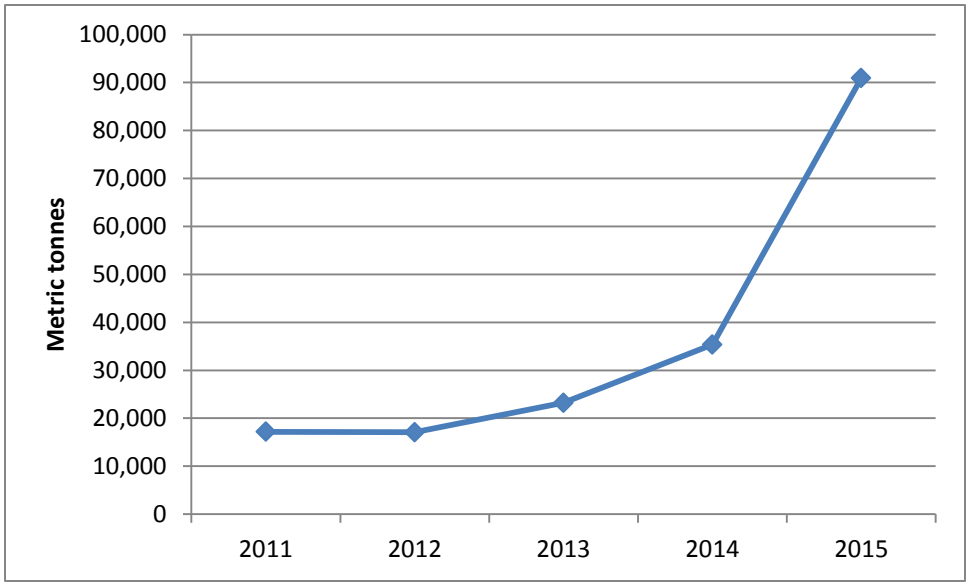


Source: Private Sector Commission 2015

Coconut

The coconut industry in Guyana has grown in recent years (Figure 6-26) and shows potential for continued growth due to high international demand for products such as coconut oil and coconut water. It ranks third after rice and sugar in terms of acreage cultivated and is grown primarily in the coastal regions, including along the Pomeroon River and the Essequibo Coast in Region 2. According to recent news media articles, the amount of land in the Pomeroon area being converted to coconut cultivation is increasing (Guyana Chronicle, 2016; Stabroek News, 2016).

Figure 6-26 Annual Coconut Production, 2011-2015



Source: Ministry of Agriculture, 2016a

Other Cash Crops

Non-traditional crops (crops other than sugar cane and rice) grown in Guyana include: tubers such as cassava, sweet potato, and eddo; vegetables such as eggplant, pumpkin, and okra; spices such as hot peppers, sweet peppers, and ginger; and fruits including banana, papaya, mango, and pineapple. Data from the Ministry of Agriculture (2016a) show that production for most tuber and vegetable crops has increased in recent years, while yields for fruits have been more variable, with some fruit crops showing declines from 2014 to 2015.

Value-added Agricultural Products

According to various interviewed stakeholders, establishment of manufacturing operations to develop value-added products such as pepper sauce, beverages, and canned fruit are priorities at both community and strategic policy levels (ERM Personal Communications 5, 10, 14, and 15). A number of agricultural co-ops in Regions 2 and 3 have achieved varying levels of success in producing and marketing such products. National-level agencies such as the Ministry of

Agriculture and the Private Sector Commission emphasize the importance of developing markets for such products to provide better stability and security to farmers. However, there are a number of challenges associated with this, including high energy costs, difficulty locating or establishing markets for products, and obtaining financing for start-up costs.

6.3.5.2 Fisheries and Aquaculture

Marine Fisheries

There are four main types of marine fisheries in Guyana (MOA, 2013) that can be defined by the species targeted, gear types used, and the depth of water where the fishery takes place. Table 6-17 summarizes the characteristics of these fisheries.

Table 6-17 Primary Characteristics of Marine Fisheries in Guyana

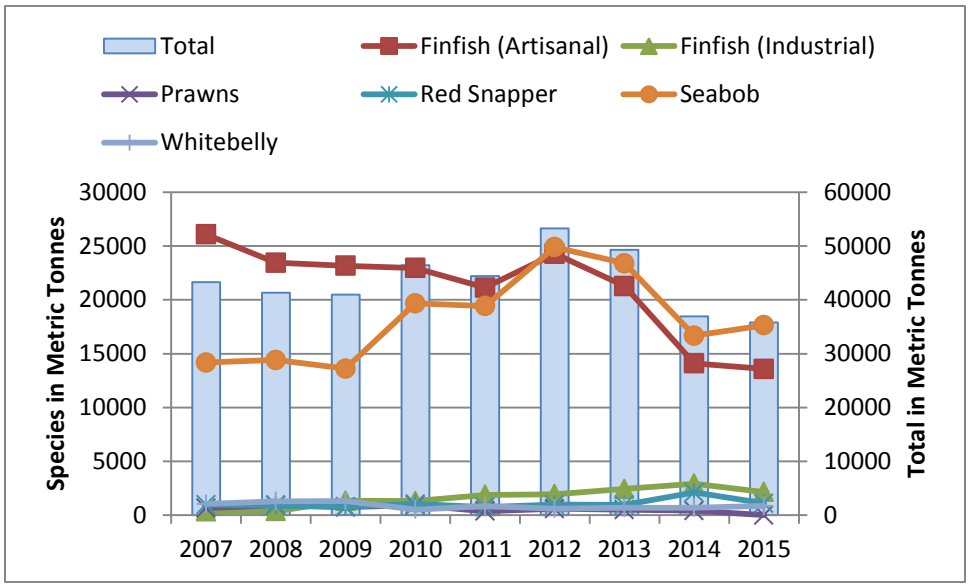
Type of Fishery	**Species**	**Gear**	**Depth**
Industrial	Seabob, shrimps, and prawns	Trawls	Primarily between 13-16 m, but can occur from 0-75 m
Semi-industrial	Red snapper and vermillion snapper	Fish traps and lines	Edge of continental shelf
Artisanal	Mixed fish and shrimp	Gillnets, seines, and others	0–18 m
Shark	Various	Trawls, gillnets, and hook and line	Throughout the continental shelf waters

Note: "Whitebelly" identified in Figure 6-27 is a species of shrimp and is included in the artisanal shrimp fishery.

According to data from the Private Sector Commission (PSC) and the Ministry of Agriculture, fishery yields declined between 2014 and 2015. The PSC attributes this to El Niño-related weather phenomena, while the Ministry of Finance characterizes this as part of a longer-term decline caused by unsustainable overfishing, including illegal fishing by foreign vessels (Ministry of Finance, 2015). Fishing interests and the Fisheries Department personnel also acknowledged the prevalence of illegal fishing by both foreign and domestic vessels, but did not specifically implicate illegal fishing in the recent declines (ERM Personal Communications 2, 14, 15, and 16).

Fishing catches for 2007 to 2015 are shown on Figure 6-27. The data indicate a declining trend for fish and seabob shrimp catches in recent years, although the recent decline follows an increasing trend for 2010 through 2014. The prawn industry has been voluntarily scaled back in response to limited catches resulting from overfishing in previous years, with approximately 15 Guyanese-registered boats in operation in 2016. Prawn fishing boats operate from the coast out to about 40 fathoms (ERM Personal Communication 2).

Figure 6-27 Commercial Fisheries Catch Volumes, 2007-2015



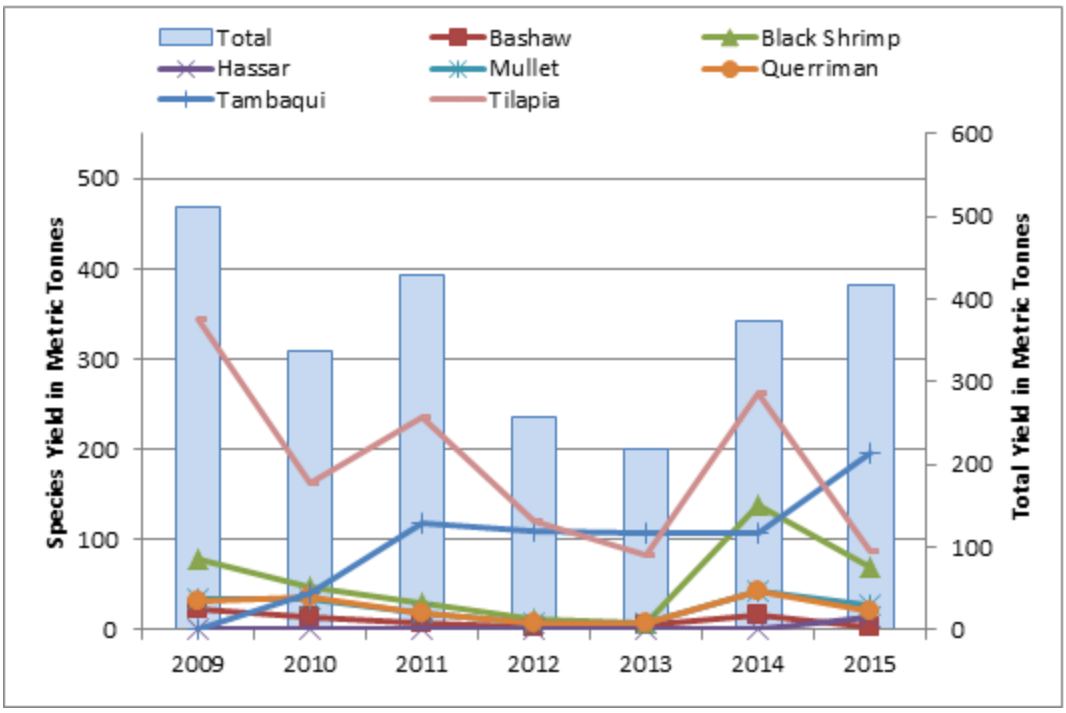
Source: Ministry of Agriculture, 2016a

The industrial seabob shrimp sector continues to be an important commercial fishery for Guyana, and industry leaders are currently in the process of applying for Marine Sustainability Council (MSC) certification (an internationally recognized voluntary process used to assess and certify the sustainability of wild capture marine and freshwater species). The seabob fleet currently operates under a voluntary management plan (the only fishery-specific management plan for fisheries operating in Guyana's territorial waters) that calls for a seven-week-long closed season each year. Seabob sector representatives expect the management plan to be adopted by the government and made compulsory in the near future (ERM Personal Communication 2).

Aquaculture

According to data from the Ministry of Agriculture, the main species produced in aquaculture establishments are the fish bashaw, hassar, mullet, querriman, tambaqui, tilapia, and black shrimp. Data show that tilapia once dominated aquacultural yields, but have declined in production, while yields of tambaqui and black shrimp have increased considerably in recent years. The total yield of aquaculture product has been variable in the period from 2009-2015 for which data are available (Figure 6-28).

Figure 6-28 Fish Yields from Aquaculture, 2009-2015



Source: Ministry of Agriculture, 2016a

According to the president of the National Aquaculture Association, aquaculture is still a small industry in Guyana. Establishments are typically set up in abandoned rice fields. By using the same water supply and drainage configuration used for rice production, the aquaculture operations avoid dependency on brackish water and can raise freshwater species despite their coastal locations. Freshwater species currently being raised in rehabilitated rice fields include hassa, arapaima, tilapia, and tobaki (pacu) (ERM Personal Communication 18).

6.3.5.3 *Mining and Quarrying*

The mining sector is an important sector for Guyana and contributed to over half of exports in 2015 (Guyana Bureau of Statistics, 2015). Most notably, raw gold, bauxite and diamonds equated to 43.5 percent, 9.1 percent, and 1.5 percent, respectively, of export totals in 2015. The Guyana Geology and Mines Commission estimated that in 2010, mining and quarrying accounted for 9 percent of GDP, and employed over 11,000 persons directly and almost 14,000 indirectly (GGMC, 2010). Due in large part to the mining sector, Guyana's economy in recent years has reflected the path of global commodity prices. Real GDP growth decelerated to 3.8 percent in 2014 and to 3.0 percent in 2015, as global commodity prices collapsed for Guyana's major mining exports (World Bank, 2016).

6.3.5.4 Manufacturing

Manufacturing contributed 7.4 percent of GDP in 2015 and grew by 5.3 percent from 2014 to 2015. The most important products in terms of volume include laundry soap, detergent, paints, putty, whitewash, oxygen, and acetylene, as well as edible goods including rice, sugar, and rum (PSC, 2015). Many of the country's manufacturing facilities are located in coastal areas (UNDP, 2005).

6.3.5.5 Tourism

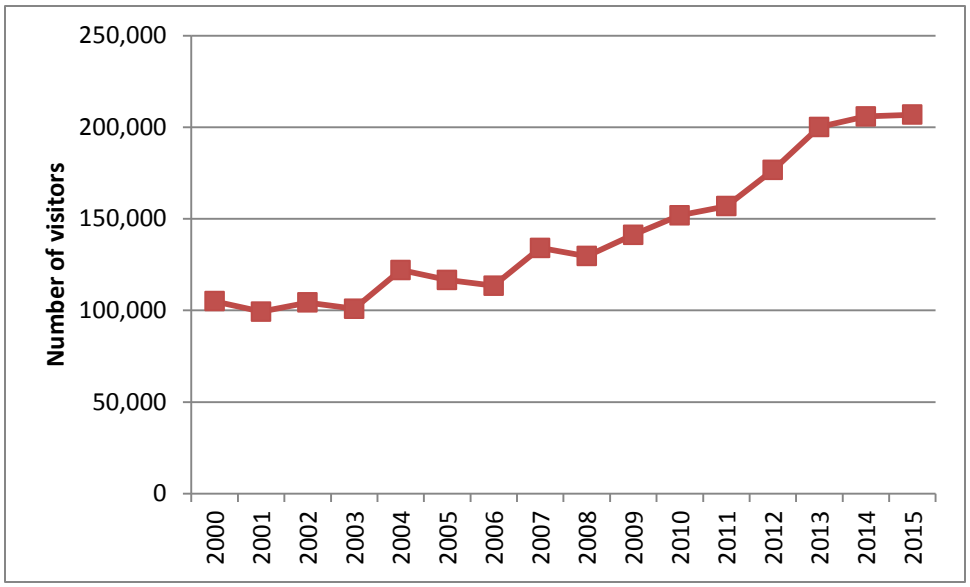
According to the World Travel and Tourism Council, tourism contributed 3.3 percent to the country's GDP in 2015. Although most tourism infrastructure (e.g., hotels) is located in the most populated townships such as Georgetown, Linden, and Berbice, many of Guyana's tourist attractions are located in the country's hinterland. These attractions offer nature, culture, and adventure-based experiences such as trips to waterfalls and Amerindian villages, which range from same-day to multiple night excursions.

Guyana is not a popular destination for cruise ships and receives only a few small ships each year. The country does not have the berthing capacity for large cruise ships (ERM Personal Communication 3).

Deposition of sediment from the mouth of the Amazon River along Guyana's coast means that there are few beach offerings for tourists. The highly turbid water along the coast also likely contributes to the relatively small numbers of tourists that visit Guyana relative to other locations with clearer water in the region. Some tourism occurs at the SBPA during the sea turtle nesting season, but because infrastructure and systems have not yet been established to facilitate travel or provide convenient accommodations, this number is limited. In general, however, Guyana is thought to have considerable ecotourism potential, and development of tourism infrastructure at the country's Protected Areas is considered a key part of the Protected Areas Commission's current strategic plan (PAC, 2016).

Data from the Department of Tourism indicate that the number of international visitors to Guyana has doubled since the early 2000s (see Figure 6-29), with the largest number of visitors originating from the United States, followed by the Caribbean, Canada, and Central and South America. Because the majority of visitors consist of Guyanese expatriates returning to visit family, visitor numbers peak during the summer vacation (July and August) and key holidays (e.g., Christmas in December). According to representatives of the Department of Tourism, increases in tourism in recent years are also attributable to increased hosting of regional sporting tournaments, particularly cricket events, in the Georgetown area. This has brought many international visitors, particularly those from the Caribbean. During major events such as the Cricket World Cup, traffic congestion beyond the norm was observed in the Georgetown area (ERM Personal Communication 3).

Figure 6-29 Annual International Visitors to Guyana, 2000-2015



Source: Department of Tourism, 2016

Most of the major tourist attractions in Guyana, such as museums, the zoo, parks, public gardens, and the Stabroek Market, are located in Georgetown. Georgetown and surrounding areas are known for their many historic buildings, which date from the late eighteenth century through the mid-nineteenth century, when Guyana was first a Dutch colony and then an English colony (National Trust of Guyana, 2009). Guided tours of Georgetown's historic buildings and sites are available, as are guided tours of attractions such as the Essequibo River, the El Dorado Rum Factory, and the Georgetown City Centre.

6.3.6 Employment and Livelihoods

Results of the most recent national census indicate that 87.5 percent of the labor force was employed and 12.5 percent was unemployed at this time (2012). Data from the previous census in 2002 indicate that the unemployment rate did not change in this 10-year period (BSG 2012; BSG 2002).

In 2012, the unemployment rate in Region 1 was the highest in the country at 19.3 percent of the labor force. Region 2 had the lowest rate of unemployment in the country at this time, at 10.6 percent. Regions 3 and 4 had rates of 11.8 percent and 11.3 percent, respectively.

Statistics from the 2012 census indicate that 23.0 percent of the employed population 15 years of age and over in Region 1, 27.9 percent in Region 2, and 18.8 percent in Region 3 had occupations in the Agriculture, Forestry, and Fishing industry group in 2012 (BSG, 2016). This was the industry group employing the largest number of workers in Regions 2 and 3, while, in Region 1, this group was second to Mining and Quarrying. After the Agriculture, Forestry and Fishing category, Mining and Quarrying employed the second largest group of people in Region 2 (14.9 percent), while in Region 3, Construction employed the second largest number of workers (12.1 percent). It should be noted that the Agriculture, Forestry, and Fishing industry group, and the

primary sector[15] in general, is dominated by male workers, with female workers making up less than ten percent of the workers employed in this industry group in these regions.

Census data show that tertiary (service) sector jobs such as wholesale and retail trade, public administration, and accommodation and food services are dominant in Region 4 (including Georgetown), making up 67.0 percent of jobs there . Female representation in this sector is high, with women making up 48.2 percent of workers in the sector (BSG, 2016). Secondary and primary sector jobs make up 21.0 percent and 12.0 percent of employment in Region 4.

The issues facing indigenous groups of Guyana are typically related to lack of empowerment and inclusion into the mainstream economy. The standard of living for the indigenous minority of Guyana continues to be lower than that of the majority of the country's citizens. A larger proportion of the Amerindian population is classified as socioeconomically disadvantaged (Minority Rights Group International, 2008), with the lack of formal employment opportunities as a significant contributing factor. Income generation opportunities in the indigenous coastal communities of Regions 1 and 2 are scarce and include heart of palm harvesting and the wildlife trade, including sale of aquarium fish (IDB, 2007). In the past, the Region 2 village of Mainstay operated an organic pineapple farm and processing facility; however, the plant was shut down several years ago (ERM Personal Communication 4). Some residents of Region 1 and 2 indigenous communities also work in mining and logging camps in the hinterland (IDB, 2007).

6.3.6.1 Fishing

Fishing along the Guyanese coast varies in scale and type. At the easternmost end of Region 2, fishing occurs at a relatively small scale, and catch is typically sold locally at roadside stands or out of vehicles (See Figure 6-30). Boats venture only a few kilometers out from the coastline, and fisherfolk typically only go out for the day. Species caught include catfish, bangamary, and bashaw (ERM Personal Communication 19). Farther west in Region 2 at Lima, larger scale fishing is practiced about 8 km (~5 mi) offshore. Small artisanal boats are still used because the coastal mudflats in this area do not allow for the use of larger boats. Fisherfolk go out for 10-12 days at a time and fish for snapper, snook, trout, wrasse, patwa, catfish, bangamary, and butterfish. Some fish are sold locally, while others are sold wholesale for resale in Georgetown (ERM Personal Communications 16, 20, and 21) (see Figure 6-31). There are no landing areas for commercial fishing vessels in Region 1; small scale fishing activity occurs along the Region 1 coast and is primarily for subsistence. Fishing yields vary by season, with interviewed fisherfolk reporting the highest yields in June through August. From September to January, catches are at their lowest due to high winds.

[15] According to the BSG, the primary sector industries (e.g., agriculture, fishing, forestry, and mining) make direct use of natural resources and include the production of raw materials and basic foods. The secondary sector is engaged in manufacturing using raw products from the primary sector and includes processing, construction, textile production, brewing and bottling, etc. The tertiary sector provides services to the general population and businesses, including retail and wholesale trade, transportation and distribution, entertainment, tourism, healthcare, etc.

Figure 6-30 Salted Fish Drying Outside a Fisherperson's Home in Region 2



Source: ERM, 2016

Figure 6-31 Fresh Fish Being Sold at Stabroek Market in Georgetown



Source: ERM, 2016

Challenges for the Fishing Industry

When asked about changes in fishing yields over the years, responses from artisanal Region 2 fisherfolk varied, with most reporting no noticeable change in catch volume. However, a fisherman with a relatively large-scale operation of three boats operating out of Charity stated that catches are declining and attributed this to an over-allocation of fishing licenses by the government (ERM Personal Communication 17). As indicated in Section 6.3.3, annual yields in the fishery sector have declined in the last four years for fish, and three of the last four years for seabob, although seabob yields recovered slightly between 2014 and 2015. Although there are no data available to quantify the impact of Illegal, Unreported, and Unregulated (IUU)[16] fishing in Guyana, its role in threatening sustainability of the country's fishery is considered to be significant (Ministry of Finance, 2015; Ministry of Agriculture, 2016b).

Another challenge faced by fisherfolk is piracy. Most of the fisherfolk interviewed by ERM in Region 2 have been victimized by pirates at some time. This typically consists of the theft of boats and/or engines, and fisherfolk are sometimes assaulted in these confrontations. Most respondents perceived that piracy had gone down in the last 5 or 10 years. Some implicated the recent establishment of a Coast Guard Station at the mouth of the Pomeroon River as having influenced the decrease in piracy. Of those who have encountered pirates, they were typically unsure of their assailants' nationality, but speculated that they could be Venezuelan, Guyanese, Surinamese, or a mixed group from different countries.

The dynamic accretion and erosion of the Guyanese coastline as a result of natural forces can also pose challenges for fisherfolk. During the August/September 2016 field visit, ERM personnel observed considerable mudflat and beach accretion at most coastal access points along the Region 2 coast, which prevents fisherfolk from landing their boats in some areas (Figure 6-32).

[16] IUU fishing takes place where vessels operate in violation of the laws of a fishery. This can apply to fisheries that are under the jurisdiction of a coastal state or to high seas fisheries regulated by regional organizations.

Figure 6-32 Fishing Boat Landed on a Coastal Mudflat in Region 2, September 2016



Source: ERM, 2016

6.3.6.2 Farming and Agricultural Processing

As discussed above, agriculture is a major livelihood activity in Region 2. Rice farming dominates agricultural production in Region 2, but other crops, such as red beans, plantains, bananas, eggplants, and other vegetables, are grown on a smaller scale in Region 2 as well. Most households also raise livestock, such as cattle, hogs, poultry, and small ruminants. The Amerindian community of Mainstay, located approximately 6 km (~3.5 mi) from the coast in Region 2, is known for its organic pineapples, which for a number of years were processed into canned chunks for export to European markets (ERM Personal Communication 4). As discussed above, coconut cultivation is becoming increasingly popular in the Pomeroon area as demand for coconut water and other value-added coconut products continues to grow. A number of farms produce coconut water for export to Trinidad and Tobago, while others produce coconut oil. A group established in 2001, the Pomeroon Women's Agro-Processors Association, also produces a number of value-added products, including virgin coconut oil, pepper sauce, cooking sauce, wine, and carambola cake mix (ERM Personal Communication 5).

In the Amerindian communities of Region 1, agricultural activities occur on a small scale and include cultivation of tubers, corn, cucumber, eggplant, ginger, peppers, plantains, bananas, watermelon, beans, okra, pumpkin, and coconut. At least one community engages in cassava processing, including cassava bread, starch, and cassareep (Protected Areas Commission, 2014).

Challenges for Farmers and Agricultural Processors

Climate change is perceived as a challenge for some agricultural producers. For example, changes in sunshine and rain patterns are thought to have contributed to decreased pineapple yields in recent years (ERM Personal Communication 4). Sea level rise potentially associated with climate change is also considered a threat for coastal farmers, given that the coastal plains, where the majority of the country's agricultural activity occurs, lies below sea level (ECLAC, 2011). Outside of flood events, saltwater sometimes enters into the irrigation canals through sluice gates at high tide or up the Pomeroon River during the dry season. This can adversely impact some crops, such as most vegetables, but may be beneficial to others, such as fruit trees (ERM Personal Communication 5). As noted above, however, the irrigation canal system for rice fields and fish farms are separated from the drainage system and draw from the water conservancies.

6.3.6.3 Speedboat Operation

Guyana's unique geography means that boating is an important mode of transport for travel between the coastal regions. Other than air travel, the most rapid and direct means of accessing Region 2 from the east coast of the Essequibo River is by speedboat, though a ferry service is also available. Speedboat operators servicing the route between Parika in Region 3 and Supenaam in Region 2 belong to the Supenaam-Parika Speedboat Owners' Association, which currently numbers 91 boats (See Figure 6-33). According to a member of the association, the majority of customers for this route are business owners, such as shopkeepers who travel to Georgetown for supplies (ERM Personal Communication 6). Speedboats are also used for transportation to communities upriver in the Essequibo and Pomeroon Rivers, and to areas of Regions 1 and 2 that are not accessible by road (i.e., areas west of Charity). More information on speedboat use in the coastal areas is provided in Section 6.3.8

Figure 6-33 Speedboats Docked in Parika, Region 3



Source: ERM, 2016

Challenges for Speedboat Operators

Although natural forces (e.g., wind, waves, sea currents, and sediments transported from the mouth of the Amazon River) create a dynamic and ever-changing coastline, speedboats are typically able to maneuver through mud and sandbanks where ferries would be unable to traverse (ERM Personal Communication 6). As a result, there are no notable seasonal factors that impact business or safety for speedboat operators. However, some stakeholders noted that along the Pomeroon River where there are many coconut plantations and processing plants, the practice of discarding coconut shells in the river poses a danger to speedboat operators and passengers (ERM Personal Communication 5 and ERM Personal Communication 6).

6.3.7 Community Health and Wellbeing

According to the Ministry of Health, health outcomes in Guyana continue to improve steadily, with life expectancy at birth increasing from 63 years in 1998 to 67 years in 2010 (Ministry of Health, 2013).

6.3.7.1 Health Status

Causes of Death

The leading causes of mortality in 2010 were chronic diseases, including cardiovascular and cerebrovascular diseases, cancers, diabetes, and hypertension (Ministry of Health, 2013b).

According to the World Health Organization, Guyana had the highest rate of suicide of any country in the world in 2015, at 44.2 deaths per 100,000 people, versus the global average of 16 (WHO, 2014). According to Guyana's Chief Medical Officer, rates are particularly high in Regions 2, 3, and 6, with the most common method being ingestion of poisons such as pesticides. No single reason is pinpointed for this phenomenon, but the shortage of mental health workers and the stigma associated with mental illness leading to untreated depression are thought to be contributing factors, as well as the ease of access to pesticides and other toxic agricultural substances (ERM Personal Communication 7).

Burden of Disease

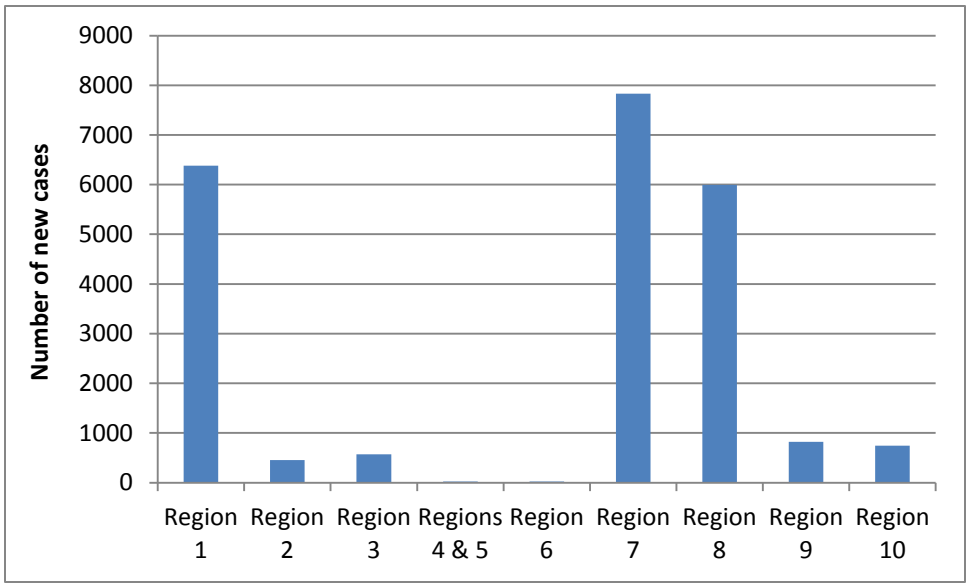
As with many other developing countries, Guyana is undergoing an epidemiological transition by which non-communicable diseases are beginning to replace communicable diseases as the leading causes of illness and mortality. This shift is largely due to trends toward more sedentary occupations and lifestyles, as well as unhealthy diets and habits such as tobacco and alcohol use. Obesity is on the rise in the country, along with other forms of malnutrition. Although Guyana is considered self-sufficient for food, accessibility and utilization of the right types of food to maintain health are of concern, leading the Ministry of Agriculture to develop the Guyana Food and Nutrition Security Strategy 2011-2020 Plan. This plan aims, among other things, to integrate agricultural practices with improved food security and nutrition (Ministry of Health, 2013a).

Communicable diseases also continue to impact productivity, quality of life, and wellbeing in Guyana, particularly in the hinterland regions. This is due to a number of interrelated factors including poverty, nutritional deficiency, and inadequate access to health services.

Malaria is found in much of Guyana and is most prevalent in Regions 1, 7, 8, and 9. Malaria control efforts, such as distribution of insecticide-treated bed nets and indoor residual spraying[17], have been ongoing in these regions for decades. After an initial reduction in malaria prevalence in the early 2000s, the number of cases increased from 2007 to 2012. Data indicate a correlation with mining activities in the hinterland areas, and the country's Central Vector Control Service now sends mobile teams to work directly with populations residing in mining camps (Ministry of Public Health, 2014).

Figure 6-34 shows the number of reported new malaria cases for each region in 2010, the most recent year for which data are available.

Figure 6-34 Malaria Incidence by Region, 2010



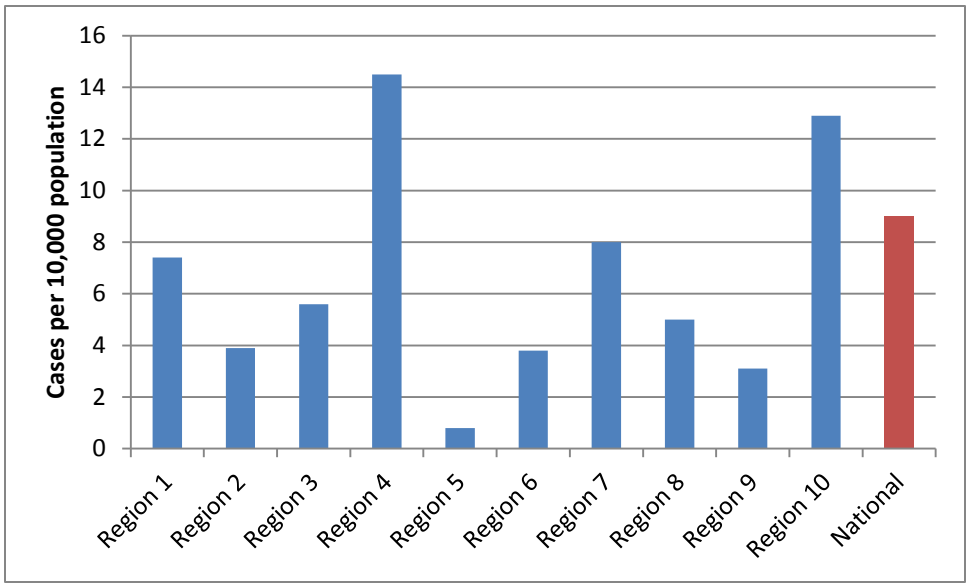
Source: Ministry of Public Health, 2013b

Dengue fever, chikungunya, lymphatic filariasis, and Zika are also locally transmitted in Guyana. Unlike malaria, transmission of these diseases tends to be common in populated and urbanized areas.

Tuberculosis (TB) continues to be a priority health concern in Guyana. It was nearly eradicated in the 1980s, but saw a resurgence in the 1990s due to its association with the HIV/AIDS epidemic. In 2010, the national average for TB incidence was nine cases per 10,000 people. Regional distribution of cases in 2010 is shown on Figure 6-35.

[17] Indoor Residual Spraying involves coating the walls and other surfaces of a house with an insecticide that has residual activity (i.e., continues to work over several months, killing mosquitos on contact with the sprayed surfaces). Source: Centers for Disease Control and Prevention, 2012.

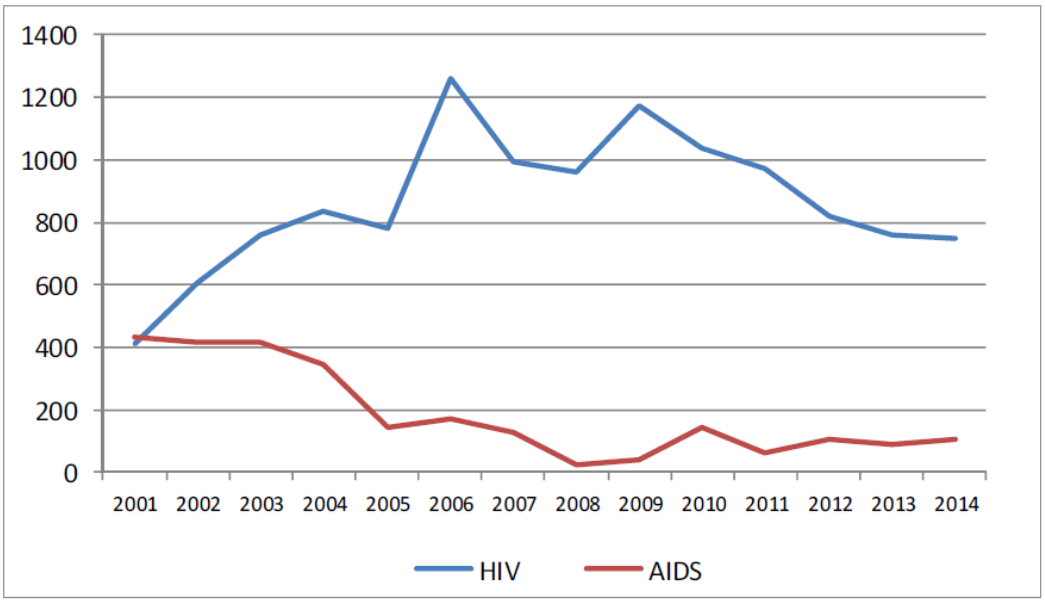
Figure 6-35 TB Incidence Rate by Region, 2010



Source: Ministry of Public Health, 2013b

In 2015, the number of people living with HIV in Guyana was estimated at 7,800, and the prevalence rate in the population aged 15 to 49 was 1.5 percent. According to the Joint United Nations Program on HIV/AIDS (UNAIDS), progress has been made in addressing the HIV epidemic in the country, with a reduction in the number of HIV cases reported since 2009, as well as a reduction in the number of AIDS cases (Figure 6-36) and AIDS-related deaths.

Figure 6-36 Annual Number of HIV and AIDS Cases, 2001-2014



Source: UNAIDS, 2015

The Neglected Tropical Diseases (NTDs) lymphatic filariasis and soil-transmitted helminthiasis continue to be problematic in Guyana, leading to deformity, malnutrition, and social stigma in

impacted populations. Efforts to combat these diseases in the country include mass drug administration campaigns and improvements in sanitation in endemic areas.

Maternal and Child Health

Guyana has made improvements in maternal and child health in recent years, but has not achieved its Millennium Development Goal (MDG) targets of reducing child mortality rates by two thirds, and maternal mortality ratio by three quarters between 1990 and 2015. Furthermore, marked disparities exist in rural and hinterland areas, with the rate of under age 5 mortality at 48 per 1,000 live births in rural areas and 11 per 1,000 live births in urban areas (UNICEF, 2014).

6.3.7.2 Health Care System

Government health spending compares favorably with other Latin American and Caribbean countries, and has averaged about 3 percent of GDP in recent years, equivalent to $11.5 billion GYD annually ($57.5 million USD) (Ministry of Public Health, 2013b). The healthcare system in the country is highly decentralized, with Regional Democratic Councils and Regional Health Authorities managing, financing, and providing health services. The system experiences a number of challenges related to human resources capacity and infrastructure capacity.

Health Facilities

Health facilities in the coastal regions are summarized in Table 6-18 below. In addition to these facilities, there is one National Ophthalmology Center and one National Psychiatric Hospital in the country, both located in Region 6.

Table 6-18 Health Facilities in the Coastal Regions

Region	Regional Hospital	District Hospital	Diagnostic Center	Health Center	Health Post
Region 1	1	4	-	4	44
Region 2	-	2	1	11	17
Region 3	1	2	1	17	22
Region 4	1	1	1	39	7
Region 5	-	1	1	14	1
Region 6	1	3	-	21	2

Source: Ministry of Public Health, 2016

According to Guyana's Chief Medical Officer, some of the biggest health system shortfalls are unreliable emergency care services. This includes the lack of a functioning air ambulance system, which is needed to adequately respond to mining injuries in the country's interior and to the large number of vehicle crash injuries. There are also shortages of blood at times, and capacity in hospitals is inadequate. The public hospital in Georgetown once had 900 beds, but due to fires and dilapidation over the years, this has been reduced to 450 (ERM Personal Communication 7).

Health Human Resources

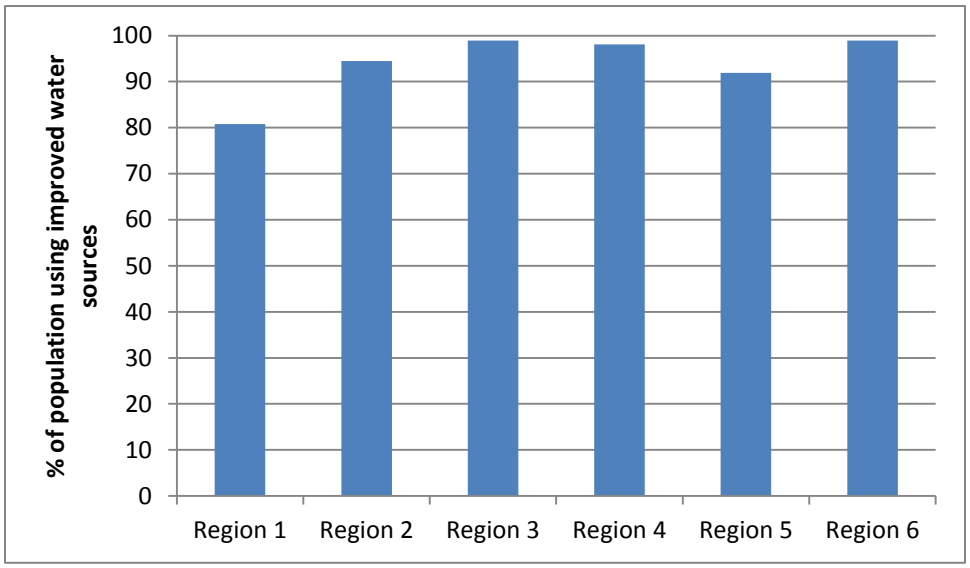
Retention of health care professionals in Guyana is a challenge, as in many other developing countries that see emigration of skilled workers to developed countries. The most recent available statistics from the Ministry of Public Health indicate that there were 6.8 physicians and 13.3 nurses per 10,000 people in the country in 2010 (Ministry of Public Health, 2013a). Guyana currently has a Health Human Resource Action Plan for Guyana 2011-2016 that is aimed at addressing this issue.

6.3.7.3 Quality of Life

Water and Sanitation

According to the most recent Guyana Multiple Indicator Cluster Survey (MICS)[18], 94 percent of Guyana's population had sustainable access to improved drinking water sources[19] as of 2014, and 95.4 percent used an improved sanitation facility[20] (UNICEF, 2014). Figure 6-37 shows the percentage of the population with access to improved sources of drinking water, by region.

Figure 6-37 Percent of Population with Access to Improved Water Sources by Region, 2014



Source: UNICEF, 2014

[18] The MICS program was developed by UNICEF and serves as an international household survey program to collect internationally comparable data on a wide range of indicators on the situation of children and women.

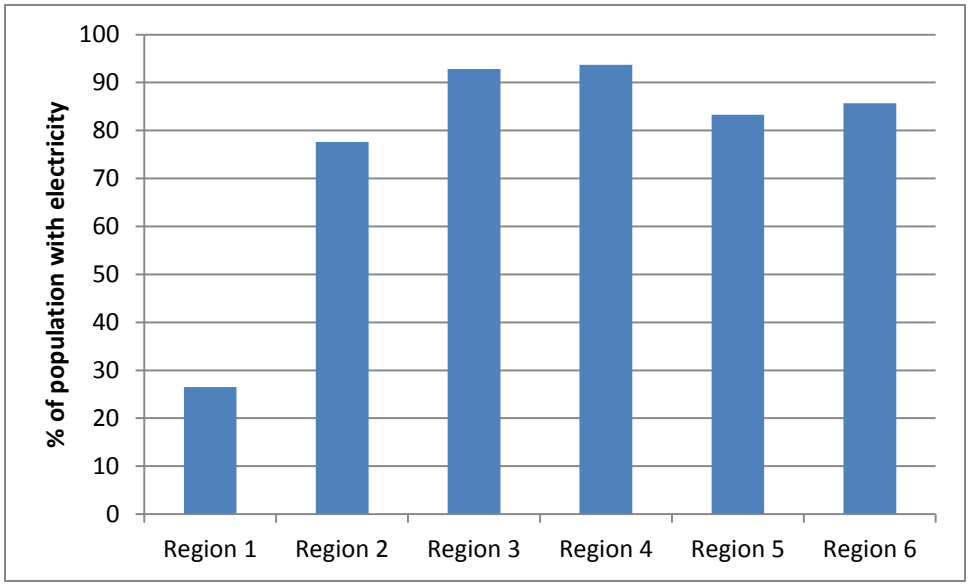
[19] Improved water sources refer to any of the following types of supply: piped water into dwelling, compound, yard, to neighbor, or to public tap/standpipe; tube well/borehole; protected well; protected spring; and rainwater collection. Bottled water is considered as an improved water source only if the household is using an improved water source for handwashing and cooking.

[20] An improved sanitation facility is defined as a facility that flushes or pour-flushes to a piped sewer system, a septic tank, a pit latrine, a ventilated improved pit latrine, or a pit latrine with slab.

Electricity

Results of the MICS indicate that an estimated 91.2 percent of the coastal population and 56.2 percent of the interior population have access to electricity. Figure 6-38 shows the percent of the population with electricity in each of the coastal regions.

Figure 6-38 Percent of Population with Electricity by Region, 2014

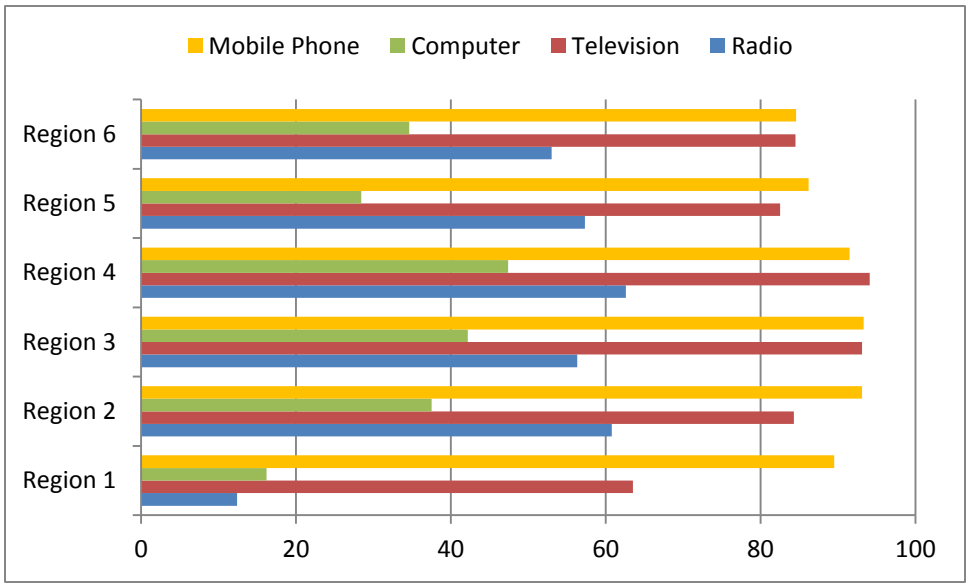


Source: UNICEF, 2014

Telecommunications

In terms of telecommunications, mobile telephone coverage is quite comparable among coastal regions, and an average of 88.6 percent of households in the country has at least one member with a mobile phone. There is more disparity in other forms of telecommunications, with Region 1 in particular showing lower levels of access to computers, television, and radio relative to other regions (Figure 6-39).

Figure 6-39 Household Access to Telecommunications, 2014



Source: UNICEF, 2014

6.3.7.4 Natural Hazards

Guyana is not threatened by many natural hazards, but due to its low-lying coastal plain it faces severe risk of flooding. Both changes in rainfall patterns and predicted sea level rise associated with climate change pose threats to the Guyanese population and its livelihoods. As such, the country invests continuously in the construction and maintenance of sea and river defense infrastructure, as well as a system of reclaimed lands, drainage and irrigation canals, and conservancy dams to protect agriculture in the vulnerable coastal areas.

In 2005, torrential rains caused many rivers and water conservancies in the coastal plain to overflow, causing flooding in Regions 1, 2, 3, 5, and 6. The floods resulted in the direct or indirect deaths of 19 people, either from drowning, acute dehydration, or succumbing to an outbreak of leptospirosis that occurred in the aftermath of the flooding (PAHO, 2005). Direct economic losses of agricultural crops, livestock, fisheries, forestry, and roads in the coastal area were estimated to total over $10 billion GYD (~$50 million USD) (UNDP, 2005).

6.3.8 Marine Use and Transportation

6.3.8.1 Introduction and Methodology

This section describes Guyana's existing marine and coastal transportation infrastructure, with particular focus on the Project AOI. Data and information in this section were primarily obtained from Project-specific documents, including the Project's Final Multi-well Environmental Management Plan (February 2016) and Strategic Environmental Assessment (March 2014). Other sources of information include key informant interviews, reports, studies, and other publicly available information.

6.3.8.2 Regional Setting

The EP Act requires EIAs to assess impacts on material assets. Nearly all the Project-related activities will occur at designated shorebases on the coast, coastal marine waters, or offshore. Therefore, for the purposes of this EIA "material assets" were determined to include the marine infrastructure within the AOI which consists of waterways, coastal shipping channels, ports, and offshore shipping lanes. Guyana has approximately 1000 km (~620 mi) of navigable rivers, which provide water access to most population and economic centers. Subsea telecommunications cables are also present in or near the PDA.

6.3.8.3 Existing Conditions in the Project Development Area

The Minister of Public Infrastructure's MARAD is responsible for ensuring the safe and efficient operation of shipping activities in Guyana territorial waters. MARAD operates in accordance with the IMO and is a party to a number of IMO Conventions, including conventions on: Safety of Life at Sea (SOLAS); Standards of Training, Certification, and Watchkeeping (STCW); and Prevention of Pollution from Ships. Jamaican and Trinidadian shipping lanes may cross the Stabroek Block (Figure 6-40).

As described in Section 6.3.2, fisheries are of significant importance to Guyana's economy, particularly in coastal areas. Marine fisheries and subsistence fishing occur throughout Guyana coastal waters, from the shore to the edge of the continental shelf, approximately 150 km (~93 mi) from shore although most fishing activity occurs well inshore from the shelf edge. Figure 6-41 depicts the primary fishing zones offshore Guyana by fishery type and the primary fishing ports or landing sites in Regions 2 and 3. There are no formal landing sites in Region 1.

The Port of Georgetown contains more than 40 separate wharves, including six primary cargo wharves ranging from approximately 130 m to 247 m (~427 ft to 810 ft) in length, as well as four tanker berths (NGIA, 2014). Other privately owned docks and portside facilities near Georgetown and the mouth of the Demerara River have staging areas or storage yards, although these facilities are congested and space is limited. Vessel call data for the Port of Georgetown are not available.

A shipping channel is maintained on the lower Demerara River for the use of private, commercial, and military vessels. Pilotage is required to access the channel, and is provided by the Stabroek Harbour Master. As of 2014, the Superintendent of Surveys of the Harbour Master Department indicated that ship draft in the channel was approximately 4.5 m (~15 ft) at low water, but that dredging work was ongoing to reach a target depth of approximately 5.5 m (~18 ft).

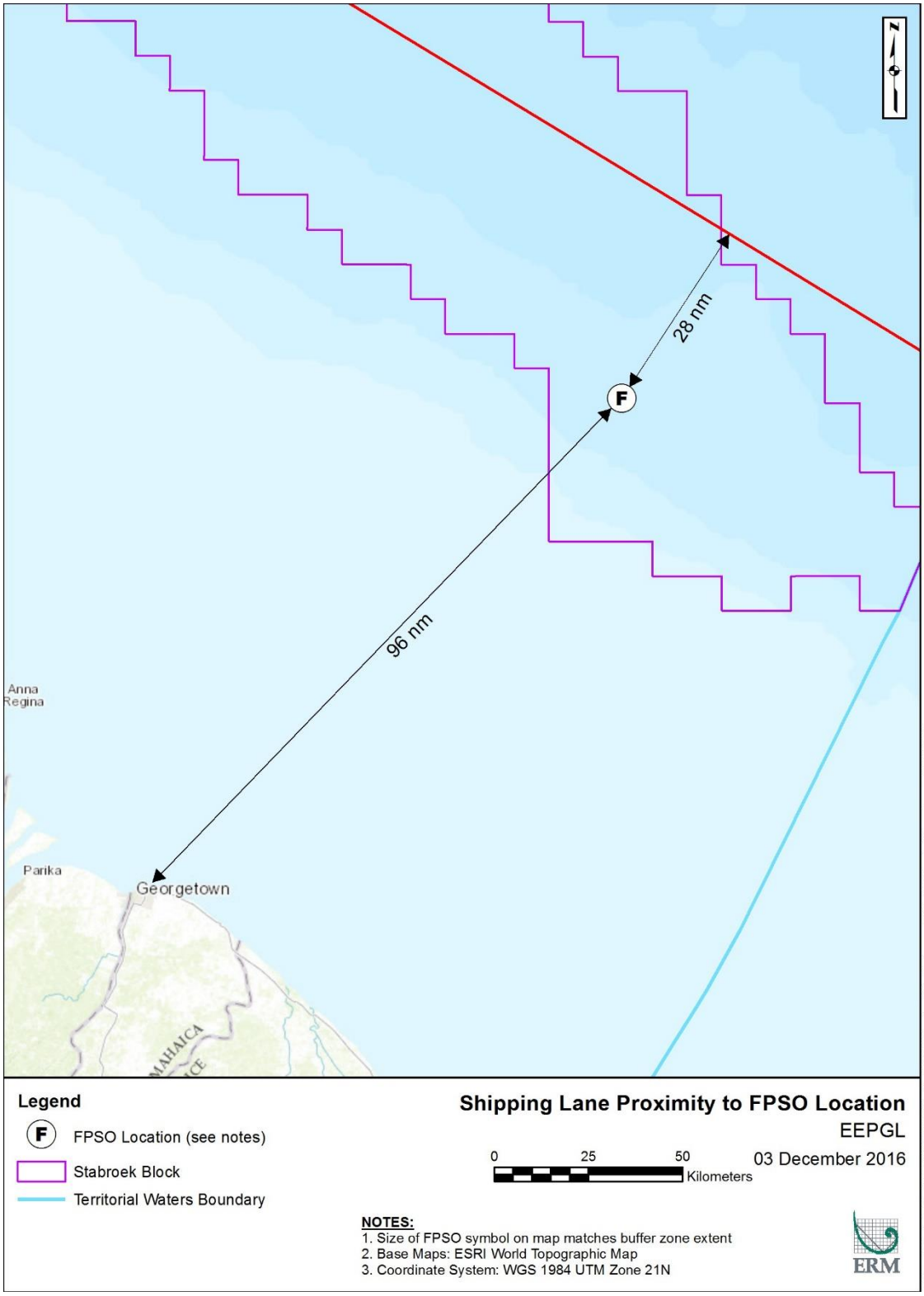
The Transport and Harbours Department is responsible for the management of the national ferry service. The department has four ferry vessels, three of which operate in the Essequibo River and one in the Berbice River. The ferries on the Essequibo River serve several ports (also known as "Stellings") on either side of the Essequibo River and on Leguan and Wakenaam Islands, as shown on Figure 6-42.

In addition to the national ferry service, many smaller vessels provide transportation between Regions 2 and 3 across the Essequibo River. These smaller vessels are collectively and informally known as "speedboats" because they typically travel faster than the ferries (Figure 6-33). These speedboats vary in size, power, and capacity, but can typically carry from 5 to 15 passengers. They operate at the same ports as the national ferry service, and may also call at smaller informal landings as client demand and conditions warrant.

Telecommunications

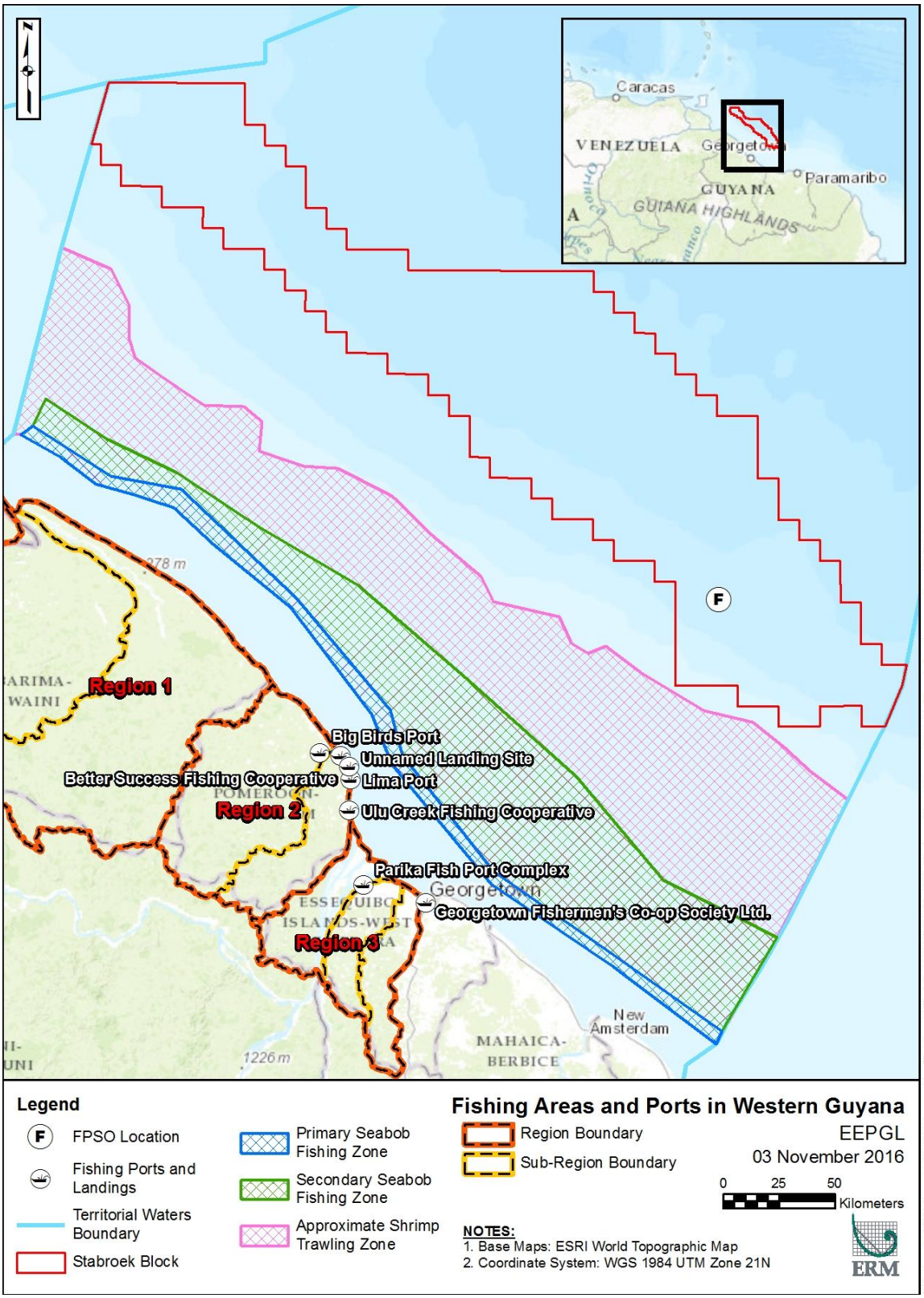
A publically mapped Guyana Telephone & Telegraph (GT&T) subsea telecommunications cable which is part of the Suriname Guyana Submarine Cable System (SGSCS) runs through the Stabroek Block, but is outside the PDA.. Since the SGSCS is outside the area of direct impact, and the Project would not have any indirect impacts on it, the SGSCS is not discussed further in this EIA.

Figure 6-40 Offshore Shipping Lanes



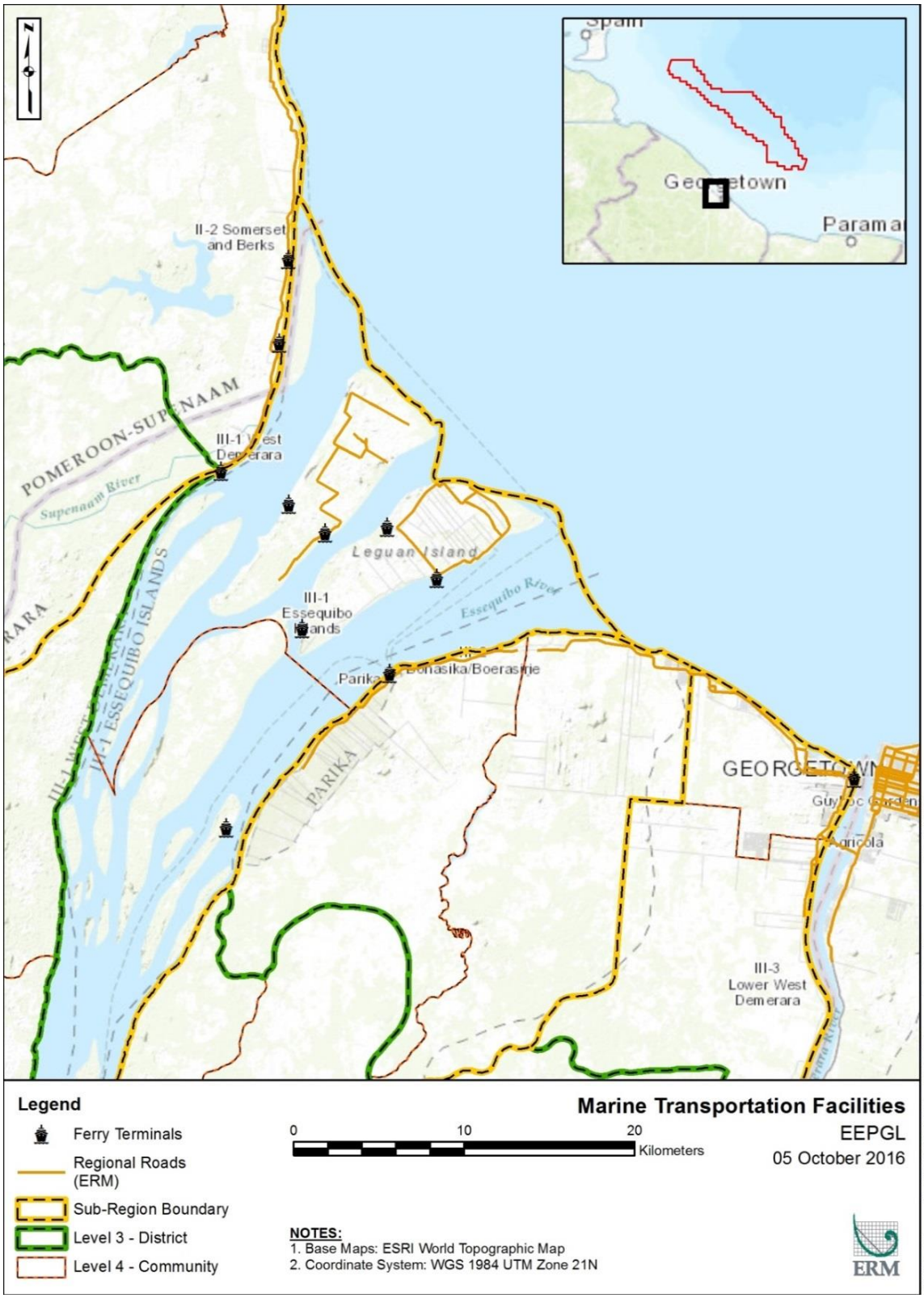
** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

Figure 6-41 Fishing Zones and Ports



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

Figure 6-42 Maritime Transportation Facilities

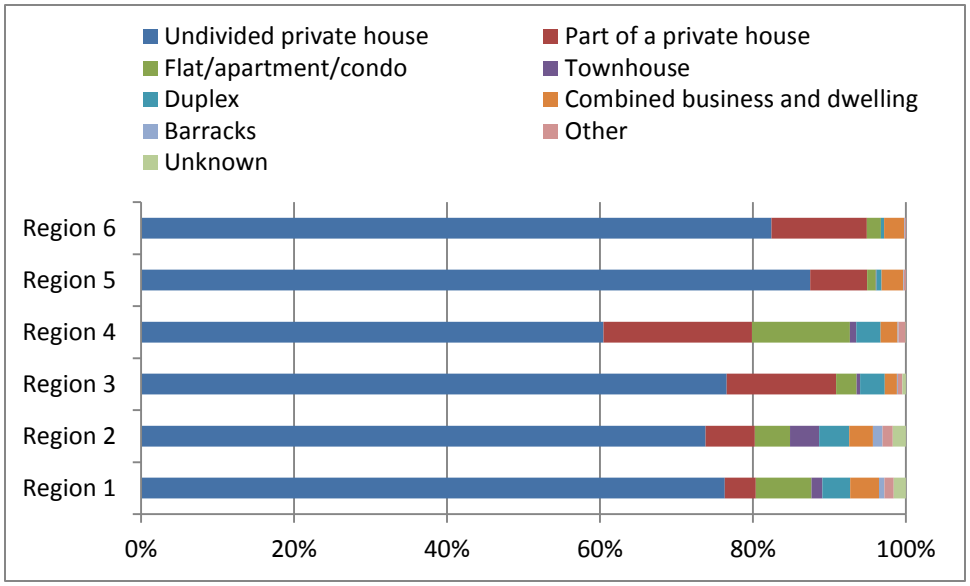


6.3.9 Social Infrastructure and Services

6.3.9.1 Housing

Figure 6-43 shows the breakdown of housing types in the coastal regions as of the 2002 census (housing data from the 2012 census are not yet available) and indicates that detached houses are the most common type of housing in all regions.

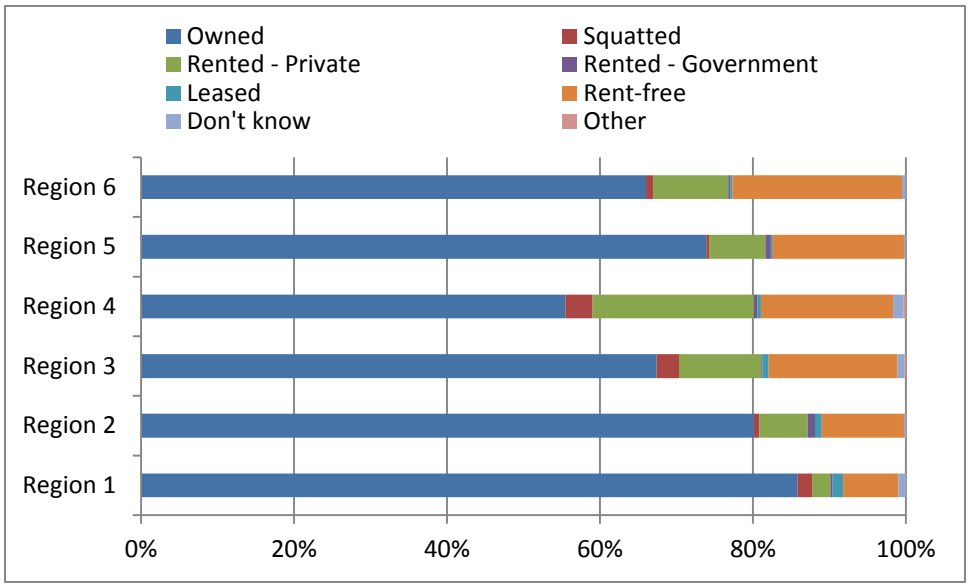
Figure 6-43 Proportion of Housing Types by Region



Source: Bureau of Statistics, 2002

Figure 6-44 shows the breakdown of home ownership types by region and shows that the majority of homes in the coastal area are owned by their occupants. However, Regions 3 and 4 have a higher proportion of rented and squatted homes. Informal housing settlements increased in the 1980s and 1990s due to housing supply constraints, causing many people to squat on vacant parcels (IDB, 2016). The Ministry of Communities has worked in recent years to regularize informal settlements, particularly in the Georgetown area, by providing services such as paved streets, drainage, septic tanks, and water supply. If settlement sites are not suitable for permanent neighborhoods, they are moved to other locations (ERM Personal Communication 8; IDB, 2008, 2016). There are currently 216 squatting areas in the country, of which 154 have been brought under the regularization program.

Figure 6-44 Proportion of Home Ownership Types by Coastal Region



Source: Bureau of Statistics, 2002

Data from the 2014 MICS indicate that the majority of homes in Guyana have a finished floor (81.2 percent), roof (97.0 percent), and walls (93.2 percent). However, housing stock in some regions is aging and in need of upgrade (IDB, 2016). According to the 2002 census, more than 30 percent of the housing stock in Regions 3, 4, 5, and 6 was built before 1970.

6.3.9.2 *Ground Transportation Infrastructure*

Guyana has an approximately 3990 km (~2,480 mi) road network that is used by the approximately 80,000 vehicles in the country. There are six main national paved roads that each have two lanes, except for four-lane segments along the East Bank and East Coast Demerara. The road network is dependent on a system of bridges and culverts that provide crossings over a dense system of canals, drains, and sluices throughout the coastal lowlands.

Georgetown has a compact, grid-based street network. Road conditions vary widely and can be poor in some locations. Most streets are no more than two lanes wide, with approximately 7 m to 8m (~23 ft to 26 ft) of paved width (Google Earth, 2016). The port area is linked to central Georgetown via East Bank Demerara Road. Most intersections are not signal controlled; where signals do exist, they are frequently out of service.

Traffic congestion is a chronic problem in and around Georgetown. Many different types of vehicles including cars, large commercial vehicles, mini-buses, horse drawn carts, bicycles, mopeds, scooters, and motorcycles all share the same travel lanes. Traffic congestion occurs frequently, including just before and just after school hours.

East Bank Demerara Road is particularly susceptible to congestion, due to backups at the Demerara Harbour Bridge, the only road crossing of the Demerara River (Figure 6-45). Daily retraction of the bridge for a period of about one hour causes severe traffic congestion at both ends of the bridge. The limited number of bridge openings causes delays and inconvenience to

ocean going vessels. The Government of Guyana has investigated replacing the existing bridge with a new bridge (with an elevated central span that would reduce or eliminate the need for drawbridge openings) further downstream (Kaieteur News 2015).

Figure 6-45 Demerara Harbour Bridge



Driving behavior also contributes to poor and dangerous land transportation conditions. Speeding, aggressive driving, and driving under the influence of alcohol contribute to traffic accidents in Georgetown. Driving at night poses additional concerns due to poor street lighting and road conditions, as well as livestock and pedestrians congregating near the roadside (OSAC 2016).

At the time of writing, the Ministry of Public Infrastructure was working with the IDB to develop a Sustainable Urban Transport Plan for Georgetown. This will focus more on management of current traffic than addition of significant new infrastructure; for example, separation of slower-moving traffic from vehicular traffic in designated lanes (ERM Personal Communication 9).

6.3.9.3 Water and Sanitation

According to the Food and Agriculture Organization (FAO), 95 percent of water usage in Guyana in 2010 was for irrigation and livestock, with four (4) percent used by municipalities and one (1) percent by industry (FAO, 2015).

Potable Water

Most potable water is obtained from the deeper aquifers that underlie Georgetown and the coastal plain. Water is distributed by Guyana Water Inc. (GWI), a commercial public enterprise

that has five service areas along the coast, and a separate program to serve communities in the hinterland. There are three major water treatment plants in the country, located in Georgetown, New Amsterdam, and Guymine (FAO, 2015).

In rural areas not served by GWI, domestic water is obtained from a mix of ground, surface, and rainwater sources. Rainwater is often used for potable household use, while river water is typically used for cleaning and other non-potable uses.

Businesses that use large quantities of water, such as beverage bottling and food processing plants, generally have their own wells to meet their needs (FAO, 2015).

Agricultural Water

Areas with fully developed drainage and irrigation systems are called Declared Drainage and Irrigation Areas (DDIAs) and are found in Regions 2, 3, 4, 5, and 6. In these regions, irrigation is by gravity from surface water resources trapped by shallow earthen dams known as "conservancies." These are located in the upper stream catchment areas and store water at higher elevations than the surrounding fields. The Tapakuma conservancy is a large human-made conservancy. It serves Region 2 and has been designed to provide irrigation to about 120 square kilometers (29,650 acres). During times of water shortage, this conservancy is supplemented by pumping from the Pomeroon River (FAO, 2015).

The National Drainage and Irrigation Authority (NDIA) has responsibility for the maintenance and delivery of the irrigation water supply throughout the country.

6.3.9.4 Power

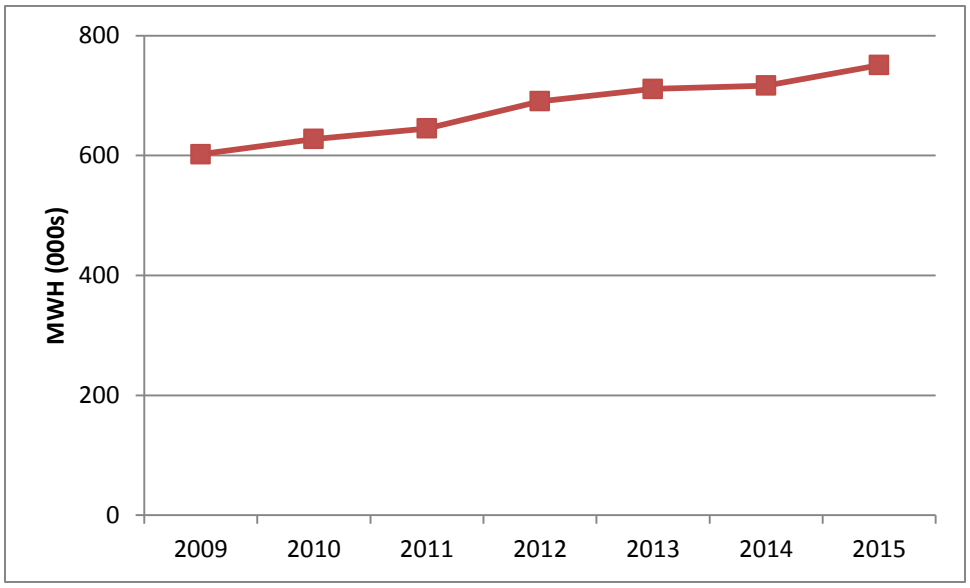
Most of the electricity in the coastal plain of Guyana is generated, transmitted and distributed by the state-owned utility Guyana Power & Light Inc (GPL). However, due to poor reliability of the electrical supply, many users also have their own diesel generators. Coastal areas that are not serviced by GPL are the Region 2 area west of Charity, and Region 1. Most areas of the hinterland do not have electricity service, and the government has implemented a number of hinterland energy development projects in recent years which have included installation of solar systems, and feasibility studies for hydropower and wind projects (GPL, 2016).

The PSC has noted that the high cost of electricity in Guyana is a major challenge for business. This was also raised as an issue by representatives of agricultural processing associations (ERM Personal Communications 1, 5, and 10).

According to the PSC, development of hydroelectricity should be a major priority for the country. The plan for the 165 megawatt (MW) Amaila Falls hydroelectric plant was cancelled in 2015 due to delays and the potential for cost overruns (ERM Personal Communication 10).

Total electricity generation output in Guyana in thousands of MW-hours for the period 2009 through 2015 is presented on Figure 6-46.

Figure 6-46 Electricity Generation in Guyana, 2009-2015



Source: Ministry of Finance, 2015

Although Guyana has significant potential for hydroelectric and biomass-fueled electricity generation, at this time, 83 percent of its installed generation capacity is thermal, relying on expensive imported liquid fuels and making average electricity prices among the highest in Latin America and the Caribbean. The remaining 17 percent of installed capacity is biomass-based, using bagasse (sugarcane fibers remaining after cane juice is extracted) as fuel to self-generate power at GuySuco's sugarcane factories. There are plans to enhance the generation capacity of the GuySuco factories such that excess power is available and can be exported to the National electrical grid, and the government continues to explore options for a hydroelectric power project (GEA, 2015; ClimateScope, 2015).

6.3.9.5 Telecommunications Infrastructure

As described in Section 6.3.7, the majority of households in the coastal regions have access to mobile phone service. However, the lack of 4G network access has been a major barrier to increased business investment in Guyana, and an issue that the PSC has prioritized. In 2016, the first 4G network in the country was installed. Fiber optic cable is also a pressing need to improve reliability and accessibility (PSC, 2015) of mobile phone services.

6.3.9.6 Educational Facilities

Table 6-19 shows the number of nursery, primary, secondary, and post-secondary schools in each of the coastal regions. The majority of post-secondary institutions (technical schools, colleges and universities) are found in Georgetown.

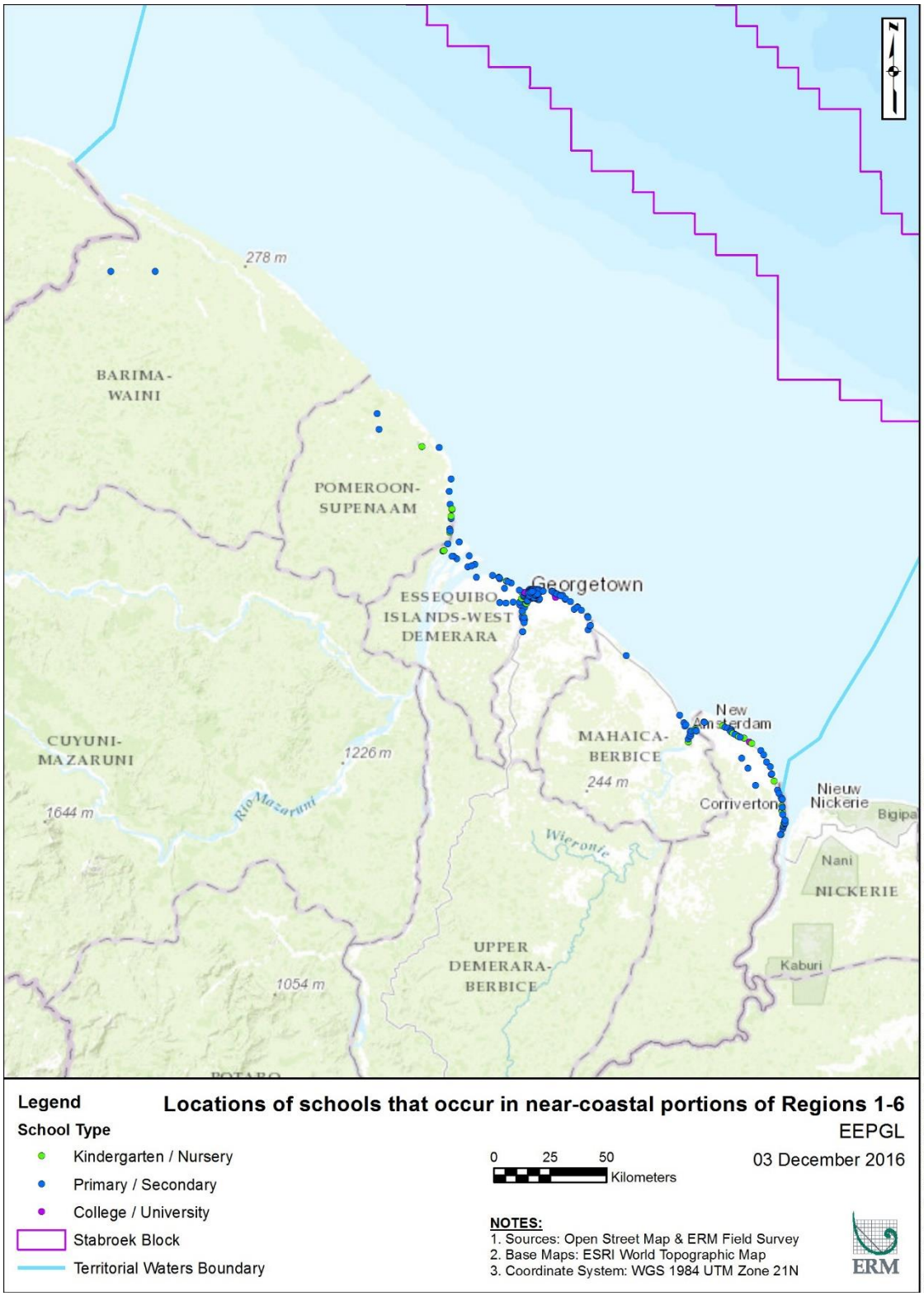
Table 6-19 Number of Educational Facilities in Guyana's Coastal Regions

	Nursery	Primary	Secondary	Technical/ Vocational	College/ University
Region 1	17	42	3	0	0
Region 2	49	37	8	1	0
Region 3	59	59	13	0	0
Region 4	65	54	15	4	7
Region 5	34	32	7	0	0
Region 6	67	54	17	1	2

Source: Guyana Ministry of Education 2013

Table 6-19 includes the full list of schools in the coastal regions as reported by the Guyana Ministry of Education, but Figure 6-47 only shows schools occurring near the coast. In general, this distribution reflects population trends along the coast. Schools are found all along the coast of Regions 3, 4 and 6, which are also the most populated regions. In Region 2, schools are found along the coast until the coastal road ends, and are much fewer in the Region 2 areas west of Charity and in Region 1.

Figure 6-47 Locations of Schools that Occur in Near-coastal Portions of Regions 1-6



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

6.3.9.7 Security Facilities

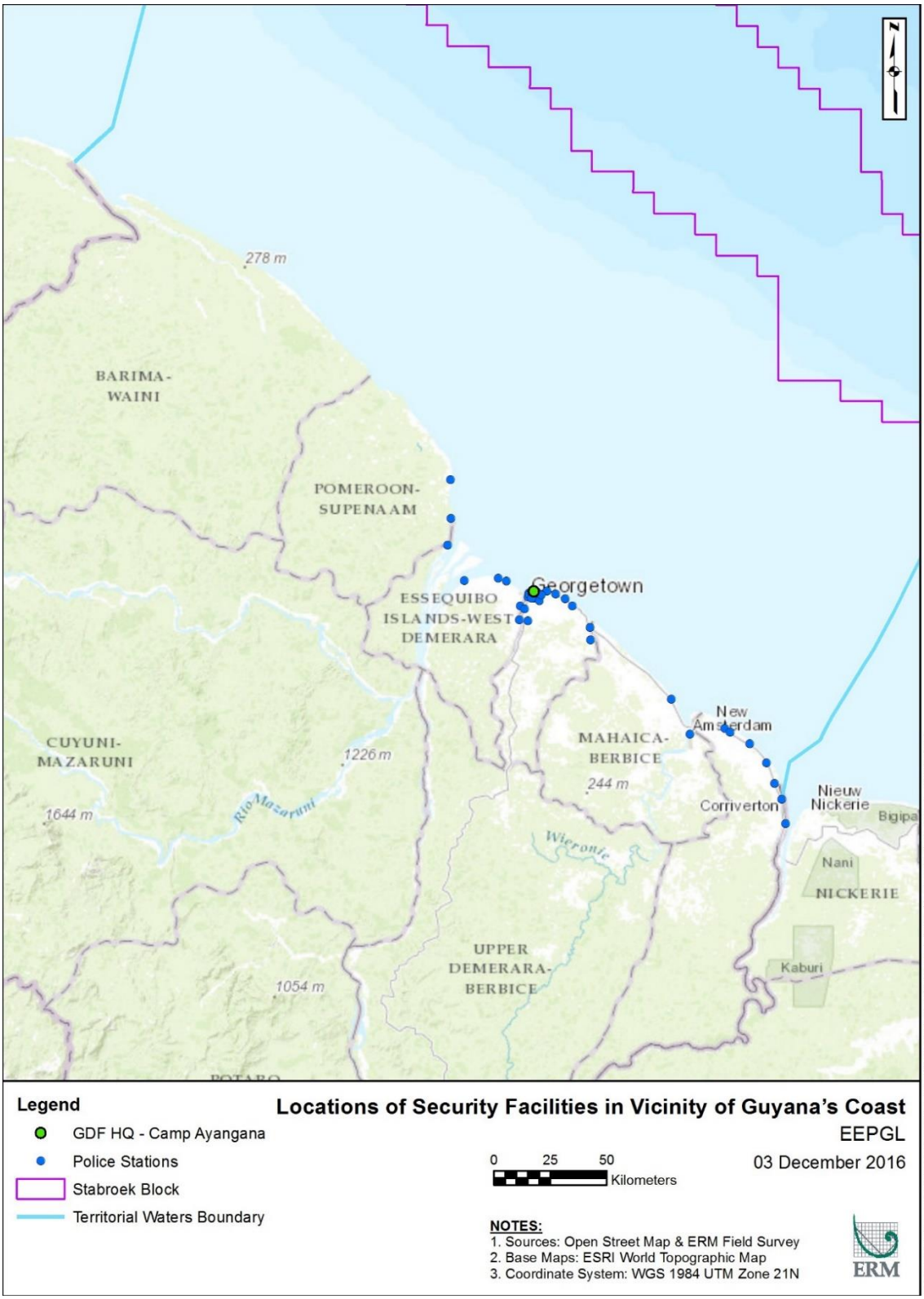
The Guyana Defense Force (GDF) is the military service of Guyana and has land, sea (Coast Guard) and air (Air Corps) units responsible for defending the territorial integrity of Guyana. In terms of internal security, the Guyana Police Force (GPF) operates as a semiautonomous agency under the Ministry of Home Affairs. The GPF has seven geographic policing divisions each with their own headquarters, stations and outposts as summarized in Table 6-20.

Table 6-20 Policing Divisions in Guyana

Division	Geographic Area	Headquarters Location	Number of Stations	Number of Outposts
A	City of Georgetown and the East Bank of the Demerara River including the Cheddi Jagan International Airport, Timehri, 25 miles from Georgetown.	Brickdam, Georgetown	9	7
B	County of Berbice but excluding Kwakani.	Coburg Street, New Amsterdam	12	5
C	County of Demerara, East of the Demerara River but excluding A Division.	Cove & John, East Coast Demerara	8	4
D	County of Demerara, West of the Demerara River and a portion of the East Bank of the Essequibo.	Leonora, West Coast Demerara	6	1
E&F	Upper Demerara including the area surrounding the bauxite holdings of Linden, Ituni and Kwakani and the Interior.	Rabbit Walk, Eve Leary, Georgetown	30	6
G	Essequibo Coast including the islands of the Essequibo and Pomeroon Rivers.	Anna Regina, Essequibo Coast	6	0

Figure 6-48 shows the locations of 35 (approximately 50 percent) of the total reported police stations in Guyana enumerated in the table above (locational data were not available for the interior outpost locations).

Figure 6-48 Locations of Security Facilities in Immediate Vicinity of Guyana's Coast



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

6.3.10 Cultural Heritage

6.3.10.1 Underwater Cultural Heritage

Prior to EEPGL's interest in the Stabroek Block, no previous cultural surveys had been undertaken within the vicinity of the PDA. EEPGL retained Fugro Marine Geoservices, Inc. (Fugro) to conduct a geophysical and remote sensing survey of the seafloor within the PDA to identify the occurrence of any potential cultural resources that may impact, or be impacted by, the design and placement of planned subsea equipment for the Project. Remote sensing surveys employ various instruments that use high and/or low frequency sound waves to collect information from the seafloor. This survey used several of these including:

- Multi-beam echo sounders (MBES), which collect bathymetric data via a wide band of high-frequency sound waves and can detect abnormal shapes (which could potentially include objects of cultural interest) against the surrounding landscape (both AUV and hull mounted used);
- Side scan sonars (SSS), which employ high frequency sound waves to collect textural data from the seafloor and provide high resolution images of objects on the seafloor surface (AUV mounted); and
- Sub-bottom profilers (SBP), which collect data on subsurface sediments and objects located beneath the seafloor via low frequency sound waves and are capable of locating buried shipwrecks beneath the seafloor surface (both AUV and hull mounted used).

Submerged archaeological sites are not expected in waters deeper than approximately 125 m (~410 ft), which was the approximate sea level during the Last Glacial Maximum (20,000 years before present). Since all Project components with the potential to disturb the seafloor would be deeper than approximately 125 m (~410 ft), the only potential cultural resources in the Project area are man-made objects that have sunk, most notably shipwrecks.

Fugro's Offshore survey operations employed AUV mounted, high-resolution, multi-beam echo sounder (MBES), side-scan sonar (SSS), chirp sub-bottom profiler (SBP), and digital camera, as well as hull mounted MBES and SBP units. The remote sensing instruments utilized and the settings employed for each instrument are provided in Table 6-21. The survey was divided into three areas: the Liza Field Development (Main AUV Survey) Area; the Upper Slope and Outer Shelf Reconnaissance (USOS Survey) Area; and the Skipjack Survey Area.

Table 6-21 Remote Sensing Instruments and Survey Settings

Type of Instrument	Model	Survey Settings	Hull or AUV Mounted	Survey Areas in which Equipment was Used
MBES	Kongsberg EM2040 bathymetric system	Frequency of 200kHz swath coverage of 150 degrees	AUV Mounted	Main AUV Survey Area/Where Possible in USOS Survey Area/ Skipjack Area
	Kongsberg EM302 bathymetric system	Frequency of 30kHz	Hull Mounted	USOS Survey Area
SSS	EdgeTech model 2200 full-spectrum system	Dual Frequencies of 105kHz and 410kHz	AUV Mounted	Main AUV Survey Area/Where Possible in USOS Survey Area/Skipjack Area
SBP	EdgeTech model DW-106 full spectrum system	Frequency Range of 1kHz to 10kHz	AUV Mounted	Main AUV Survey Area/Where Possible in USOS Survey Area/ Skipjack Area
	EdgeTech 3300 full spectrum system	Frequency Range of 1kHz to 10kHz	Hull Mounted	USOS Survey Area
Underwater Digital Camera	Prosilica Allied Vision GE4000	35 millimeter digital imagery, ~8 m (~26 ft) above seafloor	AUV Mounted	As Needed for Ground Truthing in all Survey Areas

ERM assessed Fugro's remote sensing survey methodology, including the remote sensing equipment and instrument settings employed and the results produced, according to internationally recognized standards. ERM found that the methods used by Fugro and the results yielded by their survey are sufficient to provide existing cultural heritage data for the area of anticipated impact, as the methodology and quality of data produced met the guidelines and requirements for near and offshore remote sensing cultural surveys as defined by the U.S. Bureau of Ocean Energy Management (BOEM) and the English Heritage, whose, guidelines together help frame "internationally recognized practices" for remote sensing surveys designed to locate and assess cultural heritage.

The survey was divided into three areas: the Liza Field Development (Main AUV Survey) Area; the Upper Slope and Outer Shelf Reconnaissance (USOS Survey) Area; and the Skipjack Survey Area. The main AUV Survey identified 73 Side Scan Sonar Targets (UD01- UD073), which were assessed for their potential as marine hazards and/or cultural resources. The targets ranged from approximately 0.5 m to 10.5 m wide, and from approximately 2 m to 27 m long. Only three targets, UD03, UD06, and UD070 possessed recordable height, measuring approximately 0.75 m, 1 m, and 0.5 m tall, respectively. However, none of these three targets possess shapes or other characteristics that might suggest they are culturally sensitive objects (e.g., shipwrecks),

and upon closer inspection all three targets are thought to be either pieces of debris or geological formations. Based on an analysis of the geophysical and remote sensing data, Fugro concluded that:

- One of the targets (SC17) was initially considered to be a possible vessel and thus was subjected to follow up surveys using high frequency SSS and digital photography. During this second inspection, however, target SC17 could not be relocated, though the seafloor at its previously recorded location showed signs of the object having moved downslope (drag scars). This indicates that the object is not culturally sensitive because, even if it were a cultural resource, it no longer maintains its original context (greatly diminishing its potential research value) (Figure 6-50);
- Another of the targets (SC110) was initially thought to be a potential vessel, but upon second inspection was identified as likely being a fishing net (Figure 6-51); and
- The remaining 71 targets in the main AUV Survey area were judged to be modern debris (e.g., debris associated with previous well development projects, cable laying efforts) or geological features (e.g., rock clusters or formations) of no significant cultural value. As examples of modern debris, three of the targets, UD08, UD011, and UD021 (Figure 6-49), were interpreted as discarded chain or cable coils.

In summary, upon review of the SSS imagery and data collected, ERM concluded that these 73 SSS targets are likely modern debris, fishing nets, chain or cable coils, or geological features of no significant cultural value.

Figure 6-49 SSS Targets UD08, UD011, and UD021 Found within the Main AUV Survey Area

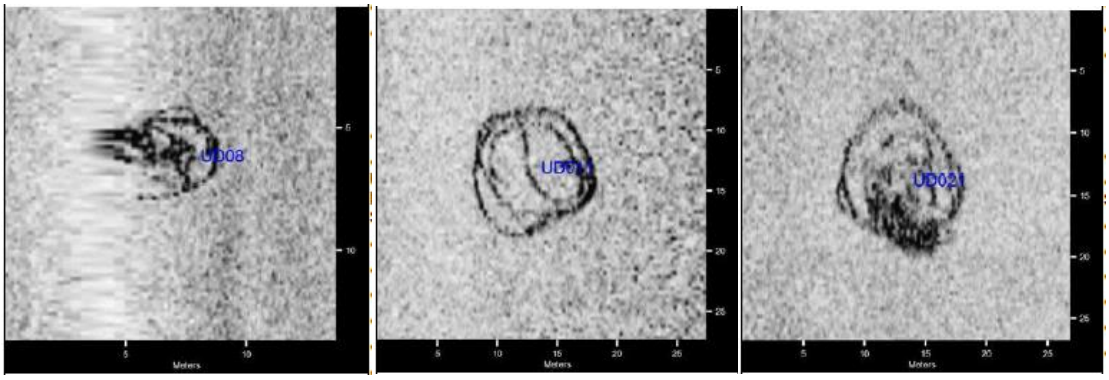


Figure 6-50 SSS Target SC17 in the Main AUV Survey Area

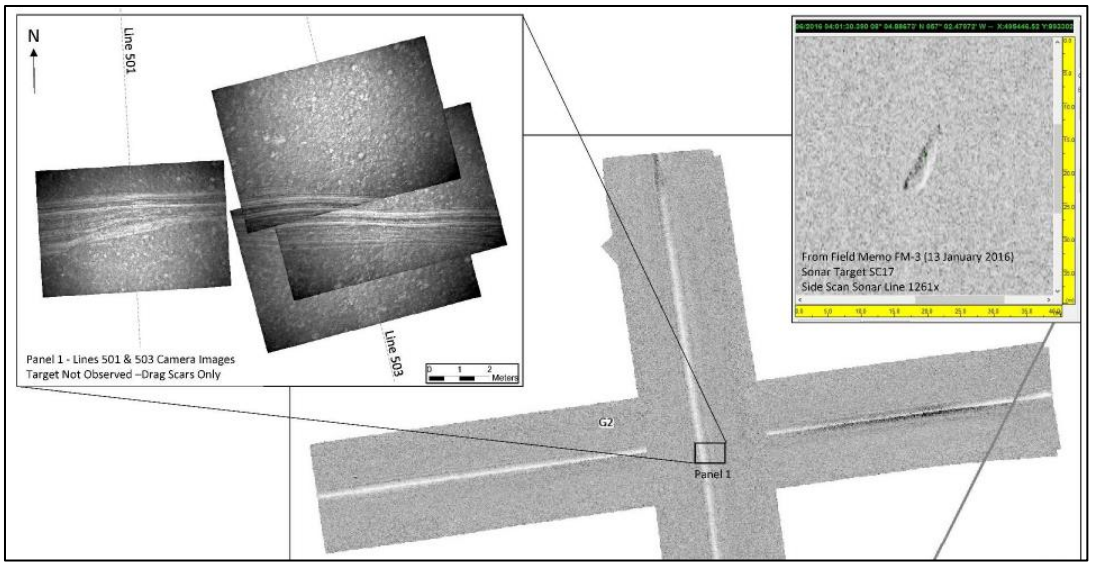
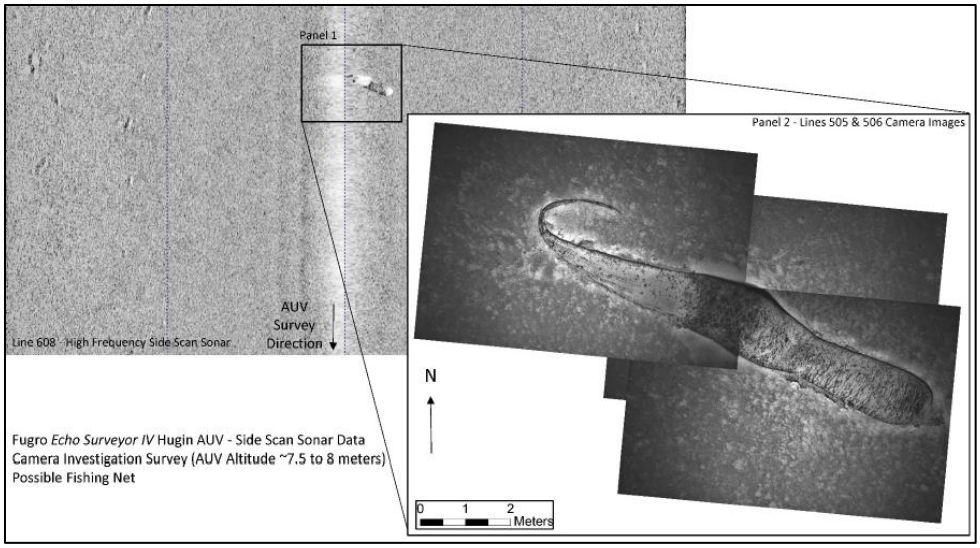


Figure 6-51 SSS Target SC110 in the Main AUV Survey Area

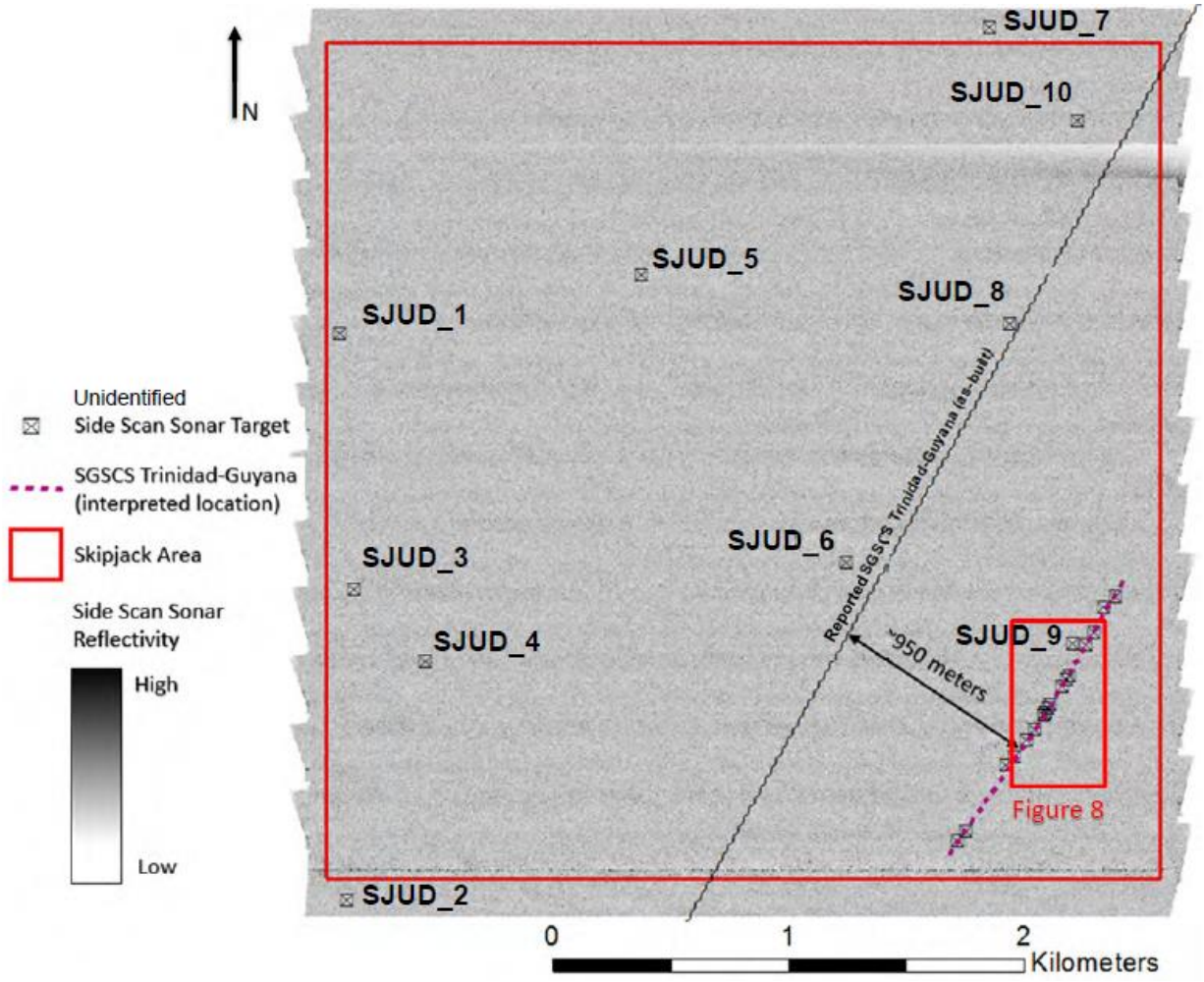


Remote sensing efforts in the USOS Survey Area revealed no discernable objects, either geological or man-made in origin, and thus it was concluded that there are no cultural concerns for the USOS Survey Area.

Ten SSS targets were identified in the SkipJack Survey Area, each of which appeared linear in shape, with lengths ranging from approximately 4 m to 78 m (~13 ft to 256 ft), widths ranging from approximately 1 m to 5.5 m (~3 ft to 18 ft), and no measureable heights (Figure 6-52). None of these targets were concluded to represent culturally significant objects, and are likely to be either geological formations or modern debris. In addition, a series of subtle reflections in the SSS data located in the southeast portion of the Skipjack Survey Area are understood to represent the Suriname-Guyana Submarine Cable System (SGSCS) Trinidad-Guyana cable.

These reflections run approximately 950 m (~3,116 ft) to the southeast and parallel to the reported as-built position of the SGSCS Trinidad-Guyana cable. The presence of this cable accounts for the presence of discarded cable or chain remains located within the main AUV survey area.

Figure 6-52 SSS Mosaic Showing SSS Targets, Including the Potential SGSCS Trinidad-Guyana Cable, in the Skipjack Survey Area



6.3.10.2 *Coastal Cultural Heritage*

Maps obtained from the Guyana National Trust also show the presence of several shell mounds, seashell deposits, quarries, and ceramic/pottery sites (i.e., scatters) along the Atlantic coast of Guyana, including archaeological sites found near Moruka, Uitvlugt, Stewartville, and Leonora. These sites are of significant cultural value to both the people of Guyana as well as researchers from other parts of the world, as they offer insight into the material culture of native peoples inhabiting the land before, during, and after contact with Europeans. However, only two of the ceramic/pottery sites on the maps are shown to be located near the shoreline.

6.3.11 Ecosystem Services

Ecosystem services are typically defined as the benefits that people obtain from the natural environment, including natural resources that underpin basic human health and survival needs, support economic activities, and provide cultural fulfilment.

Ecosystem services are divided into provisioning, regulating, cultural, and supporting services. Each of these is defined below (Millennium Ecosystem Assessment [MA], 2005).

- Provisioning services: Goods or products obtained from ecosystems such as food, freshwater, timber, fiber, and other goods.
- Regulating services: Benefits obtained from an ecosystem's control of natural processes such as climate, water flow, disease regulation, pollination, and protection from natural hazards.
- Cultural services: Non-material benefits obtained from ecosystems such as recreation, spiritual values, and aesthetic enjoyment.
- Supporting services: Natural processes such as erosion control, soil formation, nutrient cycling, and primary productivity that maintain other services.

Review of information indicates that the marine and coastal environments in Guyana provide all four categories of ecosystem services, some of which are critical for the wellbeing and livelihoods of coastal communities. These are described by category below.

6.3.11.1 Provisioning Services

As described above, marine fishing for various species of fish and shellfish is a vital source of protein and income to coastal communities. In addition to cultivated agriculture, communities in the coastal area (particularly Amerindian communities in Region 1) harvest a range of naturally occurring resources for household use and sale. This includes coconuts, manicole (heart of palm), mangrove bark, timber, tuli palm used for roof thatch, and crabwood seeds that are processed to make crabwood oil. Fishing, crabbing, and shrimping also occur on a small scale in the mangroves. There is also potential for apiculture in the mangroves. There are currently five apiaries with a total of 100 beehives in Region 1, and seven apiaries with a total of 120 beehives in Region 2. However, it is not clear whether any of these are located in mangrove forests. In Regions 4, 5, and 6, apiculture does occur in mangroves (Ministry of Agriculture, 2016). Despite their protected status, sea turtles and their eggs are sometimes poached in the coastal area (ERM Personal Communication 11).

6.3.11.2 Regulating Services

One of the most important regulating services provided by coastal ecosystems is shoreline and flood protection. Guyana's coastal plain is vulnerable to coastal flooding due to its low elevation, and mangrove forests with their dense root systems are an important component of the country's natural and manmade sea defense system. Mangroves also filter sediments, protecting sensitive seagrass beds from being smothered.

6.3.11.3 Cultural Services

Throughout Guyana's populated coastal regions, the seashore is often utilized in religious Hindu funeral and cleansing ceremonies. The Hindu community in Guyana has a number of crematoriums along the coast, and ashes are disposed in the ocean as part of funeral ceremonies. In addition, prayer and bathing ceremonies are performed informally by members of the Hindu community year round, but especially during the holy festival of Kartik Snan, which occurs in October or November each year (ERM Personal Communication 12).

Some members of African ethnic organizations also make use of the seashore to commemorate African Holocaust day at the Kingston Seawall in Georgetown, as well as other spiritual and religious events (ERM Personal Communication 13).

Although infrastructure in the area is not well developed and tourism activity is limited, the SBPA has high aesthetic and educational value and potential for ecotourism due to its importance as a sea turtle nesting area.

6.3.11.4 Supporting Services

Mangrove forests along the coast play an active role in nutrient cycling and act as nurseries for ecologically and commercially important fish and shellfish species. Mangrove and other coastal ecosystems such as brackish lagoons, brackish herbaceous swamps, and swamp forests also provide habitat for a diversity of flora and fauna, including those with tourism value and potential, such as migratory shorebirds (WWF, 2016).

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7.0 ASSESSMENT OF POTENTIAL IMPACTS

This chapter of the EIA discusses direct, indirect, and induced impacts that could occur as a result of the Project. Sections 7.1 through 7.3 discuss impacts that are expected to occur due to planned Project activities. Section 7.4 discusses impacts that are not expected to occur, but could potentially occur due to unplanned events.

As described in Chapter 4, this impact assessment was performed using the methodology of the ERM Impact Assessment Standard. This methodology takes into consideration both the magnitude of an impact and the sensitivity/vulnerability/importance of the impacted resource/receptor to determine the significance of the impact (see Figure 7-1); the methodology is described in more detail in Chapter 4.

In Chapter 7, the potential impacts to resources/receptors are described. For each potential impact, the impact magnitude and resource/receptor sensitivity/vulnerability/importance are characterized and assigned ratings as noted in Figure 7-1. Once these ratings are assigned, the matrix is used to determine the impact significance.

Figure 7-1 is annotated to show an example of a potential impact (considering embedded controls that are part of the Project design, but not yet considering any proposed mitigation measures) that is assigned a magnitude of **Small** and for which the resource has been characterized as having a **Medium** sensitivity. The resulting impact significance (which is termed the "pre-mitigation significance" is therefore determined to be **Minor** (as shown by the dashed circle). If a mitigation measure were to be proposed such that it reduced the impact magnitude to **Negligible**, for example, the impact significance would be reduced to **Negligible** (as shown by the solid circle). As described in Chapter 4, positive impacts (i.e., benefits) are not assigned magnitude ratings and the impact significance is simply expressed as **Positive**.

Figure 7-1 Evaluation of Impact Significance

Impact Significance Matrix		**Sensitivity/Vulnerability/Importance of Resource/Receptor**		
		Low	**Medium**	**High**
Negative Impacts				
Magnitude of Impact	Negligible	Negligible	Negligible	Negligible
	Small	Negligible	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major
Positive Impacts				
Magnitude of Impact	NA	Positive	Positive	Positive

The impact assessment covers the Project stages described in Chapter 2 (i.e., drilling and installation, hook-up and commissioning, production operations, and decommissioning). The nature of activities comprising the hook-up and commissioning stage are such that all potential impacts associated with this stage are also associated with at least one other Project stage. Accordingly, this impact assessment focuses on potential impacts associated with the other three stages (drilling and installation, production operations, and decommissioning), and this effectively also addresses impacts associated with the hook-up and commissioning stage.

It is also noted that not all resources/receptors have potential impacts associated with every one of these three Project stages. Accordingly, there are instances where a particular Project stage is not discussed with respect to a resource/receptor.

7.1 Physical Resources

For the purposes of this EIA, "physical resources" are intended to include non-biological natural resources.

7.1.1 Air Quality and Climate

7.1.1.1 *Introduction*

This section addresses potential impacts on air quality due to emissions resulting from Project activities. Additionally, while potential climate impacts are more of a global concern from cumulative worldwide greenhouse gas (GHG) emissions, the section addresses potential impacts on climate from Project GHG emissions. The key potential impacts assessed include increases in ambient concentrations of pollutants as a result of stationary and mobile combustion sources associated with the Project, and GHG emissions from these same sources.

7.1.1.2 *Relevant Project Activities and Potential Impacts*

Emissions generated by the Project generally emanate from two source categories: a) specific *point sources* such as the power generating units and diesel engines on drill ships and on the FPSO, flares used (non-routinely) to combust produced gas when not consumed as fuel gas on the FPSO or injected back into the Liza reservoir, vents and onboard incineration of wastes; and b) general *area sources* such as support vessels, installation vessels, tug boats, and helicopters. Such emissions contribute to increases in the ambient air concentrations of certain pollutants. Depending on the magnitude and extent of the increases relative to the location of potential receptors onshore in Guyana, the increases may have the potential to contribute to health impacts. Because air quality for Project workers will be addressed through standard occupational exposure guidelines, the air quality impact assessment was limited in consideration to these potential onshore receptors. With respect to climate, the combustion of hydrocarbons in support of Project activities will generate GHG emissions. While the GHG emissions from the Project have been estimated with an acceptable level of confidence, the potential influence of those GHG emissions on global climate change is not measurable with an acceptable level of confidence and, therefore, is not addressed in this EIA.

Table 7-1 summarizes potential Project impacts on air quality and climate.

Table 7-1 Project Activities and Potential Impacts – Air Quality and Climate

Stage	Project Activity	Resource	Key Potential Impacts
Drilling and Installation	Operation of drill ships (power generation and engines), marine support and installation vessels, and support aircraft.	Ambient air quality (onshore population as receptors)	• Increased concentrations of pollutants in ambient air, potentially contributing to health impacts in onshore receptors.
		Climate	• Increased emissions of GHGs, potentially contributing to climate impacts* (more of a global concern).
Production Operations	Operation of FPSO (power generation and engines), marine support vessels, and support aircraft; temporary, non-routine flaring of gas when not re-injected.	Ambient air quality (onshore population as receptors)	• Increased concentrations of pollutants in ambient air, potentially contributing to health impacts in onshore receptors.
		Climate	• Increased emissions of GHGs, potentially contributing to climate impacts* (more of a global concern).

**Please see discussion in Section 7.1.1.2*

7.1.1.3 *Characterization of Impacts – Air Quality*

Magnitude of Impact – Air Quality

Project Emissions

Emissions to air from the Project have been estimated based on a number of factors including activity levels, fuel type, equipment capacities, and standard emission factors that are published by the USEPA in the publication *AP-42: Compilation of Air Pollutant Emission* Factors (AP-42). As described in AP-42, an emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., milligrams of NO_x emitted per cubic meter of natural gas combusted). The use of these factors allows estimation of emissions from various sources of air pollution. In most cases, these factors are averages of available data of an acceptable quality, and are generally assumed to be representative of long-term averages for a particular type of source.

Table 7-2 provides a summary of expected annual emissions from various Project activities for three time periods: 2018-2019 (development drilling, SURF installation and commissioning, and operation of related support vessels); 2020-2021 (drilling, FPSO startup and associated temporary, non-routine flaring, beginning of production operations, tanker loading); and 2022-2040 (production operations following cessation of drilling, including temporary, non-routine flaring, operation of support vessels, and tanker loading). For each of the time periods following 2019, the annual emissions summarized in Table 7-2 represent the maximum anticipated for any one year during that time period. While there are some differences in emissions for different

years within the time periods, they are relatively minor and the use of maximum emissions for the impact assessment provides a degree of conservatism in the results.

Table 7-2 Annual Air Emissions Summary

Pollutant	Source Category	Annual Emissions (Tonnes unless otherwise specified)		
		2018-2019	2020-2021	2022-2040
Nitrogen oxides (NO_x)				
	FPSO	0	1,635	1,545
	FPSO Flaring (temporary, non-routine)	0	375	175
	Tanker Loading	0	135	140
	Area Sources	2,385	1,125	1,125
	Drill ship	1,255	1,670	0
	Total	3,640	4,945	2,975
Sulfur dioxide (SO_2)				
	FPSO	0	45	50
	FPSO Flaring (temporary, non-routine)	0	0	5
	Tanker Loading	0	110	115
	Area Sources	85	40	40
	Drill Ship	45	60	0
	Total	130	250	205
Particulate matter (PM)				
	FPSO	0	45	35
	FPSO Flaring (temporary, non-routine)	0	15	5
	Tanker Loading	0	10	10
	Area Sources	170	80	80
	Drill Ship	90	120	0
	Total	260	210	130
Carbon monoxide (CO)				
	FPSO	0	425	405
	FPSO Flaring (temporary, non-routine)	0	2,030	940
	Tanker Loading	0	30	30
	Area Sources	500	235	235
	Drill ship	265	350	0
	Total	765	3,070	1,610

Pollutant	Source Category	Annual Emissions (Tonnes unless otherwise specified)		
		2018-2019	2020-2021	2022-2040
Other Pollutants				
Hydrogen Sulfide (H_2S)	FPSO Flaring (temporary, non-routine)	n/a	<1	<1
Volatile Organic Compounds (VOCs)	All Sources	95	10,250	10,720
Greenhouse Gases (GHGs [kilotonnes CO_2-equivalents])	All Sources	195	1,510	980

Notes:
1. The annual estimated totals generally reflect the current preliminary Project schedule (see Section 2.14), which could change.
2. VOC emissions are shown in this table but were not included in the impact assessment modeling, as no ambient air quality criteria have been established for these substances.
3. PM emissions represent total PM; for the purpose of the impact assessment, the total PM values were used for modeling of both PM_{10} and $PM_{2.5}$ emissions (producing conservatively high modeling results).
4. The emission rates in this table reflect annual totals. In some cases, the activities generating the emission are not continuous during the year, or do not operate at full capacity throughout the year. For these sources, the annual emissions estimates reflect this non-continuous operation over the year. However, for the purpose of modeling conducted to compare with short-term (up to 24-hour) guidelines, activities were assumed to be operating at full capacity for the simulated period, to reflect maximum short-term emission rates.

Ambient Air Quality Guidelines and Concentrations

Ambient air quality guidelines are concentration levels in air that are established by governing authorities to protect human health in locations where exposure can occur. These generally include a margin of safety to ensure that vulnerable individuals are also protected. Guyana has not established specific ambient air quality standards (AQSs); therefore, the guidelines used for reference in this assessment were those established by the World Health Organization (WHO). The WHO guidelines are summarized in Table 7-3. These guidelines were published in *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide - Global Update 2005* (WHO, 2005) except for CO and H_2S, which were published in WHO *A*ir *Q*uality *G*uidelines *for Europe, 2nd edition, 2000* (WHO, 2000).

Existing air quality is discussed in Section 6.1.1. A concentration value of 2.5 $\mu g/m^3$ for $PM_{2.5}$ (from a Yale University 2015 study) was identified for air quality onshore Guyana. No values were found in the literature for existing onshore air quality for the other substances modeled. However, Yale University (2016) published a report that ranked Guyana 6th (from the best) out of 180 countries in air quality. Accordingly, it was concluded that onshore Guyana is an *undegraded airshed* for the purpose of impact assessment process (see below).

Table 7-3 WHO Ambient Air Quality Guidelines

Pollutant	Averaging Period	Guideline Concentration (µg/m3)
NO_2	1-hour	200
	Annual	40
SO_2	10-minute	500
	24-hour	20
PM_{10}	24-hour	50
	Annual	20
$PM_{2.5}$	24-hour	25
	Annual	10
CO	1-hour	30,000
	8-hour	10,000
H_2S	30-minute	7

Air Quality Dispersion Modeling

Air dispersion modeling was carried out to assess air quality impacts for onshore human receptors. The key elements of the modeling are discussed below, including receptors, source inputs, model selection, and meteorological data.

Receptors: A grid of potential receptor points was established for onshore areas in the Project AOI. The intent of this grid was to identify maximum predicted pollutant concentrations generated by the Project across the onshore portion of the Project AOI. The methodology utilized was to predict maximum concentrations at all of the onshore grid points using the dispersion model, and then to compare these maximum values to concentrations that may potentially result in significant impacts; if the maximum predicted concentrations are determined to be not significant, it follows that air quality impacts on any specific receptors throughout the onshore Project AOI also would be not significant. For this reason specific locations of sensitive receptors were not identified at the onset of modeling.

Sources: With regard to source characteristics, point sources were modeled with fixed *stack parameters* including physical dimensions and exhaust characteristics. Flares were also modeled as stacks, with additional calculations applied to *adjust* the release height and stack parameter to account for increased thermal buoyancy associated with the high temperature of the flare. All of the emissions sources on the FPSO were conservatively modeled at a single location (representing the highest predicted ambient air concentration scenario). Area sources (without fixed locations) were modeled in a fashion to represent their transit across planned travel areas. For example, support vessels and helicopters were assumed to operate and generate emissions within the PDA and also to transit between the shore at Georgetown and the PDA. There is a potential that additional support vessels for some stages of the Project may transit between Trinidad and Tobago and the PDA; however, based on the low level of emissions contributed by support vessel/helicopter traffic, relative to emissions from sources in the PDA, and the expectation that most support vessel/helicopter traffic will originate from Guyana shorebase

facilities, modeling of support vessel area sources was limited to vessels transiting between Guyana and the PDA.

Figure 7-2 displays the modeling domain used in this analysis, showing the locations of the main Project point sources (the FPSO and Drill Centers DC1 and DC2), and of the area sources (including support vessels, helicopters, installation vessels, and other sources without a fixed location), as configured for the modeling. Terrain elevations used in the modeling are also depicted on this figure.

*Model Selection: T*he CALPUFF model (a non-steady-state model used in the U.S. and around the globe for long-range transport and complex wind modeling) was selected for use in the assessment. CALPUFF is a Lagrangian "puff" model that treats a plume as a series of puffs that it tracks as the wind carries the plume towards potential receptor locations. CALPUFF is also capable of modeling near-field impacts.

The selection of CALPUFF was based on the long distance between the principal Project-related sources and the receptors. As shown on Figure 7-2, the distance from the PDA to the closest shoreline is greater than 190 kilometers. At this distance, emission plumes released from Project point sources would travel for 10 hours, assuming an average wind speed of 5 meters/second (typical for the area). During this transport time winds can change direction and speed. Accordingly, prediction of plume dispersion is most appropriately accomplished with a non-steady state model.

Figure 7-2 Air Quality Modeling Domain



Meteorological Data: The Weather Research and Forecasting (WRF) model was used to develop hourly meteorology inputs for CALPUFF for one year – calendar year 2014. WRF is a prognostic meteorological model that creates profiles of winds and temperature at grid points across a domain. The grid spacing chosen for this analysis was 12 km, so that a two-dimensional profile of hourly winds and temperature was developed every 12 km within the domain shown on Figure 7-2. The profiles were used by CALPUFF to simulate the transport and dispersion of emission plumes from Project sources, allowing the model to calculate ambient constituent concentrations at potential receptor locations.

Predicted Ambient Air Concentrations

Using the methodology described above, modeling was conducted with CALPUFF to estimate maximum ambient concentrations of Project-generated constituents of interest at potential onshore receptor locations. Model results were developed for each modeled constituent, for each averaging period with an associated WHO guideline concentration (Table 7-3). Results are summarized in Table 7-4.

Table 7-4 Modeling Results Summary at Potential Onshore Receptor Locations

Pollutant	Averaging Period	Guideline Concentration (µg/m3)	Maximum Predicted Concentration (µg/m3)			Percent of WHO Guideline		
			2018-2019	2020-2021	2022-2040	2018-2019	2020-2021	2022-2040
NO_2	1-hour	200	1.3	2.1	1.5	0.6%	1.0%	0.7%
	Annual	40	0.1	0.2	0.1	0.3%	0.4%	0.2%
SO_2	10-minute	500	0.1	0.7	0.6	0.0%	0.1%	0.1%
	24-hour	20	0.0	0.2	0.2	0.1%	0.9%	0.9%
PM_{10}	24-hour	50	0.0	0.1	0.0	0.1%	0.1%	0.1%
	Annual	20	0.0	0.0	0.0	0.1%	0.1%	0.0%
$PM_{2.5}$	24-hour	25	0.0	0.1	0.0	0.2%	0.2%	0.1%
	Annual	10	0.0	0.0	0.0	0.1%	0.1%	0.0%
CO	1-hour	30,000	0.3	2.6	2.6	0.0%	0.0%	0.0%
	8-hour	10,000	0.3	1.5	1.4	0.0%	0.0%	0.0%
H_2S	30-minute	7	n/a	n/a	0.00002	n/a	n/a	0.0002%

The magnitude rating for air quality is determined on the basis of two factors:

- The increase in pollutant concentrations in air as a result of the Project (Project Contribution – "PC"); and
- The total air pollutant concentrations arising as a result of the PC added to the existing conditions (the Predicted Environmental Concentration – "PEC").

The PC and PEC are considered in the context of the relevant WHO air quality guidelines. Once the PC and PEC have been estimated, there are a number of approaches that may be used to determine the magnitude of impact. In jurisdictions such as Guyana that do not have specified approaches, the most commonly used is based upon guidance from the International Finance Corporation (IFC). This approach is set out below on Figure 7-3.

As shown in Table 7-4, for all the modeled constituents, the maximum onshore concentrations predicted to result from Project activities are negligible relative to WHO guidelines (all less than or equal to 1 percent of the AQS). Accordingly, a magnitude rating of **Negligible** was assigned for impacts on air quality.

Figure 7-3 Definitions for Magnitude Ratings for Potential Impacts on Air Quality

Magnitude of Impacts

	Undegraded Airshed (Baseline < AQS)	Degraded Airshed (Baseline >AQS)
Negligible	PC < 25% of AQS	PC <10% of AQS
Small	PC >25% of AQS, <50% of AQS, and PEC <100% of AQS	PC >10% of AQS, <15% of AQS
Medium	PC >25% of AQS, <50% of AQS, and PEC >100% of AQS; or PC >50% of AQS, <100% of AQS, and PEC <100% of AQS	PC >15% of AQS, <25% of AQS
Large	PC >50% of AQS, <100% of AQS, and PEC >100%; or PC >100% of AQS	PC >25% of AQS

Undegraded airshed = environmental conditions where no existing concentrations exceed a specific air quality guideline (coastal Guyana is considered an *undegraded airshed* based on the existing concentrations presented above).

Sensitivity of Resource – Air Quality

The standard approach taken assumes that the sensitivity for human health within the general population is 'Medium'. This is on the basis that, as air quality standards are set to protect the most vulnerable individuals in society, there is inherently a margin of safety within air quality standards. There are a small number of specific cases where the sensitivity may be defined as 'High'; these cases include where there are particularly vulnerable individuals (e.g., a hospital where there are intensive care wards and high-dependency wards where patients will be particularly sensitive to air pollution).

As such, the airshed at all potential onshore receptor locations would be either a **Medium** or a **High** sensitivity rating.

Impact Significance and Mitigation Measures – Air Quality

Based on the magnitude of impact and receptor sensitivity ratings, the significance of impacts on air quality for all receptors is **Negligible**. Based on this rating, no mitigation is recommended.

7.1.1.4 *Characterization of Impacts – Climate*

Table 7-5 summarizes the estimated annual GHG emissions for the Project throughout the projected Project lifecycle.

Table 7-5 Estimated Annual Project GHG Emissions

	Estimated Annual GHG Emissions in kilotonnes CO_2-equivalents		
	2018-2019	**2020-2021**	**2022-2040**
All Project Activities	195	1,510	980

Notes:
1. The annual estimated totals generally reflect the current preliminary Project schedule (see Section 2.14), which could change.

As potential climate impacts are more of a global concern from cumulative worldwide GHG emissions, as opposed to concern for a local airshed, modeling of GHG emissions is typically not performed as part of an EIA for a proposed project. Additionally, as there are no applicable regulatory criteria to which GHG emissions can be compared, this impact was not assigned magnitude and sensitivity ratings. However, EEPGL environmental performance monitoring and reporting management systems are in line with international good practice methods with respect to GHG management. EEPGL will quantify direct Project GHG emissions from the Project facilities and equipment utilized within the Project AOI. Quantification of GHG emissions will be conducted annually in accordance with internationally recognized methodologies and good practice.

7.1.1.5 *Summary of Impact Significance Ratings*

Table 7-6 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on air quality and climate, and the impact significance rating resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-6 Air Quality and Climate - Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource/ Receptor – Impact	Magnitude	Sensitivity	Pre-mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project stages	Ambient air quality – increased concentrations of pollutants in ambient air, potentially contributing to health impacts in onshore human receptors	Negligible	Medium or High (assumed)	Negligible	None	Negligible
All Project stages	Climate – increased GHG concentrations, potentially contributing to climate impacts	NR	NR	NR	(a)	NR

NR = not rated
(a) EEPGL will quantify and report GHG emissions to the EPA consistent with international guidelines.

7.1.2 Sound

As indicated in Section 6.1.2, the Project would not be expected to result in significant airborne sound impacts or ground-borne vibration impacts due to the distance between Project sound sources and onshore communities and receptors (the Stabroek Block is approximately 190 km offshore). The only airborne sound receptors will be workers onboard the FPSO, drill ships, and other Project-associated vessels. With respect to worker protection, EEPGL will utilize industry standard engineering and administrative controls for sound mitigation, and will monitor sound levels and provide appropriate hearing protection PPE for workers as needed. Therefore, the Project's potential impacts from airborne sound and ground-borne vibration were not assessed. Potential impacts from Project-related underwater sound are discussed with respect to potential marine life receptors (in Sections 7.2.5 and 7.2.7).

7.1.3 Marine Geology and Sediments

7.1.3.1 *Introduction*

This section describes the assessment of potential impacts on marine geology and sediments. The potential impacts assessed include changes to seafloor morphology from accumulation of discharged drill cuttings on the seafloor and changes to sediment quality from the residual hydrocarbon contained on the discharged drill cuttings.

During installation of the FPSO and SURF components, there would be some localized disturbance of sediments in a limited area; however, this impact would be negligible with respect to the seafloor morphology. Additional discussion regarding potential impacts on marine benthos from these activities is provided in Section 7.2.8, Marine Benthos. No impacts on marine geology and sediments would be expected as a result of activities associated with production operations or decommissioning.

7.1.3.2 *Relevant Project Activities and Potential Impacts*

The process of drilling the wells will produce drill cuttings that are discharged either directly to the seafloor (in open hole sections drilled riserless and with seawater) or from the drill ship into the ocean (in hole sections drilled with a riser) after treatment (i.e., solids control and centrifugal cuttings dryer system). The planned development drilling program and its cuttings management approach is consistent with industry practices and protective of the environment. For each well, approximately 2,600 bbl of cuttings for the open hole sections will be discharged to the sea without treatment per standard industry practice, as these sections are drilled using WBDF instead of NADF. For sections drilled with a riser, approximately 3,300 bbl of cuttings (per well) discharged from the drill ship into the ocean would first be treated to remove associated drilling fluids to acceptable discharge thresholds. EEPGL will utilize a cuttings dryer that incorporates a high-speed centrifuge to achieve high liquids/solids separation, reducing waste volumes. Planned discharges of drill cuttings and fluids will locally impact the marine sediment layer as a result of accumulation of cuttings on the seafloor. Cuttings will accumulate on the seafloor around the well locations, with the distribution of deposition determined by oceanographic conditions.

Table 7-7 summarizes potential Project impacts on marine geology and sediments.

Table 7-7 Project Activities and Potential Impacts – Marine Geology and Sediments

Stage	Project Activity	Key Potential Impacts
Drilling and Installation	Discharge of drill cuttings during drilling of wells, and resulting deposition of cuttings on the seafloor	• Changes to seafloor morphology from accumulated drill cuttings • Impacts on sediment quality from residual hydrocarbon on discharged cuttings
Production Operations Decommissioning	No planned Project activities associated with Production Operations or Decommissioning are expected to result in impacts to Marine Geology and Sediments	• None anticipated

7.1.3.3 *Characterization of Impacts*

Drill Cuttings Deposition Modeling

Modeling of the deposition of cuttings and fluids was performed using the Generalized Integrated Fate and Transport (GEMSS-GIFT) model. This three-dimensional, particle-based model uses Lagrangian algorithms in conjunction with currents, specified mass load rates, release times and locations, particle size distributions, settling velocities, and shear stress values to calculate the fate and transport of discharged drill cuttings. Model outputs provide estimates of the thickness of deposits on the seafloor, and the mass distribution of base hydrocarbon (adhered to the cuttings) across the seafloor.

Four scenarios were modeled, considering the drill centers with the shallowest and deepest water depths (DC1-I and DC2-I, respectively), each under two current conditions: the minimum and the maximum of the monthly-averaged and depth-averaged current speeds. These current speeds were derived from the SAT-OCEAN ocean circulation models. To provide a conservatively high estimate of the potential accumulation rate, modeling was conducted assuming cuttings from the open hole sections (containing WBDF) will be discharged at the seafloor (as noted above, these cuttings may alternatively be discharged from the drill ship prior to treatment).

Table 7-8 summarizes the results of the modeling for the four drill cuttings discharge scenarios. Releases deeper in the water column at DC2-I traveled less distance and therefore resulted in a smaller depositional footprint since the currents near the seafloor were slower than currents near the seafloor at DC1-I. Higher current velocities near the surface at DC1-I also contributed to a larger overall footprint size.

Table 7-8 Summary of Modeling Results for Drill Cuttings Discharge Scenarios

Scenario	Total Area (m^2) with Thickness >1 cm	Total Area (m^2) with Thickness > 5 cm
1a DC1-I (shallowest water depth); Min Currents	23,928	4,575
1b DC1-I; Max Currents	14,725	5,815
2a DC2-I (deepest water depth); Min Currents	3,801	1,442
2b DC2-I; Max Currents	4,056	1,590

Magnitude of Impact – Sediment Morphology

Modeling of cuttings discharge and deposition indicates the maximum depositional thickness of cuttings on the seafloor is predicted to be between 19 cm and 75 cm, depending on currents and well location. The cuttings for the initial open hole sections settle relatively close to the well, as they are discharged at the seafloor. In contrast the cuttings for the lower well sections are subjected to greater dispersion as they are distributed by the currents during their settling from near the sea surface. A literature-based deposition threshold of 5 cm per month (Ellis and Heim 1985; MarLIN 2011) was used to assess the extent of the area with the potential to impact benthic organisms via smothering (an indirect impact resulting from impacts on marine sediment morphology, further discussed in Section 7.2.8). This threshold represents the accumulation rate above which benthic organisms would be expected to be unable to overcome the rate of deposition and become smothered, thereby limiting their mobility and access to oxygen. Modeling predicts the extent of cuttings deposition above this threshold is confined to within a relatively short distance from the well location, with the largest modeled area predicted to be approximately 43 m in diameter. Deposition thicknesses decrease rapidly with increasing distance from the well. Although the 1 cm thickness does not represent an impact threshold, Table 7-8, also shows the predicted areal coverage of deposition above this level for each scenario.

While the above results are expressed in terms of total depositional thickness at completion of drilling of the well, it is appropriate to compare these total thicknesses to the deposition threshold (rate) of 5 cm per month. This is based on the fact that the modeling was conducted assuming a constant well completion rate that simulates even the deepest of the modeled wells being completed in approximately 21 days. In reality, it is likely there will be some pauses and delays during the drilling of a well, meaning the actual drilling duration likely will be greater than 21 days. Under the assumption that a subsequent well at a given drill center would not be started any sooner than 30 days after the start of the previous well at that drill center, the total depositional thicknesses therefore represent a conservatively high estimate of the average depositional rate across a full month.

In terms of a magnitude rating, the impact on sediment morphology was viewed in the context of the resources' overall functionality with respect to providing a habitat for benthic organisms. In this sense, the magnitude rating is expressed based on the fraction of the overall resource being impacted at any one time by the Project. Assuming no more than two drill ships could be drilling at any one time, the conservative approach is therefore to double the highest *total area* results from Table 7-8, to reflect the largest area predicted to be subjected to a cuttings deposition rate greater than 5 cm per month at any one time. This results in a predicted area of approximately 11,600 m^2 (~124,860 ft^2), which represents approximately 0.00004 percent of the area of the Stabroek Block. Further, as described above, the currents are expected to redistribute the cuttings away from their initial deposition sites over time, gradually reducing their thickness on the seafloor at these locations. Considering the extremely limited scale of impact relative to the overall sediment resource of the Stabroek Block, the magnitude of impact on sediment morphology from drill cutting deposition was rated as **Negligible**.

Sensitivity of Resource – Sediment Morphology

The sensitivity of the overall marine sediment resource to morphology impacts from drill cuttings deposition is considered **Low**, as unlike the mud banks offshore Guyana that are of critical ecological importance as feeding zones for birds, nursery areas for fish, and habitat for a variety of invertebrates, the deepwater sediments impacted by the drill cuttings discharge do not support high densities of marine species and are not unique.

A separate consideration was made for the mud banks offshore Guyana; they are of critical ecological importance as feeding zones for birds, nursery areas for fish, and habitat for a variety of invertebrates. Thus, they were assigned a sensitivity rating of **High**.

Impact Significance and Mitigation Measures – Sediment Morphology

Based on the magnitude of impact and receptor sensitivity ratings, the significance of impacts on sediment morphology is **Negligible**. Based on this rating, no mitigation is recommended.

With respect to the mud banks, as discussed in Section 6.1.3, these features exist within 40 km (approximately 25 mi) from the shore (i.e., on the order of approximately 160 km (~100 mi) from the drilling locations). Based on the results of modeling, the cuttings would not reach the mud banks; hence, the impact magnitude rating (specifically for the mud banks) is **Negligible**. Thus, despite the **High** sensitivity rating for the mud banks, the **Negligible** impact magnitude leads to a significance rating of **Negligible** for potential morphological impacts on the mud banks. Based on this rating, no mitigation is recommended.

Magnitude of Impact – Sediment Quality

The embedded controls in the Project design to reduce the impact of drilling discharges on sediment quality include: use of WBDF to the extent reasonably practicable (for drilling of initial open hole well sections), and use of IOGP Group III NABF in all other cases. WBDF contains no hydrocarbons and is less harmful to marine organisms; accordingly, no treatment of WBDF-based cuttings is required. When NADF is used, the discharge of treated cuttings will be controlled such that residual base fluid content on discharged cuttings will average 6.9 percent (wet weight).

The NABF to be used in the NADF by EEPGL will be IOGP Group III with low to negligible aromatic content, reducing the potential that changes in sediment quality as a result of discharge of the treated cuttings will lead to toxicological impacts on benthic fauna. While the magnitude rating assigned for sediment quality was not based on a quantitative calculation, as was the case for sediment morphology, the calculation presented for sediment morphology illustrates the extremely low proportion of the Stabroek Block impacted by drill cuttings deposition. For this reason, and considering the low-toxicity nature of the NADF, the magnitude of impact is considered **Negligible**.

Sensitivity of Resource – Sediment Quality

As in the case of impacts on sediment morphology from drill cuttings deposition, the sensitivity of the marine sediment resource to sediment quality impacts from drill cuttings deposition is considered **Low**, as unlike the mud banks offshore Guyana that are of critical ecological importance as feeding zones for birds, nursery areas for fish, and habitat for a variety of invertebrates, the deepwater sediments impacted by the drill cuttings discharge do not support high densities of marine species and are not unique.

Impact Significance and Mitigation Measures – Sediment Quality

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for sediment quality impacts. Based on this rating, no mitigation is recommended.

Summary of Impact Significance Ratings

Table 7-9 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on marine geology and sediments, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-9 Marine Geology and Sediments - Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation	Sediment morphology - from accumulated drill cuttings	Negligible	Low (drill centers) High (mud banks)	Negligible	None	Negligible
	Sediment quality - from residual NABF on deposited drill cuttings	Negligible	Low (drill centers) High (mud banks)	Negligible	None	Negligible

Stage	Resource Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Production Operations Decommissioning	None anticipated	---	---	---	None	---

7.1.4 Marine Water Quality

7.1.4.1 *Introduction*

This section describes the assessment of potential impacts on marine water quality. The potential impacts assessed include changes to marine water quality physico-chemical conditions as a result of the various effluent discharges associated with the Project. The following sub-sections describe the various discharges for which marine water quality impacts were assessed, the application of computational models for impact magnitude quantification, and a discussion of the impact assessment.

7.1.4.2 Relevant Project Activities and Potential Impacts

Planned discharges of drill cuttings and fluids may have a localized impact on marine water quality as a result of increased TSS concentrations in the water column. Cuttings and fluids released during jetting and drilling of the initial sections of the well will increase TSS concentrations around the well near the seafloor. Cuttings discharged from the drill ship will increase TSS concentrations in the photic zone (the more shallow level of the water column). These increases in TSS may clog fish gills or, in the photic zone, cause light inhibition for photosynthetic organisms.

During installation and commissioning of SURF equipment, hydrotesting fluids containing biocides, oxygen scavengers, and corrosion inhibitors, as well as hydrate inhibiting fluid (such as methanol or ethylene glycol) will be discharged to the sea, resulting in localized changes to water quality.

The FPSO will have several discharges related to its operation and maintenance during production operations. The impacts from these discharges include localized changes to water quality from effluent discharges during production operations, and localized changes to water temperature from discharge of cooling water effluent.

Table 7-10 summarizes potential Project impacts on marine water quality.

Table 7-10 Project Activities and Potential Impacts – Marine Water Quality

Resource/Receptor	Stage	Project Activity	Key Potential Impacts
Marine water quality (marine fauna as receptors)	Drilling and Installation	Discharge of drill cuttings, resulting in increased TSS concentrations in water column Liquid effluent discharges from drill ships and marine installation and support vessels (chemical substances) Discharge of hydrotesting fluids	• Increased TSS concentrations in water column, potentially contributing to health impacts on marine fauna • Increased chemical concentrations in water column, potentially contributing to health impacts on marine fauna
	Production Operations	Liquid effluent discharges from FPSO and marine support vessels (chemical substances, and elevated temperature streams)	• Increased chemical concentrations in water column, potentially contributing to health impacts on marine fauna • Increased temperature in water column, potentially leading to avoidance of the area by marine fauna
	Decommissioning	Liquid effluent discharges from marine support vessels (chemical substances)	• Increased chemical concentrations in water column, potentially contributing to health impacts on marine fauna

7.1.4.3 Characterization of Impacts – Increased TSS from Drill Cuttings Discharge

Magnitude of Impact – Increased TSS from Drill Cuttings Discharge

Modeling of the deposition of cuttings and fluids was performed using the Generalized Integrated Fate and Transport (GEMSS-GIFT) model. This three-dimensional particle-based model uses Lagrangian algorithms in conjunction with currents, specified mass load rates, release times and locations, particle sizes, settling velocities, and shear stress values to calculate the fate and transport of discharged drill cuttings. Model outputs provide estimates of the TSS concentrations resulting from the planned discharges.

Four scenarios were modeled, considering the shallowest and deepest water depths of the four drill centers (DC1-I and DC2-I, respectively), each under two current conditions: the minimum and the maximum of the monthly-averaged and depth-averaged current speeds. These current speeds were provided by the SAT-OCEAN ocean circulation model. As was assumed with drill cutting deposition modeling (Section 7.1.3), modeling of increases in TSS concentrations was

conducted assuming cuttings from the open hole sections (containing WBDF) will be discharged at the seafloor (as noted above, these cuttings may alternatively be discharged from the drill ship prior to treatment, per standard industry practice). This was confirmed to be a conservative assumption, as modeling indicated the highest predicted TSS concentration increases are associated with seafloor discharge (see results discussion below).

Modeling of cuttings discharge and deposition predicts the maximum TSS concentrations at the seafloor occurring during drilling of the initial sections of the well would be between approximately 4,323 micrograms per liter (mg/L) and 9,737 mg/L, depending on currents and well location. These concentrations correspond to only the initial sections of the well, where WBDF and cuttings are discharged directly from the casing. In contrast, modeling indicates the maximum TSS concentrations in the water column for subsequent sections of the well would be between approximately 1.6 mg/L and 5.3 mg/L, depending on currents and well location. These concentrations are much lower because drill cuttings and fluids from the subsequent well sections are treated on the drill ship to remove a substantial amount of the drilling fluid prior to discharge at the surface. Additionally, the discharges near the surface are also subjected to greater mixing from the higher current speeds at the shallower depths.

A TSS threshold of 35 mg/L, recommended by MARPOL (IMO, 2006), was used to assess the extent of the area with the potential to impact photosynthesis via a reduction in light penetration (an indirect impact resulting from increased TSS concentrations in the water column). Table 7-11 summarizes the results of the modeling for the four drill cuttings discharge scenarios.

Table 7-11 Summary of TSS Modeling Results for Drill Cuttings Discharge Scenarios

Scenario	Maximum TSS (mg/L) Surface/Seafloor	Area (km²) with TSS > 35 mg/L Threshold Surface/Seafloor
1a DC1-I (shallowest water depth), Min Currents	2.1 / 4,323	0 / 0.094
1b DC1-I, Max Currents	2.9 / 5,517	0 / 0.168
2a DC2-I (deepest water depth), Min Currents	1.6 / 5,260	0 / 0.091
2b DC2-I, Max Currents	5.3 / 9,737	0 / 0.088

Modeling predicts that TSS concentrations above the 35 mg/L threshold would occur during drilling of the initial well sections only, and these instances are confined to within a relatively small area around the well locations, near the seafloor where water depths are too great to allow photosynthesis. In the case of subsequent well sections, none of the maximum predicted TSS concentrations in the photic zone exceed the 35 mg/L threshold.

Even at the seafloor, the modeling indicates TSS concentrations would be reduced to below the threshold through settling and dispersion within approximately 1 hour of cessation of the half-day of jetting and drilling for the initial well section. Based on the limited area impacted and the short time period during which concentrations above the threshold are expected to persist, the

magnitude of impacts on marine water quality from TSS increases resulting from drill cuttings discharge was rated as **Negligible**.

Sensitivity of Resource – Increased TSS Concentrations from Drill Cuttings Discharge

The sensitivity of the marine environment to increased TSS concentrations is considered **Low**, as densities of receptors (e.g., fish and photosynthetic organisms) are expected to be low in zones affected by short-lived higher TSS concentrations. Furthermore, photosynthetic impacts are less relevant to the area near the seafloor, which is well below the photic zone.

Impact Significance and Mitigation Measures – Increased TSS from Drill Cuttings Discharge

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for marine water quality impacts from increased TSS concentrations during drilling. Based on this rating, no mitigation is recommended.

7.1.4.4 Characterization of Impacts – Changes to Water Quality and Temperature

Project-Related Discharges Impacting Water Quality and Temperature

The Project will include several discharges with the potential to impact water quality and temperature. These discharges, based on the preliminary design information, are listed in Table 7-12.

Table 7-12 Summary of Project-related Discharges

Type of Discharge and Effluent Characteristics	Expected Discharge Volume/Rate	Discharge Criteria	Treatment Required to Meet Criteria?
SURF & FPSO Installation / Commissioning Discharges			
Ballast Water (FPSO initial deballasting)	≤ 500,000 bbl total	1) Perform in accordance with IMO requirements 2) No visible oil sheen on receiving water	No
Hydrostatic Test Water • Biocide: ≤ 500 ppm • Oxygen scavenger ≤ 100 ppm • Corrosion inhibitor ≤ 100 ppm	25,000 bbl (total volume for all flowlines and risers, occurring throughout SURF commissioning phase)	No visible oil sheen on receiving water	No
Gas Injection Line Commissioning Fluids • Hydrate inhibitor (e.g. methanol or ethylene glycol)	400 bbl total	None	N/A

Production Discharges			
Produced Water • Oil & Grease • Residual production and water treatment chemicals	≤ 100,000 bpd	Oil in water content: 29 mg/L (monthly average); 42 mg/L (daily maximum)	Yes
Cooling Water • Hypochlorite: ≤ 5 ppm	≤ 700,000 bpd	No visible oil sheen on receiving water Temperature rise <3°C at 100 m from discharge	No
Sulfate Removal & Potable Water Processing Brines • Hypochlorite: ≤ 1 ppm • Electrolyte: ≤ 1 ppm • Biocide: ≤ 5 ppm • Oxygen Scavenger: ≤ 10 ppm • Scale Inhibitor: ≤ 5 ppm	≤ 100,000 bpd	None	N/A
Subsea Hydraulic Fluid Discharge • Water soluble, low-toxicity	≤ 5 bpd	None	N/A
FPSO Bilge Water	1,800 bpd	Oil in water content: <15 mg/L	Yes
Inert Gas Generator Cooling Water	Negligible	None	N/A
FPSO Slop Tank Water	Negligible	Oil in water content: 29 mg/L (monthly average); 42 mg/L (daily maximum)	Yes
Miscellaneous Discharges including Boiler Blowdown, Desalinization Blowdown, Lab Sink Drainage	<10 bpd	None	N/A
Tanker Ballast Water	1,100,000 bbl total (at each tanker crude loading)	1) Perform in accordance with IMO requirements 2) No visible oil sheen on receiving water	No
BOP System Testing Water-Soluble Low Toxicity Hydraulic Fluid	30 bbl every two weeks	None	N/A
Rain Water/Deck Drainage/Wash Down Water	Rainfall dependent	No visible oil sheen on receiving water	N/A
Gray Water	5,000 bpd	None	N/A

Black Water (sewage)	4,000 bpd	Total residual chlorine as low as practical but not less than 1 ppm	Yes
Food Preparation Wastes	<30 bpd	Macerated to <25 mm diameter	Yes

Notes:
bbl = barrels
bpd = barrels per day

Based on the above estimated discharge rates, cooling water, produced water, and brines from the Sulfate Removal Unit (SRU) and freshwater Reverse Osmosis (RO) system (all associated with the production operations stage) are the operational discharges that were the focus of modeling to assess the nature and extent of associated marine water quality impacts. Additionally, although the discharge of hydrotest water and commissioning fluids will occur over only a short time period during the installation and SURF commissioning stage, they were also included in the offshore discharge modeling as a conservative measure. Potential impacts from the other effluent discharges listed above were considered to be of **Negligible** significance. There may be localized toxic effects on fish, crustacean, plankton, and benthos from chemicals in the low volume of subsea hydraulic fluid discharge, but the chemicals used will be of low toxicity and will dilute and disperse rapidly. The constituents modeled for each of these discharges are listed in Table 7-13. The constituents are associated with potential indirect impacts on marine aquatic life, as indicated in the table.

The cooling water discharge is the return flow associated with a routine operational process used to cool selected machinery onboard the FPSO. The cooling water discharge will have an elevated temperature (relative to the marine environment water temperature) and will contain a limited amount of hypochlorite (generated from seawater and added as an anti-biofouling agent). Aquatic species may be indirectly impacted by the elevated temperature and residual chlorine in the discharge. Elevated temperatures may result in avoidance of the discharge area by aquatic species. Residual chlorine may interact with naturally occurring organic matter, resulting in chlorinated by-products with the potential to result in indirect toxicity impacts on aquatic species. There are no regulatory limits for residual chlorine in marine discharges in Guyana. Residual chlorine toxicity depends not only on doseage (concentration and exposure time), but also on individual species' sensitivity. This makes defining a single impact threshold for residual chlorine exposure difficult.

Table 7-13 Summary of Discharges and Modeled Constituents for Installation and Production Operations

Discharge	Modeled Constituents	Potential Indirect Impacts on Marine Aquatic Life
Cooling Water	• Temperature • Residual Chlorine	Temperature increase and associated impacts on marine species. Increased residual chlorine concentrations and associated toxicity impacts on marine species.
Produced Water	• Oil & Grease (O&G) • Residual production and water treatment chemicals (e.g., scale and corrosion inhibitors)	Increased concentrations of O&G, production chemicals, and associated toxicity impacts on marine species.
Sulfate Removal and Potable Water Processing Brines	• Hypochlorite • Electrolyte • Biocide • Oxygen Scavenger • Scale Inhibitor	Increased chemical concentrations and associated toxicity impacts on marine species.
Hydrotest Water	• Biocides • Oxygen Scavenger • Corrosion Inhibitor	Increased chemical concentrations and associated toxicity impacts on marine species.
Gas Injection Line Commissioning Fluid	• Hydrate inhibitor (e.g., methanol or monoethylene glycol)	Increased concentrations of hydrate inhibitor and associated toxicity impacts on marine species.

Discharge of produced water containing O&G and residual quantities of certain production and water treatment chemicals can result in locally increased concentrations of chemical constituents in the marine environment. Depending on the specific constituent concentrations in these discharges, some aquatic species may experience indirect toxicity impacts from these constituents.

Hydrotest water discharges may contain biocides, oxygen scavengers, and corrosion inhibitors, which can result in locally increased concentrations of chemical constituents and associated potential for indirect toxicity impacts on aquatic species. The hydrotest discharge, hydrate inhibitor discharge, and initial FPSO ballast discharge will occur only during a limited time period during SURF installation and commissioning activities, unlike the discharge of cooling water, produced water, and wastewater, all of which will occur continuously during production operations.

Magnitude of Impacts – Changes to Water Quality and Temperature

The model used to predict the nature and extent of discharge plumes from the various discharges was USEPA's CORMIX dilution model. CORMIX is a design tool routinely used by regulatory agencies to estimate mixing zones resulting from water discharges. Understanding the mixing characteristics of the various discharges and assessing impacts requires understanding the properties of the discharged effluent (e.g., temperature), the properties of the receiving (ambient) water, and the method by which the discharge stream enters the ambient water (e.g., pipe, diffusers). Collectively, these factors control the near-field mixing and dilution of the discharge.

Discharge velocity, an important determinant of the mixing characteristics of a discharge, is directly related to the discharge pipe diameter. At a given discharge flow rate, smaller pipe diameters result in higher exit velocities, which facilitate increased mixing. However, engineering constraints may limit the degree to which the pipe diameter can be reduced. As the design for the Project has not been finalized, conservative assumptions were used for the modeled pipe diameter. Pipe diameters that are smaller than those considered in the modeling will result in increased mixing (and reduced concentrations at the edge of mixing zone).

For the receiving environment, the ambient currents selected for modeling consisted of *bounding* cases (5th and 95th percentile for the range of current velocities identified) as well as a *typical* case (50th percentile for the range of current velocities identified). Ambient temperatures selected for modeling also consisted of *bounding* cases (1st and 99th percentiles) and a *typical* case (50th percentile).

The modeling of potential impacts from these discharges found that even under the most conservative bounding case for each discharge modeling scenario, the discharges were subject to rapid mixing and consequently experienced substantial reductions in constituent concentrations within a relatively small distance from the point of discharge.

Guyana has not established a specific thermal discharge limit; therefore, 3°C maximum temperature rise at a distance of 100 m from the discharge point was used as a reference point for cooling water discharge, consistent with recognized international benchmarks and a level appropriately protective of the marine environment. Table 7-14 summarizes the results of the modeling study of discharges for the most conservative bounding cases, including percent reduction in constituent concentrations at the 100 m reference distance. International standards and guidelines and established regulatory requirements provide appropriate benchmarks for O&G content in produced water, and MARPOL specifies limits on O&G in bilge water. There are no prescribed limits for the constituents contained in the other discharge streams.

Table 7-14 Summary of Modeling Results for Most Conservative Bounding Case (predictions at 100 m reference distance)

Discharge Scenario	Most Conservative Bounding Case Conditions	Modeled Parameters/ Constituents	Modeled Results at 100 m
Cooling Water (Thermal)	Minimum ambient temperature, maximum ambient current	Temperature Rise[21]	Ambient temperature rise <3°C
Cooling Water (Residual Chlorine)	Minimum ambient temperature, maximum ambient current	Residual Chlorine	89% reduction
Produced Water	Maximum ambient current	O&G[22] Residual production chemicals	92% reduction
Sulfate Removal & Potable Water Processing Brines	Maximum ambient current	Hypochlorite Electrolytes Biocide Oxygen Scavenger Scale Inhibitor	98% reduction
Hydrotest Water	Minimum ambient current	Biocide Oxygen Scavenger Corrosion Inhibitor	99% reduction
Hydrate Inhibitor (Gas Injection Line Commissioning Fluid)	Minimum ambient current (ethylene glycol); high ambient current (methanol)	Hydrate inhibitor (either methanol or ethylene glycol)	Concentration reduces to <32% of published No Observed Effect Concentrations (NOECs) under worst-case discharge conditions

In terms of impacts on marine water quality from hydrotesting and production operations, Table 7-15 summarizes the assigned magnitude ratings based on consideration of the extent of impact and concentrations relative to the marine aquatic life thresholds identified.

[21] Design specification for the cooling water discharge port were not finalized at the time of the EIA; modeling was conducted to determine the combinations of discharge port diameters and discharge depths that would result in a temperature rise less than 3°C at the edge of the 100m mixing zone.
[22] Discharges will adhere to a limit of 42 mg/L oil & grease (daily maximum) and 29 mg/L (monthly average) at the point of discharge (consistent with recognized international benchmarks and appropriately protective of the PDA marine environment).

Table 7-15 Magnitude Ratings for Modeled Hydrotesting and Production Operations Discharges

Discharge	Impact Magnitude Rating	Rationale for Magnitude Rating
Cooling Water	Small	Modeling indicates the temperature differential in the water column will reduce to no greater than the reference temperature within the recommended 100 meter mixing zone. At this same distance, chlorine concentrations are predicted to decrease by 89 percent.
Produced Water	Negligible	At the 100 meter reference distance, O&G, and residual production and water treatment chemicals are predicted to decrease by 92 percent.
Sulfate Removal & Potable Water Processing Brines	Negligible	At the 100 meter reference distance, hypochlorite, electrolyte, biocide, oxygen scavenger and scale inhibitor concentrations are predicted to decrease by 98 percent.
Hydrotest Water	Negligible	At the 100 meter reference distance, biocide, oxygen scavenger and corrosion inhibitor concentrations are predicted to decrease by 99 to 99.5 percent, depending on pipe diameter. In addition to the minimal size of the plume, the release is temporary (approximately 60 minutes or less).
Hydrate Inhibitor (Gas Injection Line Commissioning Fluid)	Negligible	At the 100 meter reference distance, hydrate control fluid (methanol or monoethylene glycol) is predicted to decrease by 99.6 to 99.9 percent, depending on the fluid selected. In addition to the minimal size of the plume, the release is temporary (matter of hours).

Considering the information presented above, the magnitude of quality and temperature impacts on marine water quality was rated as **Negligible**.

Sensitivity of Resource – Changes to Water Quality and Temperature

The sensitivity of the marine environment to elevated constituent concentrations and increased temperature is considered **Low**, as the marine fauna (used as representative receptors) would not be sensitive to chemical constituent concentrations or temperatures at the modeled levels; furthermore, species would only be expected to be present in the area of discharge for a limited time.

Impact Significance/Mitigation Measures – Changes to Water Quality and Temperature

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for marine water quality impacts. Based on this rating, no mitigation is recommended.

7.1.4.5 Summary of Impact Significance Ratings

Table 7-16 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on marine water quality, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-16 Marine Water Quality - Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation	Increased TSS concentrations	Negligible	Low	Negligible	None	Negligible
Drilling and Installation Production Operations	Water quality and temperature changes	Negligible	Low	Negligible	None	Negligible
Decommissioning	Water quality changes	Negligible	Low	Negligible	None	Negligible

7.2 Biological Resources

For the purposes of this EIA, "biological resources" is intended to include flora, fauna, and the habitats on which they depend.

7.2.1 Protected Areas and Special Status Species

This section describes the assessment of potential impacts on protected areas and special status species.

7.2.1.1 Protected Areas

Planned activities of the Project and associated air emissions, effluent discharges, and sound generation, which will occur approximately 190 km (~120 mi) offshore, will not impact Shell Beach Protected Area (SBPA), which is Guyana's only designated protected area within the Project AOI. The Project's only potential impacts on SBPA would be as a result of an unplanned event, which is discussed in Section 7.4.

7.2.1.2 Special Status Species

Relevant Project Activities and Potential Impacts

Project-related impacts on special status species can be considered a subset of the biological resource impacts; however, potential impacts on special status species require special consideration because these species are assumed to have a diminished capacity to recover due to their conservation status. A list of species occurring in Guyana and their conservation status is provided in Appendix H.

As all of the marine turtles occurring in Guyana's waters carry a ranking of Critically Endangered, Endangered, or Vulnerable, the assessment of potential impacts to marine turtles (Section 7.2.6) effectively covers the assessment of potential impacts to special status marine turtles. One of the marine mammals species observed in the PDA carries a Vulnerable status. Accordingly, the assessment of potential impacts to marine mammals (section 7.2.5) effectively covers the assessment of potential impacts to marine mammals. For these reasons, marine turtles and marine mammals are not discussed in this section on special status species.

With respect to fishes, four Critically Endangered species (Atlantic goliath grouper, daggernose shark, Caribbean electric ray, and largetooth sawfish) and six Endangered species (Nassau grouper, golden tilefish, whale shark, squat-headed hammerhead, scalloped hammerhead, and Atlantic bluefin tuna) have the potential to occur in the nearshore and offshore areas of Guyana. All have been listed as Critically Endangered or Endangered due to a combination of fishing mortality (both as target species or bycatch), habitat loss, slow maturation rates, and low fecundity. For the Critically Endangered fish species (all estuarine and nearshore fish species), habitat loss is an important driver, whereas for the Endangered fish species (fish distributed farther offshore), habitat loss is a much less important driver than fishing-related mortality.

As the Critically Endangered fish species are estuarine and nearshore species, the planned activities of the Project will not directly impact habitat for these species. As the Endangered fishes are distributed farther offshore, they will have the potential to encounter the Project marine vessels; however, the Project will not permanently alter habitat conditions for these species. The Project will not impact fishing-related mortality rates for any fish species. Furthermore, the Project will not impact any of the underlying causes for these species' declines across their ranges as cited by the IUCN.

Giant otter (*Pteronura brasiliensis*) is also listed as Endangered. Giant otters are Endangered due to a combination of the legacy impacts of historically widespread hunting and present-day destruction of riparian tropical forests, especially along large interior rivers (IUCN, 2014). The Project will not impact giant otter habitat, nor will it impact the species' capacity to recover or rate of recovery from legacy impacts.

Vulnerable species (other than whales and turtles) include a mix of elasmobranchs (sharks and their relatives), marine mammals (West Indian manatee), fish (groupers and snappers), and the Agami heron (*Agamia agami*). Deforestation, hunting, and use of pesticides are the primary factors for the Agami heron's Vulnerable status (BirdLife International, 2012b). Numerous factors including habitat loss have been implicated in the declines of fish, and the manatee. The Near Threatened category comprises fishes (almost entirely of elasmobranchs), the neotropical otter (*Lontra longicaudis*), and the semipalmated sandpiper (*Calidris pusilla*). The elasmobranchs and bony fishes in both categories are listed primarily due to overfishing, slow maturation rates, and low fecundity. The neotropical otter is Near Threatened due to a combination of habitat destruction and local conflicts with fishermen, and is also sensitive to chemical and organic pollution (Rheingantz, 2015). Deforestation, hunting, and use of pesticides are the primary factors for the semipalmated sandpiper's Near Threatened status (BirdLife

International, 2012c). Overfishing is the primary factor implicated in the status of the Near Threatened bony fish (groupers, snappers, and tunas).

The Project will be located within offshore habitat for several of these Vulnerable and Near Threatened species and near inshore habitats, but will not alter the value of the habitats or the capacity of these habitats to support these species. The Project will not affect rates of coastal habitat loss/recovery, hunting, or residual pesticide concentrations in the Agami heron's or neotropical otter's habitat, so it will not affect these species' capacity to recover from these impacts. The combination of overfishing, slow maturation rates, and low fecundity contribute to long recovery times for listed fishes, but the Project will have no effect on these species capacity to recover.

Characterization of Impacts

Tables 7-17 and 7-18 provide the definitions used to assign impact magnitude and receptor sensitivity ratings for special status species (the same rating definitions are employed for marine turtles and marine mammals in their respective sections).

Table 7-17 Definitions for Magnitude Ratings for Special Status Species

Criterion	Definition
Magnitude	Negligible: Impact is within the normal range of variation for the population of the species.
	Small: Impact does not cause a substantial change in the population of the species, or other species dependent on it.
	Medium: Impact causes a substantial change in abundance and/or reduction in distribution of a population over one or more generations, but does not threaten the long term viability/function of that population, or any population dependent on it.
	Large: Impacts entire population, or a significant part of it causing a substantial decline in abundance and/or change in and recovery of the population (or another dependent on it) is not possible either at all, or within several generations due to natural recruitment (reproduction, immigration from unaffected areas).

Table 7-18 Definitions for Receptor Sensitivity Ratings for Special Status Species

Criterion	Definition
Sensitivity	Negligible: Species with no specific value or importance attached to them.
	Low: Species and sub-species of Least Concern on the IUCN Red List (or not meeting criteria for medium or high value), or without specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts.
	Medium: Species listed as Vulnerable, Near Threatened, or Data Deficient on the IUCN Red List, species protected under national legislation, nationally restricted range species, nationally important numbers of migratory or congregatory species, species not meeting criteria for high value, and species vital to the survival of a medium value species.
	High: Species on IUCN Red List as Critically Endangered or Endangered. Species having a globally restricted range (i.e., endemic species to a site, or found globally at fewer than 10 sites, fauna having a distribution range less than 50,000 km^2, internationally important numbers of migratory or congregatory species, key evolutionary species, and species vital to the survival of high value species.

For the marine fish species addressed in this section, the starting assumption was that the same impact magnitude ratings used for potential impacts to marine fish in general (section 7.2.7) are applicable for special status marine fish. However, additional considerations were applied to the specific special status species to assess whether these magnitude ratings are appropriate. Based on these additional considerations, magnitudes for the various special status marine fish categories were assigned as follows:

- Critically Endangered:
    - These species are all nearshore species, and thus will not be subject to the same level of potential interactions with planned Project activities that form the basis for the various potential impacts to marine fish in general. Accordingly, a magnitude of **Negligible** was assigned.
- Endangered:
    - While Nassau grouper is listed as occurring in Guyana waters, this species is primarily a coral reef species. The PDA does not include coral reefs and this species is thus not likely to be present – resulting in a magnitude rating of **Negligible**.
    - With the exception of golden tilefish, the other species are pelagic species that are not prone to congregating around offshore structures; accordingly, potential impacts that are predicated on marine fish occupying areas around Project vessels (i.e, those impacts related to marine discharges, vessel sound, attraction by light, and entrainment by seawater intake) are less of a concern than for other marine fish in general. Further, related to bottom habitat disturbance and VSP or pile driving sound, impacts are not a concern for pelagic species. Golden tilefish are known to prefer clay substrates and would not be expected to congregate over the mud substrate that dominates the PDA. For this reason, the potential impacts listed in Section 7.2.7 are all assigned a magnitude rating of **Negligible** for Endangered fish species.
    - As described above, the Project will not impact giant otter habitat, nor will it impact the species' capacity to recover from legacy impacts, resulting in a magnitude rating of **Negligible**.
- Vulnerable:
    - While the same logic applies for some of the Vulnerable fish species as for the Endangered species described above, some other Vulnerable species are likely to have similar behavioral characteristics as the marine fish in general; accordingly, as a conservative measure, the magnitude ratings from Section 7.2.7 were applied (**Small** for several potential impacts).
    - The Agami heron is a coastal species unlikely to be subject to significant interaction with Project activities, resulting in a **Negligible** impact magnitude.

- Near Threatened:
    - The same approach was used for Near Threatened fish species as for Vulnerable fish species (i.e., a magnitude of **Small** was assumed, consistent with marine fish in general).
    - The neotropical otter and semi-palmated sandpiper, are coastal species unlikely to be subject to significant interaction with Project activities, resulting in a **Negligible** impact magnitude.

Considering the information above, Table 7-19 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on special status species, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-19 Special Status Species - Pre-Mitigation and Residual Impact Significance Ratings

Group	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Atlantic goliath grouper, daggernose shark, Caribbean electric ray, and largetooth sawfish (Critically Endangered)	Negligible	High	Negligible	None	Negligible
Nassau grouper, golden tilefish, whale shark, squat-headed hammerhead, scalloped hammerhead, and Atlantic bluefin tuna (Endangered)	Negligible	High	Negligible	None	Negligible
Giant otter (Endangered)	Negligible	High	Negligible	None	Negligible
Several elasmobranchs (sharks and their relatives), fish (Vulnerable).	Small	Medium	Minor	None	Minor
Agami heron (Vulnerable)	Negligible	Medium	Negligible	None	Negligible
Several fishes (almost entirely elasmobranchs), (Near Threatened)	Small	Medium	Minor	None	Minor
Neotropical otter, semipalmated sandpiper (Near Threatened)	Negligible	Medium	Negligible	None	Negligible

Table 7-19 Special Status Species - Pre-Mitigation and Residual Impact Significance Ratings

Group	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Atlantic goliath grouper, daggernose shark, Caribbean electric ray, and largetooth sawfish (Critically Endangered)	Negligible	High	Negligible	None	Negligible
Nassau grouper, golden tilefish, whale shark, squat-headed hammerhead, scalloped hammerhead, and Atlantic bluefin tuna (Endangered)	Negligible	High	Negligible	None	Negligible
Giant otter (Endangered)	Negligible	High	Negligible	None	Negligible
Several elasmobranchs (sharks and their relatives), fish (Vulnerable).	Small	Medium	Minor	None	Minor
Agami heron (Vulnerable)	Negligible	Medium	Negligible	None	Negligible
Several fishes (almost entirely elasmobranchs), (Near Threatened)	Small	Medium	Minor	None	Minor
Neotropical otter, semipalmated sandpiper (Near Threatened)	Negligible	Medium	Negligible	None	Negligible

7.2.2 Coastal Habitats

The planned Project activities and associated air emissions, effluent discharges, and sound generation, which will occur approximately 190 km (~120 mi) offshore, will not impact any coastal habitats. Operation of the Guyana shorebase(s) will have little to no impact on coastal habitat. The shorebase(s) are expected to be located in existing developed areas. The Project's only potential impact on coastal habitats would be as a result of an unplanned event, which is discussed in Section 7.4.

7.2.3 Coastal Wildlife and Shorebirds

The planned Project activities will not impact any coastal wildlife or shorebirds. The Project will not involve any direct disturbance of these species and their habitats, and the Project's air emissions, water discharges, and sound generation, which will occur approximately 190 km (~120 mi) offshore, will not impact these species. The use of the Guyana shorebase(s) will have little to no impact on coastal species, other than common generalist species that are adapted to living in developed areas. The shorebase(s) are expected to be located in existing developed areas. The Project's only potential impact on coastal wildlife and shorebirds would be as a result of an unplanned event, which is discussed in Section 7.4.

7.2.4 Seabirds

7.2.4.1 *Introduction*

This section discusses potential impacts on seabirds from planned Project activities. Thirty seabird species have been documented in Guyana's offshore waters, including the area in and around the PDA. Several resident seabird species occur in the area throughout the year and migratory seabirds typically occur in the area starting late summer, with many remaining through winter. When seabirds are not breeding, they primarily live in offshore environments, moving with prey resources and roosting and loafing on islands or artificial structures in the ocean or simply rafting[23] on the ocean surface. The presence of seabirds in a given area is heavily resource-driven, with individuals and groups of seabirds primarily attracted to prey concentrations. No evidence suggests that large concentrations of seabird prey (primarily fish) consistently occur in the PDA that would promote regular use by foraging seabirds. Rather, seabirds in the area are likely transients, moving opportunistically with schools of fish and other prey. The turbid conditions in the PDA further reduce the likelihood that the area has significant importance for foraging seabirds. Further, no islands or artificial structures occur in the PDA, so the area does not contain any known roosting or loafing areas where large numbers of seabirds might congregate. As such, it is expected that seabirds occur in the PDA throughout the year, but at a low density and for short (transient) periods depending on prey availability.

7.2.4.2 *Relevant Project Activities and Potential Impacts*

Table 7-20 summarizes the potential impacts of planned Project activities on seabirds.

[23] Rafting is a common seabird behavior involving a tight aggregation of seabirds floating on the ocean surface to form a "raft."

Table 7-20 Project Activities and Potential Impacts – Seabirds

Stage	Project Activity	Key Potential Impact
Drilling and Installation	Presence of drill ships and installation vessels	• Physical presence of drill ships and installation vessels (with lighting), potentially acting as an attractant to seabirds, exposing them to collision risks, additional energy expenditure, and compromised navigation for night-migrating birds. • Vessels may be of benefit to some species that use the vessel for rest or shelter during long flights or adverse weather.
	Operation of supply and support vessels	• Strike-related injury or mortality, particularly with rafting seabirds. • Light and sound disturbance leading to attraction to or avoidance of the exposed area.
	Discharge of drill cuttings	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Discharge of wastewater effluents	
	Marine aviation	• Bird strike by helicopters.
Production Operations	Presence of FPSO	• Physical presence of FPSO (with lighting), potentially acting as an attractant to seabirds, exposing them to collision risks, additional energy expenditure, and compromised navigation for night-migrating birds. • Structures may be of benefit to some species that use the structure for rest or shelter during long flights or adverse weather.
	Discharge of cooling water and produced water	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Discharge of wastewater effluents	
	Operation of supply and support vessels	• Strike-related injury and mortality, lighting, disturbance.
	Non-routine flaring	• Mortality or injury from bird exposure to radiant heat from the flare.
	Marine aviation	• Bird strike by helicopters.
Decommissioning	Decommissioning activities PDA and related vessel traffic	• Ship and helicopter strike-related injury or mortality. • Light and sound disturbance from decommissioning activities leading to attraction to or avoidance of the exposed area. • Removal of a reliable food source if the FPSO acts as an attractant for seabird prey.

Potential impacts from seabird exposure to discharge of drill cuttings, produced water, and other wastewater effluents are expected to be negligible because the effluents are not highly toxic, the discharges would rapidly mix with ambient water, and the numbers of seabirds potentially exposed to the effluents is expected to be low. Sections 7.1.3 and 7.1.4 provide further analysis of the impacts of these discharges on marine sediment and water quality, respectively. While individual seabirds could be significantly impacted through contact with the flare structure, its flame, or its radiant heat plume, the likelihood of a seabird being present in the heat zone when temporary, non-routine flaring is occurring is extremely low. Accordingly, the assessment of potential impacts on seabirds is focused on: a) direct mortality and injury of seabirds related to attraction to offshore Project facilities; and b) direct mortality and injury related to vessel (ship or air) strikes.

Potential benefits from the Project to seabirds are use of the FPSO, drill ship, and installation vessels for rest or shelter during adverse weather conditions and, if such vessels acts as consistent attractants for seabird prey, providing a reliable food resource for seabirds. However, this is not expected to be a significant benefit to seabirds at the population level, and is not discussed further herein.

7.2.4.3 *Characterization of Impacts – Direct Mortality and Injury Related to Attraction to Offshore Project Facilities*

Magnitude of Impact – Direct Mortality and Injury Related to Attraction to Offshore Project Facilities

Seabirds are known to aggregate around large offshore installations such as drill ships and can be present in above-average numbers due to artificially increased food concentrations, lighting, and attraction to the structure itself for roosting (Weise et al., 2001). The impacts of attraction and aggregation by seabirds around an offshore facility can be both positive and negative and can vary considerably by species and, more specifically, a species' typical behavior and the type and length of use of the impacted area. The structure may be beneficial to seabirds by providing a resting place or shelter during feeding, migration, or adverse weather in areas where these places would otherwise not be found.

The negative impacts of seabird attraction to offshore facilities primarily relate to lighting. The drill ships, installation vessels, and FPSO will operate 24 hours a day, so at night time there will be a considerable source of artificial light in an otherwise dark environment. Lights on offshore oil platforms and other installations are known to act as an attractant to seabirds and typical offshore installation lighting extends roughly 3 to 5 km (2 to 3 mi) around the source (Weise et al., 2001). Poor weather, such as fog, precipitation, and low cloud cover can exacerbate the impact of nocturnal attraction to lights, especially when coincidental with bird migrations (Ronconi et al., 2015).

Lighting on offshore facilities can be disorienting to night migrating birds, particularly waterfowl, which migrate using stellar cues that can be obscured by lights (Gaston et al., 2013). Birds lose their stellar cues for nocturnal navigation under low cloud ceiling or other adverse weather conditions, and in these circumstances artificial lights become the strongest cues that birds have for navigation. As a result, they are attracted to the lights and will fly around them for extended periods, a phenomenon which is referred to in the scientific literature as the "trapping effect" or "light circling." The time individual birds spend circling ranges from a few minutes to several hours to days, with an average of around 15 minutes (Marquenie, 2007). The consequences of this may be: 1) energy wasted circling the installation, which can be problematic for individual birds undergoing long migrations; 2) collision with the structure or other birds resulting in mortality or injury, which can cause individual birds to remain on the structure for long periods where there is no drinking water; 3) increased exposure to Project facilities and activities from the attraction to the area and potential exposure to radiant heat from flaring events, which can cause injury or death; and 4) increased risk of predation due to weakness, disorientation, or injury following long periods of circling or collision with a Project structure (Baird, 1990; Ronconi et al.., 2015; Platteeuw and Henkens, 1997; Deda et al., 2007).

As an embedded control to manage lighting-related impacts from the Project, lighting on the FPSO and major vessels will be directed, where practicable, to required operational areas rather than at the sea surface or skyward. This will reduce the intensity and locations of lighting that seabirds may be exposed to by the Project. Further, the Project area is not located within a major seabird migratory flyway, nor is it known to support large numbers of seabirds; accordingly, the number of individuals that could be impacted by the potential impacts described above is expected to be small, meaning the Project would not impact any seabird species at the population level. As such, the overall magnitude of the impacts from seabirds being attracted to Project facilities is considered to be **Small**.

Sensitivity of Receptor – Direct Mortality and Injury Related to Attraction to Offshore Project Facilities

Seabirds are expected to occur in the PDA throughout the year but at low densities and primarily as transients moving with prey resources. All of the 30 species of seabirds known to occur in the area are listed on the IUCN Red List as Least Concern. Several impact exposure events are likely to occur for seabirds; however, taking into account their conservation status and that only a few individuals are likely to be impacted rather than whole populations, the sensitivity of the seabird receptor is considered **Low**.

Impact Significance and Mitigation Measures – Direct Mortality and Injury Related to Attraction to Offshore Project Facilities

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for direct mortality and injury impacts on seabirds related to attraction to offshore Project facilities.

7.2.4.4 *Characterization of Impact – Direct Mortality and Injury Related to Vessel or Helicopter Strikes*

Magnitude of Impact – Direct Mortality and Injury Related to Vessel or Helicopter Strikes

Rafting seabirds may suffer injury or mortality from collision with vessels transiting to and from the FPSO. However, rafters are not likely to be present in large aggregations in the PDA because of the metocean conditions offshore Guyana – namely a strong surface current, which is likely to make the surface waters unsuitable for the large aggregations of species that favor more calm and sheltered conditions. The EEPGL seismic surveys conducted in the Stabroek Block in 2015 and 2016 did not document any concentrations of rafting seabirds in the area during their survey period (RPS, 2016). On the rare occasions that suitable conditions for rafting occur in the PDA and seabirds are present in high enough concentrations to form rafts, individual seabirds could be susceptible to vessel strike and related injury or mortality. However, large seabird rafts are easily detectible by oncoming vessels, and these vessels could maneuver to avoid them if the birds do not move out of the vessels' path.

Helicopters will be used as a form of transit to / from the Guyana shorebase(s) and offshore vessels, and could adversely impact seabirds through helicopter strike of individuals flying near helicopters transiting around or in route to/from the drill ships, FPSO, and installation vessels. Helicopter trips to and from the PDA are not expected to exceed more than a few each day, so the duration and number of helicopter-bird interactions is expected to be low.

Given the low likelihood of vessels encountering rafting seabirds and EEGPL's embedded control of providing standing instruction to Project dedicated vessel masters to avoid any identified rafting seabirds when transiting to and from PDA, where safe and feasible, if the birds do not move out of the vessel's path, as well as the limited number of helicopter flights per day to the Project facilities and vessels, the magnitude of this potential impact is **Small**.

Sensitivity of Receptor – Direct Mortality and Injury Related to Vessel or Helicopter Strikes

On the same basis as described in Section 7.2.4.3, the sensitivity of the seabird receptor to this impact is considered Low.

Impact Significance and Mitigation Measures – Direct Mortality and Injury Related to Vessel or Helicopter Strikes

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for direct mortality and injury impacts on seabirds related to vessel or helicopter strikes.

7.2.4.5 Impacts Related to Decommissioning

Decommissioning activities for the FPSO and related vessel traffic may impact seabirds in similar ways to that described for the installation and production operations stages, including potential for ship and helicopter strike-related injury or mortality, and light and sound disturbance from decommissioning activities leading to avoidance of the exposed areas. As

stated previously in this section, these impacts are expected to impact individual seabirds but have negligible impacts on seabirds at the population level. Once decommissioning activities are completed, the absence of the FPSO and the activities of the related support vessels (ships and helicopters) will remove the attraction - and strike-related risks and impacts to seabirds, providing a benefit due to the elimination of ongoing risks and impacts. However, should the FPSO become an attractant for seabird prey or a regular resting place for migrating seabirds during the production operations stage, removal of the facility could have a temporary adverse impact due to the removal of a reliable food source and/or rest area. This impact would be temporary since the birds should quickly adjust to the changed condition.

7.2.4.6 *Summary of Impact Significance Ratings*

Table 7-21 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on seabirds, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-21 Seabirds - Pre-Mitigation and Residual Impact Significance Ratings

Stage	Receptor – Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation Production Operations	Seabirds – direct mortality and injury from attraction to offshore Project facilities.	Small	Low	Negligible	None	Negligible
All Project stages	Seabirds – direct mortality and injury from vessel or helicopter strikes.	Small	Low	Negligible	None	Negligible

7.2.5 Marine Mammals

7.2.5.1 *Introduction*

As described in Section 6.2.6, toothed whales (sperm, melon headed, and pilot whales) and dolphins (pantropical and bottlenose) are the most likely marine mammal species that could be encountered in the PDA. Bryde's whales and other unidentified baleen whales have also been observed in offshore waters in the PDA. Nearshore, other dolphins such as common, spotted, and spinner dolphins may be encountered. The West Indian manatee is sparsely distributed in coastal and riverine waters of the region and may be encountered in the Demerara River area.

7.2.5.2 *Relevant Project Activities and Potential Impacts*

As shown in Table 7-22, certain planned Project activities could impact marine mammals either through direct mortality (vessel strikes), or through disturbance leading to changes in behavior and reduced vigor (i.e., as a result of light, sound and/or actions from Project activities).

Table 7-22 Project Activities and Potential Impacts – Marine Mammals

Stage	Activity	Key Potential Impact
Drilling and Installation	Vessel operations	• Injury and mortality from vessel strikes • Sound exposure leading to permanent threshold shift (PTS) injury • Sound disturbance leading to deviation from area
	Power generation	• Sound exposure leading to PTS injury • Sound disturbance leading to deviation from area
	VSP	
	ROV operations	
	Pile driving	
	Lighting on Drill Ship and Installation vessels	• Offshore lighting is not considered to have a negative impact on marine mammals; it is considered to be an attractant for fishes, and therefore as a secondary attractant for some marine mammals.
	Permitted drill cuttings and fluids discharge	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Permitted liquid waste discharge	
Production Operations	Well stream production, processing, and storage operations	• Sound exposure leading to PTS injury • Sound disturbance leading to deviation from area
	Power generation	
	Permitted cooling and produced water discharge	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Permitted other liquid waste discharge	
	Lighting on FPSO	• Offshore lighting is not considered to have a negative impact on marine mammals; it is considered to be an attractant for fishes, and therefore as a secondary attractant for some marine mammals.
	Operation of tankers, tugs, and supply and support vessels	• Injury and mortality from vessel strikes • Sound exposure leading to PTS injury • Sound disturbance leading to deviation from area
Decommissioning	Vessel operations	• Injury and mortality from vessel strikes • Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts. • Sound disturbance leading to deviation from area

7.2.5.3 *Characterization of Impacts*

Injury and Mortality from Vessel Strikes

Collisions with vessels can injure or kill marine mammals. Marine mammals possess acute senses of hearing that they can use to detect approaching vessels, and they have the necessary swimming speed capability to avoid collisions. Nevertheless, marine mammals are inherently vulnerable to ship strikes when they surface to breathe or to feed. This vulnerability increases in shallow nearshore areas where opportunities to maneuver are reduced. Most Project activities will take place in deep ocean waters, and vessel speeds within the PDA will be low, reducing the potential for collisions. The only planned nearshore activities will be supply vessels entering/exiting shorebases, but even at the peak of drilling and installation the incremental increase in traffic near shorebases will represent a small increase in overall risk to marine mammals. There is very little potential for collisions to occur within the PDA, but the potential remains for individual dolphins or whales to collide with vessels transiting between the PDA and shorebases. The greatest potential for collisions to occur will be during drilling and installation, when vessel traffic is at its peak; accordingly, the risk of injury or mortality from vessel collisions will be higher during drilling and installation than during other stages of the Project.

With respect to the potential for injury and mortality from vessels strikes, EEPGL will utilize the following embedded controls measure for the Project (see Section 2.11):

- Provision of awareness training to Project dedicated marine personnel to recognize signs of marine mammals at the sea surface; and
- Standing instruction to Project dedicated vessel masters to avoid marine mammals while underway and reduce speed or deviate from course, as needed, to reduce probability of collisions.

Injury from Underwater Sound

The main sources of underwater sound associated with drilling activities are from the vertical seismic profiler (VSP)[24] activities (generating impulsive sound) and marine vessels (generating non-impulsive sound). The primary sources of sound from installation activities is from impulsive sources (impact pile drivers for the FPSO mooring system and for selected SURF equipment such as manifolds) as well as non-impulsive sources (marine vessels). Sound from production operations and decommissioning activities is primarily limited to non-impulsive sources (marine vessels).

Underwater sound can cause impacts on marine mammals due to behavioral changes impacting life functions (e.g., feeding, breeding, migration route deviations), direct physical impacts

[24] The VSP has a small source that produces seismic impulses over a period of time (for the purposes of this assessment, is was assumed that the source will produce 20 to 40 seismic pulses, less than 1 second in length, over a 6 to 12 hour period). The wavefield generated by this source is recorded by instruments in the borehole.

affecting auditory systems, or in extreme cases other physical damage or behavioral reactions leading to death.

7.2.5.4 Marine Mammal Auditory Functions

The potential for anthropogenic sound to impact marine animals depends on how well the animals can hear the sound. Sounds are less likely to disturb if they are at frequencies that the animals cannot hear well. However, when the sound pressure is high enough it can cause physical injury through non-auditory mechanisms (i.e., barotrauma). For sound levels below such extremes, frequency weighting may be applied to scale the importance of sound components at particular frequencies in a manner reflective of an animal's sensitivity to those frequencies.

Auditory weighting functions for marine mammals, called *M-weighting* functions, were proposed by Southall et al. (2007) and modified by the U.S. National Oceanic and Atmospheric Administration (NOAA, 2013) and Finneran (2015). For this study, results are presented for both the Southall et al. (2007) M-weighting functions and the weighting functions suggested by Finneran (2015).

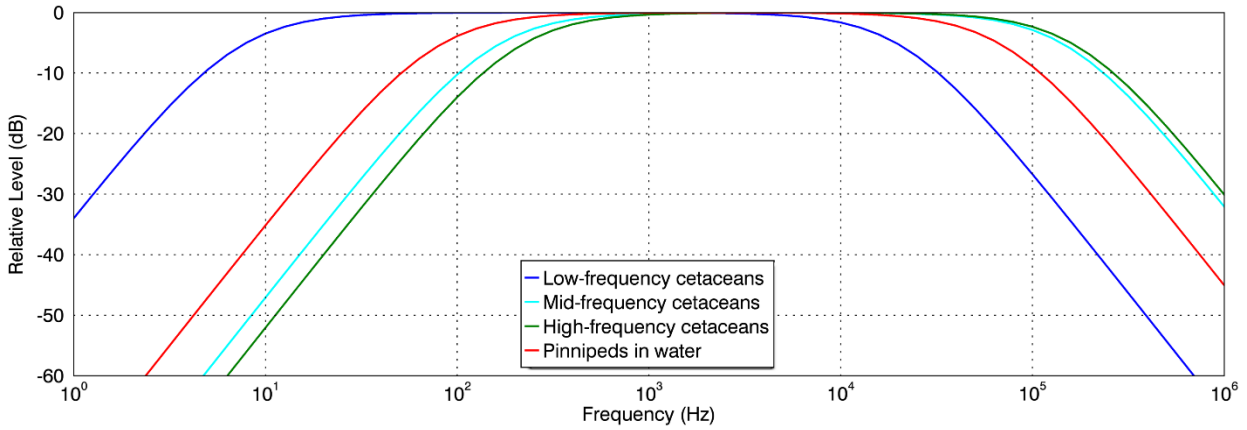
Southall et al. (2007) proposed M-weighting functions for five functional hearing groups of marine mammals:

- Low-frequency cetaceans (LFCs)—mysticetes (baleen whales);
- Mid-frequency cetaceans (MFCs)—some odontocetes (toothed whales);
- High-frequency cetaceans (HFCs)—odontocetes specialized for using high-frequencies;
- Pinnipeds in water[25]—seals, sea lions, and walrus; and
- Pinnipeds in air (not addressed here).

NOAA (2013) suggested further modifications to the LFC function, as well as two variations (for phocid and otariid pinnipeds) to the Southall et al. (2007) M-weighting curve for pinnipeds in water. In 2015, a U.S. Navy Technical Report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. Although the inclusion of some species changed (e.g., the addition of hourglass [*Lagenorhynchus cruciger*] and Peale's [*Lagenorhynchus australis*] dolphins to the high-frequency functional hearing group), the five recommended functional hearing groups remain those presented in the NOAA (2013). More information on the marine mammal auditory weighting functions described above, including the analytical formulation of these metrics, is provided in the document *Underwater Sound Associated with Liza Phase 1 Project Activities* (JASCO, 2016). The auditory weighting functions recommended by Southall et al. (2007) and Finneran (2015) are shown on Figure 7-4 and 7-5, respectively.

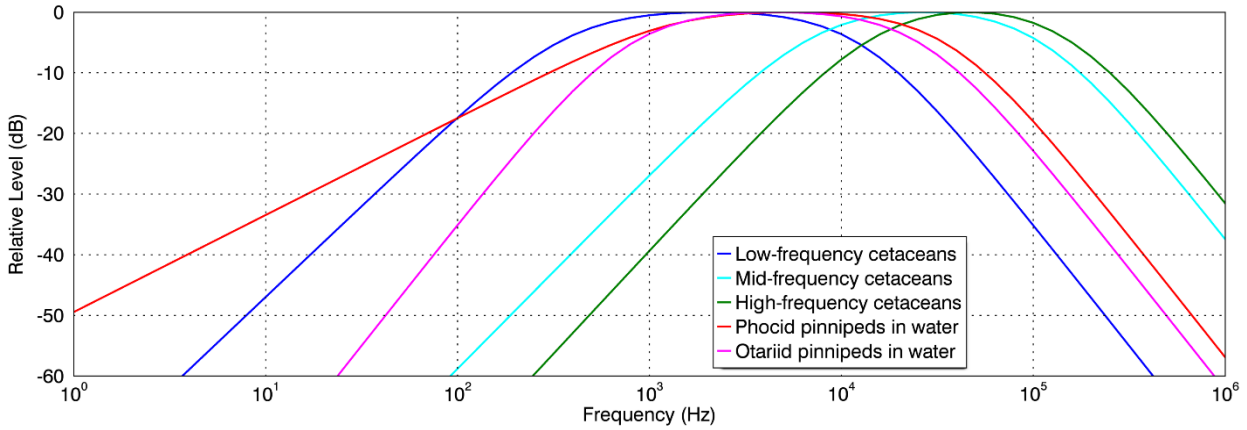
[25] Pinnipeds were included in Southall, et al 2007, but are not relevant to the analysis of auditory impacts because pinnipeds are either very rare or likely extinct offshore Guyana.

Figure 7-4 Auditory Weighting Functions for Marine Mammal Hearing Groups as Recommended by Southall el al. (2007)



Source: JASCO 2016

Figure 7-5 Auditory Weighting Functions for Marine Mammal Hearing Groups as Recommended by Finneran (2015)



Source: JASCO 2016

LFCs (including baleen whales) and MFCs (including dolphins and small whales) have been observed within or near the PDA, so this section focuses on these marine mammal hearing groups only. JASCO Applied Sciences conducted underwater sound modeling for the proposed Project activities (JASCO, 2016). The modeling was performed for two types of sources: impulsive and non-impulsive.

Impulsive sources such as VSP and impact pile driver activities are typically brief and intermittent, with a rapid rise time and decay. Piles can be driven to the seabed using different types of impact hammer types such as diesel hammer, air or steam hammer, and hydraulic hammer. Diesel hammers produce underwater sound waveforms with each pile strike that are similar to those of air hammers; hydraulic hammers produce a somewhat different waveform signature with a much more rapid rise time. Driven piles may be used in lieu of or in combination with suction piles. A suction pile or (suction caisson) can be conceptually described as an upturned bucket that is embedded in the marine sediment through pushing or

by creating a negative pressure inside the caisson skirt. The suction caisson technology functions very well in a seabed with soft clays or other low strength sediments and is in many ways easier and quieter to install than driven piles, which must be hammered into the seabed. For the purpose of this assessment, it was conservatively assumed that only impact pile drivers would be used (i.e., no suction piles).

In contrast, non-impulsive sources such as marine vessels' main propulsion systems and internal machinery (e.g., generators, cranes) can be brief or prolonged, and continuous or intermittent. However, non-impulsive sources do not have the high peak pressure and rapid rise time that impulsive sounds do.

Three complementary acoustic models (AASM[26], MONM[27], and FWRAM[28]) were used to predict underwater acoustic fields for the Project's potential sound sources. The model results were used to estimate distances to marine mammal injury (permanent threshold shift [PTS][29]) thresholds, based on best available science. Source levels for the VSP were predicted using JASCO's AASM.

The VSP source considered here is a six-element source array with a total volume of 1,200 cubic inches. AASM produces a set of "notional" signatures for each array element based on:

- Source array layout
- Volume, tow depth, and firing pressure of each element in the source array
- Interactions between different elements in the array

For the modeling, source level spectra from measurements of surrogate vessels, including FPSO, drill ship, pipelaying vessel, tugs, and support vessels, were adjusted to the specifications of the proposed Project vessels. Surrogate vessels were chosen based on the similarity in vessel specifications and types of operation.

Underwater sound propagation (i.e., transmission loss) was modeled with JASCO's MONM and FWRAM[4]. The 3D acoustic fields were computed by modeling transmission loss within multiple 2D vertical planes extending from the source. The underwater sound fields were modeled for water column sound speed profiles representative of the month of April. This time corresponds with historically lowest surface temperatures, which lead to upward sound refraction and longer-distance sound propagation. Predicted sound fields were assessed across three dimensions, and the received sound level reported at each point in the horizontal plane is the maximum predicted sound level over all modeled depths for that point.

[26] Airgun Array Source Model

[27] Marine Operations Noise Model

28 Full Waveform Range-dependent Acoustic Model

[29] PTS is a sound-induced impact that results in a permanent loss in hearing sensitivity due to destruction of sensory cells in the inner ear. This damage can be caused by long-term exposure to sound or acoustic trauma (https://www.osha.gov/dts/osta/otm/noise/health_effects/effects.html).

Based on these reported sound levels in the horizontal plane, two distance parameters were reported for each threshold:

- $R_{max,}$ maximum horizontal distance from the source where the predicted sound level reaches the threshold; and
- R95%, maximum horizontal distance from the source where the predicted sound level reaches the threshold after the 5% of the predicted threshold-exceeding area farthest from the source is excluded. Regardless of the geometric shape of the "maximum-over-depth" footprint, R95% is the predicted range encompassing at least 95% of the area (in the horizontal plane) that would be exposed to sound at or above the threshold.

Six scenarios were considered in this modeling study, which include:

1. The operation of an FPSO vessel,
2. The installation of the FPSO vessel, which includes mooring the FPSO and using several installation and service vessels, and
3. The installation and operation of a drill center, which includes the operation of a drill ship and a pipelaying vessel for the installation of subsea flowlines and risers, at Drill Center 2-P, approximately 13 km (~8 mi) north of the FPSO,
4. The operation of a VSP in the vicinity of Drill Centers 2-P and 2-I,
5. The installation of manifold foundation piles for SURF equipment at Drill Center 2-P through underwater impact pile driving, and
6. The installation of anchor mooring piles at the FPSO location through underwater impact pile driving.

The sound footprint for each scenario was modeled to estimate the above-referenced distance parameters assuming thresholds are equal to the injury criteria prescribed by Southall et al. (2007) and Finneran (2015). The sound footprints were calculated as frequency-weighted (M-weighted) sound exposure levels (SELs) assuming 24 hours of operation. The sound footprints account for source-specific sound emission characteristics and site-specific environmental parameters.

Additional information on the underwater sound modeling methodology, including a detailed description of all model input parameters and approximate locations of modeled sources for all scenarios, is provided in the document *Underwater Sound Associated with Liza Phase 1 Project Activities* (JASCO, 2016).

Underwater Sound Criteria

No regulations regarding underwater sound exist for Guyana. Accordingly, in the absence of any such limits, auditory impacts of the Project on marine mammals were evaluated using Southall et al. (2007) and Finneran (2015) acoustic threshold levels for onset of PTS in LFCs and MFCs (Table 7-23).

Table 7-23 Acoustic Threshold Levels for Onset of Permanent Threshold Shifts (PTS) in Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs)

Marine Mammal Hearing Group	Estimated Auditory Bandwidth	PTS Onset Acoustic Thresholds (Injury Criteria)			
		Impulsive		Non-impulsive	
		Peak Sound Pressure Level (unweighted) (dB peak)	Sound Exposure Level (SEL) (M-weighted) (SEL_{24h}; dB re 1 $\mu Pa^2.s$)	Peak Sound Pressure Level (unweighted) (dB peak)	Sound Exposure Level (SEL) (M-weighted) (SEL_{24h}; dB re 1 $\mu Pa^2.s$)
Southall et al. 2007					
LFCs (baleen whales)	7 Hz to 22 kHz	230	198	230	215
MFCs (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz	230	198	230	215
Finneran 2015					
LFCs (baleen whales)	7 Hz to 25 kHz	230	192	Not available	207
MFC (dolphins, toothed whales, beaked whales, bottlenose whales)	150 Hz to 160 kHz	230	187	Not available	199

Hz = hertz, kHz = kilohertz, dB = decibel; SEL = sound exposure level, 24h = 24 hour exposure, µPa = micro Pascal, s = second, m = meters

Modeling Results

Tables 7-24 to 7-29 present the above-referenced distance parameters describing modeled horizontal distances to PTS onset acoustic thresholds for LFCs and MFCs, according to Southall et al. (2007) and Finneran (2015) criteria, for the Scenarios 1 to 6, respectively. Decommissioning activities are currently not included in the scope for underwater sound modeling. Activities during the decommissioning stage would be similar to those of installation activities in terms of types of sound sources (i.e., marine vessels only). However, decommissioning activities would be shorter in duration and involve a smaller fleet of marine vessels; therefore, the potential underwater sound impacts on marine fauna for decommissioning are expected to be less than or similar to those of the installation scenario (Scenario 3).

The results presented in the tables below account for embedded underwater control measures. Specifically, EEPGL will utilize the following embedded underwater sound control measures for the Project (see Section 2.11):

- Gradually increasing intensity of seismic impulses to allow sensitive species to vacate the area before injury occurs (i.e., soft starts), use of Marine Mammal Observers (MMOs) during VSP, and implementation of other measures recommended by the Joint Nature Conservation Committee (JNCC, 2010), as applicable; and
- Maintaining equipment, marine vessels, and helicopters in good working order and operating them in accordance with manufacturers' specifications so as to limit sound levels to the extent reasonably practicable.

Table 7-24 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 1 – FPSO Operations

Marine Mammal Hearing Group	Injury Criteria and Distances to Criteria Levels					
	Southall et al (2007)			Finneran (2015)		
	Threshold (M-weighted) (SEL_{24h}; dB re 1 $\mu Pa^2.s$)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted) (SEL_{24h}; dB re 1 $\mu Pa^2.s$)	R_{max} (m)	$R_{95\%}$ (m)
Non-impulsive sources (marine vessels)						
Low-frequency cetaceans	215	6	6	207	<5	<5
Mid-frequency cetaceans	215	<5	<5	199	<5	<5

Source: JASCO, 2016

SEL = sound exposure level, 24h = 24 hour exposure, dB = decibel, µPa = micro Pascal, s = second, m = meters, Rmax = the maximum distance from the source at which the given threshold is predicted in the modeled maximum-over-depth sound field over all azimuths; R95% = the maximum distance from the source at which the given threshold is predicted in the modeled maximum-over-depth sound field over all azimuths, after the 5% of the threshold-exceeding area farthest from the source is excluded.

Table 7-25 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 2 – Installation of the FPSO Vessel, Including Mooring the FPSO and Using Several Construction and Service Vessels

Marine Mammal Hearing Group	Injury Criteria and Distances to Criteria Levels					
	Southall et al (2007)			Finneran (2015)		
	Threshold (M-weighted) (SEL_{24h}; dB re 1 $\mu Pa^2.s$)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted) (SEL_{24h}; dB re 1 $\mu Pa^2.s$)	R_{max} (m)	$R_{95\%}$ (m)
Low-frequency cetaceans	215	<5	<5	207	<5	<5
Mid-frequency cetaceans	215	No value	No value	199	--	--

Source: JASCO, 2016

SEL = sound exposure level, 24h = 24 hour exposure, dB = decibel, µPa = micro Pascal, s = second, m = meters, R_{max} = the maximum distance from the source at which the given threshold is predicted in the modeled maximum-over-depth sound field over all azimuths; $R_{95\%}$ = the maximum distance from the source at which the given threshold is predicted in the modeled maximum-over-depth sound field over all azimuths, after the 5% of the threshold-exceeding area farthest from the source is excluded

"---" = predicted sound levels at all locations are below injury criteria in the mid-frequency range

Table 7-26 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 3 – Installation of a Drill Center, Including Operation of a Drill Ship and a Pipelaying Vessel

Marine Mammal Hearing Group	Injury Criteria and Distances to Criteria Levels					
	Southall et al (2007)			Finneran (2015)		
	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)
Non-impulsive sources (marine vessels)						
Low-frequency cetaceans	215	9	9	207	6	6
Mid-frequency cetaceans	215	<5	<5	199	--	--

Source: JASCO, 2016

SEL = sound exposure level, 24h = 24 hour exposure, dB = decibel, µPa = micro Pascal, s = second, m = meters, R_{max} = the maximum distance from the source at which the given threshold is predicted in the modeled maximum-over-depth sound field over all azimuths; $R_{95\%}$ = the maximum distance from the source at which the given threshold is predicted in the modeled maximum-over-depth sound field over all azimuths, after the 5% of the threshold-exceeding area farthest from the source is excluded
"---" = predicted sound levels at all locations are below injury criteria in the mid-frequency range.

Table 7-27 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 4 – Operation of a Vertical Seismic Profiler

Marine Mammal Hearing Group	Injury Criteria and Distances to Criteria Levels					
	Southall et al (2007)			Finneran (2015)		
	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)
Low-frequency cetaceans	198	73	68	192	39	36
Mid-frequency cetaceans	198	35	32	187	--	--

Table 7-28 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 5 – Installation of Manifold Foundation Piles

Marine Mammal Hearing Group	Injury Criteria and Distances to Criteria Levels					
	Southall et al (2007)			Finneran (2015)		
	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)
Low-frequency cetaceans	198	1,300	NV	192	1,025	NV
Mid-frequency cetaceans	198	762	NV	187	136	NV

Table 7-29 Modeled Horizontal Distances to PTS Onset Acoustic Thresholds for Low-Frequency Cetaceans (LFCs) and Mid-Frequency Cetaceans (MFCs): Scenario 6 – Installation of Mooring Piles for the FPSO

Marine Mammal Hearing Group	Injury Criteria and Distances to Criteria Levels					
	Southall et al (2007)			Finneran (2015)		
	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted) (SEL_{24h}; dB re 1 µPa².s)	R_{max} (m)	$R_{95\%}$ (m)
Low-frequency cetaceans	198	1,375	NV	192	1,075	NV
Mid-frequency cetaceans	198	725	NV	187	100	NV

NV – No value

Modeling results for the six scenarios are presented below. It is important to note these results assume that the sources are stationary for 24 hours, and that the marine mammal is present within the stated distance for the entire accumulation period (24 hours). This adds an element of conservatism to the assessment because no marine mammal would be expected to stay within the modeled injury zone for the entire 24 hour duration on which the threshold is based.

Scenario 1 – Marine Vessels during FPSO Operations

Modeling predicted that non-impulsive underwater sound for Scenario 1 would attenuate to PTS onset acoustic thresholds for LFCs and MFCs at maximum horizontal distances of 6 and <5 meters, respectively (based on the more conservative injury criteria for the marine mammal hearing groups).

Scenario 2 - Marine Vessels during FPSO Installation

Modeling predicted that non-impulsive underwater sound for Scenario 2 would attenuate to PTS onset acoustic thresholds for LFCs at a maximum horizontal distance of <5 meters (based on the more conservative injury criteria for the marine mammal hearing group). Modeling predicted that MFCs would not be impacted at any distance under this scenario because the predicted underwater sound in the mid-frequency range would be below PTS onset acoustic thresholds at all locations.

Scenario 3 – Marine Vessels (Drill Ship, SURF installation vessels)

Modeling predicted that non-impulsive underwater sound for Scenario 3 would attenuate to PTS onset acoustic thresholds for LFCs and MFCs at maximum horizontal distances of 9 and <5 meters, respectively (based on the more conservative injury criteria for the marine mammal hearing groups).

Scenario 4 – Vertical Seismic Profiler during Drilling and SURF Installation

Modeling predicted that impulsive underwater sound from the VSP for Scenario 4 would attenuate to PTS onset acoustic thresholds for LFCs and MFCs at maximum horizontal distances of 73 and 35 meters (~240 and ~115 ft), respectively (based on the more conservative injury criteria for the marine mammal hearing groups).

Scenario 5 – Pile Driving during Drilling and SURF Installation

Modeling predicted that impulsive underwater sound from pile driving for Scenario 5 would attenuate to PTS onset acoustic thresholds for LFCs and MFCs at maximum horizontal distances of 1,300 and 762 meters (~4,270 and ~2,500 ft), respectively (based on the more conservative injury criteria for the marine mammal hearing groups). These maxima occur at depths of greater than 1000 meters.

Scenario 6 – Pile Driving during FPSO Installation

Modeling predicted that impulsive underwater sound for Scenario 6 would attenuate to PTS onset acoustic thresholds for LFCs and MFCs at maximum horizontal distances of 1,375 and 725 meters (~4,510 and ~2,380 ft), respectively (based on the more conservative injury criteria for the marine mammal hearing groups). These maxima occur at depths of greater than 1000 meters.

Summary of Potential for Injury Due to Underwater Sound

Modeling results indicate sound levels from vessels and the VSP are insignificant compared to the predicted sound levels from impact pile driving. The distances to injury thresholds for both LFCs and MFCs would be determined by sound from pile driving both at the FPSO and the drill center(s), although the area within which injury could potentially occur would be over 40% smaller for MFCs than for LFCs. Regardless of which type of pile installation methodology (impact driven or suction) is used, neither group of marine mammals would be expected to result in a population-level impact. Based on the premise that marine mammals would actively avoid physical discomfort associated with Project-related sound, if impact-driven piles are used MFCs would be expected to generally avoid the area within at least ~700 m from the location where pile driving is taking place and LFCs would be expected to generally avoid the area within at least ~ 1,400 m of the activity. Both categories of cetaceans would avoid these areas for the duration of the pile driving activity. Some species, including many of the larger baleen whales and dolphins would naturally avoid the area of potential effect (especially around Drill Center 2) because it would be deeper than their typical maximum dive depths. Others, such as sperm whales, dive deep enough that they could potentially be exposed to injurious sound levels throughout the PDA; however they would not be expected to dive to sufficient depths for a sufficient duration to be exposed to potential injury. PTS (were it to occur) would be irreversible by definition, but given the depth of the water in the PDA and the physiological limitations that would prevent marine mammals from diving deep enough and for a long enough period of time to experience PTS, piling driving is not expected to cause permanent injury to marine mammals or irreversible effects on their hearing abilities.

Disturbance from Underwater Sound

Anthropogenic sounds below injury thresholds have the potential to mask relevant sounds in the animals' environment. This masking can occur due to both natural and anthropogenic sounds (Hildebrand, 2005). The behavioral changes that can occur due to masking can have major ecological consequences for marine mammals. These may include changes in biologically

important behaviors (e.g., breeding, calving, feeding, or resting); changes in diving behavior (e.g., reduced or prolonged dive times, increased time at the surface, or changes in swimming speed); and changes in historical migration routes (NMFS undated).

Although the above changes could occur in the PDA as a result of Project-generated sound, findings from US territorial waters suggest that the population-level significance of disturbance from impulsive sound over a small area such as the PDA would likely be minor. NMFS reported that "…available data do not indicate that sound and disturbance from oil and gas exploration and development activities since the mid-1970s had lasting population level adverse impacts on bowhead whales. Data indicate that bowhead whales are robust, increasing in abundance, and have been approaching (or have reached) the lower limit of their historic population size at the same time that oil and gas exploration activities have been occurring in the Beaufort Sea and, to a lesser extent, the Chukchi Sea." (NMFS, 2006). BOEM found that despite over 50 years of oil and gas exploration and development in the Gulf of Mexico, there are no data to suggest that these activities are significantly impacting marine mammal populations (BOEM, 2014). Furthermore, the PDA is not known to be an important feeding, breeding, or calving area. Therefore, individual animals may divert around an operating pile driver or VSP to avoid Project-generated sound, but no significant impacts to life functions or potential population-level implications from underwater sound are expected.

Exposure to Permitted Discharges

The Project will involve routine, permitted discharges of waste streams to the sea. These discharges would begin during the drilling and installation stages and continue into the decommissioning stage. As described in Section 7.1.4, these discharges will be treated (as needed) in accordance with industry guidelines. Furthermore, marine mammals would be transient in the PDA and their exposure to any discharges would be very limited. Any impacts would be expected to be acute and recovery would be expected to occur quickly after the affected individual(s) exit the mixing zone.

Impacts from Artificial Lighting

Artificial lighting is not known to directly attract or disturb marine mammals, so any impacts of artificial light on marine mammals are likely to be indirectly caused by a potential change in local forage availability through changes in prey distribution. Fish are known to be attracted to artificial light, and even plankton are sometimes capable of weak volitional movement through the water column in response to changing ambient light levels. Small fish and/or plankton make up a substantial part of most marine mammals' diets, so to the extent that Project vessels could facilitate the concentration of plankton and/or small fish at the surface or around the vessels, food density would increase and marine mammals may also be attracted to the vessels to feed more efficiently. This impact is expected to be limited to only the immediate vicinity of the vessels.

Summary of Impact Significance Ratings

As discussed in Section 7.2.1, because one of the marine mammals observed in the PDA is listed as Vulnerable by IUCN, the impact assessment was conducted with the conservative assumption that this Vulnerable species (i.e., sperm whale) would be the receptor for the potential impact. Accordingly, the sensitivity rating definitions used for special status species (Table 7-30) was used for all potential impacts.

Table 7-30 Definitions for Receptor Sensitivity Ratings for Impacts to Special Status Species

Criterion	Definition
Sensitivity	Negligible: Species with no specific value or importance attached to them.
	Low: Species and sub-species of Least Concern on the IUCN Red List (or not meeting criteria for medium or high value), or without specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts.
	Medium: Species listed as Vulnerable, Near Threatened, or Data Deficient on the IUCN Red List, species protected under national legislation, nationally restricted range species, nationally important numbers of migratory or congregatory species, species not meeting criteria for high value, and species vital to the survival of a medium value species.
	High: Species on IUCN Red List as Critically Endangered or Endangered. Species having a globally restricted range (i.e., endemic species to a site, or found globally at fewer than 10 sites, fauna having a distribution range less than 50,000 km^2, internationally important numbers of migratory or congregatory species, key evolutionary species, and species vital to the survival of high value species.

Considering the description of potential impacts above, Table 7-31 summarizes the impact magnitude and receptor sensitivity ratings for each potential impact, together with the rationale for the ratings.

Table 7-31 Impact Magnitude and Receptor Sensitivity Ratings - Marine Mammals

Key Potential Impact	Sensitivity Rating	Magnitude Rating	Rationale for Magnitude Ratings
Injury and mortality from vessel strikes	Medium	Negligible	Although vessel traffic will be substantial during installation, the likelihood of a collision event with an Project vessel would be mitigated due to embedded controls such as standing instructions to vessel operators, low vessel operating speeds and typical marine navigation good practices. Accordingly, the magnitude of impact considering embedded controls is considered to be Negligible.
Injury (PTS) from underwater sound	Medium	Negligible	With no control measures in place, magnitude ratings for VSP and pile driving would be Medium based on the predicted extent of impact zones; however the Negligible magnitude rating is based on several factors, including:

Key Potential Impact	Sensitivity Rating	Magnitude Rating	Rationale for Magnitude Ratings
			• The activity that presents the greatest risk of injury to marine mammals (pile driving) would only occur during the initial stages of the installation phase and at great depth and therefore represents a short term risk to mammals. • EEPGL has committed to using MMOs and soft start procedures for VSPs in accordance with JNCC guidelines, and soft starts for pile driving to further reduce the potential for impacts on marine mammals. • Many marine mammals do not dive to the depths that would be required or remain submerged for sufficient time to be exposed to impacts above injury thresholds, especially near Drill Center 2. • If an individual mammal were to approach an operating VSP or pile driver, they would experience disturbance prior to being exposed to sound levels above injury thresholds, and would be expected to divert away from the source.
Disturbance from underwater sound	Medium	Medium	The potential impact zone for disturbance effects is expected to be larger than the extent for potential injury effects; accordingly, the magnitude of potential impact is considered Medium.
Impacts from permitted discharges	Medium	Negligible	Permitted discharges will be treated as needed prior to discharge and will reduce in concentration rapidly with increasing distance from the discharge point. The magnitude is therefore considered Negligible.
Impacts from artificial lighting	Positive	Positive	Impacts to marine mammals from Project lighting are considered to be Positive, due to the potential for attraction of food sources and no documented adverse effects on marine mammals from lighting.

Table 7-32 Marine Mammals - Pre-Mitigation and Residual Impact Significance Ratings

Stage	Potential Impact	Magnitude Rating	Sensitivity Rating	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project Stages	Injury from vessel strikes	Negligible	Medium	Negligible	None	Negligible
	Exposures to permitted discharges	Negligible	Medium	Negligible	None	Negligible
	Offshore lighting as an attractant of food sources for marine mammals	Positive	Positive	Positive	Not applicable	Positive
Drilling and Installation	Injury from sound exposure	Negligible	Medium	Negligible	None	Negligible
	Disturbance from sound exposure	Medium	Medium	Moderate	None, but robust implementation of embedded controls (e.g., soft start procedures for VSP and pile driving)	Moderate

Based on consideration of all of the potential impacts on marine mammals assessed, the overall residual significance rating for potential impacts on marine mammals from planned Project activities is considered to be **Negligible** to **Moderate**.

7.2.6 Marine Turtles

7.2.6.1 *Introduction*

As described in Section 6.2.6, five sea turtle species are found in the Guyanese waters and could be encountered in the PDA. Four of these species–green turtle, leatherback, hawksbill, and Olive Ridley turtle–nest on Guyana's beaches, particularly in the SBPA located near Guyana's border with Venezuela. Loggerhead turtles also occur in offshore Guyanese waters but rarely come ashore.

7.2.6.2 *Relevant Project Activities and Potential Impacts*

As shown in Table 7-33, planned Project activities could potentially impact marine turtles through direct mortality (from vessel strikes), disturbance leading to changes in behavior (from underwater sound, lighting and/or actions from Project activities), and exposures to permitted discharges. Key potential sources of impact include impulsive sound from acoustic sources (VSP activity, driven piles) and non-impulsive sound from marine vessels (FPSO, drill ship, supply vessels, work vessels, barges, light installation vessels, pipelay vessels, multi service vessels, field intervention vessels, large crane vessels, and tug boats).

Table 7-33 Project Activities and Potential Impacts – Marine Turtles

Stage	Project Activity	Key Potential Impact
Drilling and Installation	Vessel operations	• Injury and mortality from vessel strikes. • Displacement from habitat to avoid disturbance from vessel activity.
	Power generation	• Displacement from habitat to avoid disturbance from vessel activity.
	VSP and pile driving	
	ROV operations	
	Lighting on drill ship and installation vessels	• Disturbance leading to reduced fecundity.
	Permitted drill cuttings and fluids discharge	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Permitted liquid waste discharge	
Production Operations	Vessel operations (e.g., FPSO supply barges, support vessels, drill ship, platform supply vessels, fast supply vessels, large crane vessel, fast supply vessel, field intervention vessel, light installation vessel, and multi-purpose support vessels)	• Displacement from habitat to avoid disturbance from vessel activity.
	Permitted cooling and produced water discharge	• Exposures to permitted discharges,

Stage	Project Activity	Key Potential Impact
	Other permitted liquid waste discharge	potentially leading to toxicological or metabolic impacts.
	Lighting on FPSO	• Disturbance leading to reduced fecundity.
Decommissioning	Decommissioning vessels, ROVs	• Injury and mortality from vessel strikes. • Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts. • Displacement from habitat to avoid disturbance from vessel activity.

7.2.6.3 *Characterization of Impacts*

Injury and Mortality from Vessel Strikes

Collisions with vessels can injure or kill marine turtles. Sea turtles tend to spend most of their time at sea at or near the sea surface, and do not possess the acute sense of hearing or the swimming speed that cetaceans use to avoid collisions. Sea turtles are inherently more vulnerable to ship strikes in the shallow nearshore areas (where they congregate prior to coming ashore to nest) than they are in the open ocean. This increased vulnerability is caused by the higher concentrations of turtles and reduced opportunity to maneuver in shallow water. Most Project activities will take place in deep ocean waters, and vessel speeds within the PDA will be low, further reducing the potential for collisions. The only planned nearshore activities will be supply vessel entering/exiting shorebases; the anticipated options for shorebases are all located over 100 km away from the nearest portion of the SBPA, where most sea turtle nesting in Guyana occurs. There is very little potential for collisions to occur within the PDA, but the potential remains for individual turtles to collide with vessels transiting between the PDA and shorebases. The potential for the greatest number of collisions to occur will be during drilling and installation when vessel traffic is at its peak, so the risk of injury or mortality from vessel collisions will be slightly higher during drilling and installation than during other stages of the Project.

With respect to the potential for injury and mortality from vessels strikes, EEPGL will utilize the following embedded control measure for the Project (see Section 2.11):

- Standing instruction to Project dedicated vessel masters to avoid marine turtles while underway and reduce speed or deviate from course, as needed, to reduce probability of collisions.

Injury from Underwater Sound

Hearing capabilities have been studied in only a few individual marine turtles, but the available data suggest that turtles have limited hearing capacity compared to other marine taxa (e.g., cetaceans). Turtles have been shown to respond to low frequency sound, with indications that they have the highest hearing sensitivity in the frequency range 100 to 700 Hz (Bartol and Musick, 2003). Startle responses to sudden sounds have also been observed in sea turtles. For example, McCauley et al. (2000) found that turtles showed behavioral responses to approaching seismic survey sound at approximately 166 dB re 1 uPa, and more significant disturbance at 175 dB re 1 uPa. Startle responses and other behavioral changes are more likely from high level pulsed sound sources such as those produced during VSP activities and pile driving, rather than from non-pulse sources such as those from vessels.

Since turtles have been shown to respond to low frequency sounds, modeling results pertinent to low-frequency cetaceans (LFCs) (see Section 7.2.5) were used as a proxy for injury predictions for marine turtles. Modeling predicted that impulsive underwater sound from VSP and pile driving activities would attenuate to PTS onset acoustic thresholds for LFCs at maximum horizontal distances of 73 and 1,300 meters (~240 and ~4,270 ft), based on the more conservative injury criteria for the LFC marine mammal hearing group.

Dive-profile data from tagged Kemp's ridleys showed that they spent an average of 97 percent (day) or 87 percent (night) of their time within 1 m of the surface, and observational records suggest that most sea turtles show a similar pattern. The VSP source for the Project will be located within 5 m of the ocean surface, so marine turtles may be present at the same general depth as the source. However, since the sound pressure field is zero at the surface, the sound levels in excess of the proxy injury threshold will be limited to depths well below the zone where marine turtles will typically be present. While the horizontal extent of the modeled potential impact zone is significantly larger for pile driving than for VSP, turtles are not known to dive a sufficient depth (>1000 m) to enter the zone within which PTS would occur as a result of pile driving. The only low frequency sound that marine turtles could potentially be exposed to, other than VSP and pile driving, would derive mainly from vessels operating in the Project area, and vessel sounds will decrease below the threshold for injury to LFCs at 5 to 6 meters from the source. At that range, injury from a collision with the vessel poses a more likely risk to a marine turtle than injury from sound.

Anthropogenic sounds below injury thresholds have the potential to mask relevant sounds in the animals' environment (Hildebrand, 2005); however, there are no quantitative data demonstrating masking impacts for sea turtles and turtles do not vocalize or use sound for communications, so the potential risk of impacts from masking is considered insignificant.

The highest potential for auditory impacts on marine turtles will occur during VSPs, and the use of marine observers to detect sea turtles and soft start techniques will further reduce the risks to sea turtles when VSPs are occurring.

With respect to the potential for injury from underwater sound, EEPGL will utilize the following embedded underwater sound control measures for the Project (see Section 2.11):

- Gradually increasing intensity of seismic impulses to allow sensitive species to vacate the area before injury occurs (i.e., soft starts),
- Use of MMOs during VSP (although use of MMOs is more effective for identification of marine mammals, these individuals can also detect marine turtles depending on weather conditions, and they will be tasked with observing for marine turtles as well) and implementation of other measures recommended by the Joint Nature Conservation Committee (JNCC, 2010), as applicable; and
- Maintaining equipment, marine vessels, and helicopters in good working order and operating them in accordance with manufacturers' specifications so as to limit sound levels to the extent reasonably practicable

Displacement from Habitat as a Result of Disturbance

During the Project life cycle, levels of human activity (e.g., vessel traffic, equipment and materials in the water) will be higher than the very low levels that currently exist in the PDA. Marine turtles are not known to be sensitive to human activity while at sea, so this increase in human activity is expected to have little or no impact on them within the PDA. Project activity related to potential disturbance would decrease during the production operations phase, so impacts on sea turtles would decrease as well. There would be a small increase in human activity during decommissioning, but that increase would be of relatively short duration and would not rise to the same level of activity associated with drilling and installation. In summary, disturbance from human activity would be expected to have little to no impact on marine turtles throughout the duration of the Project.

Exposure to Permitted Discharges

The Project will involve routine, permitted discharges of waste streams to the sea. These discharges would begin during the drilling and installation stage and continue into the decommissioning stage. As described in Section 7.1.4, these discharges will be treated (as needed) in accordance with industry guidelines. Furthermore, sea turtles would be transient in the PDA and their exposure to any discharges would be very limited. Any impacts would be expected to be acute and recovery would be expected to occur quickly after the affected individual(s) exit the mixing zone.

Disturbance to Nesting from Artificial Lighting

Sea turtles are known to be sensitive to artificial light in close proximity to nesting beaches, because artificial light can cause a variety of impacts on the behavior of nesting turtles and hatchlings including reduced nesting rates, premature abandonment of nests/interruption of the egg laying process, and disorientation of hatchlings (Witherington and Martin 2003; NOAA 2014). There will be artificial lights in the PDA from various vessel types and the amount of light in the PDA will vary between stages of the Project; however, at no point is offshore light

expected to have significant impacts on marine turtles because sea turtles are not known to be sensitive to artificial light in the open ocean and the PDA is located so far offshore that light from the PDA will not be visible from the shore.

Summary of Impact Significance Ratings

As discussed in Section 7.2.1, because the marine turtles occurring in the PDA carry listings of Critically Endangered, Endangered, or Vulnerable by IUCN, the impact assessment was conducted with the conservative assumption that the Critically Endangered or Endangered species (i.e., Hawksbill, green, loggerhead) would be the receptor for the potential impact. Accordingly, the sensitivity rating definitions used for special status species (Table 7-34) was used for all potential impacts.

Table 7-34 Definitions for Receptor Sensitivity Ratings for Impacts to Special Status Species

Criterion	Definition
Sensitivity	Negligible: Species with no specific value or importance attached to them.
	Low: Species and sub-species of Least Concern on the IUCN Red List (or not meeting criteria for medium or high value), or without specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts.
	Medium: Species listed as Vulnerable, Near Threatened, or Data Deficient on the IUCN Red List, species protected under national legislation, nationally restricted range species, nationally important numbers of migratory or congregatory species, species not meeting criteria for high value, and species vital to the survival of a medium value species.
	High: Species on IUCN Red List as Critically Endangered or Endangered. Species having a globally restricted range (i.e., endemic species to a site, or found globally at fewer than 10 sites, fauna having a distribution range less than 50,000 km^2, internationally important numbers of migratory or congregatory species, key evolutionary species, and species vital to the survival of high value species.

Table 7-35 summarizes the impact magnitude and receptor sensitivity ratings for marine turtles. Table 7-36 summarizes the potential impact significance ratings for marine turtles, based on the discussion presented above. The impact significance ratings were assigned based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Based on consideration of all of the potential impacts on marine turtles assessed, the overall residual significance rating for potential impacts on marine turtles from planned Project activities is considered to be **Negligible** to **Minor**.

Table 7-35 Impact Magnitude and Receptor Sensitivity Ratings - Marine Turtles

Key Potential Impact	Sensitivity Rating	Magnitude Rating	Rationale for Ratings
Injury and mortality from vessel strikes	High	Small (drilling and installation) Negligible (other Project stages)	Although vessel traffic will be substantial during installation, the likelihood of a collision event with a Project vessel would be mitigated due to embedded controls such as standing instructions to vessel operators, low vessel operating speeds, and typical marine navigation good practices. The magnitude of impact considering embedded controls is considered to be Small during drilling and installation (when higher vessel traffic level will occur) and Negligible during other stages.
Injury (PTS) from underwater sound	High	Negligible	Sea turtles spend most of their time within a few meters of the sea surface where the intensity of sound from VSP will be highest, but sound from pile driving will be lowest. Considering the relatively small size of the PTS radius surrounding the VSP and the embedded controls described above, the likelihood of marine turtle exposure to sound levels above injury thresholds is low, resulting in an overall magnitude rating of Negligible.
Displacement from habitat to avoid disturbance from vessel activity	Low	Small	Increased activity in the PDA and between the PDA and shorebases, could cause turtles approaching nesting beaches from the northeast to deviate from their normal migration route, but marine turtles are not known to be sensitive to human activity while at sea. Accordingly, sensitivity is considered Low; this is used in lieu of the special status rating based on the lack of an anticipated sensitivity. The increase in vessel traffic between the shorebases and PDA could cause general avoidance in the nearshore area, but would represent an incrementally insignificant increase in total vessel traffic in the area.
Impacts from permitted discharges	High	Negligible	Permitted discharges will be treated as needed prior to discharge and will reduce in concentration rapidly with increasing distance from the discharge point. The magnitude is therefore considered Negligible.
Disturbance to nesting from artificial lighting	Low (open ocean) High (on or near shore)	Small (open ocean) Negligible (on or near shore)	Adults and newly hatched turtles are highly sensitive to artificial light in the immediate proximity to nesting beaches, but much less sensitive while offshore. Accordingly, an overall sensitivity rating of Low for the open ocean and Medium for the nearshore environment was assigned; the open ocean rating is used in lieu of the special status rating based on the lack of an anticipated sensitivity for this impact. Project vessels will constitute a source of light that is distinct from the surrounding environment, yielding a magnitude rating of Small for the offshore environment. The PDA is located so far offshore that light from the PDA will not be visible from the shore, yielding a magnitude rating of Negligible for the nearshore environment.

Table 7-36 Summary of Impacts Significance Ratings and Recommended Mitigation Measures - Marine Turtles

Stage	Key Potential Impact	Sensitivity Rating	Magnitude Rating	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project Stages	Disturbance from offshore lighting	Low to Medium	Small to Negligible	Negligible	None	Negligible
Drilling and Installation	Injury from vessel strikes	Medium	Small	Minor	None	Minor
	Injury from sound exposure	Low	Negligible	Negligible	None	Negligible
	Displacement from habitat to avoid disturbance from vessel activity	Low	Small	Negligible	None	Negligible
	Exposures to permitted discharges	Low	Negligible	Negligible	None	Negligible
Production Operations; Decommissioning	Injury from vessel strikes	Medium	Negligible	Negligible	None	Negligible
	Injury from sound exposure	Low	Negligible	Negligible	None	Negligible
	Displacement from habitat to avoid disturbance from vessel activity	Low	Negligible	Negligible	None	Negligible
	Exposures to permitted discharges	Low	Negligible	Negligible	None	Negligible

7.2.7 Marine Fish

7.2.7.1 *Introduction*

This section describes the potential impacts of the Project on marine fish. Key potential impacts on marine fish assessed include localized changes in the distribution of pelagic species as a result of altered water quality; localized changes in distribution and habitat usage due to altered bottom habitats and the presence of Project infrastructure; entrainment in water intakes; auditory impacts from vessel traffic and installation activities; and the attractive potential of artificial lights on the FPSO, drill ship, and major installation vessels.

Marine Fish receptors will include pelagic and demersal marine fishes. These groups include a combination of migratory and resident species. Some receptors will receive a larger proportion of certain impacts than others. For example, surface dwelling pelagic fish will potentially experience greater water quality impacts related to planned discharges than will bottom-dwelling species, and bottom dwelling species will be more impacted by changes in physical habitat structures than pelagic species.

7.2.7.2 *Relevant Project Activities and Potential Impacts*

Table 7-37 summarizes the Project stages and activities associated with each potential impact assessed. The highest number of impacts would be expected to occur during the initial stages of the Project, when most habitat-disturbing activities take place and human/vessel activity in the PDA will be highest. At this stage, impacts will occur throughout the water column and at the seafloor. Once drilling and installation and hook-up/commissioning are complete and production operations are the only activities occurring offshore, biological conditions at the seafloor will return to equilibrium and most of the ongoing impacts will be isolated to the upper portions of the water column and to the pelagic segment of the fish community.

Table 7-37 Project Activities and Potential Impacts – Marine Fish

Stage	Project Activities	Key Potential Impact
Drilling and Installation	Drilling operations and VSP	• Gill fouling and reduced visibility caused by TSS. • Auditory impacts from vessel sound. • Auditory impacts from sound from VSP and pile driving. • Attraction of structure-oriented species. • Localized improved access to forage for predatory fish due to prey species' attraction to artificial light. • Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Artificial lighting on drill ship and major installation vessels	
	Installation of FPSO moorings and SURF equipment, including pile driving	
	Permitted liquid waste discharge	

Stage	Project Activities	Key Potential Impact
	Permitted drill cuttings and fluids discharge	
Production Operations	Permitted liquid waste discharge (primarily cooling water and chlorinated effluent)	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.
	Tanker and tug operations	• Auditory impacts from vessel sound. • Attraction of structure-oriented species.
	Intake of seawater for cooling water, injection water, and ballast water	• Loss of fish eggs and larvae due to entrainment of immature life stages.
Decommissioning	Abandonment and removal activities	• Temporary disturbance of deepwater fish communities and possible gill fouling during decommissioning (TSS). • Permanent loss of structural habitat (FPSO only) and artificial light due to decommissioning.
	Permitted liquid waste discharge	• Exposures to permitted discharges, potentially leading to toxicological or metabolic impacts.

7.2.7.3 *Discussion of Potential Impacts*

Changes in the Distribution of Fish Due to Altered Water Quality

The Project will routinely discharge several waste streams to the sea. These discharges would begin during the drilling and installation stages and continue into the decommissioning stage.

Two discharges unique to the drilling and installation phases will be discharges of drilling fluids and cuttings. For the initial well sections which will use WBDF, the cuttings and fluids will be discharged either at the seafloor, causing turbidity around the immediate vicinity of each well, or from the drill ship. For subsequent well sections, cuttings and residual drilling fluids will be discharged from the drill ship. For discharges from the drill ship, turbidity plumes will impact a larger area as the cuttings fall through the water column, but the turbidity plume will be diluted across a larger area, thereby reducing impacts in any single location. Fish will be expected to generally avoid these turbidity plumes while drilling is occurring, reducing respiratory impacts associated with gill fouling, but would be expected to return after drilling is complete. WBDF and the residual quantities of low-toxicity NABF adhered to discharged cuttings are expected to have no measureable impacts on fish.

As described in Section 7.1.4, most of the planned discharges that would occur during production operations are not known to have negative impacts on marine life or would occur at negligible volumes, but the increased temperature and chlorine concentrations in the cooling water discharges were identified as having the potential to negatively impact marine life. Elevated temperature is known to have several physiological lethal and sub-lethal impacts on fish including reduced reproductive success, reduced early life stage survivorship, and increased metabolic stress. Thermal thresholds for such impacts vary widely by species, but thresholds from the scientific literature range from about +1.5 ˚C to +6 ˚C (Donelson et al., 2014; Pankhurst and Munday, 2011). Under the conservative assumptions described in Section 7.1.4, localized sea surface temperatures are expected to increase as a result of the Project, but these increases are predicted to diminish to 3 ˚C above ambient temperatures within 100 m (~330 ft) horizontal distance from the discharge outlet. This finding indicates that within 100 m (~330 ft) of the FPSO, the thermal impact of routine discharges would diminish to near the lower end of the range within which thermal impacts on fish are expected to occur. Most of the research on thermal thresholds for these types of impacts has focused on reef or structure-oriented species that spend their entire adult lives in a small area rather than the open-ocean pelagic species that would occur near the surface in the PDA. Pelagic species would be much more likely to move away from a thermal mixing zone that exceeds their optimum range than would structure-oriented species, so not only would thermal impacts affect a very small area of the ocean surface but the species that occur within the PDA would also be resilient to these thermal impacts based on their propensity to actively avoid suboptimal water temperatures.

Similar to temperature increases, chlorine can also induce a range of negative impacts in fish including disruption of cardiac function, respiration, and growth. There are no regulatory limits for residual chlorine in marine discharges in Guyana. Chlorine toxicity depends not only on dosage (concentration and exposure time) but also on individual species' sensitivity to chlorine. This makes defining a single impact threshold for chlorine exposure difficult. While chlorine concentrations within the immediate vicinity of the FPSO could exceed levels that may result in toxicity impacts to fish (assuming the fish remained in the area long enough to experience the impact), concentrations are expected to decrease by approximately 89 percent within 100 m of the discharge point.

The combined impact of increased temperature and chlorine concentrations would make the localized mixing zone inhospitable to some species. However, unless they are physically confined or otherwise prevented from escaping lethal water quality conditions, or water quality conditions decline so quickly that escape is impossible, fish are usually capable of detecting and avoiding harmful water quality conditions. This is especially true of water quality conditions that cause discomfort or are otherwise physically apparent at sub-lethal levels like chlorine, and is also especially true of the pelagic species that move throughout their lives and would be in the most direct contact with elevated temperatures and chlorine concentrations.

Decommissioning will cause small turbidity plumes near the seafloor if selected components of the SURF are removed and as mooring lines from the FPSO are placed on the seafloor. Impacts from these turbidity plumes will be similar to those associated with drilling and installation, although they will be smaller and have a shorter duration.

For these reasons, declines in water quality would be expected to negatively impact fish abundance in the immediate vicinity of the well heads, SURF, and drill ship during drilling and installation, the FPSO and tanker(s) during production operations, and the SURF during decommissioning, but would not be expected to cause significant fish mortality. Limited, localized impairments in water quality will not be significant enough to cause substantial changes in fish populations, nor will they significantly impact sensitive or important species (see Section 7.2.1), but they will likely cause limited changes in the distribution and composition of the fish community within parts of the PDA. As discussed below, the physical attraction that offshore facilities can exert on fish, could actually result in net increases in the abundance of certain fish species, even under slightly impaired water quality conditions. The net impact in this case is often a shift away from sensitive species (including some pelagic and sedentary species) toward sedentary or structure-oriented species that are more tolerant of minor water quality impairments. Any impacts on transient fish swimming through the mixing zone would be expected to be acute, and affected individuals would be expected to recover quickly after exiting the mixing zone.

Auditory Impacts to Fish from Vessel Activity, Vertical Seismic Profiling, and Pile Driving

The same sound sources associated with the Project that could impact marine mammals (Section 7.2.5) could also impact fish. These can be broadly separated into non-impulsive sources (e.g., vessel sound) and impulsive sources (pile driving and VSP). Hearing abilities and sensitivities differ significantly among fish species. Certain species can be classified as hearing generalists or specialists[30] based on differences in hearing ability conveyed by specific anatomical traits. Although hearing specialists are thought to be more susceptible to auditory impacts within certain audio frequencies than other species, there are no generally accepted thresholds for auditory impacts in either specialist or generalist species and many species' hearing abilities have yet to be quantified.

Non-impulsive Sound

A recent EIS conducted by the U.S. Department of the Interior as part of a Programmatic Environmental Impact Statement for proposed geological and geophysical investigations in the Atlantic Outer Continental Shelf off the south eastern U.S. in 2014 (BOEM, 2014) contained a comprehensive review of auditory impacts on fish from non-impulsive and impulsive sources (including seismic surveys). This study found that fish may experience a range of impacts from non-impulsive sound including increased stress and threshold shift, and fish may employ behavioral strategies to avoid the sound source (BOEM, 2014). However, the extent to which these impacts would actually occur is highly dependent on the hearing abilities and sensitivities

[30] Hearing specialists are species that have developed heightened sensitivities to sounds in a specific frequency range. This adaptation occurs in some species to facilitate feeding or social behavior. Hearing specialists are distinguished from hearing generalists, which hear equally well across a wider range of frequencies, but do not possess the acuity of the specialists within their specific frequency range.

of the species of fish that occur within the PDA, and these abilities and sensitivities are currently unknown.

Impulsive Sound

The impact of impulsive sounds on hearing specialists is the most important factor to consider when rating Project-related auditory impacts on fish because of the following:

- Impulsive sound is usually considered more important than non-impulsive sound in terms of impacts on fish because impulsive sound is the category most often associated with hearing loss, injury, or death of fish;
- Impulsive sources also tend to have more severe impacts on hearing specialist species and those species with well-developed swim bladders[31] than others because they tend to be more sensitive to auditory impacts especially within the range of frequencies that they are specially adapted to detect;
- High peak pressures and rapid onset and decay tend to be associated with the most severe auditory impacts on fish, and are characteristic of impulsive sources; and
- As described in Section 7.1.2, impulsive sound from driven piles and VSP would impact a larger area of the ocean than the non-impulsive sources modeled by JASCO (especially to the north of the source) and therefore could impact a larger number of species and individual fish than would the non-impulsive sources.

Larson (1985) concluded that lethal impacts in the most sensitive taxa can occur at peak pressures exceeding 229 Db re 1µPa with onset/decay times less than 1 ms. Turnpenny and Nedwell (1994) reviewed historical studies of seismic impacts on fish and determined that for exposures at close range (<10 m) transient behavioral impacts began appearing at 192 dB re 1µPa, a variety of injuries appeared at about 220 dB re 1µPa, and mortality began appearing at exposures above 230 dB re 1µPa, although these impacts did not always occur and some exposures up to 240 dB re 1µPa resulted in no observable adverse impacts.

There have been no published reports to date documenting a lasting impact on fishing or fish stock as a result of seismic surveys. BOEM (2014) concluded that although hearing specialists are more susceptible than hearing generalists to hearing loss from impulsive sound, such impacts do not always occur and are generally not permanent. Impacts would be expected to be most severe in resident fish that are oriented to structural bottom habitats and would therefore be exposed to repeated impulses at a given location over time. One such genus (*Sebastes spp*)., showed startle and alarm responses to 10-min exposures of seismic impulses at 180 dB re 1 µPa at ranges from 11m to several kilometers, but the impacts appeared to be transitory (Pearson et al. 1992). Another study of the reef-oriented pollack (*Pollachius pollachius*) documented only minor changes in behavior when exposed to seismic impulses with peak sound pressures

[31] Caged exposure tests have determined that species with large swim bladders or other highly vascularized, low density organs or structures tend to be more susceptible to acute acoustic injury than species that lack these features when exposed to such sources within a few meters.

between 195-218 dB re 1µPa at ranges of 5.3-109 m (Wardle et al, 2001). Documented recovery times vary, but generally range from a few hours to a few days.

The available literature described above suggests that behavioral impacts from impulsive sound sources may begin to occur at peak sound pressures between 180-195 dB re 1 µPa, and that injury could occur at peak sound pressures around 220 dB re 1 µPa.

Given the most sensitive receptors do not always experience impacts from impulsive sound, they usually recover from such impacts, and impulsive sound would only occur during the initial phases of the Project, population level impacts on marine fish from auditory impacts are highly unlikely. Auditory impacts will not significantly impact any rare, sensitive, or important species (see discussion in Section 7.2.1).

Changes in Distribution and Habitat Usage Due to Altered Bottom Habitats and the Presence of Project Infrastructure

Installation of moorings for the FPSO, installation of SURF equipment, and drilling wells will disturb the seafloor temporarily within the PDA. These disturbances will create turbidity plumes and alter localized bottom contours within the area. The main potential impacts of turbidity plumes on fish are gill fouling and reduced visibility. Visibility is a minor factor at the depths that occur in the PDA, but fouled gills can lead to respiratory distress over long exposures. The turbidity plumes are expected to dissipate rapidly downcurrent, and fish will be expected to temporarily vacate the immediate vicinity of activities at the seafloor until turbidity reaches acceptable levels. This behavioral response will limit fishes' exposure to turbidity, and fish would be expected to return to the vicinity of the Project subsea infrastructure once seafloor disturbance activities are complete.

Some of the deepwater species from the "red fish" zone and all of the reef-associated species identified in the McConnell study (Section 6.2.7) are structure-oriented species. Physical structures provide many benefits to these species including refuge from currents and predators as well as foraging opportunities. These species would be expected to congregate around the well heads and manifolds once the disturbance associated with installation has abated and the Project enters the production operations stage. The isolated marine communities that develop around the SURF components could contain some species that are rare or absent elsewhere in the Project AOI due to the apparent lack of hard substrate outcrops in the area. These communities could be disturbed temporarily during decommissioning if the flowlines are disconnected from the manifolds and retrieved. However, the manifolds and well heads may remain in place in perpetuity (subject to the decommissioning plan), so these facilities will continue to provide habitats for the fish community over the long term. Minor, localized impairments in water quality will not be significant enough to cause substantial changes in fish populations, nor will they significantly impact sensitive or important species (see discussion in Section 7.2.1), but they will cause small changes in the distribution and composition of the fish community within the PDA.

Attraction to Artificial Light

Artificial light has been known for many years to attract fish in a variety of settings, and this phenomenon has been documented around floodlights on offshore petroleum infrastructure (Hastings et al. 1976, Stanley & Wilson 1997, Lindquist et al. 2005). Results from studies of platforms in the northern Gulf of Mexico suggest that platforms benefit all life stages by attracting and concentrating prey and providing sufficient light to locate and capture them (Keenan et al., 2007). While this may benefit predatory species in the short term, artificially lit structures have the potential to alter predator–prey interactions by creating conditions that favor predatory species at night and disadvantaging the prey while simultaneously attracting the prey species. This could ultimately have long-term negative impacts on predatory species if localized depletion of prey resources occurs (Becker et al., 2012; Nightingale et al., 2103). The artificial light produced from vessels will not be substantial enough to alter fish populations, nor will it significantly impact sensitive or important species (see discussion in Section 7.2.1), but may cause small changes in the distribution and/or behavior of fish in the immediate vicinity of the FPSO and possibly the drill ships and installation vessels. .

Entrainment in Water Intakes

Seawater will be withdrawn from the ocean to provide water to inject into the reservoir, to cool the FPSO's processing equipment during the production operations stage, and for ballast of vessels. Larval and juvenile fish have the potential to be entrained in the intake or impinged on the screens that will be installed to remove particulates from the water before it is pumped into the treatment unit on the FPSO. Most research on entrainment and impingement involves site-specific studies at onshore power plants and has been conducted in North American and European estuaries or nearshore coastal areas where immature fish are concentrated (Barnthouse, 2013). Nearshore intakes generally pose a higher risk of entrainment and impingement than offshore intakes (WaterReUse, 2011). Information on the entrainment and/or impingement rates at offshore intakes is sparse, but there is some recent evidence that losses from entrainment and impingement are insignificant at the population level even at power plants in coastal and estuarine settings (Barnthouse, 2013) and the U.S. Minerals Management Service noted that coastal power plants require much higher volumes of water than individual offshore oil and gas facilities (approximately 10 million gallons per minute for a nuclear power plant; Martinez-Andrade and Baltz, 2003), meaning that the entrainment losses at oil and gas facilities would likely be much lower than at power plants. In most cases, extrapolation of the losses of larval fish and eggs at power plant intakes to an equivalent number of adults indicates that entrainment losses are insignificant compared to natural and fishing-related mortality (Barnthouse, 2013; WaterReUse, 2011). Cooling and ballast water intakes on the FPSO and drill ships will be equipped with screens to prevent fish entrainment. Entrainment will not significantly impact sensitive or important species (see discussion in Section 7.2.1).

7.2.7.4 *Characterization of Impacts*

Magnitude of Impact

The assessment of the Project's magnitude of impacts on marine fish from the potential impacts described above is determined based on the size of the impact relative to natural variations in the impacted population (where known), the temporal scale of the impact, and the population level at which the impact is anticipated to occur. The magnitude of potential impacts on marine fish is defined according to the definitions provided in Table 7-38.

Table 7-38 Definitions for Magnitude Ratings for Potential Impacts to Marine Fish

Criterion	Definition
Magnitude	Negligible: Impact is within the normal range of variation for the population of the species.
	Small: Impact does not cause a substantial change in the population of the species, or other species dependent on it.
	Medium: Impact causes a substantial change in abundance and/or reduction in distribution of a population over one or more generations, but does not threaten the long term viability/function of that population, or any population dependent on it.
	Large: Impacts entire population, or a significant part of it causing a substantial decline in abundance and/or change in and recovery of the population (or another dependent on it) is not possible either at all, or within several generations due to natural recruitment (reproduction, immigration from unaffected areas).

The Project includes several embedded controls that will reduce the magnitude of impacts on marine fish, including:

- FPSO onboard treatment of produced water, bilge water, and sanitary wastewater prior to discharge;
- Use of oil/water separators, to ensure compliance with an oil in water content of <15 ppm (per MARPOL) for bilge water;
- Use of Water-Based Drilling Fluids (WBDF) and low-toxicity IOGP Group III NABF;
- Utilization of solids control and drill cuttings dryer systems to treat cuttings prior to discharge;
- Gradually increase intensity of seismic pulses during VSP and hammer energy (during pile driving) to allow sensitive species to vacate the area before injury occurs; and
- Provide screening on vessels for cooling water and ballast water intakes for FPSO and drill ship to minimize the entrainment of fish

Sensitivity of Receptor

The assessment of marine fish as a receptor of impacts from the Project is based on the conservation status of the marine fish expected to occur in the vicinity of the Project. The sensitivity of marine fish is defined according to the definitions provided in Table 7-39.

Table 7-39 Definitions for Receptor Sensitivity Ratings for Impacts to Marine Fish

Criterion	Definition
Sensitivity	Negligible: Species with no specific value or importance attached to them.
	Low: Species and sub-species without specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts.
	Medium: Species with one of the following characteristics: specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts; importance to local or regional fisheries; or vital importance to the survival of another medium-sensitivity species, but not meeting criteria for high value sensitivity.
	High: Species with two of more of the following characteristics: specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts; importance to local or regional fisheries; or vital importance to the survival of another medium-sensitivity species.

Impact Significance and Mitigation Measures

Table 7-40 summarizes the magnitude, sensitivity, and impact significance ratings for the potential impacts on marine fish discussed above. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-40 Summary of Impact Significance Ratings and Recommended Mitigation Measures - Marine Fish

Stage	Key Potential Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project stages	Auditory impacts on fish from vessel activity (pelagic species)	Small	Low	Negligible	None	Negligible
All Project stages	Disturbance from or attraction to offshore lighting (pelagic species)	Small	Low	Negligible	None	Negligible
Drilling and Installation	Distribution and habitat changes from altered bottom habitats and presence of Project infrastructure (demersal species)	Small	Medium	Minor	None	Minor
	Auditory impacts from pile driving and VSP (demersal species)	Small	Medium	Minor	None	Minor
	Permitted drill cuttings and fluids discharge	Negligible	Low	Negligible	None	Negligible
	Permitted liquid	Negligible	Low	Negligible	None	Negligible

Stage	Key Potential Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
	waste discharges					
Production Operations	Distribution changes due to altered water quality (pelagic species)	Small	Low	Negligible	None	Negligible
	Entrainment via water withdrawals (pelagic species)	Small	Low	Negligible	None	Negligible
	Attraction to artificial light (pelagic species)	Small	Low	Negligible	None	Negligible

7.2.8 Marine Benthos

7.2.8.1 *Introduction*

This section describes the potential impacts of the Project on marine benthic biological resources. The key potential impacts assessed include: a) injury to benthos as a result of deposition of drill cuttings (via smothering and/or toxicity impacts from residual oil contained in the cuttings); b) injury to benthos as a result of disturbance of the seafloor during installation of Project components; and c) positive impacts on benthos through creation of artificial substrate in the form of subsea infrastructure in place during production operations and as abandoned in place upon Project decommissioning.

7.2.8.2 *Relevant Project Activities and Potential Impacts*

The PDA is located in the eastern portion of the Stabroek Block in water depths ranging from approximately 1500-1900 m. This area's macrofauna community is dominated by polychaete worms as the most abundant major taxonomic group, followed by crustaceans, mollusks, and other taxa. Benthic epifauna appear scarce on the basis of the EBS survey results; however, tube building polychaetes (possibly Sabellidae and Terebellidae) and burrowing shrimp were observed.

The Project has the potential to impact these organisms through smothering (from deposition of drill cuttings), toxicological impacts (from NABF adhered to deposited cuttings) and crushing or displacement (from placement of subsea infrastructure). Additionally, the Project has the potential to result in a positive impact through the creation of artificial substrate (from infrastructure permanently installed on the seafloor).

Table 7-41 summarizes potential Project impacts on marine benthos.

Table 7-41 Project Activities and Potential Impacts – Marine Benthos

Stage	Project Activity	Key Potential Impacts
Drilling and Installation	Discharge of drill cuttings and accumulation on seafloor Installation of FPSO anchor structures and SURF infrastructure on the seafloor	• Smothering of benthos as a result of accumulation of drill cuttings. • Toxicological impacts on benthos from NABF adhered to deposited drill cuttings. • Crushing of benthos where subsea infrastructure is placed.
Production Operations	Presence of (non-moving) infrastructure on seafloor	• Creation of artificial substrate for use by benthos, temporary for duration of production operations (positive).
Decommissioning	Presence (abandonment) of subsea infrastructure on the seafloor	• Creation of artificial substrate for use by benthos (positive).

7.2.8.3 Characterization of Impacts – Drill Cuttings Deposition

Magnitude of Impact – Drill Cuttings Deposition

Planned discharges of drill cuttings and fluids will impact marine benthos as a result of accumulation of cuttings on the seafloor around the well locations. Potential routes of impact include physical and toxicological pathways.

With regard to potential physical impacts, discharged drill cuttings will accumulate on the seafloor close to the individual wells, and some benthic fauna will likely be impacted through burial and smothering. Smothering is a biological impact on benthos induced by the physical impact of burial. The severity of burial impacts depends on the sensitivity of the benthic organism, the thickness of deposition, the amount of oxygen depleting material (and the resulting anoxic conditions beneath the depositional layer), and the duration of the burial. Thickness thresholds vary by species and sediment permeability. A threshold deposition rate of 5 cm per month for smothering impacts to benthic communities is recommended based on publications by Ellis and Heim (1985) and MarLIN (2011). Smaller threshold values as low as 1 mm have been reported (e.g., Smit et al., 2006); however, they are associated with instantaneous burials on benthic species, not gradual smothering impacts.

As described in Section 7.1.3, modeling of drill cuttings discharges for four well/current combination scenarios indicated the maximum depositional thickness of cuttings on the seafloor is predicted to be between 19 cm and 75 cm, depending on currents and well locations. The model predicted extent of cuttings deposition above the 5 cm per month threshold will be confined to within a relatively short distance from the well locations, with the largest area predicted to be approximately 43 m (~141 ft) in diameter.

In terms of potential toxicity impacts, as discussed in Section 7.1.3, the nature of the NABF in the NADF is such that toxicological impacts to benthic fauna are not expected as a result of discharge of the treated cuttings and a limited, localized proportion of the Stabroek Block will be impacted by drill cuttings deposition. Currents are expected to naturally redistribute deposited cuttings over time, and additional (non-cutting) sediments will gradually mix with

and overlay the cuttings, gradually returning the surficial sediment layer to a chemical state similar to existing conditions. Additionally, the NABF used by EEPGL will be a low-toxicity substance, reducing the potential that changes in sediment quality will lead to toxicological impacts on benthic fauna. Based on consideration of the above, the overall magnitude of drill cuttings deposition impacts on marine benthos was rated as **Negligible**.

Sensitivity of Receptor - Drill Cuttings Deposition

A study of benthic megafauna in a similar environment offshore Venezuela found that abundances in the vicinity of offshore development sites were significantly reduced after drilling. Highly mobile organisms returned to the area soon after drilling was completed. However, the species composition of sessile taxa was altered, with analyses suggesting that their density increased further away from areas that had been disturbed. The recovery potential of deep-sea marine benthic biological resources, particularly sessile taxa, following cessation of drilling activities is unknown (Jones et al., 2012).

Sessile individuals will likely experience injury or mortality in areas where drill cuttings deposition exceeds the above-referenced threshold; however, long-term impacts on the benthos population are not expected as a result of smothering of these individuals.

With respect to toxicity impacts, contaminants deposited on the seafloor can pose risks to those deep-sea benthos living within or in close association with bottom substrates that are unable to avoid exposure due to their relatively sedentary existence. These benthos perform functional roles in the deep-sea ecosystem, including sediment bioturbation and stabilization, organic matter decomposition and nutrient regeneration, and serve as food sources to higher trophic levels; accordingly, toxicity could impact the population size as well as move up the food chain via bioaccumulation.

Based on consideration of the above, the overall sensitivity of marine benthos to drill cuttings deposition impacts was rated as **Low**.

Impact Significance and Mitigation Measures – Drill Cuttings Deposition

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for impacts on marine benthos from drill cuttings deposition. Based on this rating, no mitigation is recommended.

7.2.8.1 Characterization of Impacts – FPSO and SURF Installation

Magnitude of Impact – FPSO and SURF Installation

The shallow sediment layer would be disturbed during installation of subsea infrastructure (SURF and FPSO mooring structures) on the seabed. In addition to disturbance of the habitat, individual benthic organisms are likely to be crushed, dislocated from the substrate (sessile organisms), or dismembered as a result of these occurrences. With respect to installation impacts, as indicated in Table 7-42, which summarizes the area that will be disturbed by

installation of various infrastructure components, approximately 390,000 m² (30 ha, ~74 acres) (incorporating a 50 percent contingency factor) will be subject to essentially one-time disturbance by the installation activity. The use of anchors by vessels other than the FPSO is not expected; other vessels will utilize dynamic positioning to maintain station offshore.

Table 7-42 Area of Benthic Habitat Disturbed by FPSO and SURF Subsea Infrastructure Installation

Equipment	Quantity	Unit Area / Width	Subtotal (m²)
Trees	17	21 m²	357
Flying Leads	2,474 m	1 m width	2,474
Production Manifolds	2	12.5 m²	25
Flowline Structures	5	70 m²	350
Flowlines	29,809 m	3 m width	89,427
Water Injection (WI) Manifolds	2	12.5 m²	25
WI Pipeline Structures	2	70 m²	140
WI Pipeline	16,491 m	3 m width	49,473
Gas Injection (GI) Manifolds	1	12.5 m²	13
GI Pipeline Structures	1	70 m²	70
GI Pipeline	4,352 m	3 m width	13,056
Production Umbilical	13,168 m	3 m width	39,504
Injection Umbilical	4,259 m	3 m width	12,777
Subsea Distribution Units (SDUs)	4	40 m²	160
FPSO Anchor Piles and Chains	16	250 m²	4,000
FPSO Mooring Leg Prelay	16	3000 m²	48,000
		Subtotal	259,851
		Total w/~50% Contingency	390,000

The mortality of benthos, particularly sessile taxa, which are directly contacted during installation of subsea infrastructure within this area is anticipated to be high. Although some organisms will survive, they may be left with injuries that may impair their survival by making them prone to infection or vulnerable to predators. In addition, the population structure in the specific disturbance areas may temporarily change as more motile benthos taxa enter the disturbed area to scavenge organisms that did not survive. However, this impact will only occur within a small percentage of the Stabroek Block (approximately 0.001 percent by area).

From a benthic population standpoint, this leads to an impact magnitude rating of **Negligible**.

Sensitivity of Receptor - FPSO and SURF Installation and

The sensitivity of the marine benthos population to FPSO and SURF installation impacts is considered **Low**. While the mortality rate of sessile taxa individuals from physical disturbance resulting from installation of the subsea infrastructure will be high, the population is not anticipated to be sensitive to the reduction in individuals.

Impact Significance and Mitigation Measures – FPSO and SURF Installation

These magnitude and sensitivity ratings lead to a significance rating of **Negligible** for impacts on marine benthos from FPSO and SURF installation. Based on this rating, no mitigation is recommended.

7.2.8.2 *Characterization of Impacts – Presence of Subsea Infrastructure*

Magnitude of Impact – Presence of Subsea Infrastructure

As described in Section 2.12, at the end of operations some subsea infrastructure, including the SURF equipment that is connected to the FPSO (e.g., risers, umbilical), SURF equipment sited on the seafloor, and FPSO mooring system, may be disconnected and abandoned in place on the seafloor in accordance with standard industry practice, consistent with the decommissioning plan. This would constitute an irreversible loss of natural soft bottom habitat within the collective footprint of these structures, but some species of benthos may colonize this hard substrate or be attracted to it as an artificial reef, as found in shipwrecks in the Gulf of Mexico (Kilgour and Shirley, 2008). This will only occur within the immediate footprint of the abandoned infrastructure and is expected to impact a relatively small number of organisms. From a benthic population standpoint, this leads to a **Positive** impact magnitude rating.

This positive impact is also relevant for the production operations stage, as benthic organisms will have the opportunity to colonize elements of subsea infrastructure which remain stationary through the production operations stage. These positive impacts will be temporary for any infrastructure that is removed at the time of decommissioning.

Sensitivity of Receptor – Presence of Subsea Infrastructure

The sensitivity of the marine benthos to this impact is considered **Low**, as only a small number of organisms would be impacted and those are species that are accustomed to colonizing hard substrate, in an area where this type of surface is not common.

Impact Significance and Mitigation Measures – Abandonment of Subsea Infrastructure

These magnitude and sensitivity ratings lead to a significance rating of **Positive**.

7.2.8.3 *Summary of Impact Significance Ratings*

Table 7-43 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on marine benthos, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-43 Marine Benthos - Pre-Mitigation and Residual Impact Significance Ratings

Stage	Key Potential Impact	Sensitivity	Magnitude	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation	Smothering and/or toxicity impacts Injury or disturbance	Low	Negligible	Negligible	None	Negligible
Production Operations Decommissioning	Marine benthos – from creation of artificial substrate	Low	Positive	Positive	None	Positive

7.2.9 Ecological Balance and Ecosystems

7.2.9.1 *Introduction*

This section describes the potential impacts of the Project on the key components and functions of the marine ecosystem. For over 30 years, the US National Oceanographic and Atmospheric Administration (NOAA) has used the Large Marine Ecosystem (LME) concept as a model to assess and manage ecological functions at the regional scale. LMEs are defined as relatively large areas of ocean space of approximately 200,000 km² (20,000,000 ha or ~80,000 mi²) or greater, adjacent to the continents in coastal waters where primary productivity is generally higher than in open ocean areas. The PDA is located in the northwestern portion of the North Brazil Shelf LME, which comprises the coastal waters adjacent to northeastern South America from the eastern edge of the Caribbean Sea to the Parnaiba River in Brazil. Its width varies, but it extends roughly 500 km (~300 mi) off the coast of Guyana (NOAA, 2016).

7.2.9.2 *Discussion of Potential Impacts*

All of the Project activities are broadly relevant to an assessment of impacts on ecological balance and ecosystems because the potential impacts will occur within the ecosystem and could impact one or more of its components. Therefore, rather than focusing on individual Project activities and their separate impacts on specific ecosystem components, this section identifies key ecosystem components and functions, and assesses the ecosystem level implications of the impacts identified in Sections 7.2.1 through 7.2.8 that could impact those key components and functions. Although there is no universally accepted definition of key ecological functions (in generic terms or with respect to the North Brazil Shelf LME), they generally include such basic processes as nutrient cycling, gene flow, and maintenance of biodiversity.

Changes in the Marine Nutrient Cycle

The three most important nutrients in the marine nutrient cycle are nitrogen, phosphorous, and silicon (Nihoul and Chen, 2008). The primary source of all of these nutrients in the marine food web is phytoplankton, which assimilate the nutrients from the surrounding seawater. Nitrogen and phosphorous are essential nutrients to all plant life and silicates enter the marine nutrient cycle largely through diatoms, a specific class of phytoplankton that construct hard silicate exoskeletons. The Project could potentially indirectly impact the marine nutrient cycle through its impacts on marine water quality, which could in turn impact phytoplankton growth. As discussed in Section 7.1.4, the Project is predicted to have negligible impacts on water quality, and these impacts are predicted to be limited to a relatively small, localized mixing zone around the FPSO. These impacts are likely to reduce nutrient uptake by phytoplankton within the mixing zone, but based on the significance of water quality impacts as assessed in Section 7.1.4 and the very small portion of the North Brazil Shelf LME that would be exposed to these impacts, the Project is predicted to have little if any ecosystem-level impacts on nutrient cycling.

Impacts on Gene Flow

Maintaining gene flow is critical to supporting the genetic diversity in marine biological populations, which in turn is an important factor in the general resilience and vigor of marine flora and fauna. Obstacles to efficient gene flow occur whenever physiochemical barriers to migration, breeding, or dispersal/colonization occur. Oceanic currents are a key driver of biological dispersal because many marine species spend all or part of their lives drifting as part of the plankton. A project could potentially have significant impacts on gene flow if it impacted large scale current patterns or prevented site specific reproductive events (such as spawning aggregations) from occurring. The Project is not predicted to have any appreciable impact on regional current patterns that define the North Brazil Shelf LME, nor is it predicted to impact any site-specific reproductive activities that could be considered significant at a regional or ecosystem scale.

Impacts on Biodiversity

The Project is predicted to have numerous impacts on marine species, but is not expected to impact large-scale distribution of species or cause the loss of any species from within the North Brazil Shelf LME. Some benthic species may be locally displaced from the footprint of the SURF components and some pelagic species may be locally displaced from the surface mixing zone that will form around the wastewater outfall, but these impacts would be insignificant at the ecosystem scale. Additionally, there is a negligible risk of the Project causing the extinction or extirpation of any species from the North Brazil Shelf LME, or exacerbate any of the risk factors that have contributed to the listing of the special status species assessed in Section 7.2.1.

Ballast Water and Invasive Species

Ballast water is water carried in ships' ballast tanks to improve vessel stability, balance and trim; it is essential for the safe operations of oceangoing ships. It is taken onboard or discharged

when cargo is unloaded or loaded, or when a ship needs extra stability in foul weather. When ships take on ballast water, aquatic plants and animals may also be entrained into the ballast tanks. These organisms are transported in the ballast tanks of the ships, and, upon being discharged, some of these organisms may survive and establish themselves in the new environment if the habitat conditions are suitable. The global movement of ballast water is considered to be the largest transfer mechanism for marine non-indigenous species (Ruiz et al., 2005). If the non-indigenous species become invasive, they may cause serious ecological, economic, and public health impacts (MCA, 2008). If the invasive species become dominant in the new environment, they can displace native species, change local/regional biodiversity, and affect local economies based on fisheries. In addition, these invasive species may also affect industries that withdraw coastal water and affect public health (ESMA, 2017).

The Caribbean Invasive Alien Species Working Group, of which Guyana is a member, has identified one species, the green mussel (*Perna virdis*), as having been introduced to the Caribbean and South American coastal waters via ballast water (CIASNET, 2010).

The Project has the potential to contribute to the spread of marine invasive species as the discharges of ballast water will be required for initial FPSO installation and recurring tanker offloading during production operations. As discussed in Section 2.5.8.4, ballast water will be required for FPSO transit from the shipyard to the site. Once on site, the unneeded ballast water from the FPSO may be discharged overboard. The initial FPSO ballast discharge will occur only during a limited time period during SURF installation and commissioning activities. It is estimated that no more than 500,000 barrels of ballast water would be discharged into Guyanese waters (Table 2-5) during this time. In order to mitigate the risk of invasive species, the ballast water taken on will be exchanged with water from deep international waters. This practice is generally thought to reduce the likelihood of introducing invasive species to new coastal habitats because oceanic organisms are considered unlikely to colonize coastal habitats (Ruiz et al., 2005), but the tankers will not be entering Guyana's coastal waters. The tankers will be discharging ballast water obtained from open ocean environments elsewhere to the oceanic waters in the PDA. The environmental conditions at the point where the water is withdrawn will likely be similar to the conditions in the PDA, which means that at least some organisms discharged into the PDA would be likely to survive the event, but it also means that these organisms would likely include many of the same open-ocean species that occur naturally in the PDA.

During production operations, vessels will take on water before leaving their home port, which will likely be from multiple countries. The offloading tankers will routinely discharge this ballast water in Guyanese waters as oil from the FPSO is loaded. It is estimated that approximately 1,100,000 barrels of ballast water (Table 2-5) will be offloaded during each loading. These ballast water discharges would be conducted in accordance with internationally recognized standards and in compliance with IMO requirements. The ecological effect would similar to the effect of the ballast discharge from the FPSO in the sense that organisms from the open ocean would be discharged at the FPSO, but discharges from tankers would occur multiple times per week during the peak periods of the production phase.

7.2.9.3 *Characterization of Impacts*

Magnitude of Impact

The Project's predicted ecosystem-level impacts are indirect impacts that would potentially occur as a result of direct impacts on specific abiotic and abiotic components of the larger ecosystem. The assessment of the Project's magnitude of impacts on the North Brazil LME from the potential impacts described above is determined based on the geographic extent of the impact compared to the size of the North Brazil LME, and the initial rating of the direct impact that would drive the indirect ecosystem-level impact. The magnitude of potential ecosystem-level impacts is defined according to the definitions provided in Table 7-44.

Table 7-44 Definitions for Magnitude Ratings for Potential Impacts to Ecological Balance and Ecosystems

Criterion	Definition
Magnitude	Negligible: Impact is within the normal range of variation for the ecosystem as a whole.
	Small: Impact is predicted to be outside the range of natural variation, but does not cause a substantial change in any of the key ecosystem functions identified in Section 7.2.9.1.
	Medium: Impact is predicted to be outside the range of natural variation, and causes a substantial change in one or more of the key ecosystem functions identified in Section 7.2.9.1.
	Large: Impact is predicted to be outside the range of natural variation, and causes a substantial change in two or more of the key ecosystem functions identified in Section 7.2.9.1.

All of the embedded controls identified in Section 2.11 will minimize impacts on one or more physical, biological, or chemical attributes of the ecosystem, and will therefore play a role in reducing the initial magnitude of impacts on the ecosystem.

Sensitivity of Receptor

The assessment of the ecosystem as a broad receptor of indirect impacts from the Project is based on the sensitivity of the receptor to the initial direct impact that will drive the ecosystem-level impacts. Ecosystem level sensitivity is defined according to the definitions provided in Table 7-45.

Table 7-45 Definitions for Receptor Sensitivity Ratings for Impacts to Ecological Balance and Ecosystems

Criterion	Definition
Sensitivity	Negligible: Biological impacts affect receptors with no specific value or importance attached to them.
	Low: Biological impacts affect species and sub-species of Least Concern on the IUCN Red List (or not meeting criteria for medium or high value), or without specific anatomical, behavioral, or ecological susceptibilities to Project-related impacts.
	Medium: Biological impacts affect species listed as Vulnerable, Near Threatened, or Data Deficient on the IUCN Red List, species protected under national legislation, nationally restricted range species, nationally important numbers of migratory or congregatory species, species not meeting criteria for high value, and species vital to the survival of a medium value species.
	High: Biological impacts affect species on IUCN Red List as Critically Endangered or Endangered. Species having a globally restricted range (e.g., fauna having a distribution range less than 50,000 km^2 (20,000 mi^2), internationally important numbers of migratory, or congregatory species, key evolutionary species, and species vital to the survival of high value species.

Impact Significance and Mitigation Measures

Table 7-46 summarizes the magnitude, sensitivity, and impact significance ratings for the potential ecosystem level impacts discussed above. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-46 Summary of Impact Significance Ratings and Recommended Mitigation Measures – Ecological Balance and Ecosystems

Stage	Resource / Receptor Impact	Sensitivity	Magnitude	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project stages	Nutrient uptake by phytoplankton; localized and temporary changes in species distribution	Low	Small	Negligible	None	Negligible
Production Operations	Marine biota that could be affected by invasive species introduced by ballast water	Low	Medium	Minor	None	Minor

7.3 Socioeconomic Environment

For the purposes of this EIA, "socioeconomic environment" is intended to encompass the human aspects of the affected environment, with specific emphasis on the social and economic characteristics of society that could be affected by the Project. This section identifies and assesses the potential impacts on the existing socioeconomic environment in the Project AOI, including community health and cultural heritage, as a result of Project-related activities. The methodologies specific to the assessment of socioeconomic impacts build upon the general assessment methodology outlined in Chapter 4. This general approach and methodology has been adapted for use in evaluating impacts to socioeconomic receptors. The evaluation criteria used to determine impact magnitude and sensitivity for specific socioeconomic receptors are summarized in Table 4-2.

Stakeholder engagement is critical to a robust impact assessment process. A range of stakeholders were interviewed to deepen ERM's understanding of the existing socioeconomic conditions (presented in Chapter 6). The information gathered was also used to inform the sensitivity and magnitude designations used in this assessment. The following socioeconomic resources with the potential to be impacted by the Project within the Project AOI are assessed in this section:

- Economic conditions
- Employment and livelihoods
- Community health and wellbeing
- Marine use and transportation
- Social infrastructure and services
- Land use
- Ecosystem services
- Indigenous Peoples
- Cultural Heritage

7.3.1 Project Activities and Receptors

As the Project's primary activities are located more than 190 kilometers (~120 miles) offshore, impacts on socioeconomic resources as a result of planned Project activities are expected to be limited. The main Project activities[32] with potential to result in socioeconomic impacts are:

- Installation and operation of the FPSO and SURF
- Drilling of wells
- Government revenue generation from Project
- Project employment and procurement
- Worker presence in the Georgetown area

[32] Other Project activities considered in this assessment include discharges of process and waste waters; utilization of an FPSO marine exclusion zone; changes in land use; and aviation activities. However, impacts on socioeconomic conditions from these activities were considered negligible.

- Project use of emergency and health services in the Georgetown area
- Project use of roads and transportation services in the Georgetown area
- Marine vessel transit between the PDA and shorebase facilities in Guyana and Trinidad

Potential receptors for socioeconomic impacts during planned Project activities are outlined in Table 7-47, along with the rationale for their inclusion and the associated potential impacts:

Table 7-47 Socioeconomic Receptors and Potential Impacts as a Result of Project Activities

Receptor	Rationale for Inclusion	Potential Impacts
General Guyanese population	The Project could have far-reaching economic impacts throughout the country, which could impact all segments of the population.	• Increased government revenues potentially leading to increased social spending and investment throughout the country. • Increased business activity and related employment.
General population of Georgetown	The limited amount of time that offshore-based Project workers (those who are foreign) will be onshore will likely be spent in transit in Georgetown, where they will interact with and make use of the same resources and infrastructure as the local population. Project procurement and increased worker spending level may result in higher demand for goods and services. The Project may result in induced influx of job-seekers from other areas of Guyana to the Georgetown area. The Project may rely, in a very limited manner, on some medical and health facilities in the Georgetown area to address worker illness and injury.	• Changes to community dynamics, identity, and sense of safety/security. • Increased cost of living. • Increased risk of communicable disease transmission. • Decreased accessibility or quality of medical and health service.
Road users in Georgetown (both motorized and non-motorized [e.g., cyclists, pedestrians] modes)	The Project will use existing roads for transporting materials and equipment from warehouses or storage facilities to the Georgetown area shorebases.	• Increased traffic congestion. • Increased risk of property damage and injury due to vehicle accidents.
Marine vessel operators in the Georgetown Harbour and along the coast	The Project will involve transit of various marine vessels such as support vessels and tugs from the Georgetown area shorebase facilities to the PDA.	• Increased marine traffic congestion in Georgetown Harbour and coastal waters between Georgetown and the PDA. • Increased risk of marine accidents.
Marine vessel operators in the vicinity of the PDA	The Project will establish marine safety exclusion zones around the FPSO, drill ship, and major installation vessels, precluding use of this area for other activities such as fishing.	• Reduced availability of ocean areas for non-Project livelihood activities such as fishing.

Receptor	Rationale for Inclusion	Potential Impacts
Archaeology and heritage resources	The Project will disturb the seafloor in the process of drilling development wells, installing FPSO components, and installing SURF components	• Damage to underwater archaeological or historical sites.

7.3.2 Economic Conditions

7.3.2.1 *Introduction*

This section assesses potential Project impacts on economic conditions in the Project AOI. The key impacts considered for planned Project activities include: Project-related revenue generation and increased tax revenues for the government, potentially resulting in increased government spending (typically on social services and infrastructure); potential increased local business activity and related employment as a result of Project procurement and employment; potential increased Project worker spending levels; and potential increased cost of living to citizens due to higher demand for goods and services.

The extent and type of Guyanese employment and procurement opportunities are outside the scope of the EIA. Such considerations will be addressed as part of EEPGL's preparation of a local content plan consistent with the requirements of the petroleum agreement.

7.3.2.2 *Relevant Project Activities and Potential Impacts*

The Project would contribute directly and positively to increased national revenues through a petroleum agreement between EEPGL and the government. The Project would also benefit the economy through local procurement of select goods and services, limited direct local employment, and spending in local communities by Project workers.

In addition to direct expenditures and employment, the Project would also likely generate induced economic benefits as other non-Project related businesses benefiting from direct Project purchases or worker spending will re-invest locally or expand spending in the area, thereby also generating more local value-added tax. These beneficial "multiplier" impacts will occur throughout the Project life.

Potential adverse impacts of the Project on economic conditions associated with planned Project activities could include the potential for cost of living to increase due to a higher demand for some goods and services, either through direct Project procurement or through Project worker purchases.

Potential impacts on economic conditions from the Project are summarized in Table 7-48.

Table 7-48 Project Activities and Potential Impacts – Economic Conditions

Stage	Receptor(s)	Project Activity	Key Potential Impacts
All Project stages	Guyanese population	Project revenue generation	• Potential government investment in social services and economic development/ diversification. • Potential government infrastructure projects.
		Project procurement of selected goods and services	• Increased sales tax revenues. • Increased local business activity and growth. • Increased demand for services and infrastructure, leading to increased cost of living.
		Project worker spending	
		Limited local employment (direct and indirect)	

7.3.2.3 *Magnitude of Impact - Economic Conditions*

The Project has the potential to impact economic conditions both positively and negatively. Project revenues to the government through its revenue sharing agreement with EEPGL can allow for increased government spending on social infrastructure, services, and programs, as well as investment in infrastructure programs and different economic sectors. Economic conditions can also be impacted positively by select local Project procurement and through Project worker spending.

An adverse impact could occur from increases in the cost of living due to higher demand for some goods and services. Given the Project's small workforce and predominantly offshore footprint, such increases are expected to be limited.

Economic benefits of the Project are expected to outweigh potential negative impacts such that overall impacts on the economy are expected to be **Positive**. As described in Chapter 4, this assessment does not develop ratings for positive impacts.

7.3.2.4 *Sensitivity of Receptors - Economic Conditions*

The receptors most likely to be most impacted by impacts to economic conditions are residents in the Georgetown area. As discussed below, vulnerable (lower-income) populations are considered to be more sensitive to this impact and are therefore considered separately. Sensitivity of the receptors is determined based on the definitions in Table 7-49.

Table 7-49 Definitions for Receptor Sensitivity for Impacts to Economic Conditions

Criterion	Definition
Sensitivity	Low: The local and regional economies are highly diversified and not highly dependent on any one sector. The workforce is highly skilled, would not experience major challenges in shifting to different occupations, and is well positioned to benefit from the Project.
	Medium: The local and regional economies are somewhat diverse and dependent on a few key industrial sectors that are not all natural resources-based. Alternate economic opportunities, including from the Project, are possible but the workforce may require additional training to be able to pursue such opportunities.
	High: The local and regional economies are highly dependent on one or a few industrial sectors that are largely natural resource sectors. There are few alternate economic opportunities in the area and/or the workforce does not have the skills to shift to pursue alternate economic opportunities.

Receptors in the Georgetown area (Region 4) are considered to have a **Medium** level of sensitivity to economic impacts since the economy in this region is relatively diverse and less dependent on natural resources than in other areas of the country, with 12 percent of jobs in the primary sector, 21 percent in the secondary sector and 67 percent in the tertiary sector[33].

Individuals and households of lower socioeconomic status are considered to have a **High** level of sensitivity to economic impacts due to their lower capacity to benefit from the Project and the business opportunities it may bring, and to their higher level of vulnerability to an increased cost of living. However, this vulnerable population would benefit from increased government revenues along with the general population, should such government revenues be invested in social infrastructure, services, and programs, as well as investment in infrastructure programs and different economic sectors.

7.3.2.5 *Impact Significance and Mitigation Measures - Economic Conditions*

As discussed above, this impact is considered to be **Positive**, for both the general population and the low-income subpopulation in the Georgetown area. As described in Chapter 4, this assessment does not develop significance ratings for positive impacts.

[33] According to the BSG, the primary industrial sectors (e.g., agriculture, fishing, forestry, and mining) make direct use of natural resources and include the production of raw materials and basic foods. The secondary sector is engaged in manufacturing using raw products from the primary sector and includes processing, construction, textile production, brewing and bottling, etc. The tertiary sector provides services to the general population and businesses, including retail and wholesale trade, transportation and distribution, entertainment, tourism, healthcare, etc.

As this is a positive impact, no mitigation measures are required. To enhance the benefits from this positive impact, the Project intends to procure select Project goods and services locally to the extent reasonably practicable. While it is expected that the number of Guyanese workers will be small, the Project also intends to utilize Guyanese nationals where reasonably practicable.

Table 7-50 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on economic conditions, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-50 Economic Conditions – Pre-Mitigation and Residual Impact Significance Ratings

Phase	Resource/ Receptor Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project stages	Guyanese population including lower income subpopulation - increased government revenues, increased employment, increased local business activity, potential for increased cost of living.	Not assessed	Medium High (lower socio-economic groups)	Positive	None	Positive

7.3.3 Employment and Livelihoods

7.3.3.1 *Introduction*

This section assesses potential Project impacts on employment and livelihoods in the Project AOI. The key impacts considered for planned Project activities are: potential increased local business activity and employment due to select Project employment and select Project procurement and due to Project worker spending; potential occupational health and safety impacts to Project workers; and potential for restricted access to fishing locations, and damage to fishing vessels and equipment from Project vessel movements.

The extent and type of Guyanese employment and procurement opportunities are outside the scope of the EIA. Such considerations will be addressed as part of EEPGL's preparation of a local content plan consistent with the requirements of the petroleum agreement.

7.3.3.2 *Relevant Project Activities and Potential Impacts*

The primary Project activities will occur approximately 190 kilometers (~120 miles) offshore and are not expected to significantly impact non-Project activities occurring on the Guyana coast. Project workers onboard the FPSO and other Project vessels may be exposed to occupational hazards which will be managed through training and the use of protective equipment as appropriate. The only direct planned Project activities that will be perceptible from the shore will be support vessel trips originating from and returning to shorebase facilities in Georgetown. In addition, the Project will engage select local companies for the provision of various goods and services (e.g., catering, transportation, logistics) to support Project activities. Table 7-51 summarizes potential Project impacts on employment and livelihoods.

Table 7-51 Project Activities and Potential Impacts – Employment and Livelihoods

Stage	Receptor(s)	Project Activity	Key Potential Impacts
All Project stages	Population of Georgetown and vicinity	Project procurement of select goods and services	• Increased local business activity and growth • Increased employment
		Worker spending	
		Limited local employment (direct and indirect)	
	Fishing vessel operators in the coastal area	Transit of Project vessels between the PDA and shorebase(s) in Georgetown and in Guyanese waters between PDA and shorebase(s) in Trinidad and Tobago	• Damage to fishing vessels and equipment impacting fishing livelihoods

7.3.3.3 *Magnitude of Impact - Employment and Livelihoods*

The assessment of the Project's magnitude of impacts on employment and livelihoods is determined based on consideration of geographic extent, frequency, duration, and scale. The scale of potential impacts on employment and livelihoods is defined according to the definitions provided in Table 7-52.

Table 7-52 Definitions for Scale Ratings for Potential Impacts on Employment and Livelihoods

Criterion	Definition
Scale	Negligible: Changes do not bring about any loss of livelihood or employment.
	Small: The changes impact some individual receptors' ability to engage in their current livelihood(s) at the same level of productivity.
	Medium: The changes impact the receptors' ability to engage in their current livelihood(s) at the same level of productivity, and/or cause a loss of working days. An entire sector within a community may be impacted in this way.
	Large: The changes cause the receptors to cease their current livelihood activities for an extended period of time, or indefinitely. An entire sector within a community or region may be impacted in this way.

Few adverse impacts on employment or livelihoods are expected as a result of planned Project activities. Fishing activities (both industrial and artisanal) rarely occur as far offshore as the PDA, and therefore the FPSO marine safety exclusion zone will have little or no impact on existing fishing activity. As a mitigation measure, the Project intends to issue notices to mariners via MARAD, the Trawler's Association, and fishing co-ops for major marine vessel movements, including movements of the FPSO, drill ship, and major installation vessels. The Project will also communicate major vessel movements to commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and where possible communicate Project activities to those individuals to aid them in avoiding Project vessels through the stakeholder engagement process. This will allow fishing boat operators to adjust their fishing locations if needed to avoid these offshore locations with higher densities of Project vessels.

Project interactions with fisherfolk would likely be limited to encounters with support vessels transiting between the PDA and the shorebases in Georgetown and Trinidad and Tobago. This could result in some limited and temporary disruption to fishing activity; there is also minimal potential for support vessels to cause damage to fishing vessels or equipment such as nets during transiting. The potential for interactions between fishing vessels and support vessels is highest near the Port of Georgetown and the Demerara River mouth, where commercial vessel traffic is already present. Considering these planned measures, and given the familiarity of fishing vessels on the coast with commercial vessel traffic, and the occasional and temporary nature of the Project's marine vessel transiting, the magnitude of the impact is considered to be **Negligible**.

In addition to direct employment, the Project will result in the indirect employment of workers through procurement of select local goods and services such as food, transportation, and logistical support. Local and foreign workers that are off shift also will spend a portion of their salaries in the Georgetown area on local accommodations, food, transportation, and entertainment. This increase in business for these local service providers could potentially lead to increased incomes, additional hiring, and continued investment in these local businesses, allowing for further growth. This impact is considered to be **Positive** and as such, a magnitude rating is not assigned.

7.3.3.4 *Sensitivity of Receptors - Employment and Livelihoods*

Potential receptors for employment and livelihood impacts are the general population in Georgetown and its vicinity; subsistence and commercial fisherfolk as well as farmers operating on the Guyanese coast; and Project workers based offshore. The receptor sensitivity ratings for employment and livelihoods are defined according to the definitions provided in Table 7-53.

Table 7-53 Definitions for Receptor Sensitivity Ratings for Employment and Livelihood Impacts

Criterion	Definition
Sensitivity	Low: The receptor can easily adapt to the change without assistance or can shift to alternate livelihood opportunities without impacting ability to subsist and/or earn income.
	Medium: The receptor may adapt to the change or shift to alternate livelihood activities with assistance and with some disruption to ability to subsist and/or earn income.
	High: The receptor cannot adapt to the change without difficulty and cannot easily transition to alternate livelihood activities. Impacts on current livelihood activities will pose a threat to the receptor's ability to subsist, earn income, and maintain current quality of life.

The Guyanese population continues to rely heavily on primary sector livelihoods such as agriculture and fisheries; however, the share of primary sector jobs has been decreasing steadily in favor of more secondary and tertiary (service) sector jobs. Based on the definitions above, the general Guyanese population is considered to have a **Medium** level of sensitivity to potential employment and livelihood impacts from planned Project activities. Fisherfolk engaging in fishing on the Guyanese coast are also considered to have a **Medium** level of sensitivity to such impacts.

7.3.3.5 *Impact Significance and Mitigation Measures - Employment and Livelihoods*

Based on the magnitude of impact and the receptor sensitivity ratings, the significance of livelihood and employment impacts on fisherfolk operating in the coastal area is **Minor**. The significance of livelihood and employment impacts for Project workers based offshore is also **Minor**.

As discussed above, the positive impacts on employment and livelihoods that will result from Project employment, procurement, and worker spending will outweigh potential adverse impacts for an overall **Positive** impact. As discussed above, the Project will (as a mitigation measure) seek to enhance positive benefits by procuring select goods and services locally (potentially leading to enhanced local employment and livelihood benefits) to the extent reasonably practicable, and this has been considered as part of the **Positive** rating.

Beyond these mitigation measures, no additional mitigation measures for potential adverse impacts are necessary.

Table 7-54 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on employment and livelihoods, and the impact significance ratings resulting

therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-54 Employment and Livelihoods – Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource/ Receptor Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project stages	Population of Georgetown and vicinity - increased employment, local business activity, and household incomes.	Not assessed	Medium	Positive	None	Positive
	Fisherfolk - Impacts on fishing livelihoods	Negligible	Medium	Negligible	None	Negligible

7.3.4 Community Health and Wellbeing

7.3.4.1 *Introduction*

This section assesses potential impacts from the Project on community health and wellbeing in the Project AOI. The key potential impacts considered as a result of planned Project activities are increased risk of communicable disease transmission, decreased public safety from interactions with Project activities, and decreased availability of emergency medical and health services. Increased risks of marine and road accidents to the public are assessed in Section 7.3.5 and Section 7.3.6, respectively.

7.3.4.2 *Relevant Project Activities and Potential Impacts*

The Project will involve a range of activities that could potentially impact public health. Shifts in demographic patterns, including the influx of foreign workers or the spatial concentration of working-age populations, has the potential to cause changes in disease transmission patterns, and to impact public safety. Project onshore and nearshore transportation activities could increase the risk for vehicular and marine accidents. The potential for these impacts are limited due to the Project's limited onshore footprint.

Table 7-55 Project Activities and Potential Impacts - Community Health and Wellbeing

Stage	Receptor(s)	Project Activity	Key Potential Impacts
All Project Stages	General population of Georgetown and vicinity	Project worker presence Project use of medical and health resources in the Georgetown area	• Increased risk of communicable disease transmission. • Impacts on public safety. • Overburdening of medical and health services.
	Road users in Georgetown and vicinity Marine users in vicinity of Georgetown shorebase(s)	Project transportation (marine and road)	• Increased risk of vessel collisions and vehicle accidents (refer to assessments in section 7.3.5 and 7.3.6).

7.3.4.3 *Magnitude of Impact - Community Health and Wellbeing*

The assessment of the Project's magnitude of impacts on community health and wellbeing is determined based on consideration of geographic extent, frequency, duration, and scale. The scale of potential impacts on community health and wellbeing is defined according to the definitions provided in Table 7-56.

Table 7-56 Definitions for Scale Ratings for Potential Impacts on Community Health and Wellbeing

Criterion	Definition
Scale	Negligible: No discernible change in health status of the population.
	Small: Changes to health status occur in some individuals and households, but changes are minor, temporary and reversible without medical or public health intervention.
	Medium: Changes to health status occur at the population level and are reversible over time or with medical or public health intervention.
	Large: Profound and measurable changes to health status are evident at the population level. Some health impacts may be severe or permanently debilitating, requiring medical or public health intervention or other forms of assistance for treatment and recovery.

Population shifts caused by the influx of workers from other parts of the country or from foreign countries has the potential to cause changes in transmission patterns of some communicable diseases, particularly if workers originate from countries with higher rates of diseases that are transmitted person-to-person, such as TB and sexually transmitted infections. At this time, the countries of origin of the Project workers are not known. Guyana has a lower rate of TB incidence than the global average (90 cases per 100,000 population, versus the global average of 133) but has a higher rate than most developed countries. Guyana's rate of HIV prevalence is comparable to the global average. Potential communicable disease transmission risks will vary according to the workforce's primary countries of origin; however, regardless of worker origin, the Project will establish a worker health screening program and take

precautions to avoid both internal and external communicable disease risks. Given the small size of the Project workforce in comparison with the receiving community (less than one percent of the population of Georgetown), the Project workers' limited onshore presence, and the embedded health controls in place to further reduce risk, the magnitude of impact is expected to be **Negligible**.

Increases in population, and the presence of transient populations has the potential to contribute to increased rates of crime. Georgetown has a high rate of crime, with reported cases on the rise in recent years. This is attributed largely to high rates of poverty and unemployment. It is not expected that the influx of Project workers to/through the Georgetown area would contribute significantly to local crime rates. Furthermore, the Project workforce will represent less than one percent of the population of Georgetown, and workers' onshore presence will be limited and occasional. As such, the magnitude of impact is expected to be **Negligible**.

The Project will have a medical facility onboard the FPSO to treat minor medical issues. Installation vessels will also have their own medical facility and a medical professional. In the event that an offshore worker requires medical evacuation/referral onshore, a medical professional will be available onshore to support the response/referral. In the event of more serious illness or injury that cannot be handled by the offshore medical professionals, patients would be medically evacuated to a healthcare facility in Georgetown and potentially outside of Guyana, depending on the type of medical issue. Reliance on Guyanese healthcare facilities could potentially compromise availability and access for the Guyanese local population. The Project currently plans to make use of a designated local Guyanese physician, as well as hospitals in Georgetown in the event of both work related and non-work related medical and health emergencies. However, for the most part, these hospitals will be relied upon only for initial evaluations or, in the case of life-threatening emergencies, stabilization before evacuation of foreign workers out of country to another facility.

Given that reliance on local Guyanese facilities will be limited, the magnitude of impact is therefore considered to be **Small**.

7.3.4.4 *Community Health and Wellbeing - Sensitivity of Receptors*

The receptors that could potentially experience health and wellbeing impacts as a result of planned Project activities are residents of Georgetown and its vicinity.

The receptor sensitivity ratings for community health and wellbeing are defined according to the definitions provided in Table 7-57 below.

Table 7-57 Definitions for Receptor Sensitivity Ratings for Community Health and Wellbeing Impacts

Criterion	Definition
Sensitivity	Low: The population does not have many areas of health vulnerability. Individuals and households have the personal resources and capacity to protect and promote health. The community is well equipped with resources and infrastructure to provide routine medical and health care and address medical and health emergencies.
	Medium: The population has multiple areas of health vulnerability, due either to environmental or social factors. Portions of the population face socioeconomic challenges that act as barriers to health protection and promotion. There are shortfalls in local medical and health resources and infrastructure that compromise ability to provide timely and appropriate medical and health care in some situations.
	High: The population has many areas of health vulnerability due to environmental and social factors. A large proportion of the population is disadvantaged, which acts as a barrier to protecting and promoting health. Adequate medical health resources and infrastructure are lacking, often not allowing for timely and appropriate medical and health care.

The Guyanese population is in a transitional phase whereby both communicable and non-communicable diseases contribute considerably to the burden of illness and mortality. However, urban populations have measurably higher health status than rural populations, and are less likely to suffer from some communicable diseases such as malaria, lymphatic filariasis, and soil-transmitted helminths. Georgetown has a high concentration of medical and health facilities relative to other parts of Guyana, although emergency care capacity and health related human resources are considered lacking throughout the country. Guyana's emergency medical system is in transition at this time; until recently, the country did not have an ambulance system to respond to emergencies. As of 2014, an ambulance pilot program through the Georgetown Public Hospital Corporation (GPHC) and with assistance from Vanderbilt University had been established, with seven ambulances and 21 trained emergency medical technicians (EMTs). According to Guyana's Chief Medical Officer, the country's emergency medical services are still insufficient to respond to the needs of the population. The country does not have an air ambulance to transfer injured patients from mining areas in the hinterland and to respond to serious vehicle collisions that occur on Guyana's roads. Hospital capacity is also lacking; at this time the GPHC has 450 beds but requires about 600 to adequately serve the population (ERM Personal Communication 7).

Based on the definitions above, the population in Georgetown has a **Medium** level of sensitivity to community health and wellbeing impacts.

7.3.4.5 *Impact Significance and Mitigation Measures - Community Health and Wellbeing*

Based on the magnitude of impact and receptor sensitivity ratings, the significance of increased communicable disease risk is **Negligible**, while the significance of impacts on public safety is **Negligible** and impacts on emergency health services access are **Moderate**. Assessment of transportation safety risks are presented in Sections 7.3.5 and 7.3.6.

Given the **Negligible** significance of communicable disease and public safety impacts from the Project, mitigation measures are not required, but the Project will nonetheless work closely with police and other public safety authorities to address any related concerns. In addition, the Project workers will be required to adhere to a worker code of conduct.

Table 7-58 summarizes the impact magnitude and resource sensitivity ratings for potential Project impacts on community health and wellbeing, and the impact significance ratings resulting therefrom. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-58 Community Health and Wellbeing – Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource/ Receptor Impact	Sensitivity	Magnitude	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
All Project stages	General population of Georgetown and vicinity - increased risk of communicable disease transmission	Medium	Negligible	Negligible	None	Negligible
	General population of Georgetown and vicinity - impacts on public safety	Medium	Negligible	Negligible	None	Negligible
	General population of Georgetown and vicinity – reduced access to emergency and health services	Medium	Small	Minor	None	Minor

7.3.5 Marine Use and Transportation

7.3.5.1 *Introduction*

The Project involves the drilling of development wells, the installation and long-term operations of an FPSO and SURF, and transit of Project support vessels between the PDA and the Guyana shorebases, as well as between the PDA and shorebases in Trinidad and Tobago.

The specific shorebase(s) and onshore support facilities (e.g., warehouses, laydown yards) to be utilized in Guyana have not yet been identified by EEPGL. Accordingly, ERM has performed

the impact assessment on the basis that the Project will utilize existing shorebase(s) located in Georgetown. Should any new or expanded shorebase(s) or onshore support facilities be utilized, the construction/expansion and any required dredging, as well as the associated permitting, of such facilities would be the responsibility of the owner/operator and such work scope would not be included in the scope of the EIA.

The assessment of potential impacts on marine use and transportation from these Project activities was based on the following assumptions:

- Most support vessel trips would originate from (and return to) shorebase facilities in Georgetown, while larger-draft vessels, such as drill ships, could transit between the PDA and shorebases in Trinidad and Tobago.
- The drilling stage could potentially utilize up to two drill ships on station simultaneously.
- The marine safety infrastructure available in Guyana (e.g., navigation aids) is adequate.

7.3.5.2 *Relevant Project Activities and Potential Impacts*

Table 7-59 summarizes the relevant Project activities and their potential impacts on marine use and transportation.

The FPSO will be anchored to the seafloor for the duration of the production operations stage, which is intended to last approximately 20 years. During the production operations stage, the FPSO will have a 2 nautical mile (nm) radius marine safety exclusion zone (covering approximately 4,300 ha), in which no unauthorized vessels will be allowed to enter. In addition, the drill ship and drill centers will have 500-meter radius marine safety exclusion zones during drilling operations and well workovers; a 500-meter radius marine safety exclusion zone will also be maintained around major installation vessels during the installation stage. Notices to mariners would be issued via MARAD to the Trawler's Association and fishing co-ops for planned Project marine vessel movements, including the FPSO, drill ship, and major installation vessels to be utilized during the installation stage. EEPGL will also communicate major Project vessel movements to commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and where possible communicate Project activities to those individuals to aid them in avoiding Project vessels through the stakeholder engagement process.

The Project would generate a variety of marine support vessel trips throughout the Project life. Support vessel activities would consist of:

- Approximately five vessels conducting re-supply trips to the FPSO and drill ships;
- Tanker movements and tugs supporting tanker loading activities;
- Subsea installation and maintenance activities; and
- Other vessels supporting installation activities.

Based on similar developments, the Project would generate an average of 12 vessel round-trips (between the PDA and shorebase) per week during development drilling and FPSO/SURF installation, and 7 vessel round-trips per week during FPSO/SURF production operations.

These vessel round-trips would originate from and return to shorebase facilities in Guyana and/or Trinidad and Tobago.

As described in Section 2.9, End of Operations, EEPGL has not prepared detailed plans for the decommissioning phase. As such, the number of vessel trips associated with decommissioning is not known. For the purposes of the impact analysis, vessel traffic associated with Project decommissioning is assumed to be similar to that for the drilling and installation stage: 12 vessel round trips per week.

For the purposes of the impact assessment, marine safety exclusion zones are an embedded control, considered part of the Project design. Accordingly, the "pre-mitigation" impact assessment considered the inclusion of this measure.

Table 7-59 Project Activities and Potential Impacts – Marine Use and Transportation

Stages	Project Activity	Key Potential Impacts
Drilling and Installation	Maritime transport of Project materials, supplies, and personnel	• Increased vessel traffic in Georgetown Harbour, coastal waters between Georgetown and the PDA, along transit routes leading to Georgetown. • Increased risk of marine casualty event (e.g., collision, grounding) involving third parties and Project vessels in Georgetown Harbour or in coastal waters.
	Presence of FPSO, drill ship, and installation vessels	• Reduced availability of ocean surface areas for non-Project activities due to marine safety exclusion zones around the FPSO, drill ship, and major installation vessels. • Increased risk of marine casualty events (e.g., collision, grounding) involving third parties and the FPSO in transit and while anchored, as well as drill ship installation vessels in transit and on station.
Production Operations	Maritime transport of Project materials, supplies, and personnel	• Increased vessel traffic in Georgetown Harbour, coastal waters between ports and the PDA, and along transit routes leading to Georgetown. • Increased risk of marine casualty event (e.g., collision, grounding) involving third parties and Project vessels in Georgetown Harbour or in coastal waters.
	Presence of FPSO, tanker, drill ship, and workover vessel	• Reduced availability of ocean surface areas for non-Project activities due to marine safety exclusion zones around the FPSO, tanker, drill ship, and workover vessel. • Increased risk of marine casualty event (e.g., collision, grounding) involving third parties FPSO, tanker, drill ship, and tankers on station.
Decommissioning	Maritime transport of Project materials, supplies, and personnel	• Increased vessel traffic in Georgetown Harbour, coastal waters between ports and the PDA, and along transit routes leading to Georgetown.
	FPSO removal and decommissioning vessel support	• Increased risk of marine casualty events (e.g., collision, grounding) involving third parties and the FPSO in transit, as well as decommissioning support vessels.

7.3.5.3 *Magnitude of Impact - Marine Use and Transportation*

Table 7-60 summarizes the definitions used to rate impact scale of the Project's potential impacts on marine use and transportation. Considering these definitions, Table 7-61 summarizes the assigned impact magnitude ratings for the various impacts. The Project's marine activities would impact cargo vessel traffic into and out of the Port of Georgetown, open-ocean shipping in the vicinity of the Stabroek Block in Guyanese waters, and commercial and subsistence fishing activity throughout impacted portions of Guyana's coastal waters. As described in Section 7.3.5.1, support vessel traffic would be higher during the development drilling stage relative to the production operations stage. Because the FPSO and support vessels would be present throughout the duration of the Project, the nature of impacts on marine use and transportation would generally be similar across various stages of the Project.

Vessels transiting the PDA would need to avoid the marine safety exclusion zones around the drill ships, major installation vessels, and the FPSO. The FPSO marine safety exclusion zone would require non-Project vessels to avoid approximately 4,300 ha (~10,600 acres) (approximately 0.2 percent) of the Stabroek Block's approximately 2.7 million ha (~6,671,845 acres) for approximately 20 years. Because the FPSO will be anchored to the seafloor, its marine safety exclusion zone would essentially be a permanent navigation feature until the decommissioning stage. The marine safety exclusion zones around the drill ships/drill centers would be small (~79 ha), and would be in force only during development drilling activity, which is anticipated to last approximately 3 years, and on occasion during well workover activity in later years. Similar sized marine safety exclusion zones around major installation vessels would occur only during the installation stage, or in the event repairs or maintenance.

The Stabroek Harbour Master has advised EEPGL that Jamaican and Trinidadian vessel shipping lanes intersect the Stabroek Block. As such, shipping traffic could potentially intersect the PDA, as well. Shipping lane maps indicate the FPSO would likely be more than 30 nautical miles from the nearest generalized shipping lane. More importantly, the shipping lanes in question are traditional, and are not precisely demarcated. Accordingly, even if Project vessels are in close proximity of mapped lanes, shipping lane users would have ample warning and space to navigate, and there is no reason to believe that the Project would meaningfully impede non-Project shipping traffic. No interference with shipping traffic was experienced during previous seismic surveys or the Liza exploration drilling activities.

Fishing vessels would lose use of the defined marine safety exclusion zones for fishing activities; however, as described in Sections 6.3.2 and 6.3.3, most subsistence fishing occurs in nearshore areas, and most commercial fishing occurs between the coast and the edge of the continental shelf (i.e., shoreward of the PDA). Thus, the highest potential for interactions between fishing vessels and Project vessels in Guyana waters is near the Port of Georgetown and the Demerara River mouth, where commercial vessel traffic is already present. As a result, the Project's impacts on marine use for subsistence activity are likely to be limited. The social and economic impacts of the Project's exclusion zones on commercial and subsistence fishing are described in Sections 7.3.2 and 7.3.3.

With respect to commercial fishing, the majority of the PDA is in deeper waters that are less often used for commercial fishing, and the size of the FPSO marine safety exclusion zone is negligible relative to the water available for fishing. As a result, the Project's impacts on marine use for commercial fishing activity also are likely to be limited.

During development drilling and again during decommissioning, the Project could generate one or two daily vessel departures and arrivals from the Port of Georgetown. Although call data for the Port are not available, this frequency of activity is unlikely to exceed the Port's vessel throughput capacity. Support vessels would typically be smaller and more maneuverable than the cargo or tanker vessels that call on the Ports of Georgetown or ports in Trinidad and Tobago, and thus would not present significant incremental navigation hazards within or near these ports.

The scale of potential impacts on maritime use and transportation are defined according to the definitions provided in Table 7-60 below.

Table 7-60 Definitions for Scale Ratings - Potential Impacts on Maritime Use and Transportation

Criterion	Definition
Scale	Negligible: No discernible change in transportation activity or demands on other infrastructure.
	Small: Increased transportation activity or marine infrastructure demand is perceptible, but does not measurably impact the capacity of transportation or other infrastructure, and does not measurably increase safety risks on waterways.
	Medium: Increased transportation activity or marine infrastructure demand is perceptible, reduces transportation system or infrastructure capacity, and/or measurably increase safety risks on waterways. These impacts do not require a change in typical travel behavior.
	Large: Increased transportation activity or marine infrastructure demand causes substantial delay, congestion, and/or increased safety risks on waterways, to the point where vessel operators or other users of infrastructure must consistently and frequently change their typical daily behavior.

Table 7-61 Magnitude Ratings – Potential Impacts on Marine Use and Transportation

Stage	Potential Impact	Magnitude	Rationale for Rating
Drilling and Installation Decommissioning	Maritime safety in Georgetown Harbour and shipping channel	Small	The drilling and installation stages would involve regular supply vessel trips in and out of Georgetown Harbour.
	Offshore maritime travel and safety	Small	While the marine safety exclusion zones around the FPSO and drill ships would be medium- to long-term, the FPSO will remain moored in one location, and the drill ships would only move between the two established drill centers.
Production Operations	Maritime safety in Georgetown Harbour and shipping channel	Small	Operations stage marine transport activity would be similar to, but less frequent than, for the drilling and installation stages.
	Offshore maritime travel and safety	Small	The FPSO will be stationary for the life of the Project, and its associated marine safety exclusion zones would become a known, mapped navigation feature for other vessel operators.

7.3.5.4 *Sensitivity of Receptors – Marine Use and Transportation*

Potential receptors for the Project's marine use and transportation impacts include current users of Georgetown Harbour and Guyanese coastal waters. Table 7-62 defines the receptor sensitivity ratings used in the assessment.

Table 7-62 Definitions for Receptor Sensitivity Ratings – Potential Impacts to Maritime Use and Transportation

Criterion	Definition
Sensitivity	Low: The receptor is accustomed to or specifically anticipates the type of activity proposed by the Project; existing transportation activities can easily adapt to additional transportation activity with no outside assistance or mitigation.
	Medium: The receptor is not specifically accustomed to the type of activity proposed by the Project. The receptor can adapt to additional transportation activity and maritime safety risks with outside assistance or mitigation.
	High: The receptor is poorly suited to the type of activity proposed by the Project, and cannot fully adapt to increased transportation activity and maritime safety risks, even with outside assistance or mitigation.

Table 7-63 identifies and characterizes the sensitivity of receptors that could potentially experience marine use and transportation impacts from the Project.

Table 7-63 Sensitivity Ratings for Marine Use and Transportation Receptors

Receptor	Definition and Rationale for Inclusion	Sensitivity/ Vulnerability Rating	Rationale for Rating
Commercial cargo vessels	Includes all international and regional commercial cargo vessel activity making calls at Georgetown Harbour, as well as traversing the northern coast of South America. Project activities would occur in areas potentially used by commercial shipping organizations, and would require use of Georgetown Harbour.	Low	Georgetown Harbour is an active commercial port, where vessel traffic—such as Project-related traffic—is expected. Commercial vessels in international waters are expected to be able to safely navigate around other vessels (whether in transit or stationary).
Commercial fishing vessels	Includes commercial fishing vessels (i.e., those who sell their product to local or international markets) that operate in Guyana coastal waters. These vessels may interact with Project vessels, or may currently conduct fishing operations in or near defined marine safety exclusion zones in the PDA.	Low	Commercial fishing vessel operators are likely to be aware of Project activities, or at least of commercial shipping activity in the vicinity of Georgetown, and can alter their fishing grounds to avoid defined marine safety exclusion zones in the PDA.
Subsistence fishing vessels	Includes individuals whose fishing activity is primarily or solely to feed themselves, their family, or their community, and not for commercial sales. These individuals generally operate near shore.	High	Subsistence fishing vessels are usually small, with limited ability to identify or avoid Project vessels.

7.3.5.5 *Impact Significance and Mitigation Measures – Marine Use and Transportation*

To further reduce the possibility and severity of marine use and transportation impacts, EEPGL will augment its ongoing stakeholder engagement process (and will work with government authorities through their existing notification/control processes) to identify commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and communicate Project activities to those individuals/entities to aid them in avoiding major Project vessels where possible, as further mitigation. No additional mitigation measures have been proposed related to vessel activity or maritime navigation.

Considering these mitigations, Table 7-64 summarizes the pre-mitigation and residual significance of the Project's potential maritime use and transportation impacts. Residual impacts related to maritime capacity, navigation, and safety are **Negligible** to **Minor**. As discussed above, impacts during decommissioning are assumed to be similar to those experienced during drilling and installation.

The Project may induce shorebase operators to make improvements to existing facilities to make the shorebase(s) fit for purpose. These improvements would enhance the valuable of the shorebase(s) as material assets. Assuming that these improvements were small in scale and did not require physical expansion of the existing facilities, they would be considered a **Positive** impact on Guyana's marine infrastructure. Larger scale improvements would be outside the scope of the EIA.

The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter. Considering all of the individual impacts listed in Table 7-64, the Project would have overall **Negligible** residual impact significance for marine use and transportation.

Table 7-64 Marine Use and Transportation Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource/ Receptor Impact	Embedded Controls	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation Decommissioning	Commercial cargo vessels—port and channel operations and maritime safety	Marine safety exclusion zones around FPSO, drill ship, and major installation vessels.	Small	Low	Negligible	Communication and notification	Negligible
	Commercial fishing vessels—port and channel operations and maritime safety		Small	Low	Negligible	Communication and notification	Negligible
	Commercial cargo vessels—offshore navigation and maritime safety		Small	Low	Negligible	Communication and notification	Negligible
	Commercial fishing vessels—offshore navigation and maritime safety		Small	Low	Negligible	Communication and notification	Negligible
	Subsistence fishing vessels—offshore navigation and maritime safety		Small	High	Moderate	Communication and notification	Minor
Production Operations	Commercial cargo vessels—port and channel operations and maritime safety	Marine safety exclusion zones around FPSO and major installation vessels.	Small	Low	Negligible	Communication and notification	Negligible
	Commercial fishing vessels—port and channel operations and maritime safety		Small	Low	Negligible	Communication and notification	Negligible

Stage	Resource/ Receptor Impact	Embedded Controls	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
	Commercial cargo vessels—offshore navigation and maritime safety		Small	Low	Negligible	Communication and notification	Negligible
	Commercial fishing vessels—offshore navigation and maritime safety		Small	Low	Negligible	Communication and notification	Negligible
	Subsistence fishing vessels—offshore navigation and maritime safety		Small	High	Moderate	Communication and notification	Minor

7.3.6 Social Infrastructure and Services

7.3.6.1 *Introduction*

This section assesses potential Project impacts on social infrastructure and services in the Project AOI. The planned Project activities that have the potential to impact social infrastructure and services are Project worker presence (with the potential to impact availability or cost of housing and utilities) and ground and air transportation (with the potential to increase traffic congestion and impact public safety). The impacts associated with these two Project activities are assessed separately in this section. Impacts on health service access are assessed in Section 7.3.4.

7.3.6.2 *Housing and Utilities*

Relevant Project Activities and Potential Impacts

The Project's limited onshore activity during drilling, installation, production operations, and decommissioning has the potential to impact housing and utilities in the Georgetown area. Table 7-65 summarizes the potential impacts on housing and utilities.

Table 7-65 Project Activities and Potential Impacts – Social Infrastructure and Services (Housing and Utilities)

Stage	Receptor(s)	Project Activity	Key Potential Impacts
All Project Stages	General population in Georgetown and vicinity	Project worker presence in Georgetown area	• Increased demand or use of housing and utilities service and infrastructure, leading to reduced availability and/or increased cost
		(Induced) influx of job-seekers to Georgetown area	

Magnitude of Impact - Housing and Utilities

The assessment of the Project's magnitude of impacts on housing and utilities is determined based on consideration of geographic extent, frequency, duration, and scale. The scale of potential impacts on housing and utilities is defined according to the definitions provided in Table 7-66.

Table 7-66 Definitions for Scale Ratings for Potential Impacts on Housing and Utilities

Criterion	Definition
Scale	Negligible: No discernible change in demand for housing or utilities.
	Small: Limited increases in demand for housing and utilities are perceptible, causing slight changes in the availability, quality and/or cost of these resources and services.
	Medium: Increases in demand for housing and utilities are evident and lead to frequent and widespread shortfalls in availability or quality of housing and utilities, or measurable increases in costs.
	Large: Increases in demand for housing and utilities are sufficient to cause conditions of chronic shortage and inflated costs.

The Project will require up to approximately 1,200 workers during the peak of drilling and installation stages, and up to approximately 140 workers during the production operations stage. Since the majority of the workforce for these stages will be based offshore, the limited time spent onshore would be in temporary accommodations such as hotels. As such, the Project workforce is not expected to impact for-sale or rental housing stock, and thus would not be expected to require any new utilities connections. It is not anticipated that the Project's worker presence onshore at any given time would be enough to drive development of new temporary housing (hotel) establishments. Some induced population influx from other regions of Guyana may occur as job-seekers move to the Georgetown area seeking direct or indirect employment from the Project; this incoming population could access for-sale or rental housing stock. This influx is expected to be limited and short term in nature, given EEPGL's efforts to communicate the Project's limited workforce requirements to stakeholders.

Based on the definitions presented in Table 7-66, the magnitude of impact on housing and utilities is considered to be **Minor** during the drilling, installation, and decommissioning stages of the Project and **Negligible** during the production operations stage.

Sensitivity of Receptors - Housing and Utilities

The receptors that could be potentially impacted by changes to housing and utilities are the current general population of Georgetown. The receptor sensitivity ratings for housing and utilities are defined according to the definitions provided in Table 7-67.

Table 7-67 Definitions for Receptor Sensitivity Ratings for Housing and Utilities Impacts

Criterion	Definition
Sensitivity	Low: Existing infrastructure and services have excess capacity and/or the community has the resources and capability to expand in a timely manner.
	Medium: Existing infrastructure and services have little excess capacity and the community has limited resources or capability to expand in a timely manner and thus would require assistance in upgrading or supplementing current infrastructure and service provision in the community.
	High: Existing infrastructure and services have little or no excess capacity and the community does not have the resources or capability to respond to a potential increase in population.

As the capital of Guyana, Georgetown has a relatively high concentration of social services and infrastructure; however, according to a study by the Inter-American Development Bank (IDB), there are currently shortfalls of housing and appropriate utilities infrastructure in Georgetown, which the government is addressing with regularization initiatives for informal communities. Given these shortfalls, the population has a **Medium** level of sensitivity to increased demand for housing and utilities infrastructure.

Impact Significance and Mitigation Measures - Housing and Utilities

Based on the magnitude of impact and receptor sensitivity ratings, the significance of housing and utilities impacts for the drilling, installation, and decommissioning stages is **Minor**. During the production operations stage, this is reduced to a **Negligible** level of significance.

No mitigation measures are required to address potential impacts on housing and utilities. However, the Project will proactively manage messaging about the Project's limited workforce needs to stakeholders in order to reduce the potential for induced population influx.

The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter. Table 7-68 below summarizes potential Project impacts on housing and utilities. The impact will remain **Negligible** after mitigation.

Table 7-68 Housing and Utilities Pre-Mitigation and Residual Impact Significance Ratings

Stage	Resource/ Receptor Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling, Installation and Decommissioning	General population of Georgetown and vicinity – Decreased availability/ increased cost of housing and utilities	Small	Medium	Minor	Proactive messaging regarding Project employment opportunities	Minor
Production operations	General Georgetown population and vicinity – Decreased availability/ increased cost of housing and utilities	Negligible	Medium	Negligible	None	Negligible

7.3.6.3 *Onshore and Air Transportation*

Relevant Project Activities and Potential Impacts

The specific shorebase(s) and onshore support facilities (e.g., warehouses, laydown yards) to be utilized in Guyana have not yet been identified by EEPGL. Accordingly, ERM has performed the impact assessment on the basis that the Project will utilize existing shorebase(s) located in Georgetown. Should any new or expanded shorebase(s) or onshore support facilities be utilized, the construction/expansion and any required dredging, as well as the associated permitting, of such facilities would be the responsibility of the owner/operator and such work scope would not be included in the scope of the EIA.

The travel route, frequency, and type of vehicle trips between the Georgetown shorebase(s) and offsite facilities (i.e., not contained within the shorebases) are not known. Such offsite activity could impact onshore transportation by adding vehicle trips (likely in the form of heavy truck trips) between the offsite facility and the Georgetown shorebase(s). As was the case for the Liza exploration activities, a Road Safety Management Procedure would be developed for all Project-related land transport activities.

This assessment includes a qualitative analysis of the impacts of those land-based trips. The impact scenario assumes vehicle movements between an offsite facility somewhere along the East Bank Demerara Road and a shorebase within the Port of Georgetown. Table 7-69 summarizes the potential impacts to onshore transportation.

The Project would also generate up to 35 round-trip helicopter flights per week during development drilling and installation, and up to 25 round-trips per week during production operations. All round-trip flights would originate from and return to Correia International Airport (hereafter referred to as "Ogle Airport"), east of Georgetown.

As described in Section 2.9, End of Operations, EEPGL has not prepared detailed plans for the decommissioning stage. As such, the level of onshore and air transportation activity associated with decommissioning is not known. For purposes of impact analysis, onshore and air traffic associated with Project decommissioning is assumed to be similar to that of the drilling and installation stage.

Table 7-69 Project Activities and Potential Impacts – Onshore and Air Transportation

Stage	Receptors	Project Activity	Key Potential Impacts
All Project stages	Road users, including drivers, cyclists, and pedestrians	Onshore movement of Project materials, supplies, and personnel	• Increased vehicle traffic on public roads in and around Georgetown.
All Project stages	Other aircraft and users of Ogle Airport	Helicopter flights to/from PDA	• Increased air traffic leading to potential impacts on Ogle Airport capacity.

Magnitude of Impact – Onshore and Air Transportation

If offsite storage/warehousing facilities are required, materials would be transported between the offsite facilities and the shorebases by road. The Project's land activities would impact vehicle traffic in Georgetown, particularly in the vicinity of the shorebases and any offsite yards or warehouses. As stated above, the assessment assumes that land transport would include heavy truck trips along the East Bank Demerara Road. The number and frequency of these trips is unknown. It is assumed that truck trips would occur over the course of the Project. During this period of time, truck trips are unlikely to measurably change existing traffic congestion, due to the relatively small number of likely truck trips.

Project-related air activity would include approximately five helicopter flights per day during the drilling, installation, and decommissioning stages and three to four flights per day during the production operations stage. This level of activity is unlikely to meaningfully impact Ogle Airport's capacity or operations.

The assessment of the Project's magnitude of impacts on onshore and air transportation is summarized in Table 7-70.

Table 7-70 Magnitude of Impacts – Onshore and Air Transportation

Stage	Impact	Magnitude	Rationale for Rating
Drilling and Installation; Decommissioning	Road capacity and congestion from transportation of materials to the Georgetown shorebases.	Small	Although the number of trips between yards/warehouse sites is not known, these trips are unlikely to contribute to traffic congestion.
	Capacity limitations and safety risks from Project-related helicopter flights to and from Ogle Airport.	Negligible	Five helicopter round trip flights per day (i.e., less than one movement per daylight hour) are unlikely to meaningfully impact operations or air safety.
Production Operations	Road capacity and congestion from transportation of materials to the Georgetown shorebases.	Negligible	Similar type of impacts, but lower traffic volume than during the drilling and installation stages.
	Capacity limitations and safety risks from Project-related helicopter flights to and from Ogle Airport.	Negligible	Three to four helicopter round trip flights per day (i.e., less than one movement per daylight hour) are unlikely to meaningfully impact operations.

Sensitivity of Receptors – Onshore and Air Transportation

The receptors that could potentially experience impacts on onshore transportation include current users of the Georgetown road network. Existing drivers would have a medium level of sensitivity. This rating reflects relatively high traffic volumes and existing congestion in the vicinity of the Demerara Harbour Bridge, as well as the lack of travel alternatives (i.e., other travel routes or modes of transportation) for non-Project drivers.

Receptors for air transportation impacts include airport and airspace users and commercial, cargo, and private pilots, crew, and passengers. The receptor sensitivity ratings for onshore and air transportation are summarized in Table 7-71.

Table 7-71 Receptor Sensitivity Ratings – Onshore and Air Transportation

Receptor	Definition and Rationale for Inclusion of Receptors	Sensitivity Rating	Rationale for Rating
Drivers of motor vehicles	Includes existing travelers in and around Georgetown, who could interact with and be impacted by Project-related traffic.	Medium	Drivers already experience substantial traffic congestion and road safety risks in parts of Georgetown. Additional traffic would likely be viewed as incremental, but not a fundamental shift in conditions.
Airport and airspace users	Includes existing air travelers who could be impacted by Project-related aviation operations.	Low	The aviation environment is highly regulated. Other air traffic—such as Project-related flights—is expected. All pilots are expected to be able to navigate in the presence of other aircraft.

Impact Significance and Mitigation Measures – Onshore and Air Transportation

Based on the magnitude of impact and receptor sensitivity ratings, the significance of onshore transportation impacts for the drilling, installation, and decommissioning stages will be **Minor**. During the production operations stage, this is reduced to **Negligible**. The significance of air transportation impacts would be **Negligible**. No mitigation measures are required to address potential impacts on onshore and air transportation.

Table 7-72 below summarizes potential Project impacts on onshore and air transportation. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-72 Onshore and Air Transportation – Summary of Pre-Mitigation and Residual Impacts

Stage	Resource/ Receptor Impact	Embedded Controls	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation Decommissioning	Non-Project drivers—Project-related traffic congestion	None identified	Small	Medium	Minor	None	Minor
	Air travelers—air operations	None identified	Negligible	Low	Negligible	None	Negligible
Production Operations	Non-Project drivers—Project-related traffic congestion	None identified	Negligible	Medium	Negligible	None	Negligible
	Air travelers—air operations	None identified	Negligible	Low	Negligible	None	Negligible

7.3.7 Cultural Heritage

7.3.7.1 *Introduction*

This section assesses potential Project impacts on cultural heritage. The laws and conventions governing the protection and management of Guyana's cultural heritage include Guyana's National Trust Act (1972), Guyana's Maritime Zones Act (2010), the 1972 United Nations Educational, Scientific and Cultural Organization (UNESCO) Convention on Cultural Heritage, and the 2001 UNESCO Convention on Underwater Cultural Heritage. Guyana's National Trust Act, as well as the 2001 UNESCO Convention on Underwater Cultural Heritage, urge the protection of submerged "monuments" within Guyana's territorial waters, and encourage the practice of in situ preservation of cultural heritage whenever possible.

7.3.7.2 *Relevant Project Activities and Potential Impacts*

Project drilling and installation activities that have the potential to adversely impact cultural heritage located on or beneath the seafloor include the drilling of development wells, the installation of FPSO anchoring structures, and the installation of SURF components.

The Project is not expected to require ground-disturbing activities in onshore areas that have not already been disturbed by prior development. Furthermore, any construction/expansion of onshore facilities, which would disturb new onshore areas, would be performed by the owners/operators of such facilities, and would be out of the scope of this EIA. As a result, the Project will not impact any terrestrial archaeological sites. Onshore logistical support would involve use of Guyana port facilities, warehouses, pipe yards, and waste management facilities (e.g., landfills). Use of these facilities will not impact any archaeological sites, as these lands have already been disturbed and therefore are unlikely to contain intact archaeological sites.

Table 7-73 summarizes potential Project impacts on marine cultural heritage.

Table 7-73 Summary of Relevant Project Activities and Potential Key Impacts

Stage	Project Activity	Key Potential Impact
Drilling and Installation	Drilling of Development Wells.	Damage to Shipwrecks and Submerged Archaeological Sites
	Installation of FPSO Anchoring Structures	
	Installation of SURF Components.	

7.3.7.3 *Magnitude of Impact – Cultural Heritage*

The assessment of the Project's magnitude of impacts on cultural heritage in the Project AOI is determined based on consideration of geographic extent, frequency, duration, and scale. The scale of potential impacts on cultural heritage is defined according to the definitions provided in Table 7-74.

Table 7-74 Definitions for Scale Ratings for Potential Impacts on Cultural Heritage Impacts

Criterion	Definition
Scale	Negligible: No discernible change in the physical condition, setting, or accessibility of sites.
	Small: A small part of sites are lost or damaged, resulting in a loss of scientific or cultural value; setting undergoes temporary or permanent change that has limited impact on the sites' perceived value to stakeholders; stakeholder/public or scientific access to the sites is temporarily impeded.
	Medium: A significant portion of sites are lost or damaged, resulting in a loss of scientific value; setting undergoes permanent change that permanently diminishes the sites' perceived value to stakeholders; sites become inaccessible for the life of the Project to stakeholders including traditional users or researchers.
	Large: Entire sites are damaged or lost, resulting in a nearly complete or complete loss of scientific or cultural value; setting is sufficiently impacted to cause sites to lose nearly all or all cultural value or functionality; sites become permanently inaccessible to stakeholders including traditional users or researchers.

The Project will not impact any known underwater cultural heritage based on the geophysical survey and remote sensing studies conducted for the Project. However, there is the potential for previously unrecorded cultural remains, or chance finds, to be encountered and impacted during Project drilling and installation activities. Underwater chance finds could include shipwrecks and associated artifact scatters that were not identified during the geophysical survey and remote sensing studies. It is conservatively assumed that the scale of impact on a previously unidentified cultural resource could be as high as **Medium** if seabed disturbing activities took place in the location of a previously unidentified cultural heritage site. If this were to occur, the Project would most likely relocate the SURF component (up to a few meters) to the extent practicable. Given this, and considering the low likelihood that surveys failed to identify significant cultural heritage in the planned disturbance area, the magnitude of impact for drilling and installation stages is considered **Low**. For the production operations stage, disturbance of the seafloor will not occur; accordingly, the magnitude rating for this stage is **Negligible**.

7.3.7.4 *Sensitivity of Resource - Cultural Heritage*

The resource sensitivity ratings for cultural heritage are defined in Table 7-75.

Table 7-75 Definitions for Sensitivity Ratings for Potential Impacts on Cultural Heritage

Criterion	Definition
Sensitivity	Low: Site is not specifically protected under local, national, or international laws or treaties; site can be moved to another location or replaced by a similar site, or is of a type that is common in surrounding region; site has limited or no cultural value to local, national, or international stakeholders; and/or site has limited scientific value or similar information can be obtained at numerous sites.
	Medium: Site is specifically or generally protected by local or national laws, but laws allow for mitigated impacts; site can be moved or replaced, or data and artifacts recovered in consultation with stakeholders; site has considerable cultural value for local and/or national stakeholders; and/or site has substantial scientific value but similar information can be obtained at a limited number of other sites.
	High: Site is protected by local, national, and international laws or treaties; site cannot be moved or replaced without major loss of cultural value; legal status specifically prohibits direct impacts or encroachment on site and/or protection zone; site has substantial value to local, national, and international stakeholders; and/or site has exceptional scientific value and similar site types are rare or non-existent.

Depending on the nature of the specific resources encountered, encountered shipwrecks and/or submerged archaeological sites could be specifically protected by national laws such as the Guyana National Trust Act, or international conventions such as the 2001 UNESCO Convention on Underwater Cultural Heritage and could possess research and cultural value. For the purpose of this assessment, it was assumed that an as-of-yet unidentified cultural resource could have a sensitivity rating of **Medium**.

7.3.7.5 *Impact Significance and Mitigation Measures – Cultural Heritage*

Based on the magnitude of impact and the receptor sensitivity ratings, the significance of potential cultural resource impacts during drilling and installation is **Minor**. Since production operations are not anticipated to involve any seabed-disturbing activities, the significance of potential cultural resource impacts during production operations is **Negligible**.

As discussed in Chapter 6, ERM has conducted a survey of the planned seabed disturbance area to assess the presence of any marine cultural heritage. This has significantly increased the level of certainty that planned Project activities will not disturb significant cultural heritage.

In any case, ERM has developed a Chance Finds Procedure, which requires temporary cessation of Project activities in the event of a chance find, assessment of the chance find by a cultural heritage specialist, and the development of a treatment plan for significant chance finds in consultation with the Guyana National Trust and other cultural heritage stakeholders, as appropriate. The Chance Finds Procedure also addresses monitoring and training requirements to support the Procedure.

Considering the implementation of the measures outlined in the Chance Finds Procedure, the scale of impact would be expected to be reduced, as activities would be adjusted/curtailed upon discovery of a previously unidentified cultural resource. This would reduce the impact significance rating to **Negligible**.

Table 7-76 summarizes potential Project impacts on cultural heritage. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-76 Summary of Pre-Mitigation and Residual Impacts – Cultural Heritage

Stage	Resource/ Receptor Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation	Marine cultural heritage – destruction from Project activities disturbing the seabed	Low	Medium	Minor	Implement Chance Finds Procedure as needed	Negligible
Production Operations	Marine cultural heritage – destruction from Project activities disturbing the seabed	Negligible	Medium	Negligible	N/A	Negligible

7.3.8 Land Use

7.3.8.1 *Introduction*

This section assesses potential impact on land use and ownership by the Project. The key potential impacts considered are conversion of land from one use to another, physical/economic displacement, and change of land ownership type.

7.3.8.2 *Relevant Project Activities and Potential Impacts*

The majority of the Project's activities will occur offshore. Some limited onshore activities will occur, particularly at the beginning of the drilling and installation stage while wells are being drilled and SURF infrastructure is being installed. These facilities would not be owned or operated by EEPGL. If the owners/operators of such facilities find it necessary to expand the existing sites onto adjacent land or in separate new areas, potential land use impacts associated with these expansions would be addressed by the owners/operators of such facilities, and would be out of the scope of this EIA.

Table 7-77 summarizes the potential impacts on land use from Project activities.

Table 7-77 Project Activities and Potential Impacts – Land Use

Stage	Receptor(s)	Project Activity	Key Potential Impacts
All Project stages	Current owner(s) and/or user(s) of land in Georgetown	Use of land for Project materials storage	Conversion of land from other use(s)

7.3.8.3 *Magnitude of Impact – Land Use*

The assessment of the Project's magnitude of impacts on land use is based on consideration of geographic extent, frequency, duration, and scale. The scale of potential impacts on land use is defined in Table 7-78.

Table 7-78 Definitions for Scale Ratings for Potential Impacts on Land Use

Criterion	Definition
Scale	Negligible: No change in land use type or ownership type.
	Small: Land use change occurs for one or multiple parcels, but consists of change to a land use type similar to the current use (e.g., change from one type of agricultural activity to another, or from industrial to commercial). No changes occur in ownership type (government-owned, Amerindian-owned or privately owned).
	Medium: Land use changes occur for multiple land parcels or tracts and may consist of profound changes (e.g., clearing of forest or other vegetation, loss of residential units). Changes to ownership type (government-owned, Amerindian-owned or privately owned) do not occur.
	Large: Land use changes occur for large areas of land and may consist of profound changes (e.g., clearing of forest or other vegetation, loss of residential units). Changes may occur to ownership type.

The Project may require the use of offsite onshore storage facilities for Project materials (e.g., pipe joints). At this time, potential storage facility locations are not known, but it is expected that any such facility will be located as near to the shorebase(s) as possible to minimize hauling time.

Given that the storage facilities will likely be located in an industrial area, rather than natural or agricultural in character, it is not expected that major changes in land use types, or any change in land ownership type, would occur. The magnitude of impact is therefore considered to be **Small**.

7.3.8.4 *Sensitivity of Receptors - Land Use*

Receptors for this impact would be the current owner(s) of the land to be used for the storage facility, as well as the user(s) or beneficiaries of that land, if any. The receptor sensitivity ratings for land use are defined in Table 7-79.

Table 7-79 Definitions for Receptor Sensitivity Ratings for Land Use Impacts

Criterion	Definition
Sensitivity	Low: Receptor(s) do not currently reside on the land or make use of it for subsistence or primary livelihood activities, or recreation.
	Medium: Receptor(s) do not currently reside on the land or make use of it for subsistence but may rely on it for income generation or recreation.
	High: Receptor(s) currently reside on the land and/or use it for subsistence, or for their primary/sole means of livelihood.

At this time, it is not known whether the onshore storage facilities will be required, or where such a facility would be located if it is required. However, assuming that the property used for the storage facility will be on land currently used for industrial purposes, it is not expected that this property would be relied upon for residential, agricultural, commercial, or recreational use. As such, receptors are expected to have a **Low** level of sensitivity.

7.3.8.5 *Impact Significance and Mitigation Measures – Land Use*

Based on the magnitude of impact and receptor sensitivity ratings, the significance of land use impacts for the drilling and installation stage is **Negligible.**

No mitigations are required or planned since it is not yet known whether the offsite storage facilities will be required. If it is decided a storage facility is required, the owners/operators of the facilities will select the site in a manner that will avoid or minimize land use impacts.

Table 7-80 below summarizes potential Project impacts on land use. The significance of impacts was assessed based on the impact assessment methodology described in Chapter 4 and summarized at the beginning of this chapter.

Table 7-80 Summary of Pre-Mitigation and Residual Impacts – Land Use

Stage	Resource/ Receptor Impact	Magnitude	Sensitivity	Pre-Mitigation Significance Rating	Proposed Mitigation Measures	Residual Significance Rating
Drilling and Installation	Current owner(s) or user(s) of land at site of future storage facility	Small	Low	Negligible	None	Negligible

7.3.9 Ecosystem Services

Planned Project activities will not impact ecosystem services[34]. Although the Project will have minor impacts on water quality, benthic communities, and marine wildlife in the immediate vicinity of the SURF components and in the mixing zones surrounding the FPSO and the tanker, these impacts are not expected to have significant impacts on ecosystem services. They are not expected to impact the processes that regulate the physio-chemical attributes of the North Brazil Shelf LME as a whole (e.g., water quality, currents, oceanographic conditions, bathymetry), nor are they expected to cause significant impacts on fishery production offshore Guyana. There are no human communities located offshore of Guyana so the offshore environment does not provide any cultural services that could be impacted.

The only Project-related impacts in nearshore marine waters would be an incremental increase in ship traffic in and out of Georgetown Harbour as ships transit between the shorebase(s) and the PDA. As discussed previously, an increase in ship traffic could have minor effects on marine life, but none that would be significant at the ecosystem level. Therefore the Project would have no impacts on ecosystem services provided by the nearshore marine ecosystem.

The Project will not involve any direct disturbance of any coastal habitats and the Project's air emissions, water discharges, and sound generation, all of which will occur approximately 190 km (~120 mi) offshore, will not impact these habitats. Project use of the Guyana shorebase(s) and onshore support facilities will have no impact on ecosystem services. The Project's only potential impact on ecosystem services would be as a result of an unplanned event, which is discussed in Section 7.4.

7.3.10 Indigenous Peoples

Planned Project activities will not impact indigenous peoples (typically referred to as Amerindians in Guyana). The Project will not involve any direct disturbance of any indigenous communities, or coastal habitats upon which they rely, and the Project's air emissions, water discharges, and sound generation, all of which will occur approximately 190 km (~120 mi) offshore, will not impact their communities or associated habitats. Project use of the Guyana shorebases and onshore support facilities will have no impact on indigenous peoples. These facilities are well removed from any traditional indigenous communities. The Project's only potential impact on indigenous peoples would be as a result of an unplanned event, which is discussed in Section 7.4.

[34] Ecosystem services are typically defined as the benefits that people obtain from the natural environment, including natural resources that underpin basic human health and survival needs, support economic activities, and provide cultural fulfilment.

7.4 Unplanned Events

7.4.1 Introduction

An unplanned event is defined as an event that is not planned to occur as part of the Project (e.g., accidents), but that has the potential to occur. Since such events are not planned, they are evaluated in a different manner from planned events, specifically by evaluating the consequence of a realistic scenario for an unplanned event and taking into consideration the *likelihood* that the event will occur. Three levels of likelihood are used: unlikely, possible, and likely, as defined in Table 7-81.

Table 7-81 Levels of Likelihood for Unplanned Event Impact Assessment

Likelihood	Definition
Unlikely	Considered a rare event, and there is a small likelihood that an event could occur;
Possible	The event has a reasonable chance to occur at some time during normal operating conditions; and
Likely	The event is expected to occur during the life of the facility.

As described in Chapter 4, a risk matrix using the likelihood and consequence/severity of the event is used to evaluate the potential significance of unplanned events. The consequence/severity of the unplanned event is measured in terms of the importance/ vulnerability/sensitivity of the resource/receptor and the magnitude of the impact.

Figure 7-6 Unplanned Events Risk Matrix

Risk Matrix		Consequence/Severity		
		Low	Medium	High
Likelihood	Unlikely	Minor	Minor	Moderate
	Possible	Minor	Moderate	Major
	Likely	Moderate	Major	Major

For the purposes of the Project, the following unplanned events are considered as having the potential to occur during the Project life, should a combination of standard and Project-specific safety controls fail concurrently:

- Hydrocarbon spill
- Marine vessel collision
- Onshore vehicular accident

These potential unplanned events are described in more detail below. There are other minor unplanned events (e.g., dropped objects, small spills on deck that do not enter the ocean) that have a realistic probability of occurrence, but which would not significantly impact any resources/receptors considered in this EIA. These other unplanned events would occur on the drill ship, installation vessels, supply vessels, or the FPSO and their impacts would tend to be limited to Project employees and contractors (e.g., a variety of accidents that could result in worker injury, but no measurable impact on natural resources or the public). These events are

addressed primarily through EEPGL and its contractors' health and safety policies and procedures, which are beyond the scope of this EIA.

The specific shorebase(s) and onshore support facilities (e.g., warehouses, laydown yards) to be utilized in Guyana have not yet been identified by EEPGL. Accordingly, ERM has performed the impact assessment for unplanned events on the basis that the Project will utilize existing shorebase(s) located in Georgetown. Should any new or expanded shorebase(s) or onshore support facilities be utilized, the construction/expansion and any required dredging, as well as the associated permitting, of such facilities would be the responsibility of the owner/operator and such work scope would not be included in the scope of this EIA.

7.4.1.1 Hydrocarbon Spill

Producing, processing, storing, and offloading oil are core Project activities. There are multiple layers of control in place with respect to these activities; however, if multiple controls fail there is the potential for an oil spill to occur. EEPGL categorizes oil spills into three tiers:

- Tier I – Spill is small, the source of spill is under control, and response would be managed by EEPGL and its contractors using local resources;
- Tier II – Spill is moderate, the source can be quickly brought under control, local response equipment immediately available, and broader response would be managed in a coordinator manner using regional resources as needed; and
- Tier III – Spill is large, the source of the spill is not under control, and response would be managed in a coordinated manner with regional and internationally sourced resources.

Hydrocarbons that could potentially be released include crude oil, marine diesel, fuel oil, lubricating oil, and non-aqueous drilling fluid (NADF). EEPGL and ERM have identified nine possible spill scenarios, categorized below in Table 7-82 by tier. These scenarios consider spills at the Guyana shorebases (Georgetown area basis), into the Demerara River or other estuarine waters (e.g., from supply vessels), and into the Atlantic Ocean (e.g., from drill ship, supply vessels, tankers, and the FPSO).

Table 7-82 Possible Hydrocarbon Spill Scenarios by Tier

#	Tier	Location	Possible Scenario	Potential Impact
1	I	Shorebase	Onshore spill of less than 10 bbl (e.g., partial loss of diesel storage tank contents)	Contained onshore; no shoreline impact.
2	I	Drill ship or FPSO offshore	Offshore spill of less than 50 bbl (e.g., leak or release due to human error or failure of equipment)	Contained on deck of vessel or enters offshore Atlantic Ocean; no shoreline impact likely.
3	I	Supply vessel offshore	Offshore spill of less than 50 bbl (e.g., accidental discharge of untreated bilge water)	Hydrocarbons enter water, creating sheen on the water surface; no shoreline impact likely.
4	II	Shorebase	On water spill of less than 100 bbl (e.g., shore to vessel bunkering spill)	Diesel enters Demerara River estuary; possible minor shoreline impact.
5	II	Drill ship / well offshore	Offshore release of 2,200 bbl of NADF due to loss of riser contents after emergency disconnect due to Dynamic Positioning (DP) station keeping failure	NADF enters water near the seafloor; no shoreline impact likely.
6	II	Supply vessel at shorebase	On water release of 500 bbl of diesel (e.g., shore to vessel bunkering)	Diesel enters Demerara River estuary; possible shoreline impact.
7	II	Drill ship/well offshore	Well control release of less than 250 bbl (e.g., well becomes unbalanced during the drilling process and begins flowing at a low release rate prior to containment	Hydrocarbons enter Atlantic Ocean; no shoreline impact likely.
8	II	FPSO, offloading tanker offshore	Offshore release of 2,500 bbl of oil (e.g., failure of offloading hose during offloading from FPSO to tanker)	Oil enters Atlantic Ocean; no shoreline impact likely.
9	III	Drill ship / well offshore	Offshore release of oil from well control event (30 day duration at 20,000 bpd)	Oil enters Atlantic Ocean; possible shoreline impact.

Hydrocarbon releases under Scenarios 1 through 4 would all be small and under control quickly, and would be managed with locally available spill control equipment. A temporary visible sheen on the water surface may occur, water quality would be temporarily impaired in a small area, a very sensitive receptor (e.g., plankton and possibly some shorebirds) may be locally affected, but there is not considered to be potential for any long-term or ecosystem level impacts on ecologically important or protected species. These spills are, therefore, not considered further in this EIA.

A hydrocarbon release under Scenario 5 would involve a spill of approximately 2,200 bbl of NADF into the ocean near the seafloor. Under this scenario, the spill would be somewhat controlled because the volume is limited to the capacity of the drilling riser. There is the potential for temporary impacts on several resources/receptors, such as water quality and marine fish and wildlife, but these impacts would be generally short term and limited in area, with rapid resource/receptor recovery expected.

A hydrocarbon release under Scenario 6 would involve a spill of approximately 500 bbl of diesel into the Demerara River. Under this scenario, the spill would be quickly controlled and contained because of the relatively small volumes and the ready access to spill control

equipment. There is the potential for impacts on several resources/receptors, such as water quality and coastal fish and wildlife, but these impacts would occur in a more developed urban harbor setting, be generally short term, limited in area, and readily mitigated, with rapid resource/receptor recovery expected.

Hydrocarbon releases under Scenarios 7 (minor well control release during drilling), 8 (release during offloading from FPSO to tanker), and 9 (major well control incident) would all involve an oil spill in the PDA either at a well or at the FPSO. Although the potential spill volumes vary (i.e., from 250 bbl total to 20,000 BOPD for a duration of 30 days) and the location of the spill differ (i.e., at seafloor or ocean surface), the resources/receptors at risk are similar, although the magnitude of the risk increases from Scenario 7 to Scenario 9. Oil spill modeling and coastal sensitivity mapping have been conducted to identify and characterize the resources/receptors with the potential to be exposed to oil. An overview of this modeling and mapping for Scenarios 8 and 9 is provided in Sections 7.4.1.4 and 7.4.1.5. The potential risks associated with the smaller volume offshore oil spills are encompassed within the modeling.

It should be noted, however, that an oil spill and release of NADF are considered highly unlikely primarily because of controls EEPGL and its contractors put in place to prevent a spill from occurring. Section 2.11 (Embedded Controls) provides a description of the embedded controls related to spill prevention.

Despite the unlikely probability of an oil spill, the impacts assessment addresses potential impacts associated with Scenario 6, which are referred to as "Coastal Oil Spill," as well as Scenarios 7, 8, and 9, which are collectively referred to as "Marine Oil Spills." Scenario 5 is referred to as a "NADF Release" and impacts on relevant receptors are assessed as a separate category of release.

7.4.1.2 Factors Impacting Severity of Hydrocarbon Spills

Several factors impact the severity of hydrocarbon spills and the options for, and effectiveness of, a range of spill response measures. These factors include the hydrocarbon properties, volume and location of the spill, metocean conditions, and seasonal factors impacting the presence of wildlife (Dicks, 1998).

Hydrocarbon products vary widely in their physical and chemical properties, as well as their potential impacts on marine organisms (Figure 7-7). Heavy oils have the potential to cause more significant and longer term impacts as they may persist along shorelines and cause smothering of intertidal plants and coral reef habitats. In contrast, light oils tend to be more toxic, but dissipate much more quickly through evaporation and dispersion, so they are generally less impactful overall and their potential toxic impacts are likely to be localized and short lived (ITOPF, Undated; ITOPF No. 2, Undated; Dicks, 1998). The oil produced from the Liza field is a "light crude" oil with a specific gravity less than water. If spilled, this oil would rise quickly to the water surface, other than small fragmented droplets that become entrained in the water column due to mixing energy. As a result, the potential for persistent slicks, shoreline impacts, and smothering is reduced relative to heavy hydrocarbon products. The Project will use low-toxicity NADF, which is denser than the light crude in the Liza field and contains specific

weighting materials used during the drilling process. As such, the NADF would tend to remain near the seafloor if released from the bottom of the riser during an emergency disconnect scenario.

Figure 7-7 Typical Impacts on Marine Organisms across a Range of Oil Classes



Source: ITOPF, Technical Information Paper 13, undated

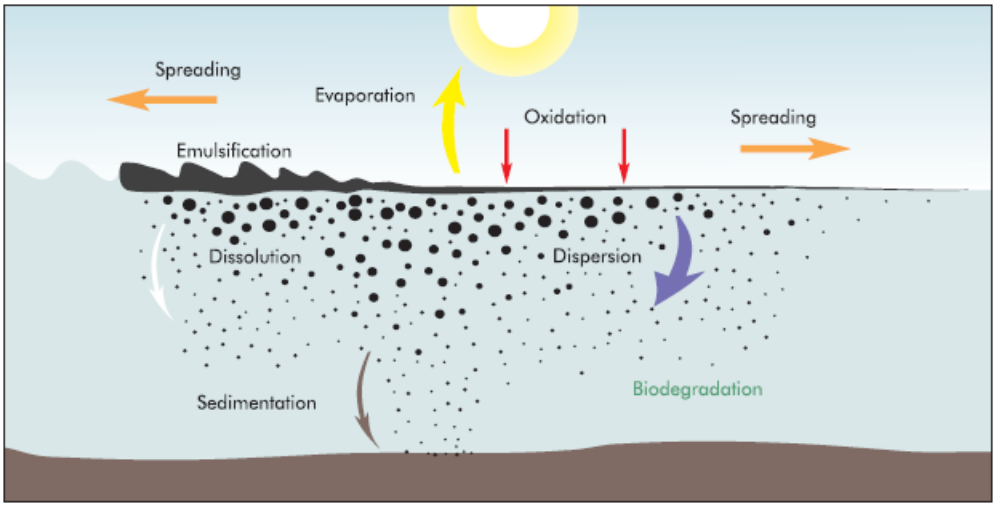
The well control event considered for the purpose of this EIA would occur in the ocean approximately 190 km (approximately 120 miles) offshore from Guyana. The open waters of the ocean, and associated pelagic and seabed communities, are typically more resilient to spills than are shoreline environments (Dicks, 1998).

Climate and weather can also impact the behavior of an oil spill. For example, oils become more viscous (i.e., flow less readily) at lower sea surface and air temperatures. In this case, the surface waters in the AOI are warm, typically ranging from 24 to 30°C, which results in the oil remaining fluid and increasing spill response options.

7.4.1.3 Weathering Processes

As soon as hydrocarbons are introduced to the ocean, advection and spreading begin immediately and result in a rapid increase in the exposure area of the product to subsequent "weathering" processes (Figure 7-8). These processes include evaporation, dissolution, vertical dispersion, emulsification, and sedimentation. All of these processes are influenced by the specific composition of the introduced hydrocarbon. In addition, some components are degraded by photochemical oxidation induced by sunlight.

Figure 7-8 Weathering Processes Acting on Spilled Oil



Source: ITOPF, 2013

The products of these processes may include hydrocarbon fractions and reaction products introduced to the atmosphere, slicks and tar lumps on the surface of the ocean, dissolved and particulate hydrocarbon materials in the water column, and similar components in the sediments. While physical and chemical processes are occurring, biological processes, including degradation of oil by microorganisms to carbon dioxide or organic components in intermediate oxidation stages, uptake by larger organisms and subsequent metabolism, storage, or discharge also act on the different fractions of the original oil.

Although not all of the same processes (e.g., photochemical oxidation, evaporation) occur at the depths that a NADF Release could occur, the NADF would be exposed to biological degradation. Biological degradation proceeds slower under anoxic conditions than under well-oxygenated conditions, so biological degradation tends to occur most rapidly when the NADF is thinly distributed over a wide area of seafloor rather than in thicker clumps over a small area.

7.4.1.4 Oil Spill Modeling Overview

Oil spill models have been in use for over 30 years to support the development of Oil Spill Response Plans (OSRP). Trajectory and fate models simulate oil transport and predict the changes the oil undergoes as it interacts with water, air, and land (oil fate). The models simulate spill events using the best available characterization of the wind and hydrodynamic (marine currents) forces that drive oil transport. The models quantify the potential consequences from a spill, which can then be used to guide response planning and prioritize response asset deployment. There are typically two modes under which the models can be used: 1) the **stochastic** (statistical) mode that examines *many potential releases* from the same point utilizing the full range of historical data for wind and currents; and, 2) the **deterministic** mode that examines a *single potential release* utilizing specific historic wind and hydrodynamic datum from the range of potential data, or utilizing forecast data for an ongoing or future event.

Extreme weather events are considered qualitatively in the oil spill modeling. The PDA is not in a seismically active area. The Project is designed to withstand other potential extreme events (e.g., hurricanes, unusual temperatures, high winds, strong currents). In fact, these extreme events have little to no effect on the wells, which are located approximately 1500 to 1900 m below the ocean surface. Weather forecasts provide advance notice of these events and would enable EEPGL to take appropriate precautions with the FPSO.

A typical approach to using oil spill models in OSRP is to first apply the stochastic model to determine the most likely trajectory for the spill scenarios of interest. The stochastic approach captures variability in the trajectory by simulating hundreds of individual spills and generating a map that is a *composite* of all of the trajectories and provides a *probability footprint* showing the most likely path for a given spill scenario. Spill scenarios are typically modeled in stochastic mode to provide composite footprints to estimate probability and timing for each season or wind regimes in the region.

Each stochastic scenario results in a probability map of the extent and mass of sea surface oiling, the extent of shoreline oiling, and the minimum time of oil arrival in each location contaminated

by the oil. Examples of stochastic maps are shown in Section 7.4.1.5 (Oil Spill Modeling Results). Calculation of the probabilities is based on oil present in excess of a specified thickness threshold. The thresholds are specific to the purpose of the modeling or the type of impact being considered, including ecological and socioeconomic. They are used in the determination of oiling probability to determine if oil is present in a quantity exceeding the threshold. For example, a surface slick thickness threshold can be based on the minimum thickness that can be mechanically recovered or on the minimum thickness that is thought to cause ecological or socioeconomic impacts. When applied in this way, a trajectory and fate model can quantify the likelihood of specific spill consequences, which is supportive of OSRP planning and environmental impact analysis.

When considering oil contamination thresholds, surface oil thickness is typically expressed in units of mass per unit area (e.g., grams per square meter [g/m^2]). Table 7-83 lists approximate thickness and mass per unit area ranges for surface oil of varying appearance.

Table 7-83 Oil Thickness (g/m^2) and Appearance on Water (NRC, 1985)

Minimum	Maximum	Appearance
0.05	0.2	Colorless and silver sheen
0.2	0.8	Rainbow sheen
1	4	Dull brown sheen
10	100	Dark brown sheen
1,000	10,000	Black oil

Oil spill deterministic models predict where spilled oil from a single release will go and, how quickly it travels and arrives at given locations. The trajectory of the spill is determined by the specific modeled wind and current and the properties of the discharged oil. The model determines the spill pathway by calculating the movement of the oil for individual short increments of time over the spill's duration, which cumulatively results in the spill trajectory. Knowing the distance traveled by the oil over a period of time also provides a prediction of the time of travel for the spill. Consequences from the spill are determined by running the model within a geospatial framework so that interactions between the oil and elements of the environment (habitats and species) can be considered. Given an adequate definition of currents, winds and the environment, a deterministic model can provide comprehensive predictions of the trajectory, fate, and effects of the oil.

Oil spill trajectory and fate models provide a quantifiable and consistent means to quantify spill consequences. A trajectory and fate model can also simulate spill response activities such as mechanical recovery, dispersant application, and in-situ burning. Model simulations run with and without spill mitigation measures calculate the effectiveness of different response strategies and equipment which can be used to help validate and improve spill response plans and contribute to a Net Environmental Benefit Analysis (NEBA) process. The NEBA process examines the benefit of using various spill response technologies against the effect of the oil spill itself prior to deploying the preferred technologies in a spill event.

Once individual spill events have been identified based on the desired criterion, a deterministic map showing the trajectory and fate of the spill is generated along with a graphical representation of the oil quantities predicted to reach the different parts of the environment. This breakdown of the oil quantities by environmental compartment, referred to as an oil mass balance, provides a time history of the entire spilled oil mass over the period of the model simulation. The trajectory maps and oil mass balance graphs can be generated for a range of spill scenarios and included in an OSRP. Examples of deterministic maps and oil mass balance graphs are shown in Section 7.4.1.5 (Oil Spill Modeling Results).

When applied to OSRP activities, an oil spill model is used to simulate scenarios selected to be representative of anticipated spill events. These typically include operational spills, smaller volume releases to the water surface, and larger volume spills related to production or drilling operations originating either at the sea surface or from the seabed. In both cases the oil spill model is applied to determine the most likely pathway for a spill from each scenario and to quantify the oil fate.

The trajectory and fate model provides input to the OSRP process by determining spill pathways and quantifying potential spill consequences. Determining the consequences from a spill typically has two components: determining the likelihood that a spill will contaminate a given part of the environment, and; what will be its ecological and socioeconomic consequences.

7.4.1.5 Oil Spill Modeling Results

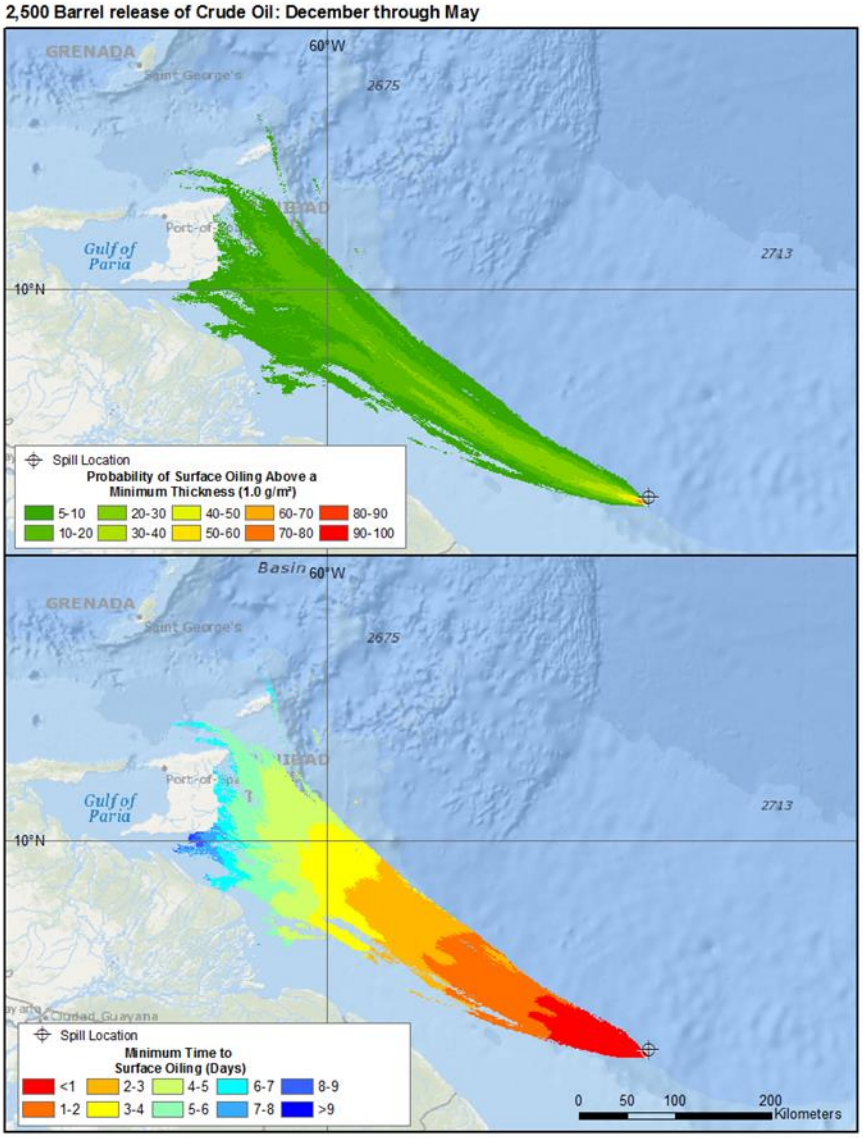
Oil spill modeling results for oil spill Scenarios 8 and 9 are summarized in this section. Additional modeling results are included in the OSRP. Scenario 8 includes the modeling of a 2,500 bbl leak associated with FPSO offloading to a conventional tanker. Scenario 9 includes the modeling of a 20,000 BOPD well control event of a 30-day spill duration, which included an extension of an additional 15 days after oil discharge ceased.

The modeled results show potential impacts in the absence of spill response measures, which would be expected to significantly reduce the severity and extent of a spill and its impacts. Subsequent sections of this document describe how EEPGL and its contractors will respond to mitigate environmental impacts in the unlikely event of an incident similar to or less severe than the modeled scenario.

Spills originating at the seafloor were simulated using the OILMAP DEEP model to predict the discharge plume geometry, droplet size distribution discharged into the water column, and the fate of the oil plume. The SIMAP model system was used to predict the probability of the extent of oil contamination on the sea surface and the shoreline, taking into account the weathering profile of the oil that would result in a proportion of the product evaporation or dispersing into the water column. Spills were simulated taking into consideration the quantity of product released, the type of product and its characteristics (e.g., density), historical seasonal wind and current patterns, and water depth, among other factors.

Modeling has been performed for the summer season (June through November), as well as the winter season (December through May). The results of modeling for the winter season are presented in the figures below, as they provide more conservative results for the purposes of the EIA based on higher current speeds and more northerly winds.

Figure 7-9 Stochastic Map for Scenario 8 – Unmitigated 2,500-Barrel Release of Crude Oil (December through May)



The top panel of Figure 7-9 is a stochastic map which, based on hundreds of simulations, shows the probability of surface oiling above a minimum thickness of 1.0 g/m^2 in the winter season from a 2,500 barrel spill that originates at the FPSO location. This stochastic map indicates there is a zero percent probability that oil at that thickness would make contact with the Guyanese coast.

The bottom panel of Figure 7-9 is a stochastic map, based on hundreds of simulations, which shows the minimum amount of time for surface oiling above a minimum thickness of 1.0 g/m^2 to occur from a 2,500 barrel spill that originates at the FPSO location in the winter season.

Figure 7-10 is a deterministic map that predicts where a single simulation of a 2,500 bbl spill from the FPSO location would go under a set of wind and current conditions typical of the winter season. This deterministic map indicates that oil would not make contact with the Guyanese coast. The gray area shows the "swept area" which is the path the oil spill is projected to follow. The black area shows the fate of the surface oil. The red area shows the fate of the oil that makes shoreline contact.

Figure 7-10 Deterministic Map for Scenario 8 – Unmitigated 2,500-Barrel Release of Crude Oil (December through May) Depicting Weathering and Fate

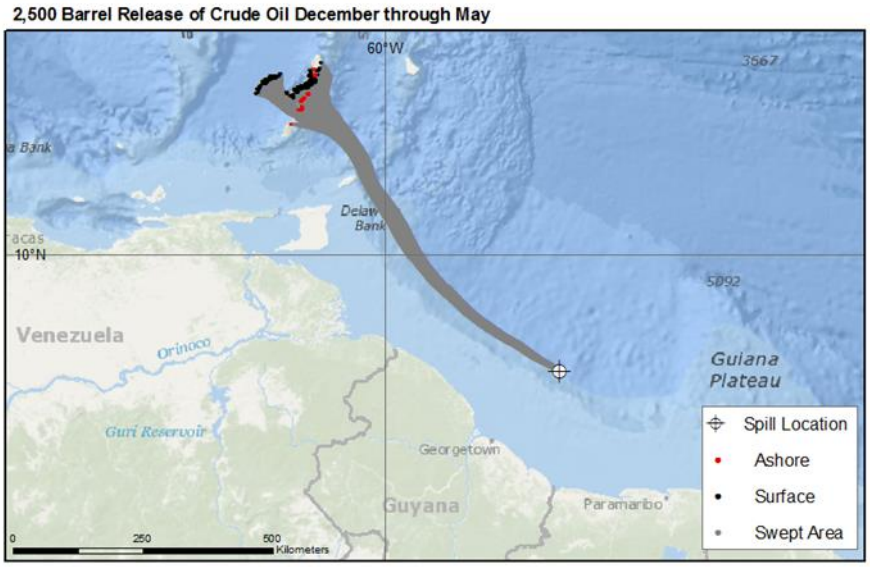
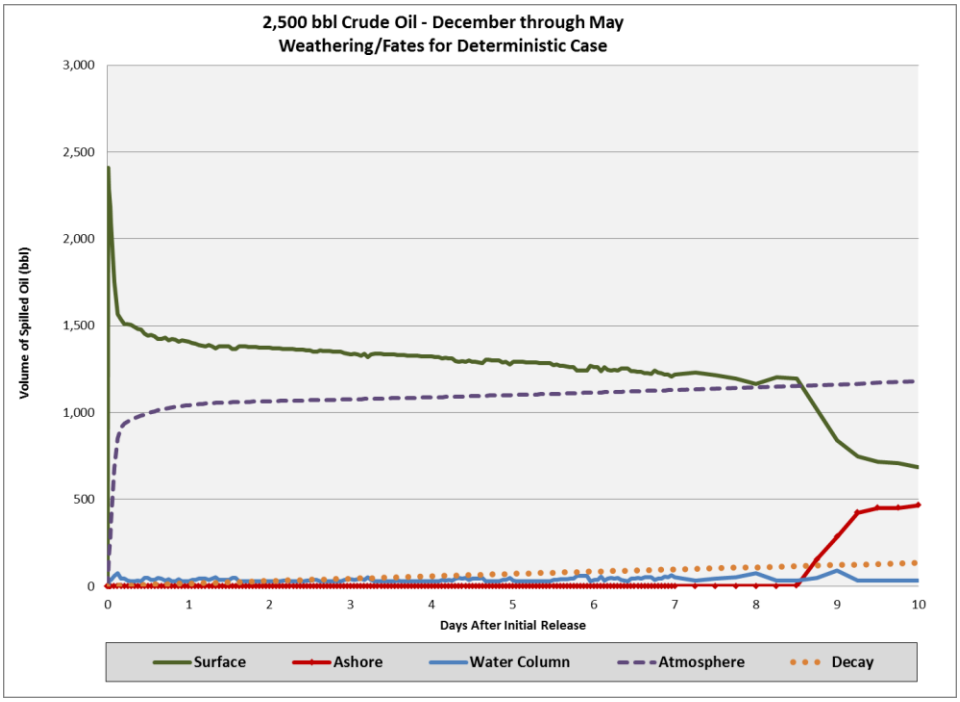


Figure 7-11 is an oil mass balance graph that is associated with the deterministic map in Figure 7-10 (which shows where a single simulation of a 2,500 bbl spill from the FPSO location would go in the winter season). Figure 7-11 provides a graphical representation of the oil quantities predicted to reach different parts of the environment over time. The green line represents the volume of spilled oil which would be on the ocean surface over time. The red line represents the volume of spilled oil which would make coastal contact (in this case, outside of Guyana) over time. The blue line represents the volume of spilled oil which would remain in the water column over time. The dotted orange line represents the volume of spilled oil which would decay over time. The dotted gray line represents the volume of spilled oil which would be

released to the atmosphere over time, which represents the vast majority of the spill volume (approximately 50 percent). For perspective, a Scenario 8 oil spill has the potential to occur during the production operations stage (at least 20 years).

Figure 7-11 Oil Mass Balance Graph for Scenario 8 – Unmitigated 2,500-Barrel Release of Crude Oil (December through May) Depicting Weathering and Fate



The top panel of Figure 7-12 is a stochastic map which, based on hundreds of simulations, shows the probability of surface oiling above a minimum thickness of 1.0 g/m^2 in the winter season from a 20,000 bpd spill that originates at a well location in the PDA and lasts for 30-days. This stochastic map indicates there would be a 5 to 10 percent probability that oil at that thickness would make contact with the northwest-most area of the Guyanese coast. The value of 1.0 g/m^2 is commonly used as a threshold in oil spill modeling as it represents the mass of oil where biological impacts can occur, based on research and experience (McCay, 2016).

The bottom panel of Figure 7-12 is a stochastic map, based on hundreds of simulations, which shows the minimum amount of time for surface oiling above a minimum thickness of 1.0 g/m^2 to occur from a 20,000 bpd spill that originates at a well location in the PDA and lasts for 30-days in the winter season. Minimum time for reaching the northwest-most area of the Guyanese coast would be approximately 5 to 10 days, although some of the oil may arrive in the 10 to 15 day time period.

Figure 7-12 Stochastic Map for Scenario 9 – Unmitigated 20,000-Barrel-per-Day Release of Crude Oil for 30 days (December through May)

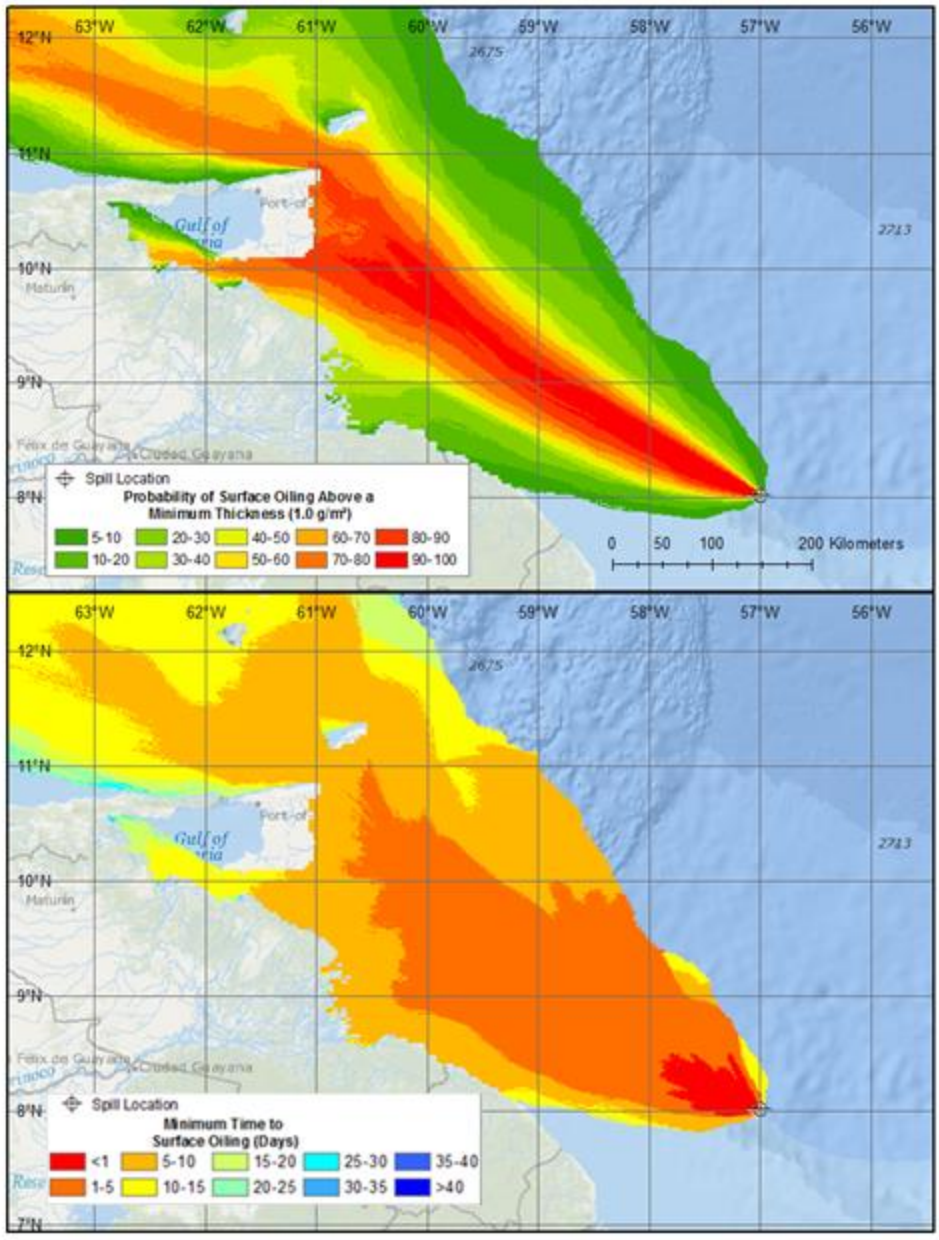


Figure 7-13 is a deterministic map which predicts the fate of a single simulation of a 20,000 bpd spill that originates at a well location in the PDA and lasts for 30-days in the winter season. This deterministic map indicates that oil would not make contact with the Guyanese coast. The gray area shows the "swept area" which is the path the oil spill is projected to follow. The black area shows the fate of the surface oil. The red area shows the fate of the oil that makes shoreline contact.

Figure 7-13 Deterministic Map for Scenario 9 – Unmitigated 20,000-Barrel-per-Day Release of Crude Oil for 30 days (December through May) Depicting Weathering and Fate

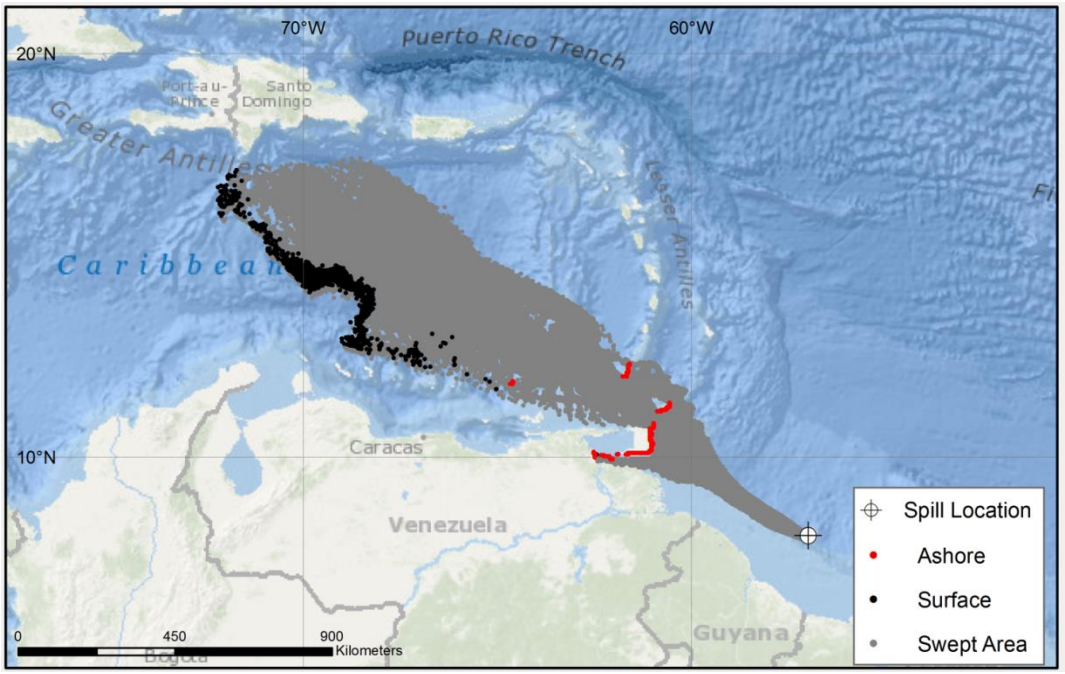
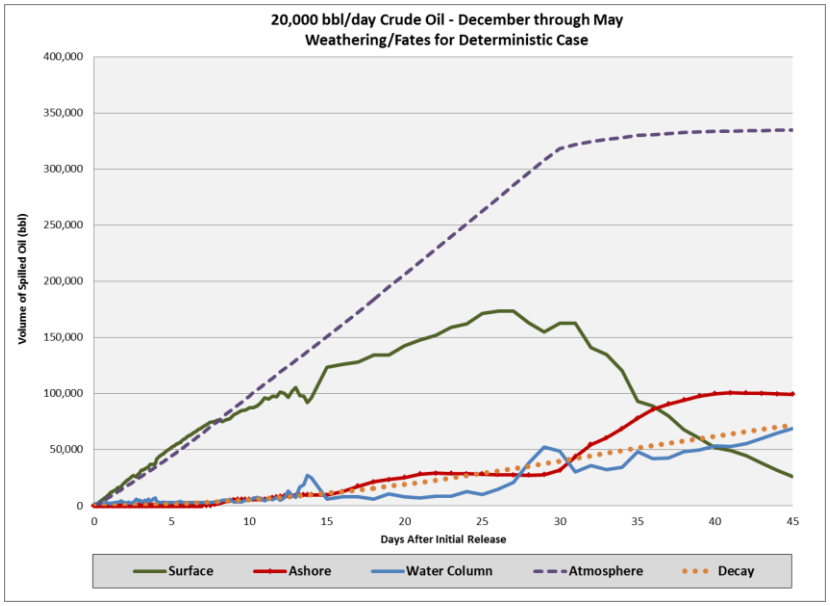


Figure 7-14 is an oil mass balance graph that is associated with the deterministic map in Figure 7-13 (which shows where a single simulation of a 20,000 bpd spill that originates at a well location in the PDA and lasts for 30 days in the winter season). Figure 7-14 provides a graphical representation of the oil quantities predicted to reach different parts of the environment over time. The green line represents the volume of spilled oil which would be on the ocean surface over time. The red line represents the volume of spilled oil which would make coastal contact (in this case, outside of Guyana) over time. The blue line represents the volume of spilled oil which would remain in the water column over time. The dotted orange line represents the volume of spilled oil which has decayed over time. The dotted gray line represents the volume of spilled oil which would be released to the atmosphere over time, which represents the vast majority of the spill volume (approximately 50 percent).

For perspective, the Scenario 9 oil spill has the potential to occur during the drilling stage (approximately up to four years).

Figure 7-14 Oil Mass Balance Graph for Scenario 9 – Unmitigated 20,000-Barrel-per-Day Release of Crude Oil for 30 days (December through May) Depicting Weathering and Fate



7.4.1.6 *Coastal Sensitivity Mapping*

Coastal sensitivity mapping was conducted for the entire coastal area identified in the oil spill modeling as being potentially exposed to hydrocarbons as a result of a Tier III Marine Oil Spill (Scenario 9). The mapping included the following resources and receptors:

- Environmental – protected areas, wetlands, mangroves, beach types, seagrass beds, coral reefs, and other sensitive habitats; and
- Socioeconomic – coastal and/or indigenous peoples communities (e.g., location and socioeconomic characteristics), coast-dependent commercial and artisanal activities (e.g., fishing, foraging), other industrial activities, and infrastructure (e.g., water intake facilities).

This information enables EEPGL to prioritize the mobilization of emergency response resources (manpower and equipment) to those areas most sensitive to a spill. These maps are included in the OSRP.

7.4.1.7 *Oil Spill Prevention, Control, and Emergency Response Measures*

Regarding spill prevention controls associated with Scenario 9 (well control release), EEPGL's well control philosophy is focused on spill prevention using safety and risk management systems, management of change procedures, global standards, and trained experienced personnel. EEPGL has a mature OIMS that emphasizes attention to safety, well control, and environmental protection. Measures to avoid any loss of well control include proper preparation for wells (well design, well control equipment inspection and testing), automatic

detecting of any excess pressure entering the well during drilling, the use of physical barriers including automatic BOPs, personnel training and proficiency drills for well control, and the use of drilling fluids to control pressures within the well. See Chapter 2 for additional information.

Regarding spill prevention controls associated with Scenario 8 (FPSO offloading spill), the major spill prevention controls associated with FPSO offloading include: FPSO and tanker collision avoidance controls described in Section 7.1.4.8; use of a certified engineered floating hose system; floating hose damage protection controls; use of emergency disconnect controls on the floating hose system; use of load monitoring systems in FPSO control room; and use of leak detection controls including infrared leak detection, flood lighting for night operations, and volumetric checks during offloading. See Section 2.11 Embedded Controls for additional information. Spill controls associated with other Scenarios are also included in Section 2.11.

In addition to the established spill prevention controls, EEPGL also has developed a detailed Oil Spill Response Plan (OSRP), which is included in the Project's ESMP, to ensure an effective response to an oil spill, if one were to occur. The OSRP builds on the coastal sensitivity mapping and oil spill modeling described herein. The OSRP describes the response measures which are dependent on the magnitude and complexity of the spill.

The OSRP clearly delineates the responsibilities of each entity that would take part in a response and describes how EEPGL and its contractors would mobilize local oil spill response resources, which would be complemented by the regional and international resources provided by its oil spill response contractors. The OSRP describes the EEPGL process for notifying the government of Guyana with respect to mobilizing its resources. The lead agency for oil spill response in Guyana is MARAD, which falls under the Ministry of Public Works and Communication. Maritime responsibilities are handled by several departments and ministries, though the Coast Guard, under the auspices of MARAD, which enforces all maritime regulations and is the primary response organization in any marine pollution incident in navigable waters. In addition, the Guyana Defense Force and the Fire Service also assume an operational role for pollution response.

Due to the precautionary measures utilized by EEPGL to prevent and control an oil spill, as described above and in Chapter 2, the likelihood of a Tier II or III oil spill occurring is expected to be **Unlikely**.

7.4.1.8 Vessel Collision

Two scenarios for vessel collisions, which can be enabling incidents for oil spills, have been considered based on the nature of Project operations:

- Collision between the FPSO and an offloading tanker – during offloading of crude oil for export, the offloading tanker must approach at a controlled, safe speed within about 120 m (~390 ft) of the FPSO. To minimize the risk of collision during the approach to the FPSO and during offloading, EEPGL will utilize a Mooring Master onboard the offloading tanker. The Mooring Master will guide the offloading tanker to the FPSO for offloading, remain on

board during offloading, and then guide the offloading tanker away from the FPSO upon completion of offloading. Up to three assistance tugs will assist in positioning the offloading tanker during the approach to the FPSO to maintain a safe separation from the FPSO. During offloading, these tugs along with a hawser (taunt line connecting the FPSO and tanker) will help ensure the offloading tanker maintains a safe distance from the FPSO at all times (see Figure 2-17). Offloading will only occur when weather and sea conditions allow for safe operations. If the environmental conditions prior to the commencement of offloading are not suitable, the tanker will standby at a safe distance away until conditions are within acceptable limits. If unexpected adverse weather (e.g., a squall) occurs during offloading operations, the offloading operation will be stopped, and the tanker disconnected and moved away from the FPSO until conditions are again within approved safe limits. Considering these precautions, the potential for a collision between the FPSO and the offloading tanker is considered **Unlikely**. In the unlikely event that a collision would occur during the tanker approach to or departure from the FPSO, the risk of an oil spill is greatly reduced by the construction and design of the vessels. Both the tanker and FPSO are double-hulled, meaning that there is a space between the outer hull of the vessel and any storage or fuel compartments. The FPSO is stationary and the offloading tanker would be travelling at a very slow maneuvering speed, therefore, there is not expected to be sufficient collision energy to breach the hulls.

- Collision near shore between a Project supply vessel and another (non-Project) vessel or structure – there are a variety of vessels that will supply and support drilling, installation, and production operations activities. These vessels will operate from Guyana and Trinidad shorebases. There is the potential for collisions between these vessels and other vessels/structures in the Georgetown Harbour/Demerara River or the grounding of a vessel. Such an incident may result from navigation error or a temporary loss of power that affected the ability of a vessel to steer. The potential environmental impacts from such a collision might result from a spill of fuel oil or lubricating oils from the vessels involved in the incident. Damage to structures may result in the requirement for repairs, and in extreme cases, temporary closure of the structure, which have occurred before in Guyana (e.g., damage to and temporary closure of the Demerara Harbour Bridge). Note the Georgetown shorebase(s) are downstream of the Demerara Harbour Bridge, which reduces the probability of collision with this structure.

A number of controls will be implemented to prevent these types of vessel incidents from occurring. EEPGL has comprehensive contractor selection guidelines to ensure contractors are qualified and have robust safety, health, and environmental management systems. EEPGL will provide active oversight over its contractors to verify they are complying with its requirements. Contractors are required to perform regular inspections of their vessels which address marine safety and maintenance considerations, which should reduce the risk of loss of power incident scenario. In addition, vessels operating within the Georgetown Harbour or other coastal areas will be adhering to speed restrictions and navigation aids. Therefore, the risk of vessel accidents

causing any significant damage to vessels or structures, or significant injury is considered *unlikely*.

Other vessel collisions (e.g., collisions between drill ship, installation vessels, or the FPSO and other vessels) are not considered reasonably foreseeable scenarios given the following safety measures that will be put in place:

- MARAD will issue notices to mariners concerning safety at sea and the location of the drill ship, installation vessels, and FPSO. EEPGL will also communicate major Project vessel movements to commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and where possible communicate Project activities to those individuals to aid them in avoiding Project vessels through the stakeholder engagement process. Marine safety exclusion zones with a 500 m (~1,640 ft) radius will be established around the drill ship during drilling operations and around drill centers during well workovers, in accordance with industry standards and practices. No unauthorized vessels will be allowed to enter these marine safety exclusion zones. Similar marine safety exclusion zones will be established for the major installation vessels.
- A marine safety exclusion zone of 2 nautical miles will be established around the FPSO. No unauthorized vessels will be allowed to enter this marine safety exclusion zone.
- EEPGL will utilize a Simultaneous Operations procedure to safely manage Project marine vessels which are performing work in the same vicinity of each other, which will include considerations to avoid vessel collisions.
- Marine vessels will have industry proven station-keeping systems (e.g., FPSO mooring system, dynamic position systems on drill ship, support vessels) to maintain station in the offshore environment.

7.4.1.9 Onshore Vehicular Accident

The Project will result in an increase in onshore vehicular traffic generated primarily by additional activity around the Georgetown base(s) that support the Project. As a result of this increased traffic, there will be an increased risk of vehicular accidents that could cause property damage and/or injury to third parties.

The likelihood of a vehicular accident causing a major injury or fatality is considered *possible* given the relatively low Project-related traffic volumes and the generally low vehicular speeds in Georgetown. EEPGL will implement a Road Safety Management Procedure –as described in Section 7.4.4.2 to minimize this risk.

7.4.1.10 Summary of Unplanned Events Interactions with Resources/Receptors

Table 7-84 indicates which resources/receptors would potentially be impacted by a NADF Release (Scenario 5), oil spills (i.e., Coastal Oil Spill [Scenario 6] and Marine Oil Spill [Scenarios 7, 8, and 9], and by vehicular or vessel accidents. The remainder of Section 7.4 evaluates the significance of these unplanned events on each of these resources/receptors. For simplicity,

although NADF is technically a "hydrocarbon" and not an "oil," releases of both NADF and oil are generically referred to as "oil spills" in the remainder of this section.

Table 7-84 Resources/Receptors Potentially Impacted by Unplanned Events

Resource/Receptor	Oil Spill			Vehicular or Vessel Accident
	Marine	Coastal	NADF	
Physical Resources				
Air Quality and Climate	X			
Sound (airborne)				
Marine Geology and Sediments	X		X	
Marine Water Quality	X		X	
Biological Resources				
Protected Areas and Special Status Species	X	X		
Coastal Habitats	X	X		
Coastal Wildlife and Shorebirds	X	X		
Seabirds	X			
Marine Mammals	X			
Marine Turtles	X			
Marine Fish	X		X	
Marine Benthos	X		X	
Ecological Balance and Ecosystems	X		X	
Socioeconomic Resources				
Economics Conditions/ Employment and Livelihoods	X	X		
Community Health and Wellbeing	X	X		X
Marine Use and Transportation	X	X		X
Social Infrastructure and Services	X	X		X
Cultural Heritage	X	X	X	
Land Use				
Ecosystem Services	X	X		
Indigenous Peoples	X			

7.4.2 Physical Resources

As shown in Table 7-84, the only unplanned event with the potential to significantly impact physical resources is a Marine Oil Spill event in the Project AOI. Accordingly, discussions of potential impacts in this section relate to that unplanned event only.

7.4.2.1 Air Quality and Climate

Crude oil is a mixture of hydrocarbons, made up of light, medium, and heavy constituents. In the event of an oil spill, the lighter hydrocarbons (including benzene, xylene, and toluene) tend to quickly evaporate into the air. Accordingly, concentrations of these constituents typically drop rapidly during the first 24 hours of a spill. Elevated hydrocarbon concentrations in air are primarily found in the immediate vicinity of a spill and some distance downwind, depending on wind speeds. These constituents would primarily impact oil spill response workers, so air monitoring equipment would be deployed to monitor levels of air pollutants and appropriate PPE would be provided as necessary to those oil spill response workers who are exposed.

For an offshore spill, the potential for any harmful concentrations of air contaminants to reach the Guyana coastline is considered very low even for a large Marine Oil Spill considering prevailing winds away from the mainland and the distance to shore (approximately 190 km [~120 miles]). Further, any air quality impacts would be temporary. Similarly, in the event of a spill reaching shorelines, air contamination would be generally localized to the area where the oil came ashore. Therefore, the consequence to air quality of an oil spill is considered **Low**. In combination with a likelihood rating of **Unlikely** for a large Marine Oil Spill, the overall risk to air quality from an oil spill is **Minor**.

With respect to climate impacts, there would be an indirect impact associated with additional fossil fuel combustion by response vessels and equipment and with some potential for release of methane to the atmosphere, resulting in increased GHG emissions as compared to planned activities. However, the scale and duration of these additional GHG emissions would be limited, leading to a consequence rating of **Low**. In combination with a likelihood rating of **Unlikely** for an oil spill, the overall risk to climate from an oil spill is **Minor**.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure for the drill ship, lighter oil fractions would likely rise into the mid water column and dissipate laterally as they rise, while the NADF would remain at or near the seafloor and would not reach the atmosphere. Therefore, a NADF Release would have no impact on air quality or climate.

Table 7-85 Risk Rating for Oil Spill Impacts to Air Quality

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measure	Residual Risk Rating
Marine Oil Spill	Air Quality	Unlikely	Low	Minor	Implement OSRP, air quality monitoring during response, provision of PPE to response workers	Minor
	Climate	Unlikely	Low	Minor	None	Minor

7.4.2.2 Marine Geology and Sediments

An oil spill would not impact marine geology, but in the event of sedimentation (where hydrocarbons adhere to other material and settle) or shoreline stranding of the spill, hydrocarbons may be mixed within marine or intertidal sediments. This would primarily be expected in the vicinity of the well release offshore and in the nearshore wave zone. One study determined that less than 1 percent of the oil from a major loss of well control event in the U.S. Gulf of Mexico was found in sediments, and this was principally within an 8 km (5-mile) radius of the release point (U.S. National Research Council, 1985). The heavier oil fractions that may sink to the seafloor would continue to be subjected to weathering processes. Research has indicated that the overall impact of a Marine Oil Spill on the seafloor is **Low**, especially when lighter oils are involved (ITOPF, Undated). Therefore, the consequence of an oil spill on the seabed and marine sediments is considered **Low**. In combination with a likelihood rating of **Unlikely** for a large Marine Oil Spill, the overall risk to marine geology and sediments from an oil spill is **Minor**.

In the event of an emergency disconnect of the drilling riser and release of NADF near the seafloor, cuttings would also be released. Neither the NADF nor the cuttings would have any effect on the underlying marine geology of the PDA. The NADF would remain suspended in the water column and have no effect on sediments, but the cuttings would accumulate on the seafloor. Cuttings deposits would tend to be deeper and coarser in the immediate vicinity of the wellhead, and decrease in thickness and grain size with increasing distance from the well. The strength of the bottom currents in the PDA would likely erode any significant deposits near the wellhead over time, dispersing all but the coarsest cuttings down current. The only lasting effect of such an event would likely be a change in the grain size distribution of marine sediment within the deposition field; although this effect would diminish over time as benthic infauna and natural sediment deposition would bury the deposited cuttings. The NADF to be used by EEPGL contains IOGP Group III NABF with low to negligible aromatic content, reducing the potential that changes in marine sediments as a result of discharge of the NADF will lead to toxicological impacts on benthic infauna. Given the short-term nature of such an event, the low-toxicity NADF, and that the total volume of material that would be discharged would be limited to the volume of the riser, the consequence of a release of NADF on the seabed and marine sediments is considered **Low**. In combination with a likelihood rating of **Unlikely** for such an event, the overall risk to marine sediments from a release of NADF is **Minor**.

Table 7-86 Risk Rating for Oil Spill Impacts on Marine Geology and Sediments

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Marine Sediments	Unlikely	Low	Minor	None	Minor
NADF Release	Marine Sediments	Unlikely	Low	Minor	None	Minor

7.4.2.3 Marine Water Quality

As described in Section 7.4.1, marine oil spills are subject to a range of weathering processes that will result in the hydrocarbon partitioning in different parts of the marine environment, and include the loss of some of the spill by way of evaporation and photo-oxidation. Microbial and photochemical degradation processes will gradually remove remaining contamination from the marine environment. The proportion of the spill that becomes entrained in the water column through wave energy will be subject to rapid, high levels of three-dimensional dilution along with biodegradation. Some oil constituents, especially aromatics, are also soluble in water. Together the entrained and dissolved fractions will increase hydrocarbon concentrations in the water column and result in localized reductions in water quality. Monitoring of oil spills has shown that concentrations of oil and its constituents in the water column rapidly decline after a spill, and are usually confined to an area near the source (ITOPF, Undated). The oil that would be released from a spill in the PDA would be what is known as a light crude. Lighter crude oils generally have higher biological availability and are generally associated with higher toxicity impacts versus heavier crudes. This impact, however, is offset by the relatively rapid dissipation of light oils through evaporation and dispersion, which means light oils may be less impacting to the environment overall, relative to heavier oils, as long as sensitive resources are sufficiently distant from the immediate source of the spill.

The mixing energy resulting from a loss of well control event may result in higher levels of entrained and dissolved hydrocarbons than a surface spill, as the slick will be fragmented into smaller droplets by reservoir pressure.

Accordingly, a Marine Oil Spill is considered to have a **High** severity rating with respect to impacts on water quality, taking into consideration the higher toxicity of the light oil fractions and the magnitude and extent of the spill scenario, balanced against the limited geographic extent and duration of the toxicity impacts as a result of relatively rapid loss of lighter fractions. In combination with a likelihood rating of **Unlikely** for a large Marine Oil Spill, the overall risk to marine water quality from an oil spill is **Moderate**. Even with implementation of the OSRP, the residual risk rating remains **Moderate.**

As discussed in Section 7.4.2.3, NADF would be exposed to biological degradation after being released from the drilling riser. This process can result in localized decreases in dissolved oxygen concentrations, although this is more likely to be observed in the pore water between the cuttings grains deposited on the seafloor than in the water column due to the dissolution of NADF in the water column caused by the strong marine currents in the region. Organic enrichment of sediments speeds the biodegradation process, which tends to accelerate oxygen depletion and NADF cuttings tend to contain higher concentrations of biodegradable matter than WBDF. Conditions favoring eutrophication and hypoxia in the near-surface pore water within the deposition zone may exist temporarily following a release of NADF, but the high current velocities in the area would tend to prevent formation of large piles of cuttings where these conditions would persist. Eutrophication and resulting hypoxia at the seafloor or within the pore water could be sufficient to cause localized changes in the marine biota, but these changes would likely be short term. Although the NADF used by EEPGL will contain IOGP

Group III NABF, it will have low to negligible aromatic content, reducing the potential that changes in marine water quality as a result of discharge of the NADF will lead to toxicological impacts. Therefore, a NADF Release is considered to have a **Medium** severity rating with respect to impacts on water quality. In combination with a likelihood rating of **Unlikely**, the overall risk to marine water quality from a NADF Release is **Minor**.

Table 7-87 Risk Rating for Oil Spill Impacts on Water Quality

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Water Quality	Unlikely	High	Moderate	Implement OSRP	Moderate
NADF Release	Water Quality	Unlikely	Medium	Minor	None	Minor

7.4.3 Biological Resources

The only unplanned events with the potential to impact biological resources would be a Marine Oil Spill, a Coastal Oil Spill, or a NADF spill (collectively referred to as oil spills). Oil spills can impact marine biological resources both as a result of physical smothering and toxic impacts. The severity of the impact typically depends on the location of the spill, the quantity and type of hydrocarbon spilled, the environmental conditions (e.g., wind, currents), and the sensitivity of the impacted receptors and their habitats ultimately exposed to the oil (ITOPF, undated).

Due to rapid dilution of hydrocarbons in the water column, the most significant impacts on biological resources are generally impacts on seabirds and other species that encounter surface slicks. Impacts may also occur in shallow subtidal or intertidal areas that are exposed to higher concentrations where hydrocarbons are entrained by breaking waves or where species are foraging on sand, mudflats, or wetlands.

7.4.3.1 Protected Areas and Special Status Species

Potential impacts from a Marine Oil Spill or a Coastal Oil Spill on protected areas and special status species are discussed in this sub-section.

Protected Areas

The Shell Beach Protected Area (SBPA) provides habitat for numerous coastal wildlife and shorebird species, including several species of critically endangered/endangered marine turtles. The SBPA would be highly sensitive to a large Marine Oil Spill if it were to reach the shoreline. However, as discussed in Section 6.1.4.1, Guyana's oceanic waters are influenced by the Guiana Current and the North Brazil Current, and oil spill modeling indicates that oil spilled from the modeled loss of well control event would have a 5 to 10 percent probability would reach the Guyana shoreline, without considering the effects of emergency spill response. Nevertheless,

SBPA has been included in the coastal sensitivity mapping, and in the event of an oil spill, resources and equipment would be mobilized to protect Shell Beach as necessary.

Based on the sensitivity of the SBPA, the consequence of an oil spill reaching the SBPA would be **High**. The low probability (5 to 10 percent) of oil from a large Marine Oil Spill actually reaching the Guyana shoreline supports a likelihood rating of **Unlikely**. Therefore, the overall risk to the SBPA from a large Marine Oil Spill is considered **Moderate**. With the effective implementation of the OSRP, the residual (post-mitigation) risk is considered **Minor**.

A Coastal Oil Spill (e.g., Scenario 6 from Table 7-82) would not be expected to impact SBPA because it would be limited to near Project shorebases and onshore support facilities, which would be distant from SBPA.

A NADF spill would not be expected to impact the SBPA because of the limited volume spilled, and the depth and distance to shore at which the spill would occur.

Special Status Species

Special Status Species include critically endangered, endangered, threatened, and vulnerable species that are found in the Project AOI.

The Critically Endangered species in the AOI are all coastal fish species that would only exposed to oil if it reached coastal waters. If oil were to reach the coast in sufficient quantities to cause lethal or sublethal impacts on fish, the loss of even a few individuals in this category could cause significant impacts at the population level. Based on this rationale, the consequence or severity of an oil spill on Critically Endangered species is considered **High**. A large Marine Oil Spill or a Coastal Oil Spill are the only spill scenarios that could result in such quantities of oil reaching coastal waters and these events are considered **Unlikely**. Therefore, the overall risk of a large Marine Oil Spill or a Coastal Oil Spill to Critically Endangered species is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by further reducing the probability of oil reaching the Guyana coast line.

There are a few terrestrial special status species, such as the Agami heron and Semipalmated sandpiper that could encounter weathered oil along the coast, or ingest fish that had been exposed to or ingested oil themselves. This would be most likely to occur under a large Marine Oil Spill or Coastal Oil Spill in which oil could approach or reach the Guyana coast. Such an event could cause significant impacts at the population level, depending on the size of the spill and the proportion of available forage and habitat affected. Therefore the consequence or severity of an oil spill on Critically Endangered species is considered **High**. The likelihood rating of such an event occurring is considered **Unlikely** for the same reasons cited above for Critically Endangered species. Therefore, the overall risk of a large Marine Oil Spill or a Coastal Oil Spill to terrestrial special status species is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by further reducing the probability of oil reaching the Guyana coast line.

The Endangered and Vulnerable species are primarily open water fish that would occur in the PDA. fish have no need to surface and can therefore avoid floating oil, and the depths present

offshore of Guyana would provide sufficient opportunity to do avoid slicks and sheens. Fish would have the potential to encounter emulsified oil rising through the water column from a loss of well control at the wellhead, but most of the Endangered and Vulnerable species are pelagic species that would be expected to rapidly vacate areas with harmful concentrations of oil in the water column, so exposure times would be brief. Losses of a small numbers of individuals of Endangered or Vulnerable species could have significant population level effects, but would have less of an impact than losses of equivalent numbers of Critically Endangered species.

Based on this rationale the consequence or severity of a large Marine Oil Spill on Endangered or Vulnerable species is considered **Medium**. The severity of a spill event's impacts on green sea turtles and black capped petrels would be higher than on the fishes that comprise most of the Endangered and Vulnerable categories, and impacts of unplanned events on sea birds and sea turtles are assessed in other sections, with the higher sensitivities of these two species to oil spills are not sufficient to elevate the consequence rating for impacts on the remaining species in the Endangered and Vulnerable categories. Therefore, the overall risk of a large Marine Oil Spill to Endangered and Vulnerable species is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by further reducing the probability of oil reaching the Guyana coast line.

The Near Threatened category includes a mix of offshore and coastal species, but most species are primarily found offshore. These species are considered less at-risk than Endangered or Vulnerable species, so the consequence or severity of a large Marine Oil Spill or Coastal Oil Spill on these species is considered **Medium**. Most species in the Endangered and Vulnerable categories occur offshore, so the likelihood of an oil spill impacting these species is rated as **Unlikely** based on the same rationale presented above for Endangered or Vulnerable species. Therefore, the overall risk of a large Marine Oil Spill or Coastal Oil Spill to Endangered and Vulnerable species is considered **Minor**. Effective implementation of the OSRP would further reduce the geographic extent of a spill.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure for the drill ship, lighter oil fractions would likely rise into the mid water column and dissipate laterally as they rise, while the NADF would remain at or near the seafloor. A few of the deepwater-adapted special status fishes (e.g., hollownose grenadier and frilled shark) may occur occasionally in the shallowest portion of the PDA, but the PDA is too deep to be within the preferred habitat of any special status species. Therefore, a NADF Release would not be expected to have a population-level impact on special status species.

Table 7-88 Risk Rating for Oil Spill Impacts on Protected Areas and Special Status Species

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Protected Areas (SBPA)	Unlikely	High	Moderate	Implement OSRP	Minor
Marine Oil Spill or Coastal Oil Spill	Special Status Species					
	Critically Endangered Species	Unlikely	High	Moderate	Implement OSRP	Minor
	Endangered Fish and Black Capped Petrel	Unlikely	High	Moderate	Implement OSRP	Minor
	Vulnerable/ Near Threatened Species	Unlikely	Medium	Minor	Implement OSRP	Minor

7.4.3.2 Coastal Habitats

As indicated in Table 7-84, the unplanned events with the potential for any measureable impacts on coastal habitats would be from a large Marine Oil Spill or Coastal Oil Spill.

In Guyana, the coastal habitats most at risk from an oil spill would be mangroves and other wetland habitats (e.g., mudflats). Other habitats that are known to be sensitive to oil spills are coral reefs and seagrass beds, but which are not present in Guyana.

Mangroves, of which the largest remaining stands in Guyana occur in the SBPA, are important providers of a number of ecological services upon which fish, wildlife, and humans rely. Mangroves provide valuable habitat for crabs and important nursery areas for fish and shrimp, and provide coastal protection from wave action. Mangroves are typically found along the margins of shorelines at the saltwater interface Due to this physical location, mangroves are vulnerable to exposure during oil spills. Mangroves are considered to be sensitive to heavy contamination by oil for several reasons (ITOPF, undated):

- Mangroves rely on oxygen supplied through small pores (lenticels) on their aerial roots. Smothering of the aerial roots by heavy hydrocarbons can block this important oxygen pathway;
- The toxic component of oil can interfere with mangroves' systems for maintaining salt balance, impacting their ability to tolerate salt water;

- Oil can become trapped in mangrove sediments, where it may remain in a relatively unweathered state and be gradually remobilized over a long period, causing repeated "pulses" of exposure; and
- If impacted, mangrove habitats are typically slow to recover from oil exposure, often taking 10 years or longer, especially where the shoreline protection services of the mangroves has been compromised.

For these reasons, the consequence or severity of a large Marine Oil Spill on mangroves is considered **High**. However, oil spill modeling of a loss of well control event indicates a 5 to 10 percent chance of oil reaching the Guyana shoreline, supporting a likelihood rating of **Unlikely**. Therefore, the overall risk of a Marine Oil Spill on coastal habitats is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by further reducing the probability of oil reaching the Guyana coast line.

There is also the potential for a Coastal Oil Spill in the Demerara River or near shorebases located elsewhere in Guyana (see Section 7.5 for discussion of shorebases in Trinidad). Scenario 6 (Table 7-82) assumes a spill of 500 bbl of diesel oil, which may occur during bunkering. Under this scenario, the spill would be quickly controlled and contained because of the relatively small volumes and the ready access to spill control equipment. Although mangrove forests are not extensive near the mouth of the Demerara or the Essequibo rivers, fringe mangroves do exist and would be susceptible to exposure to an oil spill. Other coastal habitats that are particularly susceptible to oil spills (e.g., coral reefs, seagrass beds) are not found in these coastal areas of Guyana. These impacts would generally be temporary, limited in area, and readily mitigated, with rapid habitat recovery expected.

Nevertheless, considering the sensitivity of mangroves to oil spills, the consequence or severity of a Coastal Oil Spill on mangroves is considered **High** and the occurrence of this event is considered **Unlikely**. Therefore, the overall risk of a Coastal Oil Spill to coastal habitats is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by further reducing the spread of oil in coastal waters.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure on the drill ship, the NADF would not be expected to reach the coast. Therefore, a NADF Release would have no impact on coastal habitats.

Table 7-89 Risk Rating for Oil Spill Impacts on Coastal Habitats

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Coastal Habitats	Unlikely	High	Moderate	Implement OSRP	Minor
Coastal Oil Spill	Coastal Habitats	Unlikely	High	Moderate	Implement OSRP	Minor

7.4.3.3 Coastal Wildlife and Shorebirds

As indicated in Table 7-84, the unplanned events with the potential for any measureable impacts on coastal wildlife and shorebirds would be a large Marine Oil Spill or a Coastal Oil Spill.

As described in Section 6.2.3, the Guyana coastal habitats support a rich and diverse collection of species, including shorebirds. Many of these species are dependent on mangroves and other wetland habitats, which are particularly sensitive to oil spills. In addition, there is the potential for some oil that reaches the Guyana shoreline to move upstream into the tidal portions of rivers and other estuarine areas as a result of tidal action, where it could impact fur-bearing species like the neotropical and giant river otter. Oil can impact the physical structure of feathers and fur, causing a loss of waterproofing and thermoregulation. In addition, animals can inhale hydrocarbons or ingest oil when they groom themselves or feed, which can damage their lungs, cause ulcers, and result in liver and kidney damage.

For these reasons, the consequences or severity of a large Marine Oil Spill on coastal wildlife and seabirds is considered **High**. However, oil spill modeling of a loss of well control event indicates a 5 to 10 percent chance of oil reaching the Guyana shoreline, supporting a likelihood rating of **Unlikely**. Therefore, the overall risk of a large oil spill on coastal wildlife and shorebirds is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by reducing the probability of oil reaching the Guyana coast line.

A Coastal Oil Spill (e.g., Scenario 6 from Table 7-82) would more directly impact estuarine wildlife than the small portion of a larger Marine Oil Spill that reaches the coastal portion of Guyana. The giant river otter, however, is not found in estuarine waters, and emergency response measures should be able to prevent any hydrocarbons from a spill like this from migrating upstream into fresh water habitats where this species may be found. There could be impacts to the neotropical otter, which can be found in estuarine areas, shorebirds, and other wildlife from oiling, but because of the more limited magnitude of the spill and its location in a more controllable setting (i.e., riverine vs open ocean), the impacts would be limited to those individuals in the limited impacted area, and these impacts would be expected to be temporary, with no impacts at the population level for any species.

Nevertheless, considering the sensitivity of some of these coastal species, the consequence or severity of a Coastal Oil Spill on coastal wildlife and shorebirds is considered **High** and the occurrence of this event is considered **Unlikely**. Therefore, the overall risk of a Coastal Oil Spill on coastal habitats is considered **Moderate**. Effective implementation of the OSRP would further reduce this risk to **Minor** by further reducing the spread of oil in coastal waters.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure on the drill ship, the NADF would not be expected to reach the coast. Therefore, a NADF Release would have no impact on coastal wildlife or shorebirds.

Table 7-90 Risk Rating for Oil Spill Impacts on Coastal Wildlife and Shorebirds

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Coastal Wildlife and Shorebirds	Unlikely	High	Moderate	Implement OSRP	Minor
Coastal Oil Spill	Coastal Wildlife and Shorebirds	Unlikely	High	Moderate	Implement OSRP	Minor

7.4.3.4 Seabirds

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on seabirds would be a Marine Oil Spill.

During most oil spills, seabirds are harmed and killed in greater numbers than other kinds of creatures (NOAA, 2016b). An oil spill could pose a risk to seabirds through direct and indirect mechanisms, including the following:

- Loss of insulating and water repelling properties from oiling of plumage, leading to increased mortality;
- Loss or impairment of flight and buoyancy from oiling of plumage, which can render birds unable to feed at sea, which can quickly lead to dehydration and starvation;
- Toxic impacts from the ingestion of hydrocarbons during preening, ingestion of contaminated prey, inhalation of fumes or absorption of hydrocarbons through skin or eggs, leading to increased mortality;
- Habitat degradation at sea and at island or shoreline breeding sites; and
- Mortality of food resources.

Since most oils float at least initially following a release, seabird species that spend significant time resting or foraging on the water's surface are most at risk from direct exposure. Diving birds and waterfowl are considered to have the highest risk of oiling.

No marine Important Bird Areas ("IBAs", e.g., seabird breeding colonies and surrounding foraging areas, non-breeding concentrations, feeding areas for pelagic species) have been identified in Guyana. For colonial nesting species, if a spill occurs during the breeding period and oil reaches a breeding colony or impacts individuals that introduce oil to the colony, the impacts on seabirds would be more severe compared with those during the non-breeding season. This is because colonial seabird species typically nest close together on islands or shorelines and forage at higher density in proximity to the nesting sites, making larger numbers of birds and their eggs susceptible to oiling. Reproducing requires a lot of energy and a bird's demand for food resources can double or triple during the breeding season. If an oil spill causes

mortality or contamination of the birds' food resources, it can inhibit the birds' ability to successfully mate and produce eggs (Henkel et al., 2012). Eggs and very young birds are particularly sensitive to oil exposure, which typically causes embryonic mortality in eggs or death from exposure in chicks (Finch et al., 2011). Some seabirds lay only one egg at a time, so they have an already low reproductive rate, which makes these species more susceptible to adverse impacts from spills that occur in the breeding season (because they could lose an entire recruitment year) (NOAA, 2016).

Given their susceptibility and sensitivity, the consequence of a Marine Oil Spill on seabirds is considered **High**. This is offset to some extent by the **Unlikely** likelihood of a Marine Oil Spill. Therefore, the overall risk of an oil spill on seabirds is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by limiting the geographic extent of the oil spill and the number of individual birds impacted.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure on the drill ship, the NADF would not be expected to reach the surface of the ocean where seabirds are active. Therefore, a NADF Release would have no impact on seabirds.

Table 7-91 Risk Rating for Oil Spill Impacts on Seabirds

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Seabirds	Unlikely	High	Moderate	Implement OSRP	Minor

7.4.3.5 Marine Mammals

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on marine mammals would be a Marine Oil Spill.

In the unlikely event of an oil spill, marine mammals (i.e., whales, dolphins, manatees) may be exposed when they surface to breathe or breach in the area of a fresh slick. Exposure to oil may harm their respiratory tissue and eyes, and increase their susceptibility to infections. Baleen whales may be more susceptible because of the potential for oil to foul their baleen plates if the whales filter feed in the vicinity of the oil spill. Although not the most common whales in the Project AOI, three species of baleen whales have been documented in the area: Sei, Minke, and Bryde's whales. Marine mammals may also be impacted by indirect impacts associated with oil spills, including increased exposure to sound and risk of injury from ship strikes by response vessels.

Despite these risks, serious health impacts or deaths in marine mammals due to oil spills are rare. This is attributed to their smooth, hairless skin, to which oil does not readily adhere, and their ability to take evasive action and avoid areas impacted by spills. Depending on time of year, however, marine mammals could be directly exposed to oil and suffer a range of health consequences.

For these reasons, and especially considering the presence and susceptibility of baleen whales, the consequence of a Marine Oil Spill on marine mammals is considered **High**. This is offset to some extent by the **Unlikely** likelihood of an oil spill. Therefore, the overall risk of an oil spill on marine mammals is considered **Moderate**. Effective implementation of the OSRP would reduce the geographic extent of the spill, but considering the susceptibility of baleen whales to oil spills, their presence in the Project AOI, and their endangered/threatened status, the risk remains **Moderate**.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure for the drill ship, lighter oil fractions would likely rise into the mid water column and dissipate laterally as they rise, while the NADF would remain at or near the seafloor. This is deeper than most marine mammals occur, and it would be too deep to affect the preferred forage species of any marine mammal species known occur in the AOI. Therefore, a NADF Release would have no impact on marine mammals.

Table 7-92 Risk Ratings for Oil Spill Impacts on Marine Mammals

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Marine Mammals	Unlikely	High	Moderate	Implement OSRP	Moderate

7.4.3.6 Marine Turtles

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on marine turtles would be a Marine Oil Spill.

In the unlikely event of an oil spill, several aspects of sea turtle biology place them at particular risk across all of their life stages. Marine turtles nest on sandy beaches. If such beaches were to become oiled, the laid eggs may be contaminated either because there is oil in the nest or the adult turtles pick up oil as they cross the beach. The eggs are susceptible to oil through absorption, which can inhibit their development. Newly hatched turtles can become oiled after emerging from their nests and crossing an oiled beach on their way to the water. Oiling of juvenile and adult turtles in the water can adversely impact their eyes, mucous membranes, skin, blood, digestive and immune systems, and salt glands.

Several aspects of sea turtle behavior also compound their biological susceptibility to oil. These behaviors include:

- Lack of avoidance behavior – marine turtles are not known to consistently take evasive action away from oil spills;
- Indiscriminate feeding – marine turtles have a habit of ingesting floating objects, including the ingestion of oil-fouled food and floating tar balls they mistake for food; and
- Large pre-dive inhalations – if turtles surface to breathe in a fresh slick, the oil can impact their eyes and damage their airways and/or lungs, especially with their large pre-dive breaths which can introduce airborne toxins deep into their respiratory system.

There are five species of marine turtles found in Guyana waters, four of which are known to nest at Shell Beach. The populations of all of these species are under threat and they are classified as Vulnerable to Critically Endangered by the IUCN.

The consequence of a Marine Oil Spill on marine turtles is considered **High** taking into consideration their susceptibility to oil contamination, their presence and important nesting site in the Project AOI, and their threatened status. As explained previously, a large Marine Oil Spill from a well control event is considered **Unlikely**, with oil spill modeling indicating a 5 to 10 percent chance that oil would reach the Guyana shoreline and Shell Beach. Therefore, considering both consequence and likelihood, the overall risk to marine turtles from an oil spill is **Moderate**. Effective implementation of the OSRP would reduce the overall risk by reducing the probability of oil reaching the Guyana coast line. However, given the Critically Endangered and Endangered IUCN classifications for several of these turtle species, the residual (post-mitigation) risk rating remains **Moderate**.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure for the drill ship, lighter oil fractions would likely rise into the mid water column and dissipate laterally as they rise, while the NADF would remain at or near the seafloor. No marine turtles are known to dive to the depths that occur in the PDA, and it would be too deep to affect the preferred forage species of any marine turtle species known occur in the AOI. Therefore, a NADF Release would have no impact on marine turtles.

Table 7-93 Risk Rating for Oil Spill Impacts on Marine Turtles

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Marine Turtles	Unlikely	High	Moderate	Implement OSRP	Moderate

7.4.3.7 Marine Fish

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on marine fish would be a Marine Oil Spill.

Impacts to fish are related to both water column concentrations of, and the duration of exposure to, dissolved hydrocarbons (primarily polynuclear aromatic hydrocarbons, or PAH). Contamination in the water column changes rapidly in space and time, such that exposures are typically brief (i.e., typically measures in hours). Exposure to microscopic oil droplets may also impact aquatic biota either mechanically (especially filter feeders) or as a conduit for exposure to semi-soluble hydrocarbons (which might be taken up in the gills or digestive tract via dissolution from the micro-droplets).

Fish are generally only slightly impacted by oil spills because of their limited exposure to surface slicks and the dispersed oil being rapidly diluted to very low concentrations in open water environments. Fish may also actively avoid oil as they can detect hydrocarbons in the

water. Juvenile life stages of marine fish tend to be more susceptible to impacts from oil spill than adults for several reasons, including:

- Most marine fishes spend at least their initial larval stages in the plankton, which renders them unable to move away from oil at the surface;
- Oil tends to concentrate at the water surface, at least initially following a release; and
- In addition to acute ingestion- and dermal contact-related impacts, early life stages are also exposed to developmental related impacts (which may include deformities in heart, jaw, and eye tissues) that may manifest later in life (Press, 2015).

Despite the susceptibility of juvenile stages of fish to relatively low concentrations of oil in the upper water column, high mortality of planktonic life stages of fish would be expected to have minor impacts on the long-term populations of most open-ocean species. Very high natural mortality rates for larval life stages (exceeding 99 percent for most marine fishes) (MBC, 2011) suggest that most ichthyoplankton that could be killed during an oil spill event would die naturally from other causes in the absence of a spill. Therefore localized, high losses of these juvenile life stages rarely equate to any measurable loss of adult life stages in the population.

Although adult fish tend to be resilient to the impacts of oil spills in the open ocean, fish at all life stages can be substantially impacted in some circumstances, especially when oil spills into shallow or confined waters. In exceptional circumstances, depletion of a year class for a particular species has been recorded in industry, but mass fish mortalities as a result of an oil spill are rare. Mortalities that have occurred have been associated with very high, localized concentrations of dispersed oil in the water column in storm conditions, with the release of substantial quantities of light oils into breaking surf along a shoreline, or with spills in rivers (ITOPF, Undated). If a spill were to reach these areas and penetrate the shallow creeks and lagoons within the mangroves, mortality of adult and subadult life stages could be much higher. The consequence of an oil spill impacting marine fish is therefore considered **Moderate**.

The likelihood of oil reaching the coast, where fish would be most vulnerable to adverse impacts, would be highest under a large Marine Oil Spill scenario. But even if such an event occurred during the season when winds and currents were most favorable for oil to reach the coast, the probability of oil actually reaching the Guyanese coast would remain between 5 to 10 percent, supporting a likelihood rating of **Unlikely**. This means that the impacts of most oil spills on marine fish would be mostly confined to early life stages of pelagic fish and would have limited impacts at the population or species level. Considering the consequence and likelihood ratings, the risk to marine fish from a Marine Oil Spill is rated as **Minor**. Effective implementation of the OSRP would further reduce the risk by limiting the geographic extent of the oil spill.

In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure for the drill ship, lighter oil fractions would likely rise into the mid water column and dissipate laterally as they rise, while the NADF would remain at or near the seafloor. In the event of a release of NADF caused by an emergency riser disconnect due to DP station keeping failure on the drill ship, the NADF would remain at or near the seafloor. Such an event would expose deepwater-adapted fishes within the PDA to NADF, but a NADF

release would be expected to only temporarily affect a small area around the release point. Therefore, the risk to marine fish from a NADF Release is rated as **Minor**.

Table 7-94 Risk Rating for Oil Spill Impacts on Marine Fish

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Marine Fish	Unlikely	Moderate	Minor	Implement OSRP	Minor
NADF Release	Marine Fish	Unlikely	Low	Minor	None	Minor

7.4.3.8 Marine Benthos

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on marine benthos would be a Marine Oil Spill.

Benthic resources would be in close proximity to spilled oil from a loss of well control event. The impact of oil contamination on deep-sea benthic biological resources, however, is poorly understood by academia and industry. As discussed previously, most of the spilled oil would be expected to rapidly surface, but some oil may bind with sediments and settle to the bottom, with the potential to expose benthic organisms to toxic constituents. Results from a study initiated after the Deepwater Horizon oil spill found that areas within about 3 km (1.8 miles) of the wellhead had low taxa richness and high nematode/harpacticoid-copepod ratios, indicative of contamination (Montagna et al., 2013). It should be noted that these impacts are considered to have resulted from attempts to kill the well by injection of drilling fluids into the open wellhead rather than the loss of well control. Polychaete worms, the most common benthic species in the PDA, display varied responses to oil pollution. After an initial die-off, some polychaete species may increase in abundance and rapidly colonize damaged habitat, while other species may experience reduced populations (Xerces Society, 2014).

Considering the depth of water, relatively low species diversity, and likely limited geographic extent of impact, the consequence of a Marine Oil Spill on marine benthos is considered **Low**. Combined with the **Unlikely** event of a large Marine Oil Spill, the overall risk to marine benthos from an oil spill is considered **Minor**. There is little in the way of mitigation that would minimize the impacts of an oil spill on marine benthos in proximity to the well; rather, EEPGL's proposed embedded controls to prevent a spill from occurring represent the most effective approach to minimizing this risk.

Marine benthos would be the most sensitive of all the marine biological resources/receptors to an unplanned release of NADF from an emergency riser disconnect and loss of DP on the drill ship, due to their close proximity to the release point, the tendency of the NADF and cuttings plume to remain at or near the seafloor, and their limited capacity to move away from the impacted area compared to other marine biota. A review of impacts of NADF and cutting deposition on marine benthos documented burial, changes in sediment texture, and hypoxia in sediments as the three primary mechanisms of impact on marine biota from a release such as

Scenario 5 (IOGP, 2016). The smaller and less mobile organisms (including burrowing species, worms, and sessile lifeforms such as sponges, bryozoans, gorgonians, and most mollusks) are usually affected to greater degree by such events, while the larger and more mobile species (e.g., large crustaceans, cephalopods) are affected to a lesser degree and can move away from impacted areas. As described in Sections 7.4.2.2 and 7.4.2.3, marine currents in the AOI would mitigate the potential for burial and formation of hypoxic zones within the sediment. When such events occur, recovery through natural recruitment from adjacent undisturbed areas is typically well underway within a year of the impact having occurred, but the potential does exist for short term impacts on marine benthos in the event of a release, and such an event would likely cause at least a temporary decrease in both the abundance and diversity of marine benthos within the deposition zone. While the NADF to be used by EEPGL contains IOGP Group III NABF with low to negligible aromatic content, reducing the potential that changes in marine sediments as a result of discharge of the NADF will lead to toxicological impacts on marine benthos, a NADF Release is considered to have a **Medium** severity rating with respect to impacts on marine benthos. In combination with a likelihood rating of **Unlikely**, the overall risk to marine water quality from a NADF Release is **Minor**.

Table 7-95 Risk Rating for Oil Spill Impacts on Marine Benthos

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Marine Benthos	Unlikely	Low	Minor	None	Minor
NADF Release	Marine Sediments	Unlikely	Medium	Minor	None	Minor

7.4.3.9 Ecological Balance and Ecosystems

As described in Section 7.2.9.2, maintaining ecological balance in the North Brazil Shelf LME is essential to maintaining nutrient cycling, gene flow, and biodiversity. As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on ecological balance and ecosystems would be a large Marine Oil Spill.

Impacts on the Marine Nutrient Cycle

Nitrogen, phosphorous, and silicon all enter the marine food web through metabolism by phytoplankton (Nihoul and Chen, 2008), so the impact on the food web from an oil spill would be determined by the impact of the spill on phytoplankton. The available literature suggests that toxicological impacts of oil on phytoplankton vary widely according to nutrient content of the water, temperature, type of oil, and exposure. A persistent, heavy surface slick has the potential to reduce gas exchange and light transmission at the water's surface, which generally reduces photosynthetic activity and primary productivity in the impacted area (Ozhan et al., 2014). Reduced cellular activity in the phytoplankton would reduce the uptake of nutrients (nitrogen, phosphorous, and silicates) into the base of the aquatic food web. However, these

impacts would be short lived, localized, and the proportion of the phytoplankton populations impacted would be limited. As the oil weathers, the slick would begin to break apart and light transmission would be restored, and plankton not impacted would be carried into the Project AOI from unaffected areas to the east by the Guiana Current. Hydrocarbons in the water column would be rapidly diluted to levels below those expected to cause toxicity to planktonic species. The phytoplankton community would be expected to recover quickly due to the influx of unaffected plankton and phytoplankton's short generation times relative to other marine taxa.

Impacts on Gene Flow

As described in Section 7.2.9.2, obstacles to efficient gene flow occur when physiochemical barriers to migration, breeding, or dispersal/colonization occur. A large Marine Oil Spill would represent a potential short term physiochemical barrier to migration through the Project AOI, although the significance of this barrier impact would vary across species and seasons. Impacts on gene flow in marine fish would be negligible because there are no known sensitive spawning aggregations or habitat that would support such aggregations in the vicinity of the Project AOI and because fish traveling through the Project AOI en route to more distant aggregation sites would be expected to take an alternate route to avoid an area impacted by a spill. Marine mammals would also be expected to avoid the impacted area, although in the initial stages of a spill they could be impacted to a greater degree than the fish if they inhaled vapors or oil at the surface prior to vacating the area. Sea turtle and birds would more sensitive to impacts on gene flow because they do congregate to breed in portions of the Project AOI (see Sections 7.4.3.4 and 7.4.3.6).

Impacts on Biodiversity

A large Marine Oil Spill has the potential to cause a short-term decline in biodiversity. Some species may exhibit avoidance behavior, and sensitive species that remain in the area may experience localized population declines or a declines in vigor. Small spill events would have little if any long-term impact on biodiversity across the North Brazil LME because these events would impact relatively localized areas, and although there can be minor local decreases in biodiversity associated with even a small spill, recovery would be expected to occur relatively rapidly. The same factors would impact biodiversity in the event of a more extensive oil spill, but declines in biodiversity within the Project AOI may occur over a larger area and impact a larger number of ecosystem types, so recovery may occur more slowly. For taxonomic groups that could experience significant reproductive and/or gene flow impacts depending on the timing, duration, and extent of the spill (such as sea turtles), declines in biodiversity could be regional and span multiple generations.

Trophic Impacts

A large Marine Oil Spill from a well control event could have ecosystem-level trophic level impacts if hydrocarbons persisted in the food web and had toxic impacts on organisms, or if

underlying changes in abundance or distribution of prey caused shifts in feeding behavior or effectiveness in upper trophic levels. Although the assimilation of hydrocarbons into living tissues is well established at multiple trophic levels (Teal and Howarth, 1984; Neff 2002; Chanton et al., 2012; GOMRI, 2015), there has been no conclusive documentation of biomagnification of hydrocarbons up the food chain following a major oil spill. Research on fish following oil spills has documented residence of PAHs in fatty tissues, but also indicates that fish and other higher vertebrates are able to dispose of the hydrocarbons rapidly through metabolic means, such as the Cytochrome P 450 process (Neff, 2002).

Most marine taxa would be able to avoid oil spills and would be able to recover relatively quickly from impacts should they occur. Several studies have documented post-spill shifts in feeding behavior in birds and fish, but studies of spill-related impacts on other marine taxa are generally lacking. Most studies cite short-term adjustments in feeding strategies by birds or fish following a spill, but many cite the need for longer-term study to document the role of spills in these shifts or an inability to identify hydrocarbon contamination as a driving factor due to confounding environmental impacts, or both (GOMRI, 2015; Piatt and Anderson; 1996). Studies that successfully control for such factors and purport to document a causal relationship between oil spills and trophic shifts typically document a shift back to pre-spill conditions within a few years (Moreno et al., 2013; GOMRI, 2015).

For these reasons, the consequence of impacts from a large Marine Oil Spill on ecological balance and ecosystems is rated Medium. Combined with the Unlikely event of a large Marine Oil Spill occurring, the overall risk to ecological balance and ecosystems from an oil spill is considered **Minor.** Additionally, at the onset of an oil release, a wildlife response program would be established to help minimize these impacts.

Release of NADF near the seafloor as described under Scenario 5 would enrich the nutrient content of the marine sediment down current of the wellhead due to the presence of biodegradable organic material in the fluid, and the eutrophic condition that could result would cause temporary shifts in the food chain as the makeup of the marine benthos changed. It is unlikely that these changes in the benthic community would cause substantial changes in upper trophic levels, however, so a NADF Release is considered to have a **Low** severity rating with respect to impacts on ecological balance and ecosystems. In combination with a likelihood rating of **Unlikely**, the overall risk to ecological balance and ecosystems from a NADF Release is **Minor**.

Table 7-96 Risk Rating for Oil Spill Impacts on Ecological Balance and Ecosystems

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Ecological Balance and Ecosystems	Unlikely	Medium	Minor	Wildlife Oil Response Program	Minor
NADF Release	Ecological Balance and Ecosystems	Unlikely	Low	Minor	None	Minor

7.4.4 Socioeconomic Resources

The only unplanned events with the potential to impact socioeconomic resources would be a large Marine Oil Spill or a Coastal Oil Spill. A NADF spill would not be expected to impact socioeconomic resources, with the possible exception of submerged cultural heritage, because of the limited volume of the potential spill, and the water depth and distance to shore at which the spill would occur.

7.4.4.1 Economic Conditions / Employment and Livelihoods

As indicated in Table 7-84, the unplanned events with the potential for any measureable impacts on economic conditions or employment and livelihoods in the Project AOI would be a large Marine Oil Spill or a Coastal Oil Spill, which through decreased fishery and agricultural yields could potentially impact the fishery and agriculture sectors that currently account for a large part of the country's GDP.

The economy in Regions 1, 2 and 3 are highly dependent on fishing and agriculture for employment, income generation, and subsistence. Although the economy in Region 4 is relatively diversified, populations in the rural areas also rely on agriculture and fishing, with the largest number of fishermen in the country located in Region 4. These economies would be sensitive to any impact on fisheries and crop production that could result from an oil spill. These potential impacts are discussed below.

Fisheries could be impacted by a large Marine Oil Spill, especially if the oil reaches near-coastal waters where most artisanal and commercial fishing occurs. Although considered unlikely based on the results of modeling and the sensitivity of fish species to spills, as discussed above, these fisheries may be impacted by any reduction in fish populations or closure of active fishing areas to allow for clean-up or to avoid potential public health impacts or potential tainting of commercial products. Impacts on mangrove habitats could impact fishery nursery grounds and impact future year class populations. Adult fish, however, are relatively resilient to oil spills because they are mobile and can quickly relocate away from an oil spill (see Section 7.4.3.7). Further, oil spill modeling for a well control event indicates 5 to 10 percent probability of oil reaching near-coastal waters in the unlikely event an oil spill occurs. There would be several days advance notice before any oil would reach the Guyana coast, so fisherfolk would be able to move their boats to unaffected areas.

Therefore, while the consequence of a large Marine Oil Spill impacting commercial fisheries could be considered **High**, given that a large Marine Oil Spill reaching the Guyana coast is considered **Unlikely**, the risk to commercial fishing is considered **Moderate**. The coastal sensitivity mapping that supports the OSRP includes mangroves as a sensitive coastal resource and in the unlikely event of an oil spill; EEPGL will deploy emergency response equipment to protect these sensitive resources, as appropriate. Effective implementation of the OSRP would reduce this risk to **Minor** by reducing the probability of oil reaching the Guyana coast. Additionally, a claims process would be established at the onset of a large Marine Oil Spill

incident to compensate fisherfolk for loss of harvest due to regional fisheries closures that were attributed to the oil spill.

In the event that a spill reaches the shore, there would be the potential to impact agriculture. Rice farming, which makes up the majority of agricultural activity in the coastal area of Region 2, would not be impacted by potential oiling of the coastline since rice fields are irrigated from inland water conservancies. Non-traditional crops such as fruits, vegetables, and coconuts, particularly along the Pomeroon River, have the potential to be impacted by contaminated seawater entering the drainage system through sluice gates, but this is considered highly unlikely as the movement of oil upstream would be limited by tidal action, farmers would have ample notice to close sluice gates, and spill responders would have time to install absorbent booms or other spill control equipment to prevent oil from reaching farmer's crops or drainage inlets. Therefore, the consequence of an oil spill that reaches the Guyana coast on economic conditions in coastal communities is considered **Medium**, and considering the **Unlikely** likelihood of an oil spill that reaches the Guyana shoreline, the overall risk to agricultural activities in coastal communities is considered **Minor**. Effective implementation of the OSRP and a claims process would further reduce this risk by reducing the probability of oil reaching the Guyana coast line and compensating for economic losses.

In the event of a smaller Coastal Oil Spill, the spill would be quickly controlled and contained because of the smaller volumes and the ready access to spill control equipment. There is the potential for a spill in these coastal areas, because of its proximity to fishing grounds, to impact fisherfolk. These impacts, however, would be **Minor** because of the limited affected area, short duration of the impact, and the relatively rapid expected environmental recovery. Although the response time would be less for a small oil spill relative to a larger oil spill, response efforts should be able to prevent oil from reaching agricultural areas because of the limited geographic areas impacted.

Table 7-97 Risk Rating for Oil Spill Impacts on Economic Conditions / Employment and Livelihoods

Unplanned Event	**Resource/ Receptor**	**Likelihood**	**Severity/ Consequence**	**Risk Rating**	**Proposed Mitigation Measures**	**Residual Risk Rating**
Marine Oil Spill	Coastal Communities - Fishing	Unlikely	High	Moderate	Implement OSRP and claims process	Minor
	Coastal Communities - Agriculture	Unlikely	Medium	Minor	Implement OSRP and claims process	Minor
Coastal Oil Spill	Coastal Fishing and Agricultural Communities	Unlikely	Medium	Minor	Implement OSRP and claims process	Minor

7.4.4.2 Community Health and Wellbeing

As indicated in Table 7-84, unplanned events with the potential for any measureable impacts on community health and wellbeing include a large Marine Oil Spill, Coastal Oil Spill, and vehicle accidents. Guyana is one of the poorest countries in South America, and this is particularly in rural populations. Although Guyana as a nation is considered self-sufficient for food, disparities in food supply and family incomes create challenges in maintaining food security and proper nutrition in some communities, with the result that malnutrition and anemia are among the leading causes of death in Guyanese children.

Rural communities on the Guyanese coast are dependent on fishing and agriculture for subsistence and livelihoods. Fish catches and traditional crops such as vegetables and fruits are often sold locally at markets or roadside stands. In indigenous communities in Regions 1 and 2, crabbing, shrimping and hunting of coastal game such as caiman and shorebirds are also practiced for subsistence. Adverse impacts on these resources as a result of an oil spill could have direct health impacts through entry of harmful substances into the food chain, or through malnutrition if local food supplies become unavailable. Impacts on these sectors could also have impacts via the social determinants of health; if livelihoods are impacted, increased household poverty can impact economic security, quality of life, access to education and other health-promoting and health-protective resources. Increased economic hardship can also lead to or exacerbate familial problems and mental health impacts.

Given their dependence on the coastal environment for subsistence and income, their high rate of poverty, and the current health challenges faced by the coastal population in Guyana, the health consequences of an oil spill impacting food availability in coastal communities is considered **High**. Oil spill modeling indicates that the probability of the oil from a well control event actually reaching the Guyana coast, with the potential for contaminating crops or coastal game, is 5 to 10 percent, supporting a likelihood rating of **Unlikely**. Accordingly, the overall risk to community health and wellbeing from a large Marine Oil Spill is considered **Moderate**. Effective implementation of the OSRP would reduce this risk to **Minor** by reducing the probability that oil would reach the Guyana coast.

A Coastal Oil Spill (e.g., Scenario 6 from Table 7-82) could also have similar **Minor** effects on community health and wellbeing as a large Marine Oil Spill. The geographic area affected, however, would be more limited, which would create more potential for subsistence fisherfolk to access alternative areas for fishing.

With regard to the impact of onshore traffic accidents on community health, increased vehicular trips would be expected to increase the risk of vehicular accidents, the severity of which may be greater when industrial trucks are involved. However, the Project-related increase in traffic is expected to be a minor incremental addition to the existing traffic. The relatively low traffic speeds in Georgetown due to existing congestion may reduce the likelihood of serious injuries, although the presence of bicyclists and pedestrians increases that risk. Overall, vehicular accidents are considered **Possible** and the consequence could range from **Low** to **High**

depending on the extent of damage or the severity of injury. This leads to a risk rating for vehicular accidents of **Minor** to **Major**.

Consistent with international best practice, EEPGL will develop and implement a Road Safety Management Procedure covering drivers and equipment dedicated to the Project to mitigate these risks. The Plan will include, at a minimum, the following components:

- Definition of typical, primary travel routes;
- Definition of required driver training, including (but not limited to) defensive driving, loading/unloading procedures, and safe transport of passengers, if applicable;
- Designation and enforcement of speed limits, through speed governors, GPS, or other monitoring systems;
- Avoidance of deliveries during typical peak traffic hours as well as scheduled openings of the Demerara Harbour Bridge, to the extent reasonably practicable;
- Monitoring and management of driver fatigue;
- Definition of vehicle inspection and maintenance protocols that include all applicable safety equipment;
- Community safety program for impacted schools and neighborhoods to improve traffic safety: and
- Community outreach to communicate information relating to major delivery events or periods.

With the implementation of these measures, the risk rating for vehicular accidents could be reduced to **Minor** to **Moderate**. Accidents involving Project vessels in Georgetown Harbor or near shorebases could lead to consequences ranging from cosmetic damage to injury or loss of life. Vessels operating in these areas, however, will be adhering to speed restrictions and navigation aids, which should reduce the potential for significant injury or loss of life, so the potential severity of these accidents is considered Low. Project contractors will utilize their own safety, health, and environmental programs, and EEPGL will provide active oversight of its contractors to minimize safety, health, and environmental risks. Therefore, the overall risk to Community Health and Wellbeing is considered **Minor.**

Table 7-98 Risk Rating for Oil Spill and Vehicle/Vessel Impacts on Community Health and Wellbeing

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Community Health and Wellbeing	Unlikely	High	Moderate	Implement OSRP	Minor
Coastal Oil Spill	Community Health and Wellbeing	Unlikely	Medium	Minor	Implement OSRP	Minor
Vehicular Accident	Community Health and Wellbeing	Possible	Low to High	Minor to Major	Road Safety Management Plan	Minor

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Vessel Collision	Community Health and Wellbeing	Unlikely	Low	Minor	None Required	Minor

7.4.4.3 Marine Use and Transportation

As indicated in Table 7-84, the unplanned events with the potential for measureable impacts on marine use and transportation would be a large Marine Oil Spill and a Coastal Oil Spill. As an oil spill would likely have some impact on marine use and transportation as additional marine vessels and resources would need to be mobilized to support spill response, likely resulting in increased congestion in Georgetown Harbour and/or near shorebases, and vessel movement may be restricted in some areas. The severity of these impacts could be higher if the spill occurred/drifted close to shore and impacted nearshore vessel traffic, but oil spill modeling indicates that the probability of the oil from a well control event actually reaching the Guyana coast is 5 to 10 percent for a large oil spill scenario. Accordingly, the severity of impacts on marine use and transportation from a spill is considered **Low**.

Therefore, considering that an oil spill is considered **Unlikely**, the overall risk to marine use and transportation is considered **Minor**. Effective implementation of the OSRP would further reduce the risk by reducing the probability that oil would spread in coastal areas. In the event of a loss of DP on the drill ship, the drill ship would move away from the exact drilling location as a result of ocean currents until DP power is restored and it could be brought back on station, but the event would be short term and would not constitute a hazard to shipping, so it would have no impact on marine use and transportation.

Accidents involving Project vessels in Georgetown Harbor or coastal areas (e.g., groundings or collisions) could interfere with marine use and transportation. Vessels operating in these areas, however, will be adhering to speed restrictions and navigation aids, which should reduce the likelihood and severity of such an event. Prompt emergency response in the event of such an accident and removal of any grounded or damaged vessel would limit the severity of the event, so the overall risk for marine use and transportation is considered **Minor**.

Table 7-99 Risk Rating for Oil Spill/Vessel Collision on Marine Use and Transportation

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measure	Residual Risk Rating
Marine Oil Spill	Marine Use and Transportation	Unlikely	Low	Minor	Implement OSRP	Minor
Coastal Oil Spill	Marine Use and Transportation	Unlikely	Low	Minor	Implement OSRP	Minor
Vessel Collision	Marine Use and Transportation	Unlikely	Low	Minor	Prompt removal of damaged vessel	Minor

7.4.4.4 Social Infrastructure and Services

As indicated in Table 7-84, both unplanned events considered herein (a Marine Oil Spill, a Coastal Oil Spill, and a vehicular accident) have the potential to result in measureable impacts on social infrastructure and services.

A large Marine Oil Spill could impact social infrastructure and services primarily as a result of supporting spill response and clean-up teams. These teams could overburden housing, medical, and other infrastructure and services in Guyana. These infrastructure and service demands would only be temporary (for the duration of required clean-up, likely on the order of a few weeks to months, depending on the extent of the spill and whether any oil reaches the Guyana coast). If the spill remains offshore, then most of these infrastructure and service demands would likely be concentrated in Georgetown, where most response vessels would likely be based, but also where infrastructure and services are concentrated. If oil were to reach the Guyana shoreline, then land-based clean-up would be required, potentially in Regions 1, 2, and/or 3, where little infrastructure or service capacity exists. Oil spill modeling, however, indicates the probability of oil reaching the Guyana shoreline in the unlikely event of a large oil spill associated with a well control event is only 5 to 10 percent. The consequence of an oil spill on social infrastructure and services is therefore considered **Medium**, given the anticipated temporary impact on services. Given that a large Marine Oil Spill is considered **Unlikely**, the overall risk to social infrastructure and services is considered **Minor**. Effective implementation of the OSRP would further reduce this risk by reducing the probability that oil would reach the Guyana coast. A smaller Coastal Oil Spill would not require spill response measures and teams that would cause any meaningful impact to social infrastructure and services. Response to a release of NADF under Scenario 5 would involve a fraction of the crew and vessels that would be required to respond to a large Marine Oil Spill, so it would not be expected to cause any impact on social infrastructure and services.

With regard to impacts of vehicular accidents on social infrastructure and services, accident rates from ground transportation associated with the Project (e.g., workers commuting, truck transport of materials) are expected to be low and would represent a negligible fraction of the accidents occurring in Georgetown. As a result, the potential consequence level for isolated, temporary impacts on road congestion and healthcare utilization resulting from vehicle accidents would be **Low**. The risk of vehicle accidents associated with the Project causing measurable impact on congestion or healthcare utilization is considered **Minor**. Consistent with international best practice, EEPGL will develop and implement a Road Safety Management Procedure, as summarized in Section 7.4.4.2, to further reduce this risk.

Table 7-100 Risk Rating for Oil Spill and Vehicular Accident Risks to Social Infrastructure and Services

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Social Infrastructure and Services	Unlikely	Medium	Minor	Implement OSRP	Minor
Coastal Oil Spill	Social Infrastructure and Services	Unlikely	Medium	Minor	Implement OSRP	Minor
Vehicular Accident	Social Infrastructure and Services	Possible	Low	Minor	Road Safety Management Procedure	Minor

7.4.4.5 Cultural Heritage

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on cultural heritage would be a large Marine Oil Spill or a Coastal Oil Spill.

Desktop research identified two known ceramic/pottery sites near the coastline. Based on the ubiquity of past human occupations (and thus archaeological sites), especially along coastlines, it is likely that there are many more unidentified archaeological resources along Guyana's coastline. It should be noted, however, that Marine Oil Spills from well control events that reach the coast (5-10 percent probably of contacting the coast) generally only impact the intertidal zone, unless the spill coincides with a significant storm surge. While archaeological sites are common along coastlines, sites in the intertidal zone tend to lack stratigraphic integrity due to the dynamic interface between the ocean and the land, especially along beaches.

Some oil would be expected to settle to the seafloor and could damage submerged cultural heritage (e.g., shipwrecks), but this would be expected to be in proximity to the spill source. No shipwrecks or associated artifact scatters were identified within the PDA, and therefore the risk to underwater cultural heritage is considered **Low**. The same factors would apply to a release of NADF, so the risk to underwater cultural heritage posed by Scenario 5 is also considered **Low.**

As a result, the consequence of a large Marine Oil Spill or release of NADF on coastal archaeological sites and submerged cultural heritage is considered to be **Low.** NADF is not expected to reach the coast under any conditions and considering the **Unlikely** likelihood of an oil spill that reaches the Guyana shoreline, the overall risk to coastal cultural heritage from an oil spill or NADF Release is considered **Minor**. The consequence of a Coastal Oil Spill on archaeological sites would be similar to that for a large Marine Oil Spill. Effective implementation of the OSRP would further reduce the risk of a large oil spill by reducing the probability and limiting the geographic extent of oil reaching the Guyana coast.

Table 7-101 Summary of Oil Spill Risk to Cultural Heritage

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Cultural Heritage	Unlikely	Low	Minor	Implement OSRP	Minor
Coastal Oil Spill	Cultural Heritage	Unlikely	Low	Minor	Implement OSRP	Minor
NADF Release	Cultural Heritage	Unlikely	Low	Minor	None	Minor

7.4.4.6 Land Use

As indicated in Table 7-84, none of the identified unplanned events are expected to have any impact on land use.

7.4.4.7 Ecosystem Services

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on ecosystem services would be a large Marine Oil Spill.

Guyana is a country that is rich in natural resources, and these are still relied upon by a large proportion of the population for livelihoods and subsistence. Fisheries and agriculture are still among the top contributors to the country's GDP, and these activities occur primarily in the coastal areas. The Region 2 and 3 economies derive a large share of their income from farming, with rice being predominant in Region 2 and sugarcane in Region 3. Populations in these regions also grow many non-traditional crops for local sale and consumption. In Region 1, agriculture occurs at a relatively small scale but a number of other natural resource-based activities take place, particularly by indigenous communities. Along the coast and at the river mouths, these include fishing, crabbing, hunting, and trapping. Some communities also hunt shorebirds and sea turtles, as well as collect sea turtle eggs from the Shell Beach area. While the Region 4 economy is more diversified relative to the other coastal regions, there is still a large fishing sector and considerable agricultural activity in the rural parts of the region.

In addition to provisioning services, the marine and coastal ecosystems in Guyana render a range of other important services that offer protection and are necessary for the functioning and support of ecosystems and both human and non-human life. This includes the coastal flood protection offered by mangrove forests and wildlife habitat provided by mangrove forests, mud banks, and coastal swamps. In the unlikely event of an oil spill from a well control event reaching the coast, important habitats such as mangrove forests, mud flats, swamps, and beaches could be impacted. These provide a range of ecosystem services to coastal populations in Regions 1 and 2. If oiling is severe enough to cause the loss of some mangrove forests, this would weaken a critical component of the country's sea defense system and expose the coastal population to increased coastal flooding hazard, especially in Region 1, where agricultural areas are not protected from flooding by the same system of irrigation and drainage canals as in Regions 2 to 6.

In terms of cultural services, the coast is important for religious and traditional ceremonies for ethnic groups in Guyana. Many members of the Hindu community conduct funeral ceremonies on the seashore, with disposal of ashes in the ocean. Throughout the year and during holy festivals, Hindus also perform cleansing ceremonies on the seashore. African cultural organizations perform traditional emancipation ceremonies at a specific seawall location in the Georgetown area.

Table 7-102 provides a summary of the potential ecosystem services impacts that could be experienced by various receptor groups as a result of a large Marine Oil Spill from a well control event. A Coastal Oil Spill would affect a limited geographic area and would not be considered to pose any significant risk to ecosystem services other than in the localized area of the spill.

Table 7-102 Potential Ecosystem Services Receptors and Impacts from a Large Marine Oil Spill

Receptor(s)	Key Potential Impacts
Coastal population in Regions 1, 2, 3 and 4	• Impacts on agriculture (non-traditional crops) and fisheries • Impacts on shoreline protection provided by mangroves
Hindu population in Regions 1, 2, 3 and 4	• Disruption of religious ceremonies (funeral and cleansing ceremonies)
Afro-Guyanese population in Region 4	• Disruption of traditional ceremonies (emancipation ceremonies)
Coastal indigenous communities in Regions 1 and 2	• Impacts on agriculture, fishing, crabbing, hunting, trapping, non-timber forest product harvesting • Impacts on shoreline protection provided by mangroves

Considering the reliance of much of the population of Regions 1, 2, 3, and to a lesser extent Region 4, on ecosystem services (e.g., for food, housing materials, medicinal plants, income producing products), the extent these services would be impacted by an oil spill if it were to reach shore, and the lack of alternatives to replace the lost sources of sustenance and income, the consequence of a large Marine Oil Spill from a well control event reaching the coast is rated as **High**. As explained previously, such an oil spill is considered unlikely, and even if one were to occur, the probability of oil reaching the Guyana coastline is only 5 to 10 percent according to the oil spill modeling, supporting a likelihood rating of **Unlikely**. Therefore, the overall risk of an oil spill to ecosystem services is considered **Moderate**.

The Project will establish an OSRP that will be followed in the event of a spill of any size. Additionally, a claims process would be established at the onset of a large Marine Oil Spill incident to compensate for loss of sustenance and income. Effective implementation of the OSRP and a claims process would further reduce this risk to **Minor** by reducing the probability of oil reaching the Guyana coast line and compensating for economic losses.

Table 7-103 Risk Rating for Oil Spill Impacts on Ecosystem Services

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Rating	Proposed Mitigation Measures	Residual Risk Rating
Marine Oil Spill	Ecosystem Services	Unlikely	High	Moderate	Implement OSRP and claims process	Minor
Coastal Oil Spill	Ecosystem Services	Unlikely	Medium	Minor	Implement OSRP and claims process	Minor

7.4.4.8 Indigenous Peoples

As indicated in Table 7-84, the only unplanned event with the potential for any measureable impacts on indigenous peoples would be a large Marine Oil Spill.

Indigenous peoples are often among the most marginalized segments of the population in their respective societies. The majority of Guyana's indigenous people live in remote portions of the country and many continue to operate outside of the formal economy, depending on a subsistence way of life. Those living on the coast, including along the coastal road of Regions 2, 3, and 4, tend to be culturally integrated with the Afro- and Indo-Guyanese population, but indigenous groups typically have a lower overall standard of living than the general population.

As discussed in Section 7.3.9, indigenous populations in the more remote coastal areas of Regions 1 and 2 make use of a range of coastal resources for subsistence and livelihoods. Communities that are directly adjacent to the coast include Three Brothers, Almond Beach, Father's Beach, and Unity Grant. Indigenous villages located 5 to 10 km (~3 to 6 mi) inland from the coast in Regions 1 and 2 are Santa Rosa, Waramuri, Manawurin, Assakata, and Wakapau. These communities engage in a number of natural resource-based activities including agriculture, fishing, crabbing, shrimping, hunting, palm harvesting, and natural medicine harvesting on the coast. In the SBPA, fishing and crabbing activity is particularly active at the westernmost end of Shell Beach, at the mouth of the Waini River, although these activities also occur to a lesser extent at the eastern end of Shell Beach by the community of Father's Beach. The percent of indigenous people in Regions 3 and 4 is less than the national average.

Indigenous communities in remote areas of Regions 1 and 2 rely on the coastal habitats for subsistence and livelihoods and have less availability of alternative food, particularly in Region 1. In the event of an oil spill reaching the coast, provisioning resources could be adversely impacted. In the event that mangrove forests and swamps along the coast are oiled, species such as fish, crabs and caiman, which are depended upon for protein, are likely to be impacted.

For these reasons, the consequence of a Marine Oil Spill on coastal Indigenous Peoples communities could be **High**. As explained previously, a large Marine Oil Spill from a well control event is considered unlikely, and even if one was to occur, oil spill modeling indicates a

5 to 10 percent chance oil would reach the Guyana shoreline, supporting a likelihood rating of **Unlikely**. Therefore, considering both consequence and likelihood, the overall risk to Indigenous Peoples of a large Marine Oil Spill is **Moderate**.

The area potentially impacted by a Coastal Oil Spill would be limited to areas near Project shorebases, which are not expected to occur in the more remote areas supporting larger indigenous populations. The Project will establish an OSRP that will be followed in the event of a spill of any size. Additionally, a claims process would be established at the onset of a large Marine Oil Spill incident to compensate for loss of sustenance and income. Effective implementation of the OSRP and a claims process would reduce this overall risk to **Minor** by reducing the probability of oil reaching the Guyana coast line and compensating for economic losses.

Table 7-104 Risk Rating for Oil Spill Impacts on Indigenous Peoples

Unplanned Event	Resource/ Receptor	Likelihood	Severity/ Consequence	Risk Level	Proposed Mitigation Measures	Residual Risk Level
Marine Oil Spill	Indigenous Peoples	Unlikely	High	Moderate	Oil Spill Response Plan	Minor

7.4.5 Transboundary Impacts

The planned Project is not predicted to have any measureable "transboundary impacts" (i.e., impacts outside the Guyana Exclusive Economic Zone [EEZ]). All impacts from planned activities will occur within the Guyana EEZ. However, there is the potential for transboundary impacts to result from unplanned events, such as oil spills, that may occur. As the oil spill modeling indicates, transboundary impacts may occur under Scenarios 8 (2,500 bbl offloading spill) and 9 (20,000 bpd release from a well control event over 30 days) as defined in Table 7-82. The model results indicate that there is the potential for oil to reach at least portions of Venezuela, Trinidad and Tobago, Grenada, St. Vincent and the Grenadines, and St. Lucia (see Figure 7-12).

The models predict that surface oil would travel towards the northwest in all scenarios during both the summer (June to November) and winter (December to May) seasons. Differences in seasonal wind speed and direction result in a range of shoreline length oiled. Stronger easterly winds would result in the potential for more significant shoreline oiling, particularly in Venezuela and Trinidad and Tobago, while lower wind speeds allow the surface plume to be transported to the north of Trinidad and Tobago and into a portion the Caribbean Sea.

Impacts on resources and receptors in these other countries would be similar to those discussed in Sections 7.4.2 to 7.4.4 for Guyana. Although the likelihood of a spill remains unlikely, there would be the potential to impact water quality; sediments; protected areas; marine fish, turtles, mammals, and seabirds; coastal fish and wildlife; coastal communities and indigenous peoples who rely on coastal resources for their livelihoods or sustenance. There are, however, some resources (e.g., coral reefs) found in these other potentially affected countries that are not found

in Guyana. The coastal mapping that was conducted, as described in Section 7.4.1, included the coastal regions of the countries that could be impacted by a large Marine Oil Spill event, and include these other potentially affected resources; therefore, this information is available to support the OSRP. A general overview of potential effects on these countries is provided below.

Potential Effects on Trinidad and Tobago

The probability of shoreline oiling tends to be highest on the coast of Trinidad and Tobago because of the predominant current flow through the Stabroek Block and into the Caribbean Sea. The oil spill modeling indicates that the probability of oil from a large Marine Oil Spill (i.e., Scenario 9 from Table 7-82) reaching the Trinidad and Tobago coastline ranges up to approximately 90 percent, with the time of first arrival ranging from 5 to 15 days for a spill occurring during both the winter and summer seasons, respectively.

The coastal sensitivity mapping indicates that Trinidad and Tobago have several marine resources that could be impacted by an oil spill. While Trinidad lacks coral reefs, Tobago has several reefs. Most are on the west side of the island and would therefore be sheltered from oil carried west toward the island, but a few are located on the northern and southern ends of the island (including the island's largest reef, Buccoo Reef located at Tobago's southern end) that could be exposed to oiling in the unlikely event that oil reached the island. Trinidad's seagrass communities are mostly located along the northwest coast near Chaguaramas and should be sheltered from an oil spill. Tobago's seagrass communities are mostly clustered near the southern end of the island and would be more exposed to oiling if a spill reached Tobago's shoreline.

Four species of sea turtles (hawksbill, leatherback, green, and olive ridley) nest on Trinidad, and all of these except olive ridley nest on Tobago. Significant numbers of both island's nesting beaches would be exposed to oiling by a slick approaching from the east, however slightly more than half of Tobago's nesting beaches would be protected along the west coast. Nearly all of Trinidad's nesting beaches are located along the northern and eastern coasts and would be at risk of oiling if a spill reached Trinidad. The most sensitive coastal species to an oil spill reaching Trinidad and Tobago is probably the West Indian manatee. Its known habitat in the country is exclusively located on east coast of Trinidad in an area that would have up to a 90 percent probability of being oiled in the event of a large Marine Oil Spill from a well control event.

Several marine Important Bird Areas ("IBAs", e.g., seabird breeding colonies and surrounding foraging areas, non-breeding concentrations, feeding areas for pelagic species) of global or regional importance to seabirds have been designated in Trinidad and Tobago.

Numerous fishing areas are located east of Trinidad and could be impacted by a large Marine Oil Spill. The largest and most concentrated coastal/nearshore fishing activities in this part of Trinidad's EEZ are located along the southeastern coast from Cocos Bay in the north to Guayaguayare Bay in the south. These areas extend from the coast to approximately 20 km (12 mi) offshore. Further north in the vicinity of Salybia, Sena, and Saline Bays fishing is

concentrated slightly further offshore, approximately 15 to 30 km (9 to 18 mi) from the coast. All of these areas would have a high probability of being impacted by a large Marine Oil Spill from a well control event.

Potential Effects on Venezuela

The probability of shoreline oiling is high for the coast of Venezuela because of the predominant westerly current flow through the Stabroek block. The Gulf of Paria in Venezuela is located west of Trinidad and would be mostly protected from the impacts of a spill approaching from the east, however, southern portions of the gulf could be impacted by a large Marine Oil Spill if it penetrated west of Trinidad. In such a scenario the probability of oiling would vary widely. The southern and eastern portions of the gulf would have a high probability of being oiled (up to 70 percent depending on location and season) while areas slightly north and west would have a much lower probability of being oiled. The Orinoco River Delta would have a 5 to 10 percent probability of being oiled during the summer season, but that probability would increase to approximately 40 percent if a large Marine Oil Spill were to occur in the winter. The oil spill modeling indicates that the time of first arrival would be about 15 to 25 days for a spill occurring during the summer season and approximately 5 to 10 days during the winter season.

The most important areas in Venezuela that could be impacted by a large Marine Oil Spill would be the Gulf of Paria and the Orinoco River Delta. The Orinoco River Delta is located south of Trinidad in eastern Venezuela. The Orinoco River Delta and the Gulf of Paria support numerous biological resources of regional and global significance including extensive mangroves, diverse shorebird and estuarine fish communities, threatened and endangered sea turtles and marine mammals, and artisanal and commercial fisheries (Miloslavich et al., 2011). Several marine IBAs of global or regional importance to seabirds have been designated in Venezuela.

Potential Effects on Other Islands

The probability of shoreline oiling is less for the other potentially affected countries (i.e., Grenada, St. Vincent and the Grenadines, and St. Lucia) would be less than for Trinidad and Tobago and Venezuela, ranging from 5 to 40 percent with the time of first arrival ranging from 10 to 15 days, depending on the island and the time of year. The benefit of the longer time for first arrival of oil is that more time is available to implement the OSRP and provide measures to protect sensitive habitats. These islands are important tourist destinations and support valuable coral reefs, seagrass beds, and other habitats and species sensitive to oil.

Summary

It should be noted that the oil spill modeling did not take into consideration any emergency response actions. Implementation of the OSRP would help minimize transboundary impacts just as it would minimize impacts within the Guyana EEZ. EEPGL will work with representatives for the respective countries to be prepared for the unlikely event of a spill by:

- Establishing operations and communication protocols between different command posts.
- Creating a transboundary workgroup to manage waste from a product release – including identifying waste-handling locations in the impacted region and managing commercial and legal issues.
- Identifying places of refuge in the impacted region where vessels experiencing mechanical issues could go for repairs and assistance.
- Determining how EEPGL and the impacted regional stakeholders can work together to allow equipment and personnel to move to assist in a spill response outside the Guyana EEZ.
- Assigning or accepting financial liability and establishing a claims process during a response to a transboundary event.
- Informing local communities regarding response planning.

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8.0 CUMULATIVE IMPACT ASSESSMENT

Cumulative impacts arise as a result of Project-related impacts on a resource/receptor interacting with impacts on that same resource/receptor from other (non-Project) activities. Cumulative impacts can potentially result from individually insubstantial, but collectively substantial, actions undertaken over time or from the collective effect of modest impacts stemming from different sources acting on a receptor at the same time. Cumulative impact assessment considers interaction between potential impacts from the Project and impacts of other (non-Project) activities, relevant existing activities, or sufficiently approved/planned activities that are considered reasonably foreseeable.

The cumulative impact assessment for this EIA included the following two major tasks:

- Determining the scope of the cumulative impact analysis, including identification of:
  - *Potentially eligible* resources/receptors;
  - Other relevant existing/planned activities that are part of (or caused by) the Project;
  - *Relevant* resources/receptors (i.e., those that might be affected by the non-Project activities); and
  - Appropriate geographic extent and time frame of analysis

- Conducting the cumulative impacts analysis on *relevant* resources/receptors.

The specific shorebase(s) and onshore support facilities (e.g., warehouses, laydown yards) to be utilized in Guyana have not yet been identified by EEPGL. Accordingly, ERM has performed the impact assessment on the basis that the Project will utilize existing shorebase(s) located in Georgetown. Should any new or expanded shorebase(s) or onshore support facilities be utilized, the construction/expansion and any required dredging, as well as the associated permitting, of such facilities would be the responsibility of the owner/operator and such work scope is not included in the scope of this EIA.

8.1 Scope of the Cumulative Impact Analysis

8.1.1 Potentially Eligible Resources

Resources/receptors considered initially in the cumulative impacts analysis are those that would be impacted by the Project. If the residual impacts on a resource/receptor of at least one aspect of the Project was rated **Minor** or higher, the resource/receptor was identified as *potentially eligible* for the cumulative impact analysis. Unplanned events (i.e., oil spills) were not considered in this analysis, as their likelihood is considered to be **Unlikely**. Positive impacts are also excluded from the analysis. Table 8-1 lists the resources/receptors identified as *potentially eligible* for the cumulative impacts assessment based on the Project's residual impact significance ratings presented in Chapter 7.

Table 8-1 Eligibility of Resources/Receptors for Cumulative Impact Analysis

Resource	Highest Residual Impact Significance Rating	Potentially Eligible for Cumulative Impact Analysis
Special Status Species	Minor	Yes
Marine Mammals	Minor	Yes
Marine Turtles	Minor	Yes
Marine Fish	Minor	Yes
Community Health and Wellbeing	Minor	Yes
Marine Use/Transportation	Minor	Yes
Social Infrastructure/Services	Minor	Yes
Air Quality and Climate	Negligible	--
Sound	Negligible	--
Marine Geology/Sediments	Negligible	--
Marine Water Quality	Negligible	--
Protected Areas	None[a]	--
Coastal Habitats	None[a]	--
Coastal Wildlife/Shorebirds	None[a]	--
Seabirds	Negligible	--
Marine Benthos	Negligible	--
Ecological Balance & Ecosystems	Negligible	--
Economic Conditions	Negligible	--
Employment/Livelihoods	Negligible	--
Cultural Heritage	Negligible	--
Land Use	Negligible	--
Ecosystem Services	None[a]	--
Indigenous Peoples	None[a]	--

[a] None = the planned Project activities are not expected to have any impact on the resource/receptor.

8.1.2 Other (non-Project) Relevant Activities

Two other (non-Project) activities have been identified as relevant with respect to the potential for their impacts to interact with Project impacts on a given resource/receptor.

First, although no confirmed plans are in place, there is a reasonable likelihood that oil and gas companies will conduct oil and gas exploration and/or development offshore of Guyana outside of the scope of the proposed Project. As an example, depending on the experience gained from the proposed Project, EEPGL may identify opportunities to expand the development of the Liza Field. Further, EEPGL or other operators may pursue activities targeting resources outside of the Stabroek block. Future activities by EEPGL or other operators could include seismic surveys, drilling of wells, installation of subsea or surface production infrastructure, and/or production operations.

Although other operators may conduct their activities concurrently with the Project, their activities would occur outside the Stabroek Block (with exception of periodic transit). The closest that another operator's activities could be expected to approach the Project would be approximately 20 km (12 mi), which is well beyond the geographical range of the Project's impacts. There would therefore be no opportunity for cumulative effects between the Project

and activities in other blocks, so interactions between the Project and other operator's activities, as well as potential EEPGL activities in other blocks, are not considered further in this analysis.

Second, the Government of Guyana is currently considering replacement of the heavily used Demerara Harbour Bridge as a means of relieving congestion of both vehicular road and river-based vessel traffic induced by opening or closing, respectively, of the retractor spans that allow large vessels to pass. In November 2015, the Ministry of Public Infrastructure sought Expressions of Interest (EOIs) to complete a feasibility study and design for a new bridge across the Demerara River. The EOIs were due by December 1, 2015 (Kaieteur News Online, 2015), but it is currently unclear when or if the replacement project will proceed. The bridge is located several kilometers upriver from the shorebases that EEPGL currently may use to support the Project. If construction of a new bridge moves forward, there is a chance it might occur contemporaneously with some stages of the proposed Project.

8.1.3 Relevant Resources

Relevant resources are those resources that would potentially be exposed to impacts from EEPGL's activities. Table 8-2 presents the results of the analysis to determine whether or not there is a reasonable potential for Project impacts and the impacts of at least one of the identified other relevant activities to be experienced by the *potentially eligible* resources/receptors listed above. If a reasonable potential for non-Project related impacts was identified, the resource/receptor was considered to be a *relevant* resource/receptor and was therefore included in the cumulative impact analysis. Therefore, the cumulative impact assessment effort focuses on impacts on resources that ate *potentially eligible* because they will be affected by the Project, and *relevant* because they would also be exposed to impacts of one or more non-Project activities. In this case, all eight *eligible* resources/receptors were determined to be *relevant* resources/receptors with respect to at least one of the cumulative impact sources.

Table 8-2 Identification of Relevant Resources/Receptors for the Cumulative Impact Analysis

Resource/Receptor	Highest Residual Impact Significance Rating	Potential Interaction between impacts of Project and …		Included in Cumulative Impact Analysis as Relevant Resource/ Receptor?
		Future Offshore O&G Activity?	Demerara Harbour Bridge Replacement?	
Special Status Species	Minor	Yes	No	Yes
Marine Mammals	Minor	Yes	No	Yes
Marine Turtles	Minor	Yes	No	Yes
Marine Fish	Minor	Yes	No	Yes
Community Health/Wellbeing	Minor	Yes	Yes	Yes
Marine Use/Transportation	Minor	Yes	Yes	Yes
Social Infrastructure/ Services	Minor	Yes	Yes	Yes

8.1.4 Geographical Extent of Analysis

The geographic extent of the cumulative impacts analysis was defined as the direct and indirect AOI for the Project (see Chapter 4), excluding the area associated with a potential unplanned event (i.e., oil spill).

8.1.5 Time Frame for Analysis

Potential impacts of the Project will have the possibility of interacting with other non-Project impacts throughout the Project life cycle (i.e., extending approximately 20 years from the start of production operations). However, there is naturally a limit to the knowledge of what other relevant activities may occur during this period. Considering the other relevant activities described above, it was assumed that the Demerara Harbour Bridge replacement project would occur within the Project lifecycle and that other oil and gas exploration and development would extend through the end of anticipated Project production operations. Accordingly, the time frame for the cumulative impact analysis was defined as the Project life cycle.

8.2 Resource/Receptor-Specific Cumulative Impact Assessment

This section contains a summary of the cumulative impacts that would potentially result from the impacts of the Project interacting with impacts of the other relevant activities on the *relevant* resources/receptors listed in Table 8-2.

8.2.1 Special Status Species

The Project was rated as having a **Negligible** significance for residual impacts on several species listed as Critically Endangered, Endangered, Vulnerable, and Near Threatened. The Project was rated as having a **Minor** significance for residual impacts on several fish species. Similar to Chapter 7, the assessment of potential impacts on marine mammals (Section 8.2.2) effectively covers the assessment of potential impacts to marine mammals and the assessment of potential impacts to marine turtles (Section 8.2.3) effectively covers the assessment of potential impacts to special status marine turtles. This section is limited cumulative impacts on special status fish species.

8.2.1.1 Cumulative Impacts from Future EEPGL Activities

While additional production activities within the Stabroek Block may occur in the future, currently such activities are undefined (e.g., timing, location, and development concept). Cumulative impacts of future production activities have therefore not been considered in this assessment, but would be included as appropriate in future assessments. However, future exploration activities within the Stabroek block and in close proximity to the Liza field would likely include many of the same impacts on fish associated with the Project (e.g., auditory impacts, entrainment in water withdrawals, permitted discharges). The Critically Endangered species are coastal and would not be affected by the Project. The Endangered species are mostly wide ranging marine pelagic species that could be exposed to effects of the Project as well as

other EEPGL activities across the Stabroek Block, but these activities would be focused on other areas of the Stabroek Block and the species would be expected to recover from temporary exposures to Project-related impacts in the immediate vicinity of the Project before encountering similar impacts elsewhere. The Vulnerable and Near Threatened categories contain a mix of pelagic fish that would also be expected to recover from short-term exposures at individual projects, and resident species which would not move between projects and therefore would not be exposed to impacts from multiple projects. Provided that impacts from other EEPG activities would not occur in the same place and time as Project related impacts, there would be no significant cumulative effects on pelagic or resident fish, and the significance of cumulative impacts on special status fish would not increase above **Minor.**

8.2.1.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

The Critically Endangered fishes in the Project Area are generally estuarine species, and most of the remaining Endangered and Vulnerable species are exclusively marine. None of the special status fishes potentially affected by the Project would also be expected to be present in the vicinity of the Demerara Harbour Bridge project, so no cumulative impacts on special status fishes would be expected as a result of the bridge replacement project. Based on the factors discussed above, the significance rating for potential cumulative impacts on special status species was set equal to the individual Project significance rating (**Minor).**

8.2.2 Marine Mammals

The Project was rated as having a **Minor** significance for residual impacts on marine mammals, resulting primarily from behavioral disturbance.

8.2.2.1 Cumulative Impacts from Future EEPGL Activities

In terms of potential cumulative impacts between other EEPGL activities within the Stabroek Block and the Project, there is potential for spatial overlap between the impacts of individual activities but the extent of this potential overlap is currently unknown. While additional production activities within the Stabroek Block may occur in the future, currently such activities are undefined (e.g., timing, location, and development concept). Cumulative impacts of future production activities have therefore not been considered in this assessment, but would be included as appropriate in future assessments. However, many of EEPGL's future activities within the Stabroek block and in close proximity to the Liza field would likely include many of the same impacts associated with the Project (e.g.; additional vessel traffic, permitted discharges). The potential for oil and gas related impacts on marine mammals would logically rise in proportion to an increase in exploration activity, but EEPGL's future exploration activities would likely be focused on areas outside of the Project's Direct AOI. EEPL's future development activities could occur within the Project's Indirect AOI and could therefore have potential cumulative auditory impacts on marine mammals, but only if they occurred simultaneously with the installation phase of the Project when auditory impacts will be most severe, which is extremely unlikely.

The greatest additional risk of ship strike would occur in near shore areas where vessels would congregate to enter and after exiting Georgetown Harbour; however, this increased risk would represent a minimal increment to the existing risk posed by fishing and commercial vessels transiting to and from the port at Georgetown, and other fishing vessels operating in coastal waters west of Georgetown. Provided that the areas within which marine mammals could be affected by future exploration activities (e.g.; mixing zones surrounding future exploration vessels, auditory disturbance/injury thresholds) do not co-occur at the same place and time as Project related impacts, there would be no increase in the significance of cumulative impacts on marine mammals. The significance of cumulative impacts on marine mammals would not increase above **Minor.**

8.2.2.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

A few marine mammals could be present in the vicinity of the Demerara Harbour Bridge project including boto, Guyana dolphin, tuxuci, and West Indian manatee. All of these species are known to enter estuarine settings so they could encounter activities at the Georgetown shorebase(s) that the Project will be utilizing, as well as the Demerara Harbour Bridge. Pile driving and other sources of impulsive noise from bridge construction activity are likely to have a much greater effect on the underwater soundscape and hence the potential for auditory injury than the occasional (a few times a day) transit of Project vessels, which would represent a minor increment to existing river traffic. Considering the typical patterns of bridge construction activity and the low speeds at which Project vessels would be travelling within the harbor, there is no expectation of an interaction between the activities leading to increased probability of vessel strikes.

Based on the factors discussed above, the significance rating for potential cumulative impacts on marine mammals was set equal to the individual Project significance rating (**Minor).**

8.2.3 Marine Turtles

Many of the same factors that determine cumulative potential impacts on marine mammals are relevant to marine turtles. The Project would have **Minor** significance for residual impacts on marine turtles primarily as a result of potential injury from vessel strikes.

8.2.3.1 Cumulative Impacts from Future EEPGL Activities

Just as there is potential for spatial overlap between the impacts of individual future EEPGL activities on marine mammals, the impacts of future EEPGL activities on marine turtles could also overlap with impacts from the Project but their sensitivity to some Project impacts differs from that of mammals. Like marine mammals, turtles would not be expected to congregate around Project vessels. Marine turtles are less susceptible to auditory impacts than marine mammals, but spend much of their time at the sea surface and are generally slower than marine mammals, so the most likely potential for cumulative impacts between the Project and future offshore oil and gas exploration would likely be vessel strikes. Although vessel strikes are generally rare, the potential for oil and gas related vessel strikes of turtles would logically rise in

proportion to the amount of oil and gas exploration activity offshore. However, collective oil and gas-related shipping would be expected to represent a small incremental increase in risk compared to the existing risk posed by fishing and commercial vessels transiting to and from the port at Georgetown, and other fishing vessels operating in coastal waters west of Georgetown. The significance of cumulative impacts on marine turtles would not be expected to increase above **Minor.**

8.2.3.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

The marine turtle species considered in this EIA are not found within the Demerara River. As a result, the Demerara Harbour Bridge project would not be expected to contribute to potential cumulative impacts on marine turtles.

Based on the factors discussed above, the significance rating for potential cumulative impacts on marine mammals was set equal to the individual Project significance rating (**Minor).**

8.2.4 Marine Fish

The Project was rated as having a **Minor** significance for potential residual impacts on bottom-oriented fish species as a result of altered bottom habitats (e.g., from cuttings discharge during drilling, and from disturbance/coverage by installation of SURF infrastructure) and on pelagic fish species as a result of altered water quality and potential for entrainment in water intakes during production operations, as well as of potential auditory impacts from VSP during drilling and from pile driving during installation. These impacts would be most significant during drilling and installation, when most of the habitat-disturbing activities and vessel traffic would occur.

8.2.4.1 Cumulative Impacts from Future EEPGL Activities

With respect to bottom-oriented and resident species, impacts related to disturbance of bottom habitats will be temporary in nature, and fish would be expected to return to the vicinity of subsea infrastructure once seafloor disturbance activities are complete. Further, these effects would be limited to the immediate locality of Project drilling operations, and SURF infrastructure and would not overlap with impacts of additional exploration activities, which would be focused on other areas of the Stabroek Block. Impacts on pelagic species from future operations within the Stabroek Block would also be expected to be limited to the immediate vicinity of the vessels engaged in those activities and those activities would be focused on other areas of the block, so interaction between the impacts of Project and those of other activities is not expected. Provided that impacts on fish associated with future exploration activities (e.g.; mixing zones surrounding future exploration vessels, auditory disturbance/injury thresholds) do not overlap spatially and temporally with Project related impacts, there would be no interaction between them, and therefore no increase in the significance of cumulative impacts on marine fish. The significance of cumulative impacts on fish would not increase above **Minor.**

8.2.4.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

The marine fish species that would be present offshore in the PDA are generally not found within the Demerara River, and to the extent that they may enter the Demerara River as vagrants or use the mangroves in the harbor as nursery habitat, the harbor bridge would have insignificant impacts on adults and would not be expected to affect existing mangroves to a significant degree. As a result, the Demerara Harbour Bridge project would not be expected to contribute to potential cumulative impacts on marine fish.

Based on the factors discussed above, the significance rating for potential cumulative impacts on marine mammals was set equal to the individual Project significance rating (**Minor).**

8.2.5 Community Health and Wellbeing

The Project was rated as having a **Minor** significance on community health and wellbeing due to potential residual impacts on medical and health service accessibility during all Project stages.

8.2.5.1 Cumulative Impacts from Future EEPGL Activities

In the event of a serious medical emergency for either offshore or onshore personnel, the Project may rely on some local Guyanese health resources. However, such events are expected to be rare. Further, the Project will have the capability to provide medical services offshore and onshore, and has protocols to acquire medical support outside of Guyana when required. Therefore it is expected that the Project impacts on emergency medical services would be rare and of very limited duration. EEPGL would scale its own onshore medical capacity and on its vessels to the size of its workforce, so additional EEPGL projects would exert very little to no additional demand on local Guyanese health resources. Therefore the significance of cumulative impacts from other EEPGL activities on medical and health services would not increase above **Minor.**

8.2.5.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

While the Demerara Harbour Bridge project will be short-term in duration relative to the Project, its location near Georgetown means that most medical emergencies would likely be handled at medical facilities in Georgetown. As such, cumulative impacts on medical and health services from the bridge replacement project and the Project, as well as any potential future offshore oil and gas activity, are possible. However, cumulative impacts on health service accessibility are still considered to be **Minor** due to the short-term construction period for the bridge project, the likely availability of project site-based medical facilities for minor medical issues in the case of potential future offshore oil and gas projects, the low frequency of occurrence of severe injuries, the limited numbers of personnel involved, and the limited duration of patient stays. As a result, the Demerara Harbour Bridge project would not be expected to contribute to significant cumulative impacts on the accessibility of health services.

Based on the factors discussed above, the significance rating for potential cumulative impacts on community health and wellbeing was set equal to the individual Project significance rating (**Minor).**

8.2.6 Marine Use and Transportation

The Project was rated as having a **Minor** significance for potential residual impacts on commercial cargo vessels, commercial fishing vessels, and subsistence fishing vessels during drilling, installation, and production operations due to increased vessel traffic.

8.2.6.1 Cumulative Impacts from Future EEPGL Activities

EEPGL has exclusive rights to oil and gas-related activity in the Stabroek Block and will manage its own future operations to avoid conflicts with other vessels and ensure maritime safety, in cooperation with MARAD. Therefore cumulative impacts on marine use and transportation as a result of future EEPGL activities are considered to be **Minor**.

8.2.6.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

The Demerara Harbour Bridge project would involve construction vessels, which would add to the vessel traffic on the Demerara River. Bridge construction activities and thus most of the bridge construction vessel traffic, however, would be focused near the bridge site. The site for the new bridge is not yet determined, nor has the shorebase(s) to be used by the Project been selected. However, the shorebases being considered are seaward of the existing bridge location, which would limit Project vessel interaction with the new bridge construction area. Project-related vessel traffic along the river is expected to be modest, limited to a few vessels per day, and are not expected to appreciably affect the volume of vessel traffic on the river. Thus, cumulative impacts on marine use and transportation from the bridge replacement project are considered to be **Minor**.

Based on the factors discussed above, the significance rating for potential cumulative impacts on community health and wellbeing was set equal to the individual Project significance rating (**Minor).**

8.2.7 Social Infrastructure and Services

Residual impacts on housing and utilities during the drilling and installation stage of the Project were rated as **Minor** in significance, as this stage will require the largest number of Project workers (up to approximately 1,500 at peak, of which approximately 150 would be based onshore) and would likely have the most potential for induced population influx to the Georgetown area by job seekers. Operations stage impacts were rated as **Negligible** and are therefore out of scope for the cumulative impact assessment.

8.2.7.1 Cumulative Impacts from Future EEPGL Activities

At this time, the number, nature, and timing of additional offshore activities that EEPGL may undertake during the Project life cycle, and thus the number of workers at any given time, cannot be predicted. However, increases in the offshore workforce would likely occur gradually or at different stages over a relatively long timeframe, during which time housing markets and utility providers would be able to respond to increases in demand. Given the uncertainty regarding the extent of additional EEPGL activities during the life of the Project, the significance of cumulative impacts on housing and utilities combined with other offshore oil and gas activity is considered to range from **Minor** to **Moderate** in significance, depending on the scale of worker and job-seeker influx associated with potential future offshore projects.

8.2.7.2 Cumulative Impacts from the Demerara Harbour Bridge Replacement

Construction of the Demerara Harbour Bridge may potentially attract workers and job-seekers from other areas of the country. The bridge replacement project would likely coincide with the Project's production operations stage, when the Project's offshore workforce is estimated at about 100 to 140 workers, and most of these workers would be based on the FPSO except when off rotation. Onshore workers for the Project during this period are estimated at about 100. The bridge replacement project is also expected to be of short duration relative to the Project.

Given the short duration of the Demerara Harbour Bridge replacement project relative to the Project, and the likelihood that it would overlap primarily with the operations and productions phases of the Project when traffic is expected to be relatively low, the cumulative impact on onshore transport generated from the bridge replacement project and the Liza Phase 1 Project is considered to be **Minor**.

9.0 ENVIRONMENTAL AND SOCIOECONOMIC MANAGEMENT PLAN FRAMEWORK

9.1 Introduction

This chapter provides a framework for the Project Environmental and Socioeconomic Management Plan (ESMP). The ESMP is the document that describes the measures EEPGL will implement to manage the Project's potential environmental and socioeconomic risks and reduce impacts to the environment and communities.

The scope of this chapter includes the following:

- Provide an overview of the policy framework underpinning the ESMP;
- Describe the ESMP structure;
- Describe general ESMP guiding principles;
- Describe the general content of the Management Plans; and
- Describe how changes to the ESMP will be managed.

The individual Management Plans that comprise the ESMP have been prepared consistent with this framework. Management Plans are required to be completed prior to Environmental Authorisation of the Project, and will be updated to include final conditions from the Environmental Authorisation.

9.2 Regulatory and Policy Framework

The Project is subject to various regulatory requirements as further described in Chapter 3 of the EIA, as well as the conditions established by the Guyana EPA upon issuance of the environmental authorization for the Project, and the conditions of the Petroleum Production Licence and approval of the Project Development Plan by the GGMC. Other Guyana government agencies including, but not limited to, the Fisheries Department of the Ministry of Agriculture (MoA), Guyana Revenue Authority (GRA), Civil Defense Commission (CDC), and Maritime Administration (MARAD) have regulatory authority over aspects of the Project.

EEPGL is committed to ensuring compliance with the laws and regulations of Guyana, while conducting business in a manner that is compatible with the environmental and socioeconomic needs of the communities in which it operates, and in a manner that protects the safety, security, and health of its employees, those involved with its operations, its customers, and the public. These commitments are documented in its Safety, Security, Health, Environmental, and Product Safety policies. These policies are put into practice through a disciplined management framework called the Operations Integrity Management System (OIMS), which is described in Section 3.4.

9.3 ESMP Structure

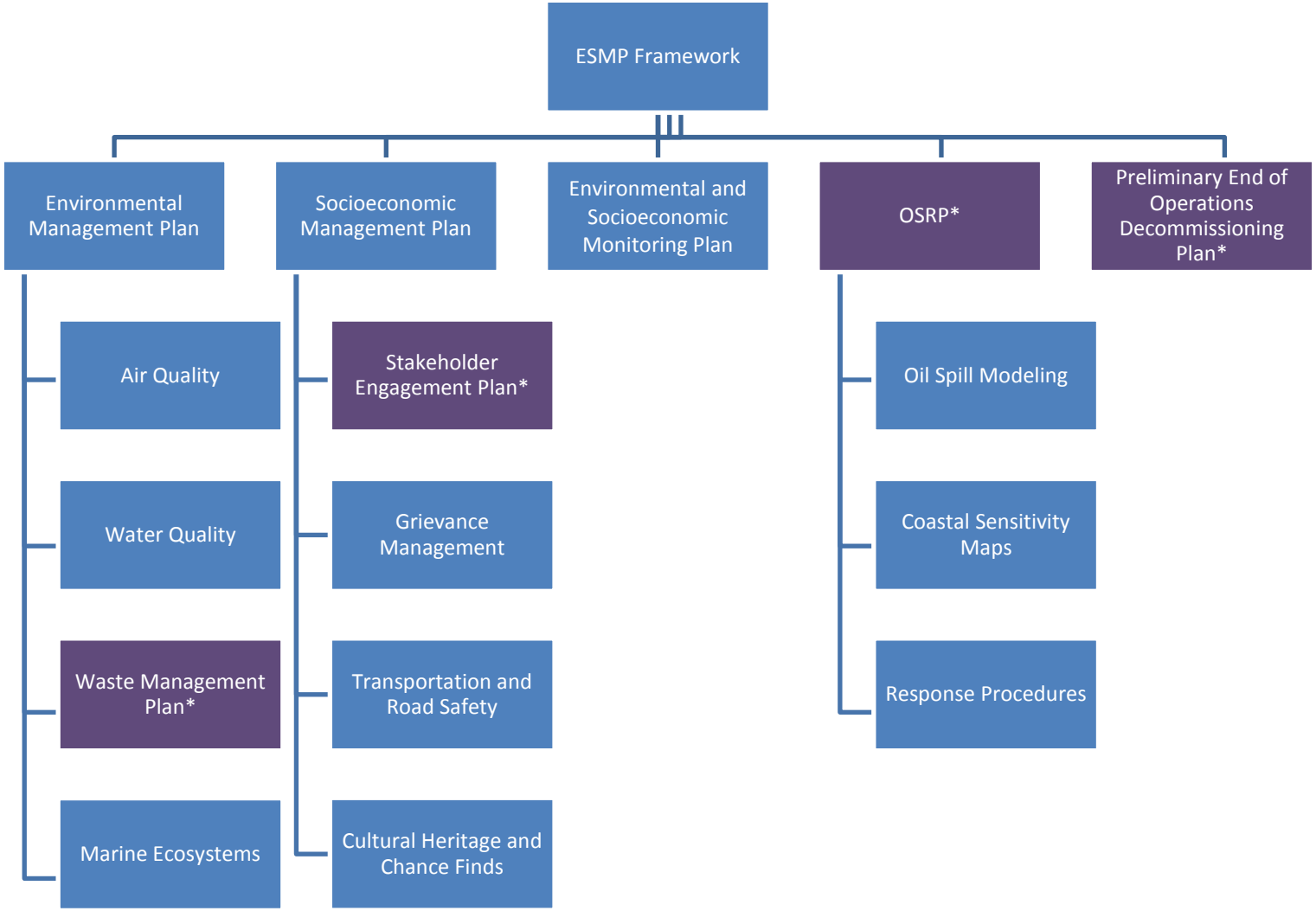
The overall structure of the Project ESMP is depicted in Figure 9-1. The specific Project Management Plans are organized into five categories:

- Environmental Management Plan (EMP)
- Socioeconomic Management Plan (SMP)
- Environmental and Socioeconomic (E&S) Monitoring Plan
- Oil Spill Response Plan (OSRP)
- Preliminary End of Operations Decommissioning Plan[35]

Each of these categories includes one or more specific management plans, which are included in this document unless otherwise noted, as shown in Figure 9-1.

[35] In alignment with the EPA's Initial Closure and Reclamation Plan

Figure 9-1 ESMP Structure



** Due to the size and/or complexity of these documents, these are standalone plans, and are provided either as an Appendix to this ESMP or as a separate volume to the regulatory submittal for the Liza Phase 1 Project (i.e., OSRP).*

9.4 General ESMP Guiding Principles

The overall ESMP, and each of the specific Management Plans it contains, have been developed consistent with these guiding principles. Each

- Covers all Project stages (i.e., there are not separate Management Plans for each Project stage), although there is a Preliminary End of Operations Decommissioning Plan ;
- Contains a level of detail for each individual Management Plan that is fit for purpose and varies among the individual Management Plans;
- Represents a "living document" which may be revised or amended as the Project progresses in response to changing circumstances, lessons learned, or other appropriate reasons; and
- Reflects all regulatory commitments and obligations including those from the EIA, supporting plans, and environmental authorizations.

9.5 Management Plan Contents

The Management Plan Framework contains an introduction and scope as well as a summary of the applicable regulations, standards, and guidelines.

As indicated above, each Management Plan is fit for purpose, and therefore varies to some extent in content, but contains specific Management Measures for each component that are based on the Embedded Controls provided in this EIA. The plans also include the following information for each control/measure:

- The specific Project stage or component that will be responsible for implementing the Management Measure (e.g., FPSO, Support Vessels, Shorebase, etc.)
- The specific stage or stages of the Project during which each measure will be implemented (e.g., Drilling, Installation, Production Operations)
- Operational requirements; and
- Monitoring requirements

9.6 Management of Change

During Project implementation, changes may be required to address unanticipated conditions or situations. Managing change is an integral part of OIMS. Risk assessments, audits, inspections, and/or observations may identify the need for amendments to the ESMP. In these cases, the ESMP will be updated to reflect change. In addition, the ESMP will be updated when applicable environmental laws, regulations, standards, and/ or company processes, systems, and/or technologies change. The EPA will be notified of any significant planned changes to the ESMP and will be provided with an updated version of the document for their records and use. The ESMP is also envisioned to be a "living and adaptive document" that will be updated to reflect continuous learning and improvements and shared with the Government of Guyana.

10.0 CONCLUSIONS AND SUMMARY OF IMPACTS

This section summarizes the predicted environmental and socioeconomic impacts of the Project resulting from planned activities and potential unplanned events (specifically an oil spill), as well the Project's contributions to cumulative impacts on important resources and receptors.

10.1 Planned Events

The planned Project is predicted to have minor impacts on physical resources (i.e., air quality, marine sediments, water quality), no impacts on coastal biological resources, minor impacts on marine biological resources, little, if any, noticeable negative impact on communities, and largely positive impacts on socioeconomics. These predictions are based on the fact that the bulk of the Project will occur approximately 190 km (~120 miles) offshore, and the Project will capture and re-inject recovered natural gas (which is not used as fuel on the FPSO) back into the Liza reservoir, treat all significant wastewater streams prior to discharge to the sea, have a very small physical footprint (e.g., installation of infrastructure will only physically disturb about 0.3 km^2 of benthic habitat), and use MMOs during VSP operations to minimize the potential for auditory damage and injury from ships strikes to marine mammals. The Project will generate benefits for the citizens of Guyana through revenue sharing with the Government of Guyana, a minor increase in employment, and select Project purchasing from Guyanese businesses.

10.2 Unplanned Events

Unplanned events, such as a potential oil spill, are considered unlikely to occur because of the extensive preventative measures employed by EEPGL; but, nevertheless, an oil spill is considered possible. The number of resources that would be impacted and the extent of the impact on those resources would depend on the volume and duration of the release as well as the time of year the release were to occur, but impacts would tend to be most significant for a well control event during the drilling stage. EEPGL has conducted oil spill modeling to evaluate the range of likely spill trajectories and rates of travel. The location of the Project 190 km (~120 miles) offshore, prevailing northwest currents, the light nature of the Liza field crude oil, and the region's warm waters would all help minimize the severity of a spill. Accounting for these factors, the modeling indicates only a 5 to 10 percent probability of oil reaching the Guyana coast, *without taking into consideration the effectiveness of any oil spill response*, and in the unlikely event that a spill were even to occur.

Although the probability of an oil spill reaching the Guyana coast is very small, a well control spill at a Liza well would likely impact marine resources found near the well, such as sea turtles and certain marine mammals (especially baleen whales) that may transit or inhabit the area impacted by a spill. Air quality, water quality, seabirds, and marine fish could also be impacted, although likely to a lesser extent because the duration of acute impacts would not be long and the impacts are reversible. A spill could potentially impact Guyanese fishermen if commercial fish and shrimp were impacted. The magnitude of this impact would depend on the volume and duration of the release as well as the time of year the release were to occur (e.g., whether a spill would coincide with the time of year [May to September] when these species are more

common in the PDA). Effective implementation of the OSRP would reduce this risk by further reducing the ocean surface area impacted by a spill and thereby reducing the exposure of these species to oil.

10.3 Cumulative Impacts

The Project's expected contribution to cumulative impacts would be limited by its distance offshore and by the small number of projects or activities either operating or currently planned to be operating offshore Guyana. There is the potential for other future offshore Guyana oil and gas exploration and possibly development. If such non-Project activities were to occur, the Project and non-Project activities together could cumulatively impact some resources such as Marine Mammals (via vessel strikes or sound), Marine Turtles (vessel strikes), Marine Fish (degraded water quality and cooling and ballast water entrainment), Community Health and Wellbeing (increased demand for limited medical treatment capacity), Marine Use and Transportation (marine congestion especially near Georgetown harbor), and Social Infrastructure and Services (increased demand for limited housing, utilities, and services). Many of the above potential impacts that require offshore interaction between the Project and others have a limited chance of occurring, given the size of the Stabroek block. All of these potential cumulative impacts were considered to be of Negligible to Minor significance.

10.4 Degree of Irreversible Damage

The planned Project would not cause irreversible damage to any onshore areas of Guyana. There would be a very minor (approximately 0.3 km^2) permanent loss of benthic habitat as a result of the installation of wells, flowlines, and other subsea equipment, which may be proposed to be left in place upon decommissioning. However, this equipment can ultimately provide the substrate for recolonization of the impacted areas. Even in the unlikely event of an oil spill, little irreversible damage would be expected, although it could take a decade or more for all resources to fully recover, depending on the on the volume and duration of the release as well as the time of year the release were to occur.

10.5 Project Benefits

The Project will generate benefits for the citizens of Guyana in several ways:

- Through revenue sharing with the Government of Guyana, although the details of this revenue sharing is confidential. The type and extent of benefits associated with revenue sharing will depend on how decision makers in government decide to prioritize and allocate funding for future programs, which is unknown and outside the scope of the EIA;
- By procuring select Project goods and services from Guyanese businesses to the extent reasonably practicable; and
- By hiring Guyanese nationals where reasonably practicable, although the potential magnitude of hiring will be limited.

In addition to direct revenue sharing, expenditures, and employment, the Project would also likely generate induced economic benefits as other non-Project related businesses benefiting from direct Project purchases or worker spending will re-invest locally or expand spending in the area, thereby also generating more local value-added tax. These beneficial "multiplier" impacts will occur throughout the Project life.

10.6 Summary

Table 10-1 provides a summary of the predicted residual (taking into consideration proposed mitigation measures) impact significance ratings for impacts to each of the resources/ receptors that may result from each of the Project stages (i.e., well drilling/SURF/FPSO installation, Production Operations, and Decommissioning), unplanned event (i.e., oil spill), and cumulative impacts.

Table 10-1 Summary of Residual Impact Ratings

Resource	Drilling and Installation	Production Operations	Decommissioning	Oil Spill*	Cumulative Impacts
Air Quality and Climate	Negligible	Negligible	Negligible	Minor	Negligible
Sound	None	None	None	Minor	None
Marine Geology/Sediments	Negligible	None	None	Minor	Negligible
Marine Water Quality	Negligible	Negligible	Negligible	Moderate	Negligible
Protected Areas	None	None	None	Minor	None
Special Status Species:**					
• Critically Endangered and Terrestrial Species	Negligible	Negligible	Negligible	Minor	Minor
• Vulnerable/Near Threatened Species (sharks & bony fish)	Minor	Minor	Minor	Minor	Minor
• Endangered Fish and Black Capped Petrel	Negligible	Negligible	Negligible	Minor	Minor
Coastal Habitats	None	None	None	Minor	None
Coastal Wildlife/Shorebirds	None	None	None	Minor	None
Seabirds	Negligible	Negligible	Negligible	Minor	Negligible
Marine Mammals	Moderate	Negligible	Negligible	Moderate	Minor
Marine Turtles	Minor	Negligible	Negligible	Moderate	Minor
Marine Fish	Minor	Negligible	Negligible	Minor	Minor
Marine Benthos	Negligible	Positive	Positive	Minor	Negligible
Ecological Balance & Ecosystems	Negligible	Minor	Negligible	Minor	Negligible
Economic Conditions	Positive	Positive	Positive	Minor	Negligible
Employment/Livelihoods	Positive	Positive	Positive	Minor	Negligible
Community Health & Wellbeing:	Minor	Minor	Minor	Minor	Minor
Marine Use/Transportation					
• Commercial cargo and fishing	Negligible	Negligible	Negligible	Minor	Minor
• Subsistence fishing	Minor	Minor	Minor	Minor	Minor
Social Infrastructure /Services	Negligible	Negligible	Negligible	Minor	Minor
Cultural Heritage	Negligible	Negligible	Negligible	Minor	Negligible
Land Use	Negligible	Negligible	Negligible	None	Negligible
Ecosystem Services	None	None	None	Minor	None
Indigenous Peoples	None	None	None	Minor	None

*Based on oil spill modeling of a well control event in the PDA that indicates oil reaching Guyana shoreline is highly unlikely (5-to 10 percent probability).
** Excludes listed sea turtles, which are covered in the Marine Turtles resource category.

11.0 RECOMMENDATIONS

ERM recommends the following measures be considered by EPA, GGMC, and the EAB as conditions of any approval of the Project:

- Embedded Controls – incorporate all of the proposed embedded controls (see Table 11-1).
- Mitigation Measures – adopt the recommended mitigation measures (see Table 11-2).
- Management Plans – implement the proposed Environmental and Socioeconomic Management Plan to manage and mitigate the impacts identified in the EIA. The ESMP includes the following Management Plans:
  - Environmental and Socioeconomic Management Plan Framework
  - Environmental Management Plan, including:
    - Air Quality Management
    - Water Quality Management
    - Waste Management Plan
    - Marine Ecosystems Management
  - Socioeconomic Management Plan, including:
    - Stakeholder Engagement Plan
    - Grievance Management
    - Transportation and Road Safety Management
    - Cultural Heritage Management and Chance Finds
  - Environmental and Socioeconomic Monitoring Plan
  - Preliminary End of Operations Decommissioning Plan
  - Oil Spill Response Plan, including Oil Spill Modeling, Coastal Sensitivity Mapping, results of the Net Environmental Benefit Analysis, and Emergency Preparedness and Response Procedure
- Oil Spill Preparedness – EEPGL has proactively embedded many controls into the Project design to prevent a spill from occurring, and we agree that a spill is unlikely. But given the sensitivity of many of the resources that could be impacted by a spill (e.g., Shell Beach Protected Area, marine mammals, critically endangered and endangered sea turtles, Amerindian communities reliant on ecosystem services for sustenance and their livelihood), we believe it is critical that EEPGL commit to regular oil spill response drills, simulations, and exercises, document the availability of appropriate response equipment on board the FPSO, and demonstrate that offsite equipment could be mobilized for a timely response.

With the adoption of such controls, mitigation measures, and management plans, and requirements for emergency response preparedness, the Liza Phase 1 Development Project is expected to pose only minor risks to the environmental and socioeconomic resources of Guyana, while potentially offering significant economic benefits to the residents of Guyana.

Table 11-1 List of Proposed Embedded Controls

Embedded Control Measures	Resources/Receptors Benefitted
Drilling and SURF/FPSO Installation and Commissioning	
• Utilize WBDF to the extent reasonably practicable and in other cases use low-toxicity IOGP Group III NABF.	Marine sediments, water quality, mammals, turtles, fish, and benthos
• When NADF is used, utilize a solids control and cuttings dryer system to treat drill cuttings prior to discharge such that end of well maximum weighted mass ratio averaged over all well sections drilled using non-aqueous fluids shall not exceed 6.9 percent wet weight base fluid retained on cuttings.	Marine sediments, water quality, mammals, turtles, fish, and benthos
• For VSP activities, commence such operations during daylight hours after a suitable pre-watch by Marine Mammal Observers (MMOs) is performed and begin with soft start procedures in accordance with JNCC guidelines, which incrementally increase source sound levels in order to allow marine mammals and turtles time to move away from the activity before full sound source energy is utilized.	Marine mammals, marine turtles
• With respect to prevention of spills of hydrocarbons and chemicals during the drilling stage: o Change liquid hydrocarbon transfer hoses periodically o Utilize dry-break connections on liquid hydrocarbon bulk transfer hoses o Utilize a liquid hydrocarbon checklist before every bulk transfer o Perform required inspections and testing of all equipment prior to deployment/installation; o Utilize certified Blowout Prevention (BOP) equipment; o Regularly test certified BOP equipment and other spill prevention equipment; o Utilize overbalanced drilling fluids to control wells while drilling; o Perform operational training certification (including well control training) for drill ship supervisors and engineers; o Regularly audit field operations on the drill ships, FPSO, and shorebase(s) to ensure application of designed safeguards; and o Controls for mitigating a failure of the DP (dynamic positioning) system on the drill ships and maintain station keeping, which include: ▪ Use of a Class 3 DP system, which includes numerous redundancies; ▪ Rigorous personnel qualifications and training; ▪ Seatrials and acceptance criteria; ▪ Continuous DP proving trials; ▪ System Failure Mode and Effects Analysis; ▪ Continuous DP failure consequence analysis; and ▪ Establishment of well-specific operations guidelines.	Air quality, marine sediments, marine water quality, protected areas, sensitive species, coastal habitats, coastal wildlife and shorebirds, marine mammals, turtles, fish, benthos, ecology and ecosystems

Embedded Control Measures	Resources/Receptors Benefitted
• During pile driving activities, gradually increase the intensity of hammer energy to allow sensitive species to vacate the area before injury occurs (i.e., soft starts).	Marine mammals
• Maintain marine safety exclusion zones with a 500 m (~1,640 ft) radius around drill ships and major installation vessels to prevent unauthorized vessels from entering potentially hazardous areas.	Marine use and transportation safety
Production Operations	
• Re-inject produced gas which is not utilized as fuel gas on the FPSO to avoid routine flaring. With respect to non-routine flaring, the following measures will be implemented: o Monitor flare performance to maximize efficiency of flaring operation; o Ensure flare equipment is appropriately inspected and function tested prior to production operations; and o Ensure flare equipment is appropriately maintained and monitored during production operations.	Air quality
• Treat produced water on the FPSO to limit oil and grease (O&G) content to 29 mg/L monthly average and 42 mg/L daily maximum.	Marine water quality, mammals, turtles, fish, and benthos, seabirds, ecology and ecosystems
• Design cooling water process to avoid increases in ambient water temperature of more than 3˚C at 100m (~328 ft) from the FPSO when discharging.	Marine water quality, mammals, turtles, fish, and benthos, seabirds, ecology and ecosystems
• Perform onboard waste incineration for certain categories of waste.	Land use
• Utilize a Mooring Master from the FPSO located onboard the offloading tanker to support safe tanker approach/departure and offloading operations.	Marine use and transportation safety
• Utilize support tugs to aid tankers in maintaining station during approach/departure from FPSO and during offloading operations.	Marine use and transportation safety
• Utilize a hawser with a quick release mechanism to moor the FPSO to the tanker at a safe separation distance during offloading operations.	Marine use and transportation safety
• FPSO offloading to tankers will occur within an environmental operating limit that is established to ensure safe operations. In the event that adverse weather occurs during offloading operations that is beyond the environmental operating limit the tanker will cease the offloading operations, and may disconnect and safely maneuver away from the FPSO as appropriate.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Utilize a marine bonded, double-carcass floating hose system certified by Class or other certifying agency that complies with the recommendations of OCIMF Guide to Manufacturing and Purchasing Hoses for Offshore Moorings (GMPHOM) 2009 Edition or later.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Utilize breakaway couplers on offloading hose that would stop the flow of oil from FPSO during an emergency disconnect scenario.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds

Embedded Control Measures	Resources/Receptors Benefitted
• Utilize a load monitoring system in the FPSO control room to support FPSO offloading.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Utilize leak detection controls during FPSO offloading which include: o Leak detection for breach of the floating hose that complies with the recommendations of OCIMF GMPHOM 2009 Edition or later; o Utilization of instrumentation/procedures to perform volumetric checks during offloading.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Provide trained medical personnel on board the FPSO and major installation vessels to minimize reliance on medical infrastructure and facilities in Guyana.	Community health and wellbeing
• Utilize marine safety exclusion zone of 2 nautical miles around the FPSO to prevent unauthorized vessels from entering potentially hazardous areas.	Marine use and transportation safety
• Tankers will conduct ballasting operations in accordance with IMO regulations.	Ecological Balance and Ecosystems
General Measures	
• Maintain equipment, marine vessels, and helicopters in good working order and operate in accordance with manufacturer's specifications in order to reduce atmospheric emissions and sound levels to the extent reasonably practicable.	Air quality, water quality, marine mammals, marine turtles
• Regularly inspect and service shorebase cranes and construction equipment in order to mitigate the potential for spills and to maintain air emissions at optimal levels.	Air quality
• Shut down (or throttle down) sources of combustion equipment in intermittent use where reasonably practicable in order to reduce air emissions.	Air quality
• Utilize secondary containment for bulk fuel storage, drilling fluids, and hazardous materials, where practical.	Water quality
• Regularly check pipes, storage tanks, and other equipment associated with storage or transfer of hydrocarbons/chemicals for leaks.	Water quality
• Perform regular audits of field operations on the drill ship, FPSO, and shorebase to ensure application of designed safeguards.	Air quality, water quality
• Treat sewage to applicable standards under MARPOL 73/78.	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• For those wastes that cannot be reused, treated, or discharged/disposed on the drill ship or FPSO they will be manifested and safely transferred to appropriate onshore facilities for management. Waste management contractors will be vetted prior to utilization. If deficiencies in contractors' operations are noted, an action plan to address the identified deficiencies will be established.	Land use

Embedded Control Measures	Resources/Receptors Benefitted
• Utilize oil/water separators to limit oil in water content in bilge water to <15 parts per million (ppm; per MARPOL).	Marine sediments, water quality, mammals, turtles, fish, benthos, and seabirds
• Provide standing instruction to Project dedicated vessel masters to avoid marine mammals and turtles while underway and reduce speed or deviate from course, as needed, to reduce probability of collisions.	Marine mammals, marine turtles
• Provide standing instruction to Project dedicated vessel masters to avoid any identified rafting seabirds when transiting to and from PDA.	Seabirds
• Observe standard international and local navigation procedures in and around the Georgetown Harbour and Demerara River, as well as best ship-keeping and navigation practices while at sea.	Marine use and transportation safety
• Project workers will be subject to health screening procedures to minimize risks of communicable diseases.	Community health and wellbeing
• Utilize an established SSHE program to which all Project workers and contractors will be required to mitigate against risk of injury/illness to workers. • All workers and contractors will receive training on implementation and will be required to adhere to its principles.	Occupational and community health, safety, and wellbeing
• Maintain an OSRP to ensure an effective response to an oil spill, including maintaining the equipment and other resources specified in the OSRP and conducting periodic training and drills.	All resources and receptors
• Where practicable, direct lighting on FPSO and major vessels to required operational areas rather than at the sea surface or skyward.	Seabirds and marine turtles
• Provide screening on FPSO and drill ships for seawater intakes to minimize the entrainment of aquatic life, where practical.	Marine fish

Table 11-2 List of Proposed Mitigation Measures

Proposed Mitigation Measure	Resources/Receptors Benefitted
• Report direct GHG emissions from the facilities owned or controlled by the Project to the EPA on an annual basis in accordance with internationally recognized methodologies and good practice.	Climate
• Procure select goods and services locally to the extent reasonably practicable (enhancement measure).	Economic Conditions, Employment and Livelihoods
• Utilize Guyanese nationals where reasonably practicable (enhancement measure).	Economic Conditions, Employment and Livelihoods
• The Project will issue Notices to Mariners via MARAD, the Trawler's Association, and fishing co-ops for movements of major marine vessels (including the FPSO, drill ship, and installation vessels) to aid them in avoiding areas with concentrations of Project vessels and/or where marine safety exclusion zones are active.	Marine Use and Transportation

Proposed Mitigation Measure	Resources/Receptors Benefitted
• Augment ongoing stakeholder engagement process to identify commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and where possible communicate Project activities to those individuals to aid them in avoiding Project vessels.	Marine Use and Transportation
• Promptly remove damaged vessels (associated with any vessel incidents) to minimize impacts on marine use, transportation, and safety.	Marine Use and Transportation
• Proactively communicate the Project's limited staffing requirements as a measure to reduce the magnitude of potential population influx to Georgetown from job-seekers.	Social Infrastructure and Services
• Adopt and implement as needed a Chance Find Procedure that describes the requirements in the event of a potential chance find of heritage or cultural resources.	Cultural Heritage
• Project workers will be required to adhere to a Worker Code of Conduct, which will address shore-leave considerations.	Community Health and Wellbeing
• Develop and implement a Road Safety Management Procedure to mitigate increased risk of vehicular accidents associated with Project-related land transport activities. The procedure will include, at a minimum, the following components: o Definition of travel routes; o Definition of required driver training, including defensive driving, loading/unloading procedures, and safe transport of passengers, if applicable; o Designation and enforcement of speed limits, through speed governors, GPS, or other monitoring systems; o Avoidance of deliveries during typical peak traffic hours as well as scheduled openings of the Demerara Harbour Bridge, to the extent reasonably practicable; o Monitoring and management of driver fatigue; o Definition of vehicle inspection and maintenance protocols that include all applicable safety equipment; and o Community outreach to communicate information relating to major delivery events or periods.	Community Health and Wellbeing
• Implement the OSRP in the unlikely event of an oil spill, including: o Conduct air quality monitoring during emergency response; o Require use of appropriate PPE by response workers; o Implement a Wildlife Oil Response Program, as needed; and o Implement a claims process for damage caused by an oil spill, as needed.	All resources

12.0 PROJECT TEAM

Table 12-1 identifies the primary members of ERM's team and their roles in preparing this EIA. It also lists their educational qualifications (highest degree) and years of professional experience. Signatures and curriculum Vitae (CVs) for each of these team members listed in Table 12-1 are included in Appendix A and B, respectively.

Table 12-1 Project Team

Name	Role	Education (Highest Degree)	Years of Experience
David Blaha	Project Director	MS Environmental Management	35
Jason Willey	Project Manager and Marine Fish, Mammals, and Turtles	MS Environmental Science and Policy	15
Greg Lockard	EIA Coordinator and Cumulative Effects	PhD Anthropology	21
Kamal Govender	ESMPs	MS Environmental and Geographical Science	13
Karin Nunan	Social Lead	MS International Relations and Conflict Resolution	20
Peyun Kok	Social Specialist	MES Urban and Regional Planning	7
Kristina Mitchell	Stakeholder Specialist	MA International Relations	15
Benjamin Siegel	Maritime Archaeology	MA Historical & Maritime Archaeology	10
Mark Garrison	Air Quality and dispersion modeling	MS Environmental Science	2
Adeyinka Afon	Noise and Air Quality	MSE Environmental Process Engineering	12
Michael Fichera	Water Quality	MS Environmental Engineering	23
Shwet Prakash	Water Quality	MS Civil Engineering	13
Matt Erbe	Geologist	MS Hydrogeology	18
Dusty Insley	Geologist	BS Geology	10
Jonathan Connelly	Environmental Specialist	BA Environmental Studies	10

Name	Role	Education (Highest Degree)	Years of Experience
Melinda Todorov	Environmental Specialist	MS Aquatic Ecology	9
Julia Tims	Biodiversity	MS Natural Resources Management/Ecology	22
Benjamin Sussman	Transportation	MCRP (City and Regional Planning)	17
Noam Raffel	GIS Analyst	MS Geographic Information Sciences	3
Erin Rykken	Technical Editor	MA English MLS Library Science	15
Subcontractors			
Hance Thompson	Guyana Environmental and Regulatory Support, Ground Structures Engineering Consultants, Inc (GSEC), Guyana	BS, Biology; MS, Environmental and Earth Resources Management	13
Noella Arispe	Coastal Sensitivity Mapping (Venezuela), Independent Consultant	BS, Architecture; MS, Planning and Development	41
Hema David	Coastal Sensitivity Mapping (Trinidad and Tobago), Ecoengineering Consultants Limited, Trinidad	AS, Environmental Management; BS, Environmental and Natural Resources Management	7

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ERM Personal Communication 16. Email from Denzil Roberts with fish bycatch from shrimp trawling fishery. October 4, 2016."

ERM Personal Communication 17. Interview with anonymous fisherman in Charity. August 31, 2016.

ERM Personal Communication 18. Interview with National Aquaculture Association. September 6, 2016.

ERM Personal Communication 19. Interview with Vilvordeen/Fairfield Women's Association. August 31, 2016.

ERM Personal Communication 20. Interview with Member of Lima Fisherman's Development Co-operative. August 31, 2016.

ERM Personal Communication 21.Interview with Fish processor in Lima area. August 31, 2016.



Environmental Impact Assessment
Technical Appendices

Liza Phase 1 Development Project

Esso Exploration and Production Guyana, Limited

February 2017

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David W. Blaha

ERM Partner

The business of sustainability

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APPENDICES

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APPENDIX A – List of Preparers Signatures

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LIST OF PREPARERS

David Blaha, Project Director
Chapters 1 and 11, Section 7.4, and EIS

Jason Willey, Project Manager
Chapter 10 and Sections 6.2.5-7 and 7.2.5-7 and Appendix G

Greg Lockard, EIA Coordinator
Chapters 4, 5, 8, and 12

Kamal Govender
Chapters 2 and 9

Melinda Todorov
Chapters 1, 3 and Sections 6.2.8 and 7.2.8

Adeyinka Afon
Sections 6.1.2 and 7.1.2

Jonathan Connelly
Sections 6.2.1-2 and 7.2.1-3 and Appendices D and E

Matt Erbe
Sections 6.1.3 and 7.1.3

Michael Fichera
Sections 6.1.4 and 7.1.4

Mark Garrison
Sections 6.1.1 and 7.1.1

Dusty Insley
Sections 6.1.3 and 7.1.3

Peyun Kok
Sections 6.3.1-4 & 6-7 & 9 and 7.3.1-4 & 6-7 & 9 and Appendix C

Karin Nunan
Sections 6.3.1-4 & 6-7 & 9 and 7.3.1-4 & 6-7 & 9 and Appendix C

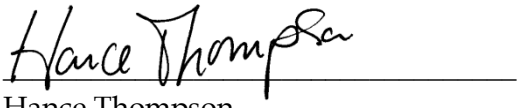
Benjamin Siegel
Sections 6.3.8 and 7.3.8

Benjamin Sussman
Sections 6.3.5 and 7.3.5

Julia Tims
Sections 6.2.3 and 7.2.4 and Appendix F

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Coastal Sensitivity Mapping

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Coastal Sensitivity Mapping



Hance Thompson
Coastal Sensitivity Mapping and Stakeholder Engagement



Todd Hall
Senior Review



Erin Rykken
Technical Editor

APPENDIX B – CVs

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David W. Blaha, AICP

Technical Director



Mr. Blaha has 31 years of experience in environmental and social impact assessment, natural and cultural resource management, sustainable development and stakeholder engagement. He routinely provides strategic advice for public and private sector clients in managing the environmental and social risks relating to obtaining regulatory approvals, lender financing, and the social license to operate for large (>$US 1 billion) mining, infrastructure, and power projects. He is thoroughly familiar with good international industry practice (e.g., IFC Performance Standards, IDB Environment and Safeguard Polices and Directives, and Equator Principles) and the application of those standards in preparing Environmental and Social Impact Assessments. Mr. Blaha has worked with many Equator Banks, bilateral and multilateral banks, and other lenders to conduct appropriate environmental and social due diligence, gap analyses, and construction/operation compliance assessments.

Professional Affiliations & Registrations

- American Institute of Certified Planners
- International Association of Impact Assessment
- American Planning Association
- American Water Resources Association

Education

- Master of Environmental Management, Duke University, 1981
- Bachelor of Arts, Biology, Gettysburg College, 1978

Honors & Awards

- Phi Beta Kappa

Key Industry Sectors

- Financial
- Oil & Gas
- Power
- Mining

Key Projects

Environmental Impact Assessment and Permitting Support, Exploration Activities, EEPGL (ExxonMobil). Project Director for comprehensive impact assessment, management planning, and environmental permitting services for ExxonMobil's local affiliate in Guyana since 2013. Worked closely with the local Exxon affiliate in Guyana to help navigate the regulatory structure in Guyana and deliver the necessary approvals to meet the client's accelerated schedule for exploration and assessment of resources in the Stabroek Block.

Guyana Goldfields Aurora Mine ESIA, Guyana. Project Director for an Environmental and Social Impact Assessment of a proposed gold mine in northwestern Guyana. Key issues included socioeconomic impacts and impacts on soil and water quality from accidental spills.

Matthews Ridge Manganese Mine IFC Gap Analysis, Guyana. Project Manager for a site assessment and document review to determine a proposed mining project's compliance with the IFC performance standards and identify any gaps.

Crown Landing Liquefied Natural Gas Project, US. Project Manager for a US$1.4 billion LNG import terminal for BP consisting of a marine terminal and an on-shore regasification facility. Responsible for advising BP on securing all necessary federal, state, and local environmental permits.

Golden Pass LNG Project, Texas. Technical coordinator for preparation of environmental resource reports for a 1.0 BCFD LNG import terminal at Sabine Pass, Texas for ExxonMobil.

Camellia Bay LNG Project (AL). Technical coordinator for preparation of environmental resource reports for a 1.0 BCFD LNG import terminal south of Mobile, AL for ExxonMobil.

Maritime Administration Deepwater Port Workshop. Project Director for coordinating a LNG Deepwater Port Conference for potential applicants and applicable state and federal agencies on behalf of MARAD,

including preparing educational and reference materials on licensing process.

HEMCO Gold and Silver Mine, Nicaragua. Project Director for an Environmental and Social Due Diligence of a proposed gold and silver mine and associated hydropower project as part of project financing on behalf of the Inter-American Investment Corporation.

Buenaventura Industrial Port Expansion ESDD, Colombia. Project Director for due diligence of a proposed Pacific container port expansion in Buenaventura on behalf of the IFC. Key issues relate to potential impacts on water quality, and temporary disruption of subsistence fishing.

Keystone XL Pipeline Environmental Impact Statement, US. Overall Senior NEPA Lead and coordinator for the alternatives and cumulative effects assessment for Supplemental EIS on behalf of the U.S. State Department for a highly controversial oil pipeline requiring a Presidential Permit for a US/Canada border crossing.

Northeast Gateway Deepwater Port LNG Import Terminal, U.S. Project Director for 400 MMcfd LNG deepwater port project proposed by Excelerate as the 3rd Party EIS contractor for the U.S. Coast Guard. The Project is located 13 miles offshore from Gloucester MA in approximately 280 feet of water and will use special purpose LNG carriers called Energy Bridge Regasification Vessels to transport and regasify the LNG. The deepwater port will connect to the interstate natural gas system via a 16.1 mile submerged pipeline lateral. The Project has been permitted and constructed.

Inter-American Development Bank (IDB) Support Services Contracts. Project Director for multi-year support contract with the IDB to provide E&S advisory services for both public sector and private sector projects throughout Latin America.

Cerrejon Coal Mine, Colombia. Serving as Project Director for an independent evaluation of a proposed expansion of the world's largest open pit bituminous coal mine. Provided advisory services regarding managing environmental and social risks, including river diversions and effects on indigeneous lands.

Pebble Gold Mine ESIA, U.S. Serving as Technical Director for an independent environmental and social evaluation of the reportedly largest gold deposit and 5th largest copper deposit in the world. Key issues include assessing effects of the project, especially the tailings storage facility, on salmon and indigeneous subsistence lifestyles in the area.

SIEPAC Construction Phase Monitoring, Central America. Project Director for the construction phase of environmental and social monitoring on behalf of the IDB for the SIEPAC transmission line project in Panama, El Salvador, and Guatemala.

Xacbal Hydroelectric Project, Guatemala. Project Director for environmental and social due diligence review of a 94 MW hydropower and 125 km transmission line project on the Xaclbal River for the Inter-American Investment Corporation. Key issues focused on ecological base flows, compensation for land acquisition, and community investment program.

Pando – Monte Virio Hydropower Project, Panama. Project Director for construction and operation phase monitoring of an 83 MW hydropower project with a 19-km transmission line located on the Chiriqui River, which forms the border with Costa Rica, to ensure project complies with lender requirements, IFC performance standards, Panamanian regulations, and the project's E&S Management Plan on behalf of the lenders, which include the IDB, IFC, and GED.

TapaJai Hydropower Project ESIA, Suriname. Project Director for a hydropower project that would divert water from the Marowijne River, which forms the international border with French Guiana, to augment flow to increase hydropower generation.

Camisea Block 56 Gas Field and Pipeline EIA, Peru; 2005. Project Director for EIA evaluating the effects of developing three gas fields, 30 km of gas flowlines, and the Malvinas gas plant in Peru for Hunt Oil/Pluspetrol. The EIA is being developed to meet Inter-American Development Bank standards.

Lake Gaston Environmental Impact Statement, US. Project manager for the development of an EIS evaluating alternative water supply sources for the City of Virginia Beach. Mobilized and coordinated 30 multidisciplinary staff from 3 offices in order to complete the project in 6 months. The FEIS was appealed to the US Supreme Court and upheld.

Nassau Plateau Bauxite Mine ESIA, Suriname. Serving as Project Director for baseline studies and preparation of an ESIA for a bauxite mine to meet both Suriname and international standards for Alcoa. Key issues include effects on endangered fish, habitat fragmentation, and water quality. Coordinating stakeholder engagement with local Maroon and Amerindian communities.

Jason Willey

Project Manager



Mr. Willey has fifteen years experience in ecology and natural resource management with specific expertise in marine and estuarine ecology. Most of his ecological work has supported environmental impact assessments and permitting projects for industrial projects, particularly for oil and gas clients. He has assessed environmental impacts of onshore and offshore components of upstream and downstream developments. various oil and gas clients in the United States and Australia for Mr. Willey works mostly in the USA, having prepared numerous impact assessments to the US National Environmental Policy Act standards, but he has also applied international environmental impact assessment protocols to projects in Southeast Asia, South America, Australia, New Zealand, Greenland, and the Caribbean.

Fields of Competence

- Environmental and Social Impact Assessment
- Aquatic and estuarine ecology, including quantitative and qualitative fish community survey methods (EPA rapid bioassessment protocol), aquatic macroinvertebrate ecology, water quality sampling, and in-stream macrohabitat assessment
- Threatened and Endangered Species Consultations (NMFS and USFWS)
- Essential Fish Habitat (EFH) assessment
- Aerial photograph, landscape feature, and habitat interpretation
- Wetland delineation and functional assessment

Education

- B.S., Biology, University of Richmond, Richmond, VA, May 1997
- M.S., Environmental Science and Policy, Johns Hopkins University, MD, May 2007

Key Projects

Environmental Impact Assessment and Permitting Support, Exploration Activities, EEPGL (ExxonMobil). Project manager for a Strategic Environmental Assessment of exploration activities in the Stabroek Block, a deepwater exploration block offshore of Guyana. Was also responsible for delivering the associated management plans and various environmental approvals for associated activities including metocean and geophysical/geotechnical surveys. Assisted ExxonMobil staff with an audit of potential service providers in Guyana and Trinidad as part of the tender evaluation process for waste management services. Has worked closely with the local Exxon affiliate in Guyana to manage several regulatory and environmental management deliverables since the inception of EEPGL's involvement in Guyana in 2013.

ION Geoventures. Managing regulatory and environmental assessment processes in Guyana, Trinidad, and Suriname for ION's planned 2D GuyanaSPAN seismic survey in October 2013.

Environmental Impact Assessment and Planning, Woodside Energy Ltd. Provided general environmental impact assessment and planning services for several petroleum exploration and production facilities around Australia. Prepared EPBC Act (Australia) referrals and environmental management plans for offshore exploration projects in the Torosa 3 gas field offshore of Western Australia. Coordinated oil spill contingency planning and sediment transport modeling to support EIA process for another offshore project in a potentially sensitive marine environment on Scott Reef (Western Australia).

Impact Assessment and Regulatory Compliance , Bass Strait Seismic Exploration, Total. Prepared EPBC Act (Australia) referrals and environmental management plans for seismic exploration in the Bass Strait, north of Tasmanaia. Assessed the potential for acoustic impacts on marine mammals and for disturbance of seabirds and fish. Determined that the project was unlikely to cause significant impacts to marine resources and that no further environmental

assessment was necessary in order to comply with the applicable Australian regulations.

Environmental Impact Assessment, Great South Basin, ExxonMobil. Managed an EIA for a marine seismic survey in the Great South Basin off the coast of New Zealand's South Island. Key issues include potential impacts on endangered marine mammals, marine fisheries, and seabirds, as well as ecosystem-level effects on sensitive habitats including the Sub-Antarctic island archipelago. Project required collating results of recent and ongoing scientific research on the effects of vessel noise, seismic noise sources, and near- to mid-field interactions with vessels on rare, threatened, and endangered marine mammals. Impact assessment process included consultation with several key government stakeholders, and resulted in finding of no significant impacts and favorable feedback from NZ regulators.

Confidential Client. Provided on-call environmental support to an Australian engineering firm bidding on the design and construction phase of a large, confidential oil and gas production project in Western Australia. Project would involve routing four gas trunklines from offshore fields through sensitive near-shore coral reef and under sea turtle nesting beaches. Recommended several key measures that could be incorporated into the project approach and design that could maximize efficiency while avoiding or minimizing environmental impacts.

Environmental Resource Report and EIS Review, Crown Landing (BP). Fisheries and aquatic biology lead on the EIS and Federal and state permit efforts for a LNG terminal and associated pipeline connections on the Delaware River in southern New Jersey. Led consultations with NMFS regarding potential impacts of the project on marine mammals, particularly the critically endangered North Atlantic right whale and the Federally listed Atlantic and shortnose sturgeons (*Acipenser oxyrhynchus* and *A. brevirostrum*).

Environmental Impact Statement, Excelerate Energy Northeast Gateway. Lead marine biologist on an EIS for a proposed offshore natural gas offloading facility in Massachusetts waters. Key biological issues included potential effects on marine mammals, loss of ichthyoplankton to ballast intakes, and effects on shellfisheries and groundfisheries. Integrated a third-party entrainment modeling and equivalent adults assessment into the EIS for the project. Developed a life stage-specific assessment of the risks posed to vulnerable life stages of over 15 species of crustaceans, fish, and marine mammals from various project related activities based on life history parameters. Particular emphasis was placed on balancing safety concerns with minimizing impacts on key resources such as Atlantic herring (*Clupea harengus*) and American lobster (*Homarus americanus*) with seasonally-dependent sensitivities to specific project-related activities.

Environmental Resource Report and EIS Review, ExxonMobil Golden Pass. Authored the FERC aquatic resources resource report for a proposed natural gas terminal on Sabine Pass in eastern Texas. Performed a preliminary assessment of potential impacts on mud, sand, and shell-hash intertidal and sub-tidal littoral habitats on the Sabine River. Evaluated potential losses of planktonic finfish and shrimp larvae from entrainment in ballast water intakes and open-rack vaporizers. Consulted with NMFS and USFWS concerning potential effects on listed species, particularly sea turtles and Gulf sturgeon (*A. desotoi*).

Confidential Client. Lead marine biologist on the Environmental and Social Impact Assessment (ESIA) for a resort planned on New Providence Island, The Bahamas. Resources of concern included listed marine reptiles, corals, seagrasses, and commercially and recreationally important fish and invertebrates. Particular emphasis was placed on the potential effects of dredging an access channel on nearshore biological communities such as patch reef, and on water quality within the proposed marina basin. Conducted ministerial-level consultations with natural resource agencies to ensure governmental support for the ESIA.

Feasibility Assessment, Aquatic Biological Survey, and Training, Suralco, Suriname. Lead aquatic ecologist on a feasibility assessment for a bauxite mine at a greenfield site in central Suriname. Supervising a multi-year aquatic survey of high altitude streams on the Nassau plateau, a laterite capped plateau in the undeveloped interior. Responsible for training Surinamese HSE staff in low-impact ecological sampling and monitoring protocols. Replaced rotenone-based collection protocols with a combination of modern electroshocking and traditional methods.

Trained local field teams, which include scientists and native assistants in new survey protocols. ERM's low-impact survey methodologies have been highly effective; work in 2009 documented seven rare species of loricariid catfish on the plateau, including one species that is new to science.

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Greg Lockard, PhD



Greg Lockard, PhD, has over 20 years of professional experience and over 13 years of experience working as a consultant on development projects in the United States and Latin America. He is a professional anthropologist and cultural heritage specialist with training and experience in social work. He is a native English speaker and is fluent in Spanish. Dr. Lockard is an experienced contract and project manager, developing, negotiating, and managing multiple contracts with a value of over $10 million for environmental services. He has extensive experience supervising cultural resource contractors and coordinating with government agencies and construction managers to ensure compliance with local and national requirements. From 2008 to 2010, he served as the lead heritage specialist for the $3.8B PERU LNG Project, which involved the construction of a natural gas pipeline, liquefaction plant, and marine terminal in Peru. Dr. Lockard is an expert in multilateral lender requirements, including the Equator Principles, the International Finance Corporation Performance Standards, the World Bank Group's EHS Guidelines, and the Inter-American Development Bank's Environment and Safeguards Compliance Policy.

At ERM, Dr. Lockard serves as an environmental consultant managing and working on international projects, especially in Latin America and the United States. His experience in Latin America includes projects in Peru, Chile, Colombia, Haiti, Nicaragua, Brazil, and Mexico, and includes environmental and social impact assessments (ESIAs), environmental and social due diligence (ESDD), and monitoring compliance with environmental, social, and cultural heritage lender requirements.

Professional Registrations & Affiliations

- Register of Professional Archaeologists (RPA), No. 15932
- Registro Nacional de Arqueólogos (RNA) del Perú, No. DL-0081
- Colegio Profesional de Arqueólogos del Perú (COARPE), No. 040780
- Society for American Archaeology (SAA)
- International Association for Impact Assessment (IAIA)
- American Anthropological Association (AAA)
- Archaeological Institute of America (AIA)
- Pre-Columbian Society of Washington, DC

Fields of Competence

- U.S. and international cultural heritage
- E&S Project Management
- U.S. cultural resource laws and regulations
- International lender requirements

Key Industry Sectors

- Oil & Gas
- U.S. Federal

Education

- PhD, Anthropology, University of New Mexico, 2005
- MA, Anthropology, University of New Mexico, 1999
- BA, History and Political Science, George Washington University, 1995

Languages

- English, native speaker
- Spanish, fluent

ERM Experience

Tres Mesas Project / OPIC (5/16-present).
Project Manager. Conducting an ESDD for a wind farm project in Tamaulipas, Mexico. Travelled to Mexico as part of the ESDD to visit the project site and interview project personnel, regulators, and affected communities (ejidos).

Lafito Industrial Free Zone and Power Plant Project / CIFI (4/16-present).
Project Manager. Conducting an ESDD for a port, industrial free zone, and power plant in Haiti. Sent a team to Haiti as part of the ESDD to visit the project site and interview project personnel and affected communities.

Fields Point Liquefaction Project / National Grid LNG, LLC (4/16-present).
Technical Section Lead. Conducting third party review of the cultural resource sections of an environmental report filed with the Federal Energy Regulatory Commission (FERC) for a gas liquefaction project in Rhode Island. Also preparing the cultural resource section of an Environmental Assessment (EA) for the project.

Driftwood LNG Project / Driftwood LNG, LLC (3/16-present).
Cultural Heritage Lead. Preparing Resource Report 4 (cultural resources) for an environmental report to be filed with the Federal Energy Regulatory Commission (FERC) for a 1200-acre liquefied natural gas (LNG) liquefaction export facility in Calcasieu Parish, Louisiana. Also coordinating consultation with the Louisiana State Historic Preservation Office (SHPO) and American Indian tribes with historic ties to the region, and reviewing cultural resource survey reports for the project.

G2 Project / G2 LNG, LLC (2/16-present).
Cultural Heritage Lead. Preparing Resource Report 4 (cultural resources) for an environmental report to be filed with the Federal Energy Regulatory Commission (FERC) for a 777-acre liquefied natural gas (LNG) liquefaction export facility and 42 miles of pipeline in Cameron Parish, Louisiana. Also coordinating consultation with the Louisiana State Historic Preservation Office (SHPO) and American Indian tribes with historic ties to the region, and reviewing cultural resource survey reports for the project.

Project Andes / EIG (11/15-present).
Project Manager. Environmental and Social Due Diligence (ESDD) for investment in an offshore LNG terminal, gas to power plant, and solar project in Chile**.**

Sucden Sugar and Bio-Energy Lending Program / Inter-American Development Bank (IDB) (7/15-present).
Project Manager. Prepared an Environmental and Social Due Diligence (ESDD) and an Environmental and Social Management System (ESMS) Protocol for a Financial Intermediary (FI) to utilize to ensure the alignment of their Sub-Borrowers (sugarcane mills in Brazil) with IDB policies and directives.

Susquehanna West, Triad, and Orion Projects / Tennessee Gas Pipeline Company (7/15-present).
Technical Section Lead. Conducting third party reviews of the cultural resource sections of environmental reports filed with the Federal Energy Regulatory Commission (FERC) for three separate and independent looping projects along a 300 mile pipeline system in Pennsylvania. Also preparing the cultural resource sections of Environmental Assessments (EAs) for the projects.

Luz del Norte Photovoltaic Project, Environmental and Social Construction Monitoring / First Solar, Inc. (2/15-present).
Cultural Heritage Lead. Monitoring review, including evaluation of alignment with IFC performance standards, of the cultural heritage program for a solar power project in northern Chile.

Red Vial 4 Highway Project, Environmental and Social Monitoring / Banco de Crédito del Perú, Corporación Andina de Fomento, and Crédit Agricole (5/15-present).
Cultural Heritage Lead. Monitoring review, including alignment with IFC performance standards, of the cultural heritage program for a 283 km highway project in northern Peru.

TISUR Amarradero "F" Expansion Project / Terminal Internacional del Sur S.A. and Mizuho Bank, Ltd. (12/15-2/16).
Project Manager. Conducted E&S Environmental Monitoring of a port facility in southern Peru to assess compliance with the project's Environmental and Social Action Plan (ESAP) and general alignment with the Equator Principles and the IFC Performance Standards.

Mississippi River LNG Project / Louisiana LNG Energy, LLC (10/15-2/16).
Cultural Heritage Lead. Preparing Resource Report 4 (cultural resources) for an environmental report to be filed with the Federal Energy Regulatory Commission (FERC) for a 250-acre liquefaction export facility and 5.2 miles of pipelines in Plaquemines Parish, Louisiana. Also coordinated consultation with the Louisiana State Historic Preservation Office (SHPO) and American Indian tribes with historic ties to the region, and reviewed cultural resource survey reports for the project.

Gasoducto Sur Peruano Project, Independent Environmental & Social Consultant / Citi and Sumitomo Mitsui Banking Corporation (1/15-12/15).
Consultant. Worked on a small team conducting a due diligence, including alignment with the Equator Principles and the IFC performance standards, for an 1100 km natural gas pipeline project in southern Peru. Assisted in the preparation of an Environmental and Social Due Diligence (ESDD) Report and Environmental and Social Action Plan (ESAP) for the project. Also conducted pre-closing monitoring to assess the project's progress towards addressing ESAP requirements.

Offshore Cape Three Points (OCTP) Project / eni Ghana (12/15).
Senior Reviewer. Reviewed the Cultural Heritage Management Plan (CHMP) for a hydrocarbon reserves development project in Ghana. The project includes offshore drilling, a 63 km subsea gas pipeline, and onshore receiving facilities**.**

Project Traverse / EIG (10/15).
Cultural Heritage Lead. Environmental and Social Due Diligence (ESDD) for investment in three natural gas pipeline projects in West Virginia, Pennsylvania, Ohio, and Michigan**.**

Project Zilkha / EIG (8/15-10/15).
Project Manager. Environmental and Social Due Diligence (ESDD) for investment in a biomass energy project in the United States and the United Kingdom**.**

Farim Phosphate Project / GB Minerals (6/15-8/15).
Senior Reviewer. Reviewed the cultural heritage baseline and cultural heritage sections of an Environmental and Social Impact Assessment (ESIA) for a mining project in Guinea-Bissau.

Tyre Casino Project (6/15-7/15).
Consultant. Conducted a cultural resources desktop analysis, including historic map research, for a casino project in Seneca County, New York.

Project Zedd / Harbour Energy (6/15).
Consultant. Worked on a small team conducting a transactional Environmental and Social Due Diligence (ESDD) of an oil & gas company in Peru.

Circum Minerals Potash Mining Project / Circum Minerals (5/15).
Senior Reviewer. Reviewed the cultural heritage baseline and cultural heritage sections of an Environmental and Social Impact Assessment (ESIA) for a potash mining project in Ethiopia's Danakil Depression.

GAC Project / Guinea Aluminum Corporation (4/15).
Senior Reviewer. Reviewed the cultural heritage baseline and cultural heritage sections of an Environmental, Social, and Health Impact Assessment (ESIA) for an aluminum mining project in Guinea.

Franklin Project / Shell (11/14-5/15).
Technical Section Lead. Prepared the cultural resources sections for an Environmental, Social, and Health Impact Assessment (ESHIA) for a proposed petrochemical facility in western Pennsylvania.

Leach XPress Project / Columbia Gas Transmission, LLC (2/15-2/16).
Technical Section Lead. Conducted a third party review of the cultural resource sections of an environmental report filed with the Federal Energy Regulatory Commission (FERC) for a 161 mile natural gas pipeline project in West Virginia and Ohio. Also prepared the

cultural resource sections of an Environmental Impact Statement (EIS) for the project.

Project Pisco / Harbour Energy (4/15-5/15).
Consultant. Worked on a small team conducting a transactional Environmental and Social Due Diligence (ESDD) of an oil & gas company in Colombia.

AMBU Project / Chevron (11/14-4/15).
Technical Section Lead. Prepared the cultural resources sections for an Environmental, Social, and Health Impact Assessment (ESHIA) for potential gas development in 26 counties in western Pennsylvania, eastern Ohio, and northern West Virgina.

Appalachia Project / Shell (3/15-4/15).
Consultant. Prepared a Cultural Heritage Support document for potential oil & gas development in Potter and Tioga Counties, Pennsylvania.

Ras al-Khair Industrial City Project / Saudi Arabia Royal Commission (4/15).
Consultant. Prepared a Cultural Heritage Management Plan (CHMP) for an economic diversification and industrialization project for the development of hydrocarbon based and energy intenstive industries in eastern Saudi Arabia.

Nicaragua Grand Canal Project / Hong Kong Nicaragua Development Company (12/14-2/15).
Cultural Heritage Specialist. Wrote the Cultural Heritage Management Plan (CHMP) and peer reviewed the cultural heritage sections of an Environmental and Social Impact Assessment (ESIA) for a major canal project in Nicaragua.

Project Base / The Carlyle Group (1/15).
Cultural Heritage Lead. Prepared the cultural resource sections of an Environmental Due Diligence report of a mining company in Wyoming.

PERU LNG Project / PERU LNG S.R.L. (4/08-9/10).
Archaeological Coordinator, Environmental Resource Management Perú, S.A. (4/08-4/09) and Compañía Operadora de LNG del Perú S.A.C (4/09-9/10). Lead archaeologist for a $3.8 billion natural gas pipeline and liquefaction plant project; Manager of a team of eight archaeologists; Coordinator with the national and local offices of Peru's Instituto Nacional de Cultura (INC) concerning archaeological work permits, document approvals, site supervisions, and construction permits; Developed, negotiated, and managed the project's archaeological services contracts, which have a combined value of over $10 million, with four separate companies; Supervised the Phase III rescue excavation of 130 archaeological sites by contractors; Supervised the investigation of 134 "chance finds," 90 of which were fully or partially excavated by contractors, as part of archaeological monitoring plans; Served as Director for one INC-approved project, Project Manager for three projects directed by COLP archaeologists, and Client-based Manager for 16 projects directed by contractors.

Non-ERM Experience

Master Environmental Consulting Services Contract / BP Exploration & Production, Inc. (8/12-11/14).
Contract Manager. Managed a contract to provide environmental services to an oil and gas client. The contract had three work releases totaling over $10M in value.

Cultural Resources-related Services at Various Locations within the NAVFAC, Southwest Area of Responsibility / NAVFAC Southwest (11/12-11/14).
Contract Manager. Managed an IDIQ contract to provide cultural resource services to the Navy. A total of 32 task orders were issued under the contract during this time period, totaling over $3.5M.

Cultural Resources Services Agreement / Delaware Department of Transportation (10/13-11/14).
Contract Manager. Managed a contract to provide cultural resource services to the Delaware DOT. Four task orders were issued under the contract during this time period, totaling over $250K.

MC 252 (Deepwater Horizon) Oil Spill Response Cultural Resources Program / BP Exploration and Production, Inc. (5/11-11/14).
Project Manager. Supervised a multi-disciplinary team providing cultural resources support for the Deepwater Horizon oil spill cleanup in coastal Louisiana, Mississippi, Alabama, and Florida. Responsible for managing subcontracts with six separate companies that supported the project. Supervised the archaeological

survey of over 6,000 km of shoreline, which recorded 115 new sites and revisited 447 previously recorded sites. Supervised an ethnographic survey of the Gulf Coast, which recorded 348 potential traditional cultural properties (TCPs) and 17 traditional cultural landscapes.

MC 252 Natural Resources Damage Assessment (NRDA) Section 106 Support Program / BP Exploration and Production, Inc. (10/11-11/14).
Project Manager. Supervised a team providing cultural resources support for the NRDA activities of the National Oceanic and Atmospheric Administration (NOAA) and the Department of Interior (DOI) related to the Deepwater Horizon oil spill cleanup.

Tactical Infrastructure Maintenance and Repair Project / U.S. Customs and Border Protection (10/10-11/14).
Technical Section Lead. Assisted in the preparation of a Programmatic Agreement (PA) and prepared the cultural resources sections for four Environmental Assessments that cover the international borders of California, Arizona, New Mexico, and Texas.

Spindrift Project / Private Client (11/12-11/14).
Contract Manager. Managed the contract for an Archaeological Data Recovery Plan (ADRP) and Cultural Materials Inventory Program (CMIP) in La Jolla, San Diego, California.

Biological and Cultural Surveys and Site Protection on the North Range Maneuver Areas of White Sands Missile Range, New Mexico / USACE Tulsa District (12/12-11/14).
Consultant. Provided project management guidance and client coordination support for the biological and archaeological survey of three tracts of land totaling 125,000 acres and subsequent testing of archaeological sites in east-central New Mexico.

Tappan Zee Hudson River Crossing / Tappan Zee Constructors / New York State Thruway Authority (2/13-11/14).
Consultant. Provided project management guidance and client coordination support for the implementation of the Section 106 Memorandum of Agreement (MOA) for the construction of the new Tappan Zee Bridge in New York. The project includes HAER documentation of the old bridge.

CSX North Branch Project / CSX Transportation (8/13-11/14).
Consultant. Oversaw a subcontractor in the execution of an MOA and provided Section 106 expertise for a project to replace a historic railroad bridge crossing the Potomac River between Maryland and West Virginia.

Champlain Hudson Power Express Project / U.S. Department of Energy (9/10-9/14).
Technical Section Lead. Prepared the cultural resources sections for an Environmental Impact Statement (EIS) for a 335-mile transmission line project in New York.

Phase I Archaeological Survey at Blossom Point Tracking Facility, Charles County, Maryland / NAVFAC Washington (8/13-6/14).
Supervised the Phase I archaeological survey of approximately 66 acres in Charles County, Maryland and peer reviewing the technical report and cultural resource sections to an Environmental Assessment.

Phase I Archaeological Survey of the DoD Owned Rail System RoW from Marine Corps Air Station Cherry Point and the Marine Corps Base Camp Lejeune, North Carolina / NAVFAC Atlantic Division (9/12-3/14).
Contract Manager. Supervised a subcontractor conducting a Phase I archaeological survey of five miles of a 6.2-mile corridor in Carteret County, North Carolina.

Phase I Archaeological Survey of Approximately 218 Acres at Marine Corps Air Station Cherry Point, North Carolina / NAVFAC Atlantic Division (9/12-3/14).
Contract Manager. Supervised a subcontractor conducting a Phase I archaeological survey of 11 areas totaling 218 acres in Craven County, North Carolina.

Section 110 Compliance Support Project / U.S. Customs and Border Protection (10/11-12/13).
Consultant. Provided client coordination support and peer review of deliverables for a multi-disciplinary and multi-faceted project to assist CBP in complying with Sections 106 and 110 of the National Historic Preservation Act for its 361 facilities nationwide. In the first phase of the project, HDR collected 361 cultural

resource reports for CBP facilities nationwide and created a database that is cross-referenced with CBP's real property inventory to store this cultural resources data. In the second phase, HDR developed a program plan that identifies facilities and locations needing cultural resources survey and NRHP eligibility evaluations and a process for systematically conducting cultural resource inventories at CBP facilities. For the third phase, HDR developed standard operating procedures for the curation of archaeological artifacts from CBP facilities nationwide. In the fourth phase, HDR surveyed 45 CBP facilities nationwide for archaeological and historic architectural resources, completed survey reports and SHPO forms, and made NRHP eligibility evaluation recommendations for surveyed resources.

Phase I Archaeological Survey of North Smithfield Air National Guard Station / Air National Guard (5/11-12/13).
Task Manager. Supervised the Phase I archaeological survey of a 34-acre ANG installation in Providence County, Rhode Island.

Archaeological Survey and Condition Assessment of Fort Livingston (16JE49), Jefferson Parish, Louisiana / BP Exploration and Production, Inc. (5/12-8/13).
Project Manager. Supervised the survey and assessment of Fort Livingston (16JE49) in Jefferson Parish, Louisiana. Fort Livingston is Civil War era fort that is listed on the National Register of Historic Places. The project includes a structural engineering assessment, LiDAR mapping, geophysical survey, historical research, archaeological shovel testing, and an architectural treatment analysis by conservation specialists.

Archaeological Survey of Cat Island, Harrison County, Mississippi / BP Exploration and Production, Inc. (1/12-6/13).
Project Manager. Supervised the Phase I archaeological survey of 37.7 km (23.4 miles) of shoreline on Cat Island in Harrison County, Mississippi.

Phase I Archaeological Investigations at Friendship Hill National Historic Site, Point Marion, Pennsylvania / National Park Service (9/12-10/12).
Project Manager. Supervised the Phase I archaeological survey of two small parcels at a historic NPS site in Fayette County, Pennsylvania.

Geoarchaeological Survey of the Proposed Car Barn Training Center for the H Street/Benning Road Streetcar Project / District Department of Transportation (DDOT) (6/12-9/12).
Task Manager. Supervised the geoarchaeological survey of a two-acre parcel in Washington, DC.

Phase I Archaeological Survey for the Homer City Upgrade Project, Wetland Replacement Areas, Black Lick and Center Townships, Indiana County, Pennsylvania / Edison Mission Energy (9/12).
Task Manager. Supervised the Phase I archaeological survey of two one-acre parcels in Indiana County, Pennsylvania.

Environmental Specialty Services Master Services Agreement / Atlantic Richfield Company (4/11-7/12).
Contract Manager. Managed a contract to provide environmental services to an oil and gas client. The contract had multiple work releases totaling over $13M in value.

Defense Supply Center Richmond / Defense Logistics Agency Enterprise Support (DES) Richmond (5/12-7/12).
Principal Investigator and Field Director. Directed the Phase II evaluations of two prehistoric artifact scatters (44CF616 and 44CF648) and a historic site (44CF650) in Chesterfield County, Virginia.

Archaeological Monitoring for Road Construction and Landscaping in the Glasshouse Area of Colonial Parkway Jamestown Unit, Colonial National Historical Park / National Park Service (10/11-7/12).
Project Manager. Supervised the archaeological monitoring of construction activities near the Glasshouse and New Towne areas of Jamestown at Colonial National Historical Park.

Phase I Archaeological Survey of Charlotte International Airport Air National Guard Base and Stanly County Airport Air National Guard Station / Air National Guard (3/12-5/12).
Principal Investigator and Field Director. Directed the Phase I archaeological survey of a 99-acre ANG installation in Mecklenberg County and a 111-acre ANG installation in Stanly County, North Carolina.

Phase I Archaeological Survey of Luis Muñoz Marín International Airport Air National Guard Base / Air National Guard (8/11-10/11).
Principal Investigator and Field Director. Directed the Phase I archaeological survey of a 95-acre Air National Guard Base in Municipality Carolina, Puerto Rico.

Defense Supply Center Richmond / Defense Logistics Agency Enterprise Support (DES) Richmond (11/10-8/11).
Principal Investigator and Field Director. Directed the Phase II evaluations of a prehistoric lithic scatter (44CF615) and two historic sites (44CF647 and 44CF649) in Chesterfield County, Virginia.

Phase IA Cultural Resources Survey of the NEON Site in Ponce, Puerto Rico / National Ecological Observatory Network (3/11-4/11).
Principal Investigator and Field Director. Directed the Phase IA cultural resources survey of a 50-acre property in Ponce, Puerto Rico.

Anacostia Streetcar Project / District Department of Transportation (DDOT) (1/11-4/11).
Archaeology Consultant. Environmental Assessment.

Cultural Resources Survey of Memphis Air National Guard Base / Air National Guard (4/11).
Archaeology Consultant. Cultural Resources Survey of a 200-acre ANG installation in Shelby County, Tennessee. No archaeological survey was required due to disturbance.

Environmental Assessment Addressing Infrastructure Upgrades for the Replacement of Nimitz-Class Carriers with Ford-Class Carriers / U.S. Naval Facilities Engineering Command (NAVFAC), Atlantic Division (10/10-3/11).
Technical Section Lead. Prepared the cultural resources sections for an Environmental Assessment (EA).

Phase I Cultural Resources Survey of the NEON Site at the Blandy Experimental Farm, Clarke County, Virginia / National Ecological Observatory Network (1/11-2/11).
Principal Investigator and Field Director. Directed the Phase I cultural resources survey of a small property in Clarke County, Virginia.

Phase IA Cultural Resources Overview of the I-64 Regional Pipeline, Shelby and Franklin Counties, Kentucky / Louisville District of the United States Army Corps of Engineers (USACE) (9/10-12/10).
Principal Investigator and Technical Section Lead. Conducted a Phase IA cultural resources overview (archival research) and prepared the cultural resources sections for an EID for a 31 mile water pipeline in Shelby and Franklin Counties, Kentucky.

Lake Royal / Fairfax County Park Authority (1/08-4/08).
Field Director. Directed the Phase III data recovery of a Late Archaic/Early Woodland campsite (44FX3175) in Fairfax County, Virginia.

Bayou Ysclosky / New Orleans, Louisiana TRO of FEMA (10/07-12/07).
Lab analyst. Assisted in the analysis of ceramic sherds, processed flotation samples, sorted faunal and botanical remains, and analyzed the malacological (i.e., shell) remains recovered during the Phase I archaeological survey of a 6.2 acre residential tract in St. Bernard Parish, Louisiana.

Surratt Property / Private Developer (7/07-9/07).
Principal Investigator and Field Director. Directed the Phase I archaeological survey of three tracts of land totaling 36 acres in Prince George's County, Maryland.

Charles Walker Community Center Relocation Project / Biloxi, Mississippi Transitional Recovery Office (TRO) of the Federal Emergency Management Agency (FEMA) (6/07-7/07).
Principal Investigator and Field Director. Directed the Phase I cultural resources survey of seven acres to be used for the relocation of a community center damaged beyond repair during Hurricane Katrina in Harrison County, Mississippi.

Charles Murphy Elementary School Relocation Project / Biloxi, Mississippi TRO of FEMA (6/07-7/07).
Principal Investigator and Field Director. Directed the Phase I cultural resources survey of 30 acres to be used for the relocation of an elementary school damaged beyond repair during Hurricane Katrina in Hancock County, Mississippi.

United States Coast Guard Waterways Project / New Orleans, Louisiana TRO of FEMA (3/07-6/07).
Archaeological Monitor. Monitored the removal of Hurricane-Katrina related debris from the Mississippi River and other waterways and assessed the impact of this work to cultural resources in the area during a three-month FEMA deployment in southern Louisiana.

Harper McCaughan Elementary School Relocation Project / FEMA's Biloxi, Mississippi TRO (2/07-3/07).
Field Director. Co-directed the Phase I cultural resources survey of 86 acres for the relocation of an elementary school damaged beyond repair during Hurricane Katrina in Harrison County, Mississippi.

Harbor Station Parkway / Private Developer (11/06-1/07).
Principal Investigator and Field Director. Directed the Phase II archaeological evaluations of an Archaic Period lithic reduction site (44PW40) and a mid 18th to early 19th century midden with a minor prehistoric component (44PW1714) in Prince William County, Virginia.

Sunrise Development / Private Developer (10/06-11/06).
Principal Investigator and Field Director. Directed the Phase I archaeological survey of two acres for a residential development in Prince George's County, Maryland.

Westphalia Property / Private Developer (10/06).
Crew Chief. Participated in the Phase I archaeological survey of 543 acres for a residential development in Prince George's County, Maryland.

Inter-County Connector (ICC) Project / Maryland State Highway Administration (9/06-10/06).
Crew Chief. Participated in the Phase II evaluation of a multi-component Archaic Period and historic site for a highway project in Montgomery County, Maryland.

Land Conveyance and Transfer (C&T) Project / U.S. Department of Energy (4/04-6/06).
Field Director, Los Alamos National Laboratory. Supervised the excavation and artifact analysis and prepared the final reports for 15 Ancestral Pueblo field houses and an early 20th century homestead consisting of a cabin, horno, shed, corral, and reservoir in Los Alamos, New Mexico.

Land Conveyance and Transfer (C&T) Project / U.S. Department of Energy (10/02-1/04).
Field Technician, Los Alamos National Laboratory. Took part in the excavation and artifact analysis of a multi-component site consisting of a Classic Period field house and a Coalition Period room block and grid garden, a Coalition Period room block with nine rooms and multiple features, a late 19th to early 20th century Jicarilla Apache tipi ring site, and an early 20th century homestead consisting of a cabin with a cistern and root cellar (not part of the C&T Project) in Los Alamos, New Mexico.

Galindo Archaeological Project / Academic project funded by the National Science Foundation and the University of New Mexico (2000-2002).
Project Director. Directed an archaeological research project at the site of Galindo, located in the Moche Valley on the North Coast of Peru. Responsibilities included obtaining funding, obtaining permission to excavate from the *Instituto Nacional de Cultura* (INC) of the Peruvian government, planning, recruiting project personnel, directing field operations and laboratory analyses, performing data analyses, and writing the final field reports to be submitted to the INC. The principal goal of the project was to study the political power of Galindo rulers through an examination of civic/ceremonial monuments and a comparison of the architectural and artifactual remains of elite vs. commoner residences. The occupational history of the site was a secondary research topic.

Proyecto Arqueológico San José de Moro / Academic project run by the Pontificia Universidad Católica del Perú (1999).
Crew Chief. Directed a crew of three Peruvian workers and an undergraduate student in the excavation of a 10 by 5 meter area at the site of San José de Moro in the Jequetepeque Valley, Peru. Responsibilities included the preliminary analysis of all recovered artifacts, filling out forms and paperwork, drawing profiles and plan view maps, and the writing of a final field report for the area.

Moche Origins Project / Academic project (1998).
Archaeologist. Responsibilities included excavation, screening, cleaning and cataloging of recovered artifacts, filling out forms and paperwork, and drawing profiles and plan view maps.

Upper Basin Archaeological Project / Archaeological field school run by the University of Cincinnati (1995).
Student Archaeologist. Responsibilities included survey, excavation, screening, cleaning and cataloging of recovered artifacts, filling out forms and paperwork, and drawing profiles and plan view maps.

Professional Publications

2013 Social Differentiation as Indicated by Archaeological Data from Late Moche Households at Galindo, Moche Valley, Peru. *Andean Past* 11:139-167.

2011 *Proyecto Arqueológico / Archaeological Project*. Bilingual book published by PERU LNG. Comunica2, Lima, Peru. Texts by Greg Lockard, editing and Design by David Vexler and Kick Off & Asociados.

2009 A Design Analysis of Moche Fineline Sherds from the Archaeological Site of Galindo, Moche Valley, Peru. *Andean Past* 9:195–228.

2009 The Occupational History of Galindo, Moche Valley, Peru. *Latin American Antiquity* 20(2):279–302.

2008 La ocupación Chimú en Galindo: Un asentamiento rural en el corazón del Reino Chimor. *Revista Arqueológica SIAN* 19:2-17.

2008 A New View of Galindo: Results of the Galindo Archaeological Project. In *Arqueología Mochica: Nuevos Enfoques*, edited by L.J. Castillo, H. Bernier, G. Lockard, and J. Rucabado, pp. 275–294. Actas del Primer Congreso Internacional de Jóvenes Investigadores de la Cultura Mochica, Lima, 4 y 5 de agosto de 2004. Instituto Francés de Estudios Andinos y Fondo editorial de la Pontificia Universidad Católica del Perú, Lima, Peru.

2008 *Arqueología Mochica: Nuevos Enfoques*. Actas del Primer Congreso Internacional de Jóvenes Investigadores de la Cultura Mochica, Lima, 4 y 5 de agosto de 2004. Instituto Francés de Estudios Andinos y Fondo editorial de la Pontificia Universidad Católica del Perú, Lima, Peru. Editor with Luis Jaime Castillo Butters, Hélène Bernier, and Julio Rucabado Yong.

2008 Intrasite Spatial Analysis. In The Land Conveyance and Transfer Data Recovery Project: 7000 Years of Land Use on the Pajarito Plateau, Volume 3: Artifact and Sample Analyses, edited by B. Vierra, K. Schmidt, and B. Harmon, pp. 839-858. Cultural Resources Report No. 273. LA-UR-07-6205, Los Alamos National Laboratory, New Mexico. With Brian Harmon and Bradley Vierra.

2005 *Political Power and Economy at the Archaeological Site of Galindo, Moche Valley, Peru*. Ph.D. dissertation, University of New Mexico. University Microfilms International, Ann Arbor.

Professional Presentations

2015 The PERU LNG Project's Contribution to World Heritage. Paper presented to the Pre-Columbian Society at the Penn Museum.

2014 The PERU LNG Project's Contribution to World Heritage. Paper presented to the Pre-Columbian Society of Washington, DC.

2013 Lithic Technology during the Transition to Agriculture at the Defense Supply Center Richmond, Chesterfield County, Virginia. Paper presented at the 78th Annual Meeting of the Society for American Archaeology, Honolulu. Second author, with Brandon Gabler.

2012 Galindo and the Last of the Southern Moche. Paper presented to the Pre-Columbian Society of Washington, DC.

2012 The PERU LNG Project's Contribution to World Heritage. Paper presented at the 32nd Annual Conference of the International Association for Impact Assessment, Porto, Portugal.

2012 Public Archaeology in Peru: Lessons Learned from the PERU LNG Archaeological Project. Paper presented at the 77th Annual Meeting of the Society for American Archaeology, Memphis.

2011 The Last of the Southern Moche: Establishing Galindo's Place in Moche History through Radiocarbon Dates and Ceramic Design Analysis. Paper presented at

the roundtable Times of Change, Changes of Time: An Inquiry about Absolute and Relative Chronologies of the Moche from Northern Peru. Sponsored by Dumbarton Oaks, Washington, DC.

2011 The Last of the Moche in the Southern Moche Region, North Coast of Peru. Paper presented at the 76th Annual Meeting of the Society for American Archaeology, Sacramento.

2010 Diferenciación social en base a la evidencia doméstica durante la ocupación Moche Tardío en Galindo, valle de Moche, Perú. Paper presented at the conference Áreas Domésticas: Reflexiones, Avances y Perspectivas. Organized by the Grupo de Investigación de Arqueología Andina (GIAA), Lima, Peru.

2009 From the Highlands to the Coast: Preliminary Results of the PERU LNG Archaeological Project. Paper presented at the Society of Petroleum Engineers (SPE) International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Rio de Janeiro, Brazil. First author, with David Vexler. Won the Knowledge Sharing Award for the best Social Responsibility Program.

2009 From the Highlands to the Coast: Preliminary Results of the PERU LNG Archaeological Project. Paper presented at the 74th Annual Meeting of the Society for American Archaeology, Atlanta.

2008 La Ocupación Chimu en Galindo: Un asentamiento rural en el corazón del reino. Paper presented at the seminario Arqueología Peruana. Sponsored by the Universidad Nacional de San Cristobal de Huamanga. Ayacucho, Peru.

2008 La Ocupación Chimu en Galindo: Un asentamiento rural en el corazón del reino. Paper presented at the roundtable Reconsidering the Late Intermediate Period on the North Coast of Peru. Sponsored by Dumbarton Oaks and the Universidad Nacional de Trujillo. Trujillo, Peru.

2007 Classic Period Field Houses in Rendija Canyon, Pajarito Plateau, New Mexico. Paper presented at the 72nd Annual Meeting of the Society for American Archaeology, Austin.

2006 A Jungian Analysis of Moche Iconography. Paper presented at the 71st Annual Meeting of the Society for American Archaeology, San Juan, Puerto Rico.

2005 Classic Period Field Houses in Rendija Canyon, Pajarito Plateau. Paper presented at the 78th Pecos Conference, Los Alamos, New Mexico.

2005 The Chimu Occupation of Galindo, Moche Valley, Peru. Paper presented at the 70th Annual Meeting of the Society for American Archaeology, Salt Lake City.

2005 Grid Gardens and Field houses: Agricultural Intensification on the Pajarito Plateau, Northern New Mexico. Poster presented at the 78th Pecos Conference, Los Alamos, New Mexico. With J. Nisengard and K. Schmidt.

2005 Grid Gardens and Field houses: Agricultural Intensification on the Pajarito Plateau, Northern New Mexico. Poster presented at the 70th Annual Meeting of the Society for American Archaeology, Salt Lake City. With J. Nisengard and K. Schmidt.

2004 A New View of Galindo: Results of the Galindo Archaeological Project. Paper presented at the Primera Conferencia Internacional de Jóvenes Investigadores sobre la Cultura Mochica. Conference sponsored by Dumbarton Oaks, the Pontificia Universidad Católica del Perú and the Museo Arqueológico Rafael Larco Herrera.

2004 La Huaca de las Abejas, Galindo. Poster presented at the Primera Conferencia Internacional de Jóvenes Investigadores sobre la Cultura Mochica. Conference sponsored by Dumbarton Oaks, the Pontificia Universidad Católica del Perú and the Museo Arqueológico Rafael Larco Herrera.

2003 Late Moche Platform Mound Architecture at the Site of Galindo, North Coast, Peru. Paper presented at the 68th Annual Meeting of the Society for American Archaeology, Milwaukee.

2003 Ceramics and the Late Moche-Chimu Transition at the Site of Galindo, North Coast, Peru. Poster presented at the 68th Annual Meeting of the Society for American Archaeology, Milwaukee. With K. Schleher.

2002 Platform Mounds and the Occupational History of the Archaeological Site of Galindo, North Coast, Peru. Paper presented at the 6th Annual Anthropology Graduate Student Union Graduate Student Spring Symposium.

2002 A Design Analysis of Moche Fineline Ceramic Sherds from the Site of Galindo, Moche Valley, Peru. Poster presented at the 66th Annual Meeting of the Society for American Archaeology, New Orleans.

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Kamal Govender

Principal Consultant
Impact Assessment and Planning (IAP)



Kamal Govender is a Principal Consultant within ERM's Impact Assessment and Planning team based in ERM's Houston office.

Kamal has 13 years of experience in environmental management, specialising in Complex Project Management, Environmental, Social and Health Impact Assessments (ESHIAs), Environmental and Social Management Plans (ESMPs), Public Participation Processes and various other activities associated with Integrated Environmental Management. Over the last seven years, Kamal has worked primarily in Africa, but also in Europe and the USA. Kamal's international experience has allowed him to deliver projects that meet local expectations and international good practice.

Kamal's focus is Capital Project support in the oil and gas, mining and energy sectors. He has managed large multi-disciplinary teams and delivered ESHIAs and ESMPs to national and international standards. Kamal has worked on projects under the requirements if the IFC Performance Standards, Equator Principles and World Bank policies. Working on Capital Projects, Kamal is able to interface with the projects' technical team easily, and ensure optimum integration of environmental and social risks with safety, technical and financial parameters.

Kamal's strengths lie in understanding clients' needs, in understanding key process and non-technical risks, and in managing people in order to deliver large, complex projects that meet expectations. He employs his skill set at all stages of a projects lifecycle from pre-feasibility (input into design, site selection, environmental and social screening and sensitivity analysis) to feasibility (managing multi-disciplinary ESHIAs and regulatory compliance, public consultation, managing non-technical risks, input into design) and to construction and operation (ongoing studies, managing performance and assurance teams, assisting with handing over environmental and social management from the project's feasibility team to operations team). The following experience listing provides examples of key projects demonstrating the above competencies.

Fields of Competence

- Capital Project support
- Project management of ESHIAs for large, complex projects
- Environmental Management Plans (EMPs)
- Public Participation

Professional Affiliations & Registrations

- Member, South African affiliate of International Association for Impact Assessment (IAIAsa)

Education

- MSc (Environmental and Geographical Science), University of Cape Town, South Africa, 2004
- BSc (Hons) (Environmental and Geographical Science), University of Cape Town, South Africa, 1999
- BSc (Environmental and Geographical Science), University of Cape Town, South Africa, 1998

Languages

- English
- Afrikaans

Key Industry Sectors

- Oil and Gas
- Mining
- Energy

Key Projects

EIA for a 3D Seismic Survey in Gabon
October 2014 to date
Project Manager
Kamal is managing the EIA process to meet Gabon standards and align with international standards for Noble Energy's offshore 3D seismic survey. The Project is located in deep water but in a region where there is growing focus on marine ecology and the need for adequate protection of endangered marine wildlife.

Pre-FID Contractor Interface support to Anadarko LNG Project
July 2014 to date
Project Manager
Kamal is responsible for liaising with the FEED/ Pre-FID contractors with respect to the implementation of the environmental and social mitigation measures in the EIA. Kamal also reviewed the final bid for on the contractors from an environmental and social perspective.

IFC Performance Standard Gap Review for Anadarko LNG Project
July 2014 to date
Project Manager
Kamal is responsible for leading a team to analyse the LNG Project with a view to identify gaps against the IFC Performance Standards and to develop actions plans to close gaps.

EIA for Maersk Oil Angola, Chissonga Project
May 2014 to date
Project Manager
Kamal took over the management of the EIA and public consultation for the Project. This entailed, liaising with specialists and the in-country partner, reviewing and finalising deliverables and managing three secondees to Maersk. The project comprises offshore drilling, a Tension Leg Well Platform, an FPSO and a gas export pipeline.

Equator Principles/ IFC Performance Standard Gap Assessment for Cobalt
July 2014
Project Manager
Undertook an Equator Principles and IFC Performance Standards Gap Assessment for Cobalt's Cameia Project in Angola. The Gap Assessment was to prepare Cobalt for engagement with an Equator Principle Financial Institution.

IFC Performance Standard Gap Assessment of Gas to Liquids Project for G2X
July 2014 to October 2014
Project Manager
Undertook an Equator Principles Gap Assessment of the project in order to assist the client prepare for discussions with an Equator Principle Financial Institution.

Equator Principles/ IFC Performance Standard Training for Cobalt
July 2014
Project Manager
Developed and provided training to Cobalt personnel for their Cameia Project in Angola.

Secondment to Anadarko
2013 to 2014
Project Manager
Kamal was seconded to Anadarko during the final months of the ESHIA. Roles and responsibilities were broad ranging but focussed on delivery of the ESHIA report, interface with the project's technical team, input into non-technical risk assessment, managing post-ESHIA studies, and interfacing with the project's EHS team. The secondment was requested by the client to ensure that Kamal's history on the project and insight into key issues was not lost after the ESHIA.

ESHIA for the proposed Anadarko LNG Facility, Offshore wellfield and subsea pipeline, Mozambique, 2011 to 2013
Project Manager
The project comprises an offshore wellfield, subsea infrastructure, onshore LNG facility and all associated infrastructure (construction camp, housing, water treatment, sewage treatment, LNG jetties and a materials offloading facility). The ESHIA meets Mozambican standards and is aligned with the requirements of the IFC Performance Standards. The core project management team comprised five people. ERM managed a multi-disciplinary team of 17 specialist studies. The ESHIA was undertaken in parallel to the FEED process and resulted in several feedback loops to ensure adequate integration – the ESHIA needed to respond to changes in project design and to influence project design. Moreover, workshops with the technical team and EPC contractors were scheduled at key points in the schedule to allow for course correction and "sense-checking" of the ESHIA documentation. .

Site Selection and Sensitivity Analysis for the proposed Anadarko LNG Facility, Mozambique, 2011
Project Manager
ERM was appointed to undertake a site selection process to assist Anadarko with identifying the most appropriate site (from an integrated environmental, social and technical perspective) for the onshore facilities. The process entailed managing a team of key specialists to undertake a baseline sensitivity analysis and integrate findings with the project's technical and financial analyses. The environmental and social inputs were important determinants in the selection of the optimum site for the LNG Facility.

EPDA for Riversdale Zambeze Mine Project, Mozambique, 2011.
Project Manager
Appointed to undertake the EPDA (Scoping) Phase for the proposed coal coal mine and associated infrastructure in Tete Province, Mozambique. The EPDA Phase entailed initial scoping site visit, wet season specialist studies, the compilation of wet season baseline reports and the compilation of the EPDA Report is to meet the Mozambican regulatory requirements as well as best practice as defined by the IFC Performance Standards.

ESIA for Riversdale Coal Barging Project, Mozambique, 2010 to 2011.
Project Manager
Appointed to undertake an ESIA for the proposed coal barging project on the Zambezi River. The project comprised a load out point on the river near, Tete, dredging various sections of the Zambezi River, and transhipment of coal at the mouth of the Zambezi River. ERM managed a team which included nine specialist studies. Some of the key challenges for the ESIA were the size of the study area (approximately 540km of river), the remoteness of the study area and a comprehensive stakeholder engagement process which needed to manage the expectations of a range of stakeholders from local level to national level. The ESIA met the Mozambican regulatory requirements as well as best practice as defined by the IFC Performance Standards..

Riversdale Coal Barging Project, Phase 1, Mozambique, 2010
Project Manager
Appointed to undertake a baseline sensitivity analysis of the proposed Zambezi River coal barging project with a view to identifying baseline sensitivities and potential fatal flaws. This process allowed ERM and Riversdale to tailor an ESIA process to address the identified sensitivities and to identify key specialist studies.

Mphanda Nkuwa Hydropower Scheme, Mozambique, 2010 to 2011
Project Manager
Appointed to act as advisors to the EIA consultants undertaking the EIA for the proposed hydropower scheme on the Zambezi River. The role entails close interaction with the EIA consultants to ensure that the process followed and outcomes accord with the requirements of the IFC Performance Standards and the Mozambican regulatory EIA requirements.

ESIA for Riversdale Transhipment Project in Beira, Mozambique, 2010 to 2011.
Project Manager
Appointed to undertake an ESIA for the proposed transhipment project in Beira. The ESIA is to meet the Mozambican regulatory requirements as well as best practice as defined by the IFC Performance Standards. The comprehensive ESIA was downgraded to a simplified EIA process following engagement with the provincial environmental authority. The simplified EIA process entailed stakeholder engagement with local, provincial and national stakeholders as well as the development of an EIA Report and EMP.

Review of EIA Report for a Mine, South Africa 2010
Project Manager
Reviewed the EIA Report on behalf of the mine with a view to identifying gaps and amendments to ensure compliance with South African regulations.

Review of Kamoto Copper Mine, DRC 2010
Task Manager
Reviewed the Mine EIA and EMP to IFC Performance Standards on behalf of an International Finance Institution.

IFC Gap Analysis and Scoping Exercise, 2010
Project Manager
Appointed to undertake an audit of a resort in the Seychelles with a view to identifying gaps between the resort's operations and the requirements if the IFC Performance Standards and EHS Guidelines. Part of the scope of work was also to develop an Action Plan to address the identified gaps. An IFC representative attended the site visit and interviews and reviewed aspects of the report.

Sasol Mafutha Project, 2009 to 2010
Project Manager
The project entails the construction and operation of a coal to liquid plant, coal mine, town and associated infrastructure in Limpopo Province, South Africa. Appointed to undertake the EIA for the Services Corridor as part of Project Mafutha. The project was undertaken to the World Bank Equator Principles.

Bannerman Uranium Mine, 2009 to 2010
Task Manager
The project entails the construction and operation of a new uranium mine in Namibia. Appointed to review the Namibian EIA, to manage the radiation study and the occupational health and safety study and to compile an ESHIA to meet international good practice, particularly the requirements of the IFC Performance Standards.

Sasol Mafutha Environmental Baseline Study, 2008 to 2009
Project Manager
Project Mafutha comprises a coal-to-liquid plant, a coal mine a town, water supply infrastructure and associated activities. As part of the pre-feasibility studies for Project Mafutha, ERM was appointed to undertake the Environmental Baseline Assessment. The project required delicate managing, in light of stakeholder expectations, Sasol's on going property purchasing negotiations, Sasol's prospecting activities, and a related basic assessment for road construction and widening (also undertaken by ERM). Managing a multi-disciplinary team of specialists (15 specialist studies), managing a desktop and detailed assessment and managing the public participation aspect required integration of different expertise and project components. The timeframe was short (12 months) and required innovative solutions to run processes in parallel to deliver on time.

Review of EIA for Tobacco Factory in Nigeria, 2009
Project Manager
Appointed to undertake a review of the EIA process and report for the tobacco factory. The EIA process and report was audited against the Nigerian regulatory EIA requirements. Recommendations were made to address gaps.

Review of EIA for Cement Factory in Nigeria, 2009
Project Manager
Appointed to undertake a detailed review of the project to IFC Performance Standards for the extension to the Larfarge WAPCO cement factory in Nigeria.

IFC Performance Appraisal, 2008
Project Manager
Appointed undertake an appraisal of several retail sites to determine degree of compliance with IFC Auditable Criteria.

Proposed Railway Link and Services Corridor in Botswana, 2007 to 2008
Project Manager
The project entailed a railway line, railway turning triangle, service yard, new road, and water supply pipelines for the Mmamabula Energy Project. The project was complex, requiring flexibility and innovation in addressing project changes, and a vociferous, organized stakeholder group of objectors.

Mmamabula Energy Project: ESHIA for Proposed coal mine and power station in Botswana, 2006 to 2009
Project Manager
The Mmamabula Energy Project involved the development of a coal mine, power station and associated infrastructure (residential area, roads, railway lines, transmission lines, etc) in southern Botswana. ERM was appointed to undertake the Bankable Feasibility Study and the ESHIA for the project to meet the IFC Performance Standards and EHS Guidelines.

Proposed coal-fired power station near Witbank, Eskom, 2006
Assistant Project Manager
Appointed by Eskom to undertake a site screening process and EIA for a proposed coal-fired power station near Witbank in Mpumalanga. Responsibilities include project management, financial management, managing the team of specialists, report writing and managing the Public Participation Process. This complex project entailed liaising closely with Eskom's technical team, identifying and proposing solutions to potential risks, and integrating a range of specialist studies into a coherent whole. The project was delivered on time to Eskom's standards.

Mossel Bay OCGT EIA: Additional units, Eskom, 2006
Project Manager
Appointed by Eskom to undertake EIA process in terms of NEMA for three additional units at the Mossel Bay OCGT power plant. Responsibilities include project management, financial management, managing the team of specialists, report writing and managing the Public Participation Process.

PetroSA Emergency Generation, Eskom, 2006
Assistant Project Manager
Assisted with EIA process for an emergency electricity generation units within the PetroSA gas-to-liquid facility in Mossel Bay.

Mossel Bay OCGT EIA, Eskom, 2005
Assistant Project Manager
Appointed by Eskom to undertake an EIA for the Open Cycle Gas Turbine power station adjacent to the PetroSA facility in Mossel Bay. Responsibilities included project and financial management (including managing the sub-consultant responsible for the EIA process) and undertaking the Public Participation Process.

Other Relevant Experience (EIAs, Basic Assessments, EMPs, etc)

Proposed decommissioning of coke oven and blast furnace gas holders at ArcelorMittal, Vanderbijlpark Works, 2008
Project Manager
Appointed to undertake a Basic Assessment process for the decommissioning of a coke oven and old blast furnace gas holder.

EIA for underground storage tank at Mafube Colliery, 2008
Project Manager
Appointed to undertake a Scoping/ EIA process for a proposed underground storage tank at Mafube Colliery.

Proposed aboveground storage facility and baghouse at ArcelorMittal, Vanderbijlpark Works, 2008
Project Manager
Appointed to undertake a Basic Assessment process for an aboveground storage facility and baghouse emission abatement technology for ArcelorMittal's Sinter Plant.

Basic Assessment for Automotive Galvanising Line, Mittal Steel, 2007.
Project Manager
Undertook a Basic Assessment process for proposed Automotive Galvanising Line in the Mittal Steel complex, Vanderbijlpark.

Basic Assessment of aboveground storage tanks, Mafube Colliery, 2007.
Project Manager
Undertook a Basic Assessment process for Anglo Mafube Colliery for a proposed aboveground storage tank facility.

Third Party Audit, Kriel Colliery, 2007.
Project Manager
Undertook a third party audit of Kriel Colliery's Performance Assessment Report in terms of the Mineral and Petroleum Resources Development Act.

Metsi Chem iKapa Section 24G application, 2006.
Project Manager
Appointed by Metsi Chem iKapa to undertake the environmental process required by S24G of NEMA (Amendment Act) for a chemical storage facility. Solely responsible for liaison with the client, liaison with the authorities, the Public Participation and the reporting.

MR108 Upgrade, Gordons Bay, 2005
Task Manager
Appointed to compile an Opportunities and Constraints report for the widening of the MR108 from the N2 to Gordon's Bay.

Chapman's Peak Toll Plaza and Realignment, Entabeni, 2003
Project Consultant
Appointed by Entabeni to undertake the environmental process associated with the Toll plaza and realignment of a section of road on Chapman's Peak Drive. Assisting with the environmental requirements, including a public participation and environmental impact assessment process.

Pniel Wastewater Treatment Works Upgrade, Pniel, 2003
Project Consultant
Facilitated compliance by the Boland District Municipality with the environmental requirements for proposed extensions to the Pniel Wastewater Treatment Works in Pniel. Completed and submitted the application form and screening checklist to the Environmental Authority.

Athlone Wastewater Treatment Works Refurbishments, Cape Town, 2000
Project Consultant
Appointed by the City of Cape Towns Wastewater Department to facilitate compliance with the environmental requirements for refurbishment activities at the Athlone Wastewater Treatment Works, which included a public process and the completion and submission of project description forms in terms of the Bulk Wastewater EIA Compliance Procedure.

Upgrading of Trunk Road 19, Eastern Cape, 2001 – 2002
Project Consultant
Appointed by the Eastern Cape Department of Roads and Public Works, and later the South African National

Roads Agency, to provide various environmental services for the proposed upgrading of a 64 km stretch of trunk road 19 in the Eastern Cape. This entailed extensive liaison with the environmental authorities and undertaking a scoping process in terms of the Environment Conservation Act.

Velddrif Jetties, 2001
Project Consultant
Assisted with the compilation of a Motivation for Exemption, on behalf of the Bergriver Municipality, for the upgrade of a jetty in Velddrif.

Engelhard, 2000 – 2001
Project Consultant
Compiled a Motivation for Exemption Report, on behalf of Engelhard, for the relocation and expansion of a catalytic converter manufacturing plant in Port Elizabeth.

Blaauwberg City East Bulk Infrastructure, Table View, 2000
Project Consultant
Assisted with the compilation of a Scoping Report on behalf of Blaauwberg Municipality for proposed bulk water and wastewater infrastructure to service the Blaauwberg City East development north of Table View.

Charcoal Pilot Project, Villiersdorp, 2000
Project Consultant
Assisted with the compilation of a Scoping Report on behalf of the Working for Water Programme, for a proposed charcoal production project near Villiersdorp.

Milnerton Golf Course Treated Effluent Pipeline, Table View, 2000
Project Consultant
Assisted with the environmental requirements for the construction of a treated effluent pipeline across the Milnerton Lagoon, within the Rietvlei Protected Natural Environment, including the compilation of a Scoping Report in terms of the Environment Conservation Act.

Resealing of TR1/2, Uniondale, 2005
Project Consultant
Appointed to develop an EMP, develop and present an education course and monitor implementation of the EMP for the resealing of Trunk Road 1, Section 2, near Uniondale.

Mossel River Dam 2003
Project Consultant
Appointed by Overstrand Municipality to develop an EMP for the refurbishment of the outlet works of the dam as well as liaise with the Fernkloof Management Committee and Fernkloof Nature Reserve.

DEAT IEM Guidelines 2003
Project Consultant
Appointed by CSIR to develop an EMP Guideline Document as part of the DEAT IEM Information Series of guideline documents. Responsible for compiling the guideline

Carinus Scour Protection, Velddirf 2003
Project Consultant
Appointed by the Provincial Administration of the Western Cape to monitor the implementation of the Environmental Management Plan for the scour protection measures to the Carinus Bridge. The Environmental Management Plan included detailed revegetation measures.

Noordhoek Social Housing Development, Velddrif, 2003
Project Consultant
Appointed by the Berg River Municipality to compile an Environmental Management Plan for the construction of a social housing development in Velddrif. This appointment included assisting with monitoring the implementation of the Environmental Management Plan during construction.

Coega: Main Road 435, Port Elizabeth, 2003
Project Consultant
Compiled the EMP compliance checklist for the rehabilitation and upgrading of Main Road 435 in the Coega Development, Port Elizabeth

Karin K. Nunan



Ms. Karin Nunan is a Principal Consultant and senior social specialist within ERM based in Washington DC. She has over 23 years of experience in the fields of stakeholder engagement, human rights, social performance, and government affairs.

Over the past several decade, Karin has been working in the extractives sector providing project management and technical support on social performance, with a focus on social impact assessment and due diligence; stakeholder engagement planning and implementation; OHS and labor and working conditions; physical and economic resettlement; human rights; and local content. She is also focused on E&S lender compliance for international financing and has acted as both the lender or client representative for over 75 international projects. Her field work has ranged from running stakeholder engagement for a $4b oilfield operation on the ground in Iraq to developing stakeholder engagement plans for the South Stream Pipeline project in Russia, Turkey and Bulgaria.

Prior to consulting, Karin was in the oil and gas sector where she spent several years in the social performance departments within the HSEE/P&GA functions for Chevron and ExxonMobil. She worked on socioeconomic initiatives within development and production projects, primarily in the Middle East and Europe. During this time she developed and implemented stakeholder engagement plans; social performance policies, standards and audit procedures; created KPIs; and ensured projects complied with all social corporate guidelines and international best practice. She worked closely with the legal, procurement, human resources, and public affairs functions on issues pertaining to resettlement, local content, community investment and human rights implementation and compliance.

Karin has also worked as a consultant providing geopolitical analysis, security and conflict assessments and social risk expertise to major corporations operating in hostile and challenging business environments – including developing corporate policies and engagement planning for the Voluntary Principles and compliance with the Global Compact.

A former US diplomat, Karin has worked in over 100 countries. She was the Human Rights officer in two of her overseas posts and contributed to the U.S. State Department Country Reports on Human Rights Practices. She has authored several technical papers on the positive social impacts of extractives companies in disadvantaged communities.

Fields of Competence

- Social Impact Assessment and Due Diligence
- Stakeholder Engagement
- Resettlement
- Human Rights
- Local Content and Supplier Development
- Community Health, Safety and Security
- Labor and Working Conditions
- Community Investment Planning

Key Industry Sectors

- Oil and Gas
- Mining

Education

- MSc, International Relations and Conflict Resolution, AMU, 2012
- MBA, International Business, UMass, 2000
- BSc, Civil Engineering, Norwich University, 1994

Professional Affiliations & Registrations

- Society of Petroleum Engineers
- Chevron Qualified Environmental Facilitator (QEF)
- US Institute for Peace Certification in Conflict Analysis, 2010
- US Government Human Rights Officer Training and Trafficking in Persons training 2002 - 2007

Key Recent Projects

Socioeconomics Corporate Policy, Plans and Procedures, O&G Major, 2014 – 2016
Development of corporate policies, plans and procedures, including tools and guidance notes, for various socioeconomic aspects, including local content development, indigenous people, stakeholder engagement, social investment, resettlement and human rights. Also working at project level to create fit-for-purpose asset plans including community feedback mechanisms.

Social Impact Assessment Due Diligence, Israel, O&G Mid-level, 2014 – 2016
Led social impact assessment due diligence for all offshore and onshore existing and planned operations. Conducted gap assessment of oil and gas company's principles and policies on social issues including labour management, stakeholder engagement, supply chain and human rights against international standards. Made recommendations to align policies more closely with international standards and reduce non-technical risks of operations.

Capacity Building Workshop – Social Challenges in Infrastructure Projects, IFC, Pakistan, 2016
Designed, organized and facilitated a capacity building workshop in partnership with IFC for their Pakistan-based Infrastructure clients. The focus of the workshop was developing solutions to the challenges faced by companies when trying to implement IFC social standards in a difficult regulatory and operating environment – including developing and implementing sound stakeholder engagement plans.

Environmental and Social Due Diligence, Confidential Client, Mexico, 2016
Project manager for E&S Due Diligence on $2b transaction of oil related assets in Mexico; developed stakeholder engagement plans for end-client; completed social due diligence and assessment to IFC PS, World Bank EHS and Equator Principle standards. Developed ESAP and conducted end-client capacity building training in E&S international standards.

Worker Welfare Assessments, Kuwait, IFI, 2016
On behalf of an Equator Principle Bank, developed the scopes of work and audit protocol for a 60,000 worker O&G development project. Work included serving as liaison with national Labor Relations Board, unions and international developers. Site issues include infringement on local fishing populations, traffic and noise concerns with local residents, and socioeconomic impacts as a result of worker livelihoods.

OHS Due Diligence, Port and Industrial Zone, Haiti, CIFI, 2016
Conducted field assessment and due diligence for a port and industrial park in Haiti facing challenges with implementing OHS and community health, safeguards and security measures throughout their supply chain. Provided recommendations on how the developer and financing team could align to PS2 existing systems with a focus on direct workers, contracted workers, workers engaged by third parties, and supply chain workers.

Social Management System Development and ESDD, World Bank, West Africa, 2015
Conducted field assessments in Mali, Senegal, Cote d'Ivoire, and Benin to assist tourism company in completing social investment and stakeholder engagement mapping for existing and new hotel facilities. Worked with senior management to build social management system and ESAP components of the ESDD to be compliant with World Bank standards. Completed gap analysis to be used at the site level to build capacity and training.

Stakeholder Engagement, SIA, RAP, Nicaragua Canal, HKND, 2014
Senior reviewer of the social impact assessment for a major infrastructure development crossing the country of Nicaragua. Assessed a suite of social and health impacts related to resettlement, labour, human rights, influx, conflict, health, natural resource, livelihoods and project security linked to development and operations. Developed management and monitoring plans pertaining to influx, local content, resettlement, stakeholder engagement, and indigenous people.

Masela Offshore LNG Facility, Indonesia, INPEX, 2013 - 2014
Provided social performance expertise to an ESHIA submission for an offshore LNG facility in Indonesia with onshore facilities being developed by an O&G major. Provided input into the stakeholder engagement plan, resettlement action plan, feasibility study, scoping report, ESMP framework, health impact due diligence, human

rights due diligence and social impact baseline. Developed human rights and supply chain auditing procedures, as well as RAP best practice procedures.

South Stream Pipeline Project, Russia, Bulgaria, Turkey, SSTTBV, 2013 - 2014
Technical director for three lender ESHIAs and three national ESIAs for all three countries. Worked alongside the South Stream ESIA teams to lead the stakeholder engagement efforts (from identification to disclosure through to monitoring) for Bulgaria, Russia and Turkey. Educated the client's key departments, including HSE, Procurement, HR and Security, on the importance of adhering to international disclosure and grievance mechanism standards as outlined by WB, IFC and other IOs. Developed Project-wide standards and a stakeholder engagement tool kit which can be applied on a regular basis to ensure constant improvement and continuous adherence.

RAP framework for Palm Oil Plantation and Processing Project, Cameroon, 2013
Developed Resettlement Action Plan Framework and Influx Management Plan for Palm Oil Plantation and Processing Facility in Cameroon. Framework and plan included linkages to other ESMS components, as well as baseline data collection and impact assessment for social aspects pertaining to the facility and local communities.

Oil Export Social Feasibility Study, E. Africa, O&G Major, 2012
Provided the social expertise to an oil and gas major investigating potential locations along the Tanzania and Kenyan coastline for an oil export terminal and SPM. This involved identifying significant positive and negative social constraints, including the identification of stakeholders, IPs, resettlement alternatives along the coastlines and likely mitigation measures which contributed to the site selection, ESIA, and RAP.

Labor and Industrial Relations benchmarking study, PNG, 2012
Benchmarking of Labour, IR and Working Conditions against best practice and national regulations for an LNG Project. Included development of management plans related to labour conditions and local content. Assessed monitoring, reporting and evaluation of OHS-relation concerns to ensure continual compliance and assurance, as well as use of recommended systems across other global development projects.

Community and Labor Working Conditions Assessment, BP Angola, 2012
As part of the SIA for a Subsea Systems Plant for BP, undertook a community and labour and working conditions assessment for onshore and offshore components. The outcome of the assessment was to consolidate mitigation measures and recommendations into the ESAP in consensus with the company's management that highlights: responsibilities for implementation of capacity, a timeframe for implementation and the process for monitoring outcomes.

ESIA and RAP for power facility, Cameroon, 2013
Drafted SIA to IFC PS12 standards, included development of a stand-alone RAP to relocate families in rural communities along 200-mile long transmission line right of way. Developed mitigations and community investment programs focused on agribusiness, microfinance in the small scale service sector, and local content.

ESIA and RAP for Tasiast Gold Mine, Mauritania, 2013
Part of multidisciplinary team preparing ESIAs for a phased expansion of a gold mine. Led social team in preparing the community sensitization toolkit and supporting literature for use in early community consultation. Also developed key components of the RAP and led later phases of resettlement monitoring.

Oil Refinery Expansion, Venezuela, PDVSA, 2014
Responsible for conducting E&S due diligence focused on Social Performance for the expansion to an existing oil refinery in Venezuela with significant social challenges. Project included ESIA due diligence, SIA management plan, Human Rights Impact Assessment and management recommendations, Human Rights due diligence workshop and supply chain audits.

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Peyun Kok

Associate Scientist, Impact Assessment and Planning



Peyun Kok is a Community Health and Social Specialist with ERM's Impact Assessment & Planning practice in Houston, TX. With training in Biology, Environmental Studies and Health Policy Research, Peyun specializes in assessing interconnected health, social and environmental impacts of development projects and helping clients mitigate associated risks. Since joining ERM she has conducted social and health baseline studies, impact assessments and due diligence assessments for a diverse range of projects in the United States, South and Central America, and Africa.

Prior to joining ERM, Peyun conducted situational assessments, baseline studies and impact assessments of communities affected by gold and bauxite mining activity in Suriname, including extensive field research at mining camps in the country's interior. She also worked on developing tools, policy and practices to assess the community health and safety impacts of urban and suburban development projects in Canada.

Peyun has worked for Health Canada, the Region of Peel's Public Health department, the Pan-American Health Organization Suriname and the Commissie Ordening Goudsector (Commission to Regulate the Gold Sector - Suriname).

Fields of Competence

- Social and health baseline studies
- Environmental, social and health impact assessment
- Environmental and social due diligence assessments
- Quantitative, qualitative and geospatial analysis
- Development of research frameworks and methodologies
- Stakeholder analysis and engagement
- Development of social investment strategies
- Policy analysis and development
- Public health program planning and evaluation

Education

- Master in Environmental Studies (Urban and Regional Planning). York University, Canada, 2009
- Graduate Diploma in Health Services and Policy Research. Ontario Training Centre in Health Services and Policy Research, Canada, 2009
- Hon B.Sc. Biology, University of Toronto, Canada, 2005.

Languages

- English (native)
- French (proficient)
- Spanish (intermediate)

Key Industry Sectors

- Oil & Gas
- Mining
- Chemical
- Transportation Infrastructure
- Government
- Public Health

Countries Worked In

- Canada
- Suriname
- Guyana
- Taiwan
- United States

Key Projects

Biofuels Site Selection Study and ESHIA, Confidential Oil and Gas Supermajor, United States, 2014-2016
ERM has provided support to a confidential O&G supermajor since 2014 in planning for the development of a proposed biofuel facility in the U.S. ERM has conducted site selection, permitting strategy, impact assessment and stakeholder engagement support for the Project as it has progressed through early stages of planning and decision-making.

ESHIA for chemical facility on the U.S. Gulf Coast, Confidential Client, Texas, 2016
ERM is currently conducting an ESHIA effort for development of a new chemical manufacturing facility and associated waste disposal wells in a coastal Texas location.

Climate Change Adaptation in Mozambique's Health Sector, World Bank, 2016
ERM was engaged to assist the Word Bank and Mozambique's Ministry of Health (MISAU) in furthering understanding on the linkages between climate change and health in the country, and in developing protocols to standardize and streamline emergency preparedness and response to climate change events among the country's provinces and districts. The analysis included GIS mapping and regression analysis to understand correlations among different climate factors and health outcomes at the district level in Mozambique.

FERC Public Participation Planning and Socioeconomic Studies for LNG Export Terminals on the U.S. Gulf Coast, Confidential Clients, Louisiana, 2015-2016
ERM has been assisting several LNG clients in coastal Louisiana with regulatory-driven stakeholder engagement and environmental review requirements, including development of Public Participation Plans and socioeconomic studies (FERC Resource Report 5).

Environmental, Social and Health Impact Assessments, Offshore Exploration Campaigns in the Mexican Gulf of Mexico, Various Geophysical Data Companies, 2015
ERM assisted a number of geophysical data companies in conducting voluntary and mandatory impact assessments for deepwater offshore seismic, multibeam and coring activities in the Gulf of Mexico. The assessments were conducted in the context of continued regulatory uncertainty and change given Mexico's ongoing Energy Reform. A major aspect of these projects was therefore continual communication with regulatory authorities to help clients successfully navigate new and changing requirements.

Mexico Country Entry Non-Technical Risk Screening, Confidential Oil and Gas Supermajor, United States, 2014-2015
In light of Mexico's Energy Reform, a confidential client wished to understand the sources of non-technical risk associated with onshore oil and gas development. NTR sources examined included personal security, corruption, organized crime, environmental liability.

Nicaragua Grand Canal and Development Project ESHIA, Hong Kong Nicaragua Canal Development Company, Nicaragua, 2014-2015
This ESHIA involved extensive research planning to ensure collection and integration of relevant primary and secondary information sources to form a picture of the social and health conditions in diverse communities along a 270-km linear infrastructure project. Tasks included stakeholder engagement planning, research planning, development of data collection tools, data analysis, social baseline development and assessment of social impacts, including cumulative impacts accounting for future climate change.

Strategic Marcellus Shale ESHIA, Confidential Oil and Gas Supermajor, United States, 2014-2015
This ESHIA was conducted to characterize baseline conditions in a 26-county area in the Marcellus Shale, as well as providing a preliminary understanding of the likely impacts of the client's potential future development in the region. Tasks included development of a community health baseline, as well as assessment of likely health impacts.

Country Entry Strategy Stakeholder Analysis Report, Confidential Oil and Gas Supermajor, Angola, 2014
This project involved the compilation of a detailed stakeholder registry and report providing characterization and analysis of stakeholder influence, interest, stance and relationships to support an oil and gas major's early entry strategy to an African country. .

Environmental, Social, Health & Safety Performance Review of a Power Facility, Confidential Power Company, Peru, 2014
This project involved an audit of the social, environmental and health & safety aspects associated with the final stage of construction of a power facility in Peru against the Equator Principles and IFC Performance Standards. Tasks included review of documentation provided by the project proponent and its contractors, data from interviews with onsite personnel, and observations from the construction site to identify social, environmental and health & safety issues requiring improvement.

Case Studies of Climate Change Adaptation, Inter-American Development Bank, Honduras and Nicaragua, 2013
The main objective of this project was to support the process of increasing climate change adaptation capacity in communities in Central America, particularly with respect to water resources management. This included a focus on identifying and laying out future potential investment projects for the IADB in the area of adaptation and resilience. Specific tasks included development of community hazard profiles, and application of community vulnerability assessment criteria used to identify, compare and characterize areas of particular vulnerability to climate change hazards.

Confidential Project Community Health Study, Confidential Oil and Gas Supermajor, United States, 2013
This study was conducted to obtain an in-depth understanding of baseline community health conditions and concerns in the vicinity of the proposed site for a major capital project. Tasks involved primary data collection in the form of interviews with health and social service providers and public safety officials, as well as collection and analysis of secondary health surveillance data and compilation of a final health baseline report.

Gulf of Mexico 5-Parish Social and Health Baseline and Stakeholder Engagement Plan, Confidential Oil and Gas Supermajor, United States, 2013
This project involved development of detailed social and health baseline studies for five coastal Louisiana parishes falling within the footprint of the client's future Gulf of Mexico offshore operations. Specific tasks included collection, integration and analysis of various sources of health surveillance, health financing, hospital, and social indicator data to provide a baseline characterization of health status, vulnerabilities and health services in each parish. Baseline findings were then used in the development of both parish-level and regional stakeholder engagement plans and social investment strategies.

Eagle Ford Shale Gas SHIA, Confidential Oil and Gas Supermajor, United States, 2012-2013
This project was a social and health impact assessment for a shale gas operation in South Texas. Tasks included desktop research, baseline report writing, and assessment of social and health impacts on residential communities in the vicinity of the Project site.

Strategic Plan for the ASGM Sub-sector, Suriname, Ordening Goudsector, 2012
This project consisted of developing a five-year strategic plan for the artisanal and small-scale gold mining sub-sector in Suriname. Tasks included background research, gap analysis, report writing and stakeholder engagement activities such as key informant interviews, public opinion focus groups and a 2-day participatory stakeholder workshop.

Situational Assessment of the ASGM Sub-sector, Suriname, Ordening Goudsector, 2011-2012
Managed and executed the development of a policy-oriented research report to fill gaps in information on health, socio-economic and environmental security issues in the lives of artisanal and small-scale gold miners in Suriname. Tasks included background research and literature review, development of conceptual model and research design, development of interview guide and survey instrument, primary data collection and analysis, generation of recommendations, and report-writing.

Feasibility study and options analysis for mining residual bauxite deposits, Suralco, Suriname, 2011
Assisted with the production of a report and analysis of relocation options to mine residual bauxite deposits adjacent to a Maroon community in Marowijne, Suriname. Tasks included background research, secondary data analysis, generation of recommendations and report writing.

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Kristina Mitchell



Ms. Kristina Mitchell is a Senior Project Manager with ERM based in Seattle, Washington. She is a member of ERM's Impact Assessment Performance and Planning Group, and has 15 years of experience in corporate social responsibility including stakeholder engagement, crisis response management, policy analysis, risk identification and management, and impact assessment. Within these areas, she is skilled in policy, strategy, guidance, toolkit design, and in-field implementation. Her field experience includes Arctic regions of Alaska, North and Latin Americas, the Balkans, and Papua New Guinea.

Working within the public, non-governmental, and private sectors, Ms. Mitchell is skilled in building partnerships and fostering the conditions required for collaborative action and shared value. She is trained in crisis response, negotiation and conflict resolution, and leadership and behaviour-based coaching.

Fields of Competence

- Crisis response
- Stakeholder engagement and planning
- Policy analysis and development
- Social impact assessment
- Corporate social responsibility strategy
- Community investment strategy/policy
- Reputation risk management
- Program and tool development
- Program and gap assessment
- Social license to operate
- Corporate communications strategy and planning
- Conflict management and negotiation
- Leadership development and ontological coaching

Education

- M.A. International Relations, Johns Hopkins School of Advanced International Studies, 2007
- B.A. International Relations and Anthropology, Boston University, 2000
- Certificate. Negotiation and Conflict Resolution, Institute for International Mediation and Conflict Resolution, South Africa, 2005
- Crisis Response Training, ExxonMobil, 2010
- Executive Leadership and Coaching Training, Accomplishment Coaching, 2015

Languages

- English (native)
- Spanish (advanced)
- French (intermediate/basic)

Key Industry Sectors

- Government
- Mining
- Oil and Gas
- Power (hydro)

Honors & Awards

- Pew Charitable Trust Fellow

Papers

- Early Stage Risk Management: Strategic Community Investment and Project Planning
  Co-authored: Kristina Mitchell and Kim Swanzey
- Effective Stakeholder Engagement to Support Critical Capital Projects
  Co-authored: Kristina Mitchell and Rob Gronewold

Key Projects

Stakeholder Engagement

Community Engagement Study, North Slope, AK, Confidential Client. Social Lead
Developed a methodology to engage community stakeholders about changes to traditional knowledge, subsistence resources and activities, other cultural practices, and community wellbeing. Conducted focus group and key informant interviews with community members, and synthesized interview information in a report on community resources, priorities, and changes to those resources.

Stakeholder Identification and Mapping, California, Confidential Client. Technical Lead
Developed a stakeholder registry and mapped groups based on influence, impact, and concern in response to an oil spill affecting onshore and offshore resources.

Stakeholder Engagement Process Development, Alaska, Confidential Client. Social Advisor
Advised client on multiple aspects of a world-class, highly complex resource development project including developing and implementing an IFC Performance Standard compliant stakeholder engagement process. The project was located in an area of extremely high biodiversity and cultural value, with significant populations of indigenous peoples.

Labor Relations and Communications Issue Resolution, China, Confidential Information Technology Client. Lead
Developed a strategy and action plan to address longstanding conflict between labor force and management in a number of facilities, related to health and safety concerns.

Community Relations and Stakeholder Engagement Plan Gap Assessment, Peru, Confidential Mining Client. Social Lead
Conducted gap assessment of EIA and current Community Relations Plan for major mining project against corporate, national, and international standards. Key issues included stakeholder engagement and consultation of indigenous peoples.

Stakeholder Engagement, Land Acquisition and Resettlement Workshops, Mexico, Confidential Hydropower Client. Senior Social Consultant
Prepared and delivered training workshops on the appropriate application of stakeholder engagement in scenarios of land acquisition for government and private sector clients in hydropower project development. Workshop content included best practices for risk management through the application of international standards on stakeholder engagement, economic resettlement, compensation and livelihood restoration, and good practices in negotiation.

Stakeholder Engagement Plan Development, USA, Confidential Mining Client. Social Lead
Prepared a stakeholder engagement plan, as part of a due diligence process, targeted toward immediate goals around permitting post acquisition and longer term acquisition of social license to operate.

Stakeholder Engagement Plan Development and In-Field Implementation, Nicaragua, HKDC. Senior Social Consultant
Prepared stakeholder engagement plan and for major infrastructure development crossing Nicaragua. Led in-country focus group consultations related to social, health, and economic aspects.

Social Impact Assessment

Environmental, Health, and Social Impact Assessment, Albania, Petromanas. Senior Consultant
Identified and assessed impacts to worker rights related to oil and gas exploration activities, and developed recommended mitigations.

Environmental Impact Statement, US Territories and Non-contiguous States, FirstNet. Senior Social Consultant
Identified and evaluated potential socioeconomic impacts and effects of a nationwide telecommunications infrastructure project.

Integrated Social and Health Impacts Review, Alaska, Confidential Client. Senior Social Consultant
Conducted a review and assessment of multiple formal impact assessment, scoping, and perception reports to identify follow-on data needs and key areas of impact and risk.

Social and Health Impact Assessment, Nicaragua, HKDC. Senior Social and Health Consultant
Assessed a suite of social and health impacts related to conflict, human rights, cultural heritage, and community safety and wellbeing.

Retrospective Social Impact Assessment, Peru, Confidential Client. Strategic Aspects Project Manager/Social Consultant
Provided project management support and assessed retrospective and future impacts related to human

rights, conflict, supply chain, labor, and institutional development for major mining project.

Social Impact Scoping Workshop, Arizona, Confidential Client. Consultant
Co-led scoping level impact assessment workshop for a client considering re-opening development of an asset. Workshop elements included identification of direct and indirect area of influence, key stakeholders and gaps in information for stakeholder mapping and planning, and scoping level impacts and Project risks.

Social Impact Assessment, Mexico, Confidential Client. Senior Technical Review
Provided technical quality assurance and control review for baseline, impact assessment and management measures for social impact assessment in a complex environment including multiple regulatory regimes.

Social Due Diligence and Risk Assessment

Global Management Principles Assessment - Labor Issues, Global, Confidential Manufacturing Client. Social Lead
Conducted an assessment of corporate labor, supply chain, and workforce safety principles for compliance with international standards on good social practice.

Social, Safety, and Community Health Due Diligence - Oyu Tolgoi Project, Mongolia. Manager
Advised a consortium of lenders (including Equator Principles banks) on environmental and social sustainability aspects, all required to be IFC Performance Standard compliant. This was a combined open-pit and underground block caving copper/gold mining operation location in the South Gobi region of Mongolia, requiring the world's largest debt financing package for a mining project. Key issues included labor management, immigration, resettlement, impacts to cultural heritage, and environmental impacts.

Material Risks Assessment, Canada, Confidential Mining Client. Social Lead
Identified and assessed key risks associated with industrial development located in a pristine area of Canada. Key risks assessed related to indigenous peoples' rights, cultural heritage, traditional land use, and community health.

Social Investment and Corporate Social Responsibility

Community Investment Strategy Design and In-Field Implementation, Papua New Guinea. Esso Highlands Limited. Corporate Citizenship and Investments Lead
Designed and implemented a multi-million dollar community investment strategy for the largest natural resource project in Papua New Guinea's history. Strategic investments portfolio included formation of stakeholder partnerships across private, public, and not for profit sectors focused on education (including teacher training and education policy); health (including improved access to services, research, and treatment of infectious disease and job creation within the health care sector); women's empowerment (including support for female entrepreneurs and community leaders and job creation); and public policy. Strategically aligned investments with PNG National Action Plans, global corporate community investment priorities and branding, United Nations Millennium Development Goals, and in country business needs. Developed tools to ensure due diligence and compliance with internal guidelines and external legal standards, and mentored local staff into department leadership roles.

Community Investment, Impact Management, and Other Community Spending Analysis, Papua New Guinea, Esso Highlands Limited. Corporate Citizenship and Community Investments Lead
Managed comprehensive look back analysis, evaluation, and mapping of multiple tens of millions of dollars in cross functional community programs against internal standards and policies, business risks, international lending guidelines, and long term corporate citizenship and objectives.

Global Environmental Community Investment Portfolio Analysis, USA, ExxonMobil. Major Program Officer
Led evaluation of $10M community investment strategy in close collaboration with Environmental, Health, and Safety group and non-profit partners. Significantly restructured portfolio, designing and implementing exit strategies and replacing dated investments with higher value projects and partnerships.

Corporate Social Responsibility Strategy Development, Mexico, Confidential Client. Senior Social Technical Review
Provided technical quality assurance and control of key processes and deliverables associated with CSR strategy development including stakeholder engagement activities and planning and land access negotiations.

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Benjamin D. Siegel

Project Archaeologist & Cultural Heritage Consultant



Benjamin D. Siegel is an Archaeologist and Cultural Heritage Consultant based in the Washington, D.C. office. He joined ERM in July of 2013 as a member of the DC Cultural Heritage team in order to help the office address both domestic and international clients' cultural heritage needs.

Ben has over 9 years of cultural hertiage experience, and has directed archaeological and historical research projects both inside the United States and abroad. Trained and well practiced in archival research, terrestrial archaeology, and underwater archaeology, Ben's unique and interdisciplinary background make him particularly well suited to assist with a wide range of cultural heritage projects.

Prior to joining ERM, Ben spent 3 years employed as an Archaeologist by domestic cultural resource management firms, where he specialized in Section 106 compliance, state archaeoligcal compliance, and archaeological surveys, throughout the Mid-Atlantic and Southeastern United States.

Over the years Ben has also accrued extensive international experience and consistently works on projects taking place around the world. Within the past year Ben has contributed to client projects in Albania, Azerbaijan, Haiti, Italy, Nicaragua, and Venezuela. Furthermore, Ben has served as the archaeological and research director for extensive international field projects including efforts in Rivas, Nicaragua (2014), Bluefields Bay, Jamaica (2009), and London, England (2006).

Familiar with both domestic and international archaeological standards and practices, and accustomed to working in a wide variety of environments, Ben consistently makes valuable contributions to cultural heritage projects for ERM's clients around the globe.

Professional Affiliations & Registrations

- Registery of Professional Archaeologists (R.P.A.)
- Archaeological Society of Maryland (A.S.M.)
- Society for Historical Archaeology (S.H.A.)
- Phi Alpha Theta Historical Honors Society
- American Academy of Underwater Sciences (AAUS)
- Certified PADI Dive Master (PADI)

Fields of Competence

- Terrestrial Archaeological field Survey and Excavations
- Underwater Archaeological Survey and Excavations
- Historical and Archival Research
- Section 106 Compliance
- International Cultural Heritage Management
- Culture and History of the U.S. and the U.K.
- Culture and History of the Caribbean & Latin America

Education

- M.A. Historical & Maritime Archaeology
  East Carolina University, 2011
- M.A. American History
  Emory University, 2007
- B.A. History & Philosophy
  Emory University, 2007

Languages

- English, native speaker

Publications

- "The Impact of Empire: The Effects of British Imperial Policy on the Maritime Landscape of Bluefields Bay, Jamaica" in *East Carolina University Press*
- "Dealing with an Independent America; the Debate Amongst British Merchants and Politicians over Anglo-American Trade Policy 1782-1785", in *Emory University Press.*

ERM Project Experience

Project: Ascent
Client: Confidential, *November/December 2014*
Co-Directed a Phase II archaeological investigation and extensive Phase I Deep Testing of an area intended for use as boat ramp and dock for an Oil and Gas refining plant along the Ohio River. The survey was designed to further refine a preliminary understanding of several sites already identified in the area during the Phase I survey.

Project: AMBU Marcellus Shale Baseline Study
Client: Chevron, *October 2014*
Conducted research for and developed the historical context for the 26 counties spread across Pennsylvania, West Virgina, and Ohio that fall within the project area. Also co-authored the Cultural Heritage section of the Baseline study, which made use of the three states' SHPO master site files to make assessments about the types and conditions of resources located within the project area.

Project: Nicaragua Canal
Client: HKND, *June - September 2014*
Directed the Archaeological Investigation of the canal route and projected canal impact areas within the Rivas Isthmus of Nicaragua. Managed a team of sub-contractors for the 2 month field effort, and was soley responsible for the write up of the field results and historical context that would comprise a large portion of the Cultural Heritage Team's baseline report.

Project: Ascent
Client: Confidential, *March - April 2014*
Co-Directed a Phase I archaeological investigation of an area intended for use as an Oil and Gas refining plant along the Ohio River. The survey was designed to further refine a preliminary understanding of several sites already identified in the area during pedestrian survey. All sites were bounded, and all artifacts collected were transported to a lab for further analysis.

Project: Azerbaijan Development
Client: Confidential, *March 2014*
Co-produced a cultural heritage management plan presentation to be distributed to construction workers and project staff to educate and inform with regard to the types of resources at risk on the project site, and explain the protocols in place for the project's chance finds plan.

Project: International Archaeological Guidance Notes
Client: Confidential, *February 2014*
Co-authored and co-edited a set of Archaeological Guidance Notes for an investment group, which codified and outlined internationally recognized best practices for lender based archaeological surveys and preservation efforts associated with major development projects. The deliverable is currently being assessed by the client, and will eventually be published by the client for distribution among its investors, benefactors, and borrowers.

Project Gulf Coast GTL Plant
Client Royal Dutch Shell, *October 2013*
Phase II archaeological investigation of future MCP site in south-central Louisiana. Carried out archaeological survey, exploratory excavation, and historical research to identify cultural resources associated with a 19th century sugar plantation in the project area. The Phase II efforts consisted of pedestrian survey, and mechanized stripping followed by ground probing.

Project Marcus Hook
Client Confidential, *Ongoing*
Created a GIS-based "change over time" study of Marcus Hook, PA, to ensure that future development in the area would comply with federal and state archaeological preservation law. Successfully managed to overlay historical maps and Sanborne fire insurance maps ontop of modern satellite images of the region to assist with the client's needs.

Project TAP
Client Confidential, *Ongoing*
Created a series of quantifiable metrics by which remote sensing data collected along a proposed underwater pipeline route within the Adriatic sea could be assessed. Conducted data assessments on data already collected and contributed to ERM's recommendations for future remote sensing surveys within the project area.

Project Nicaragua Canal
Client HKND, *Fall 2013*
Part of the team that developed a GIS-based predictive model highlighting prehistoric and historic-era archaeological site sensitivity for a region in Central America. The model will be updated as new information is received and will be used to guide field teams during archaeological survey.

Relevant Professional Experience

Excavation, Section 106 Application, and Archaelogical Review of 19th Century Farmstead and Homestead, for construction a Solar Farm in Frenchtown, NJ.
Assisted in the creation of the research design for the site assessment and Section 106 application of a historic property in Frenchtown New Jersey. Also co-directed fieldwork for the project, including test unit excavation, and shovel tests. Also created the project's master artifact catalog, and created the site map.

State Highway Administration Archaeological Surveying and Report Writing, in Talbot County, and Cumberland City, MD.
Conducted archaeological compliance surveys within the footprint of state roads to be expanded in Talbot County and Cumberland City, Maryland. Assisted in construction of the research design, aided in shovel testing, and performed research for the final reports.

Cumberland Pipeline Project, Cumberland City, MD.
Conducted a Phase I archaeological survey along a proposed pipeline cooridor that would supply natural gas to Cumberland City. The proposed coordior spanned across much of the city, and transveresed both public and private lands. The project involved extensive shovel testing, though few artifacts were ultimately recovered and processed.

Archaeological Excavation and Analysis of Cattle Pass Site, Historical Homestead, Martinsburg, WV.
Part of a small team which excavated an 18th and 19th century Homestead at the behest of the West Vrigina State Highway Administration. Extracted and later examined the architecture and cultural remains of the site, including construction materials, coins, faunal remains, and ceramics. Also helped create the project's artifact catalog, and curated all artifacts found to the standards of the West Virgina State Historic Preservation Office.

Road Development Project, Tabler Station, Maritnsburg, WV.
Conducted Phase I and Phase II investigations of a proposed route for a new road near Tabler Station, which would transect farmlands, railroad tracks, populated houses, and existing roads. Artifacts found were concentrated in one central loci, and consisted of 19th and turn of the 20th century artifacts. All artifacts were collected, labled, and taken to a lab for further analaysis.

Archaeological Investigation of Ships' Graveyards, Eagles Island, NC, and Dismal Swamp Canal in Elizabeth City, NC.
Coastline and submerged examinations of abandoned intracoastal and oceanic vessles in various sites along the North Carolina Coast. Efforts included Total Station surveying, site drawing, and follow up archival research on located vessel remains. Final report was submitted to the North Carolina State Historic Preservation Office and included Rhino 3d imaging of wrecks found.

Underwater Survey and Excavation of the Cashine River Wreck, Cashie River NC.
Conducted Archaeological Scuba dives as well as river bank terrestrial surveys to examine the remains from the Cashie River Wreck, a 16th or 17th century Collier, built in England and used in trans-Atlantic seafaring. Survey also included a bathymetric survey of the river, and a theodilte based survey of the west river bank, upon which a 17th century wharf was located. Diving consisted of low visability dives in a cold water environment.

Archaeological Survey and Monitoring and Project, Gulf of Mexico, Pensacola, FL, and Mobile, AL.
Directed Archaeological surveys along the Florida and Alabama's gulf coasts in order to document, and make assemsents on archaeological sites and resources in danger of contamination during the BP Oil Spill of 2010. Surveys were conducted on behalf of the Federal Government. Project also consisted of monitoring oil excavation efforts throughout the two states.

Archaeological Tribal Burial Reinternment Project Florida Water Management District, Everglades, Clewiston, FL.
Assisted in the relocation of, excavation of, and reinternment of Seminole Tribal remains in the Everglades at the behest of the State Tribial Historic Preservation Office and the State Historic Preservation Office. Efforts included baseline reconissance, metal detecting, and excavation.

Bluefields Bay Expedition, Jamaica.
Designed, directed, and obtained funding for an investigation of the cultural resources extant in Bluefields Bay, Jamaica. Project crew consisted of terrestrial archaeologists, underwater archaeologists, archival researches, and local support staff. Through extensive archaeological Scuba diving, site mapping, and artifact documentation, the crew located and identified a number of cultural resources from the 18th century, including British Longshank anchors, cannons, lime kilns, fortifications, and a tavern. The final report was published and submitted to the Jamaican National Heritage Trust as an advisory document for the future creation of a Cultural Heritage Museum in Bluefields Bay.

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Mark E. Garrison



Mr. Garrison has more than 28 years of experience as a meteorologist and air quality dispersion modeler in the environmental consulting field, for industry, and the U.S EPA.

Mr. Garrison has several years of experience providing expert consultation related to litigation, including expert testimony. He has extensive experience in the application of air quality models to assess releases of criteria and toxic air pollutants.

Mr. Garrison has detailed knowledge of the technical, regulatory, and policy issues related to dispersion modeling of new and existing sources and modeling the effects of accidental releases of toxic chemicals; he has special expertise in modeling sources in complex terrain and in the application of advanced models (e.g., CALPUFF, AERMOD, CTDMPLUS).

Mr. Garrison has extensive experience in modeling for PSD and NA-NSR permitting, with special emphasis on electric utility power plants. He has extensive experience in modeling concentration and deposition impacts for input to risk assessment.

Mr. Garrison has served as an invited scientific peer reviewer for two new EPA models: AERMOD and CALPUFF. He is the author of numerous papers presented at technical conferences on a wide variety of modeling topics.

Registrations & Professional Affiliations

- Air and Waste Management Association
- American Meteorological Society

Fields of Competence

- Air quality dispersion modeling
- Meteorological data evaluation and processing
- Dispersion model development
- Expert testimony
- PSD and Nonattainment New Source Review (NA-NSR) modeling
- Exposure assessment and toxic pollutant impact evaluations
- Air emissions inventory development
- Ambient impact assessments of hazardous waste sites
- Clean Air Act strategic planning
- Electric utility power plant permitting
- Modeling in support of risk assessment
- Title V permitting

Education

- M.S., Environmental Science, Drexel University, 1981
- B.S., Environmental Engineering Technology, Temple University, 1977

Languages

- English, native speaker

Key Projects

Contributed to an assessment of fine particle contributions to regional haze in collaboration with the NESCAUM organization.
Work included preparation of MM5-based meteorological inputs, and modeling of several hundred coal- and oil-fired generating units in the Northeastern U.S. using the CALPUFF model.

Conducted modeling of the atmospheric transport, transformation and fate of mercury emitted by coal-fired power plants and other source types for the Maryland Department of Natural Resources Power Plant Research Program (PPRP).
Developed a speciated mercury emissions inventories for the Eastern U.S., and developed a simplified mercury transformation scheme that has been incorporated into CALPUFF. Model evaluations were performed comparing model predictions to, and analysis of data collected at Mercury Deposition Network (MDN) sites.

Conducted modeling as part of the Maryland Department of Natural Resources Power Plant Research Program (PPRP).
Review of several new power plant applications, including the use of AERMOD, and Class I AQRV analyses utilizing the CALMET/CALPUFF modeling system and the SACTI model for cooling tower impact assessment. Sources modeled included simple and combined cycle combustion turbines and coal-fired boilers.

Performed and conducting on-going modeling with CALPUFF to determine visibility impacts on Class I areas using MM5-based data for facilities in South Carolina, Pennsylvania, Nebraska, Oklahoma, and Texas.
Modeling was conducted in support of BART exemption and BART engineering analyses.

Performed a cumulative impact analysis for several new electric generation facilities in Maryland.
Utilized CALMET and CALPUFF, including the effect of multiple plants on visibility resources in the Shenandoah National Park and an assessment of ambient standards in Maryland.

Participated in scientific peer review panels for the new AERMOD and CALPUFF models at the invitation of the U.S. EPA.
Developed comments on the scientific and performance aspects of AERMOD and CALPUFF.

Conducted modeling with the Offshore Coastal Dispersion (OCD) model to evaluate the effects of drilling operations off of the coast of Angola.
Project included processing and evaluation of both land and overwater meteorological data.

Conducted extensive air quality modeling to address SO2 ambient standards compliance issues for a refinery in Oklahoma.
Work involved model evaluation comparing predicted to measured ambient concentrations. Models included AERMOD and ISCST3. Project included processing and evaluation of meteorological data for ISCST3 and AERMOD.

Performed a full-scale analysis using the CALMET/CALPUFF modeling system to assess Nitrogen deposition to the Chesapeake Bay resulting from NOx emissions from sources located up to 1000 kilometers from the Bay.
Conducted evaluations of the performance of CALPUFF and developed proposed improvements.

Performed dispersion modeling in support of accidental release assessments for Clean Air Act 112(r) Risk Management Plan for chemical, paper and other industries at over a dozen facilities using the ALOHA, SLAB, and DEGADIS models.

Conducted modeling for input to a risk assessment for a manufacturing facility in Albuquerque, New Mexico using CALPUFF for a local, complex wind application.

Prepared a comprehensive set of input files.
Included MM4, upper air, surface, precipitation, buoy, ozone, land use, and terrain and ran CALMET for Public Service Electric and Gas in New Jersey. Provided evaluation of resultant wind fields.

Conducted air quality modeling to determine exposure assessment input to a human health risk assessment, to

address impacts of airborne pollutants from a dredging operation to clean up the Grand Calumet River near a major steel plant in Gary, IN.

Conducted air quality modeling, including multi-source regional modeling, in support of a NOx PSD application for a manufacturing facility in New York State.

Provided air quality modeling inputs (ISCST3 and AERMOD-PRIME) to a human health risk assessment for a manufacturing facility in New Jersey.

Conducted air quality modeling of benzene and other pollutants released from contaminated soil at a site in Brazil; utilized emissions measured by flux chamber.

Conducted modeling to assess impacts of the excavation and off-site disposal of asbestos-containing materials at a facility in Argentina.

Conducted air quality modeling of several compounds from contaminated soil at a site in West Virginia; utilized emissions measured by flux chamber.

Conducted modeling to determine concentration and deposition impacts for a multi-pathway risk assessment for a hazardous waste incinerator in Puerto Rico.

Prepared an expert report in support of a power company defendant involving the allegation by the government of avoidance of New Source Review (NSR) requirements for a coal-fired power plant in the remedy phase; was deposed in this case.

Assisted in the preparation of an expert report in support of a power company defendant involving allegations by the government of avoidance of New Source Review (NSR) requirements for over a dozen mid-western and eastern coal-fired power plants.

Served as an expert witness and prepared an expert report in litigation involving the air quality impacts of a gasoline spill, successfully avoiding class certification.

Prepared expert reports including dispersion modeling to address exposure to airborne asbestos particles in two court cases, both of which were settled with plaintiffs prior to trial. Prepared an expert report in an additional asbestos litigation case which is ongoing.

Conducted comprehensive modeling analyses to address AB2588 and Prop 65 risk assessment requirements for facilities in Santa Clara (BAAQMD) and Downey (SCAQMD), California.

Conducted modeling to determine HF impacts from a facility in Pennsylvania, including resolution of issues related to HF reactivity and deposition with the state agency.

Performed modeling for two Pennsylvania facilities (refinery and power plant) to address attainment of SO2 NAAQS due to multiple regional sources. Developed an innovative approach to determining background concentrations that was approved by EPA Region III.

Conducted air quality modeling for an industrial facility in Utah to demonstrate compliance with PSD Increments for PM10.

Conducted air quality modeling for two manufacturing facilities in support of insignificant impact determinations of plant modifications requiring PSD review.

Performed air quality modeling of three industrial facilities in New Jersey in support of quantitative risk assessments for the facilities. Worked with NJDEP to ensure compliance with risk modeling policies.

Performed dispersion modeling to demonstrate PM10 NAAQS attainment in the vicinity of an ore mining and processing facility in Nevada.

Conducted a model intercomparison study between the newly released ISC-PRIME model and existing downwash algorithms in ISCST3 to determine regulatory implications. Principal author and programmer of the Integrated Gaussian Model (IGM), an air quality model approved as an equivalent model

by the US EPA, developed to streamline obtaining source contribution information and to efficiently implement procedures for intermediate terrain.

Performed air quality analyses to support PSD application for an 800-MW pulverized coal-fired generating station in South Central Virginia.
Contributed substantially to preparation of PSD application. Developed IGM for use in this project.

Performed dispersion modeling studies in support of present and future plans for additional generating capacity at a utility power plant, including an assessment of existing units.
Models used included IGM in the RTDM/ISCST2 mode, CTSCREEN and CTDMPLUS. Provided interface with New Jersey Bureau of Air Quality Evaluation as needed for permitting modeling support.

Conducted modeling to determine HF impacts of two glass manufacturing facilities in New York state.
Conducted a model intercomparison study between existing complex terrain models and test versions of EPA's new AERMOD model to evaluate AERMOD's performance. Recommended changes in AERMOD formulation were implemented by EPA.

Performed an in-depth analysis of modeling results produced by plaintiffs in a suit alleging wide-spread Arsenic health impacts, significantly reducing the impact area identified by plaintiffs by correcting and improving the plaintiff s modeling.

Performed a deposition modeling study of the long-term (50 years of plant operation) impacts of a pesticide manufacturing plant in New York State. Assisted in interface with NYSDEC and EPA Region II to resolve impact issues.

Served as the work assignment manager for the initial development of Superfund air pathway analysis guidance documents.

Developed and presented a two-day training course for ERM offices nationwide.
Course included modeling fundamentals, application of models in regulatory settings, and overview of models used for accidental release modeling. Managed a fugitive dust quantification study for six coal-fired power plants to identify Title V emissions fees in Pennsylvania and West Virginia.

Managed the development of Title V permit applications for eight coal-fired generating stations in Pennsylvania.

Yinka Afon, P.E.

Senior Acoustics and Air Quality Consultant



Mr. Yinka Afon is a Senior Project Engineer within ERM based in Annapolis, MD. He has over 11 years of experience in the field of physical resources management, with specific expertise in noise, vibration, and noise impact assessment, ambient sound surveys, noise modeling, ground-borne vibration and airblast assessments, air emissions quantification, meteorology, environmental managemnet and regulatory compliance. Most of his noise, vibration, air and GHG work has supported environmental and social impact assessments (ESIA) and permitting projects for power (thermal, hydro, biomass, wind and nuclear), oil and gas, mining, manufacturing, and transportation sector clients. Mr Afon is familiar with the US National Environmental Policy Act standards and the IFC Environmental Health and Safety Guidelines and Performance Standards. Aside from the United States, Mr Afon has international ESIA experience in countries such as Nicaragua, Suriname, Dominican Republic, Guatemala, Argentina, Chile, Bahamas, Greenland, Canada, Guinea, and Nigeria.

Mr. Afon provided noise and air quality expertise for development of multiple natural gas storage and liquefaction facilities, gas compressor stations, crude oil pump stations, and associated pipelines across the US and Canada. He also served as the Noise, Vibration, Air Quality, and GHG Lead for the construction and operation of a 272 km long canal to connect the Pacific Ocean to the Caribbean Sea through Lake Nicaragua. Mr. Afon managed a group of six staff engineers and coordinated environmental monitoring at sensitive areas along the canal corridor.

Professional Affiliations & Registrations

- Registered Professional Engineer #33760, MD, 2009
- Member of Acoustical Society of America
- Member of American Institute of Chemical Engineers
- Member of Air & Waste Management Association

Fields of Competence

- Noise, vibration, air quality, and GHG impact assessment
- Regulatory compliance (NEPA, FERC, IFC)
- Emissions inventory (criteria pollutants, HAPs, GHGs)
- Noise modeling (Predeictor-Lima Software, Type 7810-G)
- Blasting assessments (airblast, groun-borne vibration)
- Environmental management and monitoring plans

Key Industry Sectors

- Power generation (thermal, hydro, biomass, wind, and nuclear)
- Oil & gas (onshore and offshore)
- Mining & ore/metals processing
- Linear infractructure (pipeline, canal and transmission lines)
- Manufacturing/ petrochemical
- Transportation

Education

- M.S.E., Environmental Process Engineering, Johns Hopkins University, Baltimore, 2004
- B.S., Chemical Engineering, Ladoke Akintola University of Technology, Nigeria, 2001

Languages

- English, native speaker
- Yoruba

Publications

- Afon Y and Ervin D. An Assessment of Air Emissions from Liquefied Natural Gas Ships Using Different Power Systems and Different Fuels . Journal of Air & Waste Management Association No.3, Vol 58, 404 – 411 (2008).

Key Projects

Nicaragua Canal Project, HKND, Nicaragua. 2014-2015. Noise, Vibration, Air Quality, and GHG Lead for preparation of an ESIA for construction and operation of a 272 km long canal to connect the Pacific Ocean to the Caribbean Sea through Lake Nicaragua. Construction activities include dredging, excavation of over 4.4 billion m^3 of material, and blasting. Operational activities include ship traffic, assist tugs, ferries, port and lock operations. Conducted noise surveys and performed noise modeling for large ships that would use the canal using Predictor V9.12 software. Evaluated noise impacts of in-water piling, dredging, and vessel use on marine mammals and fish during project construction. Quantified GHG emissions from land use change, fossil fuel combustion and indirect electricity use. Also quantified the net GHG emissions due to changes in shipping patterns with and without the canal project.

Dalton Expansion Project, Transcontinental Gas Pipe Line Company, LLC, GA. 2014-2015. Air Quality and Noise Lead for preparation of a Resource Report 9 as part of a FERC application for construction and operation of 109.3 miles of new natural gas pipelines, one new gas-fired turbine compressor station, and three meter stations in Carroll, Bartow and Murray counties, Georgia. Quantified emissions of criteria pollutants, HAPs, and GHGs. Reviewed sound survey reports and performed acoustical analysis for all aboveground facilities and nine horizontal directional drill crossings associated with the project.

Shell Franklin Petrochemical Project, Shell Chemical Appalachia, PA. 2014-2015. As Noise Lead, provided noise expertise and reporting for development of a petrochemical complex in Beaver County, PA. Performed noise modeling for the Early Works (including blasting), Main Construction, and peak hour construction traffic using Predictor V9.12 software. The software used ISO 9613-2 and FHWA TNM calculation methods.

NorthMet Mine & Ore Processing Project, PolyMet Mining Inc., MN. 2007-2015. Lead Acoustic Specialist for preparing noise and vibration sections of an EIS for the development of a 11.3 million tonne per annum open pit mine (precious metals) and ore processing facility in northeast Minnesota over a nine year period. Task included evaluation of baseline noise conditions, noise and vibration modeling, and report writing. Prepared the noise and vibration sections of the EIS in accordance with Minnesota Rules, part 7030.0040 and 6132.2900, respectively. Coordinated with cooperating agencies (USEPA, USFWS, Tribes) and addressed all their comments and concerns related to noise.

Atlantic Sunrise Project, Transcontinental Gas Pipe Line Company, LLC, PA, VA, MD, and NC. 2014-2015. Noise Lead for preparation of a noise and air quality report as part of a FERC application for construction and operation of 196.5 miles of greenfield gas pipelines and aboveground facilities in PA,VA, MD, and NC. Reviewed sound survey and acoustical analysis reports for all aboveground facilities (five compressor stations, two meter stations, three regulator stations) and three horizontal directional drill crossings associated with project.

Noise Impact Study for the River Reach Boulevard Project, Prein & Newhof, MI. 2015. Lead Acoustics Specialist for preparing a Noise Impact Study as part of an EA for the development of a new road alignment corridor (River Reach Boulevard) in the Village of Parchment, Michigan. Coordinated noise survey and performed traffic noise modeling using Bruel & Kjaer's Predictor Version 9.12 noise modeling software and FHWA's approved Traffic Noise Model (TNM) calculation method.

Keystone XL Pipeline Project, TransCanada Keystone Pipeline, LP, Canada, U.S. 2012-2014. As Senior Project Engineer and 3rd Party EIS contractor with USDOS, provided noise, air quality, and GHG expertise for preparation of a Supplemental EIS for construction and operation of approximately 875-mile heavy crude oil pipeline and associated facilities (pump stations) from Alberta (Canada) to Nebraska (US). In addition, evaluated effects of other transport alternatives by quantifying air and noise emissions from other pipeline routes, rail (diesel locomotives), and water (oil tanker) transportation. Addressed several noise, air quality, and GHG-related comments from the public, NGOs, and environmental agencies.

Dry Sorbent Injection and Subbituminous Coal Use Projects, H.A. Wagner LLC (Wagner), Baltimore, MD. 2014. Developed an air emissions inventory as part of Wagner's CPCN application to the Maryland PSC for the modification of two coal firing units to achieve compliance with federal MATS rule through use of dry sorbent injection (a proven add-on control technology for

reducing HCl emissions) and/ or subbituminous coal (to replace existing bituminous coal). As part of the emissions inventory development for the Maryland Department of Natural Resources (DNR) Power Plant Research Program (PPRP), reviewed Applicant's emissions calculations, identified minor errors (which were corrected by the Applicant through responses to data requests), and summarized findings in an ERD.

Noise Survey and Impact Study, Westward Ho Pipeline Project, Shell Pipeline Company, LA and TX. 2013-2014. Senior Project Engineer and Acoustics Lead for preparing a Noise Survey and Impact Study as part of an ESHIA for the development of a 206-mile pipeline from St. James Parish, LA to Port Neches, TX. Managed a group of four staff engineers and coordinated noise survey at multiple horizontal directional drilling (HDD) locations along the pipeline route, performed noise modeling, and assessed noise impacts to nearby receptors. Also performed a detailed noise abatement analysis for areas where noise impacts exceeded applicable limits.

Merian Gold Mine and Power Plant Project, Surgold Inc. (Newmont), Suriname. 2010-2013. Environmental Lead for preparing multiple sections of an ESIA for the development of an open pit gold mine in northeastern Suriname with planned production of 5.5 million ounces of gold over 12-14 years and processing of 150 million tonnes of ore and 680 million tonnes of waste rock. The Project also includes the installation of an onsite 52.5 MWe HFO-fired power plant. Resources evaluated include noise, ground vibration, airblast overpressure, air quality, GHGs, and climate. The Project was approved by the Government of Suriname in May 2013.

Buckeye Wind Project, Buckeye Wind LLC, Champaign County, OH. 2009-2013. Author of the noise and air quality impact assessment for a 3rd Party EIS for a 250 MW windfarm in Ohio on behalf of the USFWS. Calculated criteria pollutant and GHG emissions avoided from the proposed wind power project when compared to a typical fossil-fuel type project with the same energy generation capacity. In April 2015, the US District Court in Washington D.C. granted summary judgement in favor of the project following a suit that challenged the issuance in 2013 of an Incidental Take Permit for impacts to the endangered Indiana bat.

Perryman 6 Power Plant Project, Constellation Power Source Generation, Inc. (CPSG), Baltimore, MD. 2012-2013. Developed an air emissions inventory as part of CPSG's CPCN application to the Maryland PSC for the construction and operation of two dual natural gas/ultra low sulfur diesel-fired, simple-cycle combustion turbines with a nominal capacity of 120 MW. As part of the emissions inventory development for the Maryland DNR PPRP, reviewed Applicant's emissions calculations, identified minor errors (which were corrected by the Applicant through responses to data requests), and summarized findings in an ERD.

Fab 8 Steel Manufacturing Facility, Global Foundries, Malta, NY. 2012-2013. Completed a detailed survey of existing noise levels generated by routine manufacturing onsite and offsite to address the source of community noise complaints, given current planning of new facilities. Sound measurements were recorded at 5 minute intervals at multiple locations onsite and offsite using a Type 1 Sound Level meter equipped with a 1/3 octave band filter. Coordinated modeling of significant plant noise onsite in order to understand their relative contribution to the overall noise 'budget' at the community. Future iterations of the model considered the additive effect of the facility expansion.

Wageningen Sugarcane-to-ethanol Project, Suriname. 2010-2013. Senior Project Engineer and Physical Resources Lead for the preparation of an ESIA for constructing and operating a 80-90 million liter per year Sugarcane-to-Ethanol factory (25 MW biomass plant) in Suriname. Evaluated air quality, climate, and noise impact of the biomass project. Calculated GHG emissions avoided from the proposed biomass project when compared to a typical fossil-fuel type project with the same energy generation capacity.

Reventazon Hydroelectric Project, Instituto Costarricense de Electricidad (ICE), Costa Rica. 2011-2012. Senior Project Engineer and GHG Lead for the construction and operation of a dam and hydropower plant and associated facilities, with a total cost of US$1.06 billion. As part of the EIA required for the project to secure financing with the Inter-American Development Bank (lender). Quantified net and gross GHG emissions associated with flooding the reservoir as well as emissions that would be avoided per annum from generation of renewable energy as opposed to the annual GHG emissions that would be emitted by the generation of an equivalent amount of power from the generation supplying the Costa Rica grid.

Boca Chica Thermal Electric Power Plant Project, IIC, Dominican Republic. 2012. Acoustic lead and author of the noise section of an ESIA for the construction and operation of an 82 MW combined-cycle natural gas-fired thermal electric power plant in Boca Chica, Dominican Republic. Predicted Project noise effects on nearest receptors using ISO 9613-2 sound propagation modeling algorithms. Prepared a noise modeling report for the Project in accordance with DR noise standards and IFC Performance Standards and EHS guidelines. Recommended appropriate noise control measures for impacted receptors.

Nassau Plateau Bauxite Mine and Transport Road Project, Suralco Inc. (Alcoa), Suriname. 2008-2012. Senior Project Engineer for preparing multiple sections of an ESIA for the development of a 4.2 million tonne per annum open pit bauxite mine on Nassau Plateau and a 104 km transport road for transporting mined ore via trucks to an alumina refinery in Paranam, Suriname. Resources evaluated during pre-production, production, and closure phases include noise, ground vibration, airblast overpressure, flyrock, climate and air quality, GHGs, and natural hazards.

Greenhouse Gas Emissions Inventory, City of Bowie, MD. 2010. Developed a GHG emissions inventory (as part of an Energy Efficiency Conservation Strategy (EECS)) for the City of Bowie government facilities and operations for base year 2007 and forecast year 2015. Data from buildings and facilities, streetlights and traffic signals, water delivery facilities, wastewater facilities, vehicle fleet, and mobile source refrigerants were entered into the Clean Air and Climate Protection (CACP) software to compute municipal government operations GHG emissions in terms of carbon dioxide equivalents (CO_2e). The city's GHG inventory indicated that majority of the emissions came from government buildings and facilities and vehicle fleets. Provided strategies and opportunities for reducing GHG emissions from buildings and vehicle fleet energy use.

Agbara Industrial Estate Manufacturing Project, Proctor & Gamble, Agbara Town, Ogun State, Nigeria. 2010. Reviewed the draft ESIA associated with P&G's proposed development of a new 40 ha facility for manufacture, storage and distribution of consumer goods within Agbara Town, Ogun State, Nigeria. Participated in a Public Disclosure Meeting at the king's palace in Agbara Town to discuss potential social and environmental issues. Some of the major issues addressed at the meeting include the project's effect on traffic, solid waste handling, jobs for the locals, odor, wastewater treatment and discharge sources, noise, and air pollution.

White Pines Wind Power Project, Huron-Manistee National Forests, (Mason County, MI) 2009. Environmental Specialist for an EIS evaluating GHG emissions avoided and public safety and security issues associated with the development of a proposed wind farm near Manistee, Michigan. The wind farm is expected to have 28 wind turbine generators, each rated at 2.5 MW.

Review of AMRs and ESAPs for Projects Seeking IFC Funding, IFC, Washington D.C. 2009. Worked with IFC staff in the IFC Office in Washinton D.C for about 2 months reviewing Annual Monitoring Reports (AMRs) and Environmental and Social Action Plans (ESAP) for numerous manufacturing and pharmaceutical projects in developing countries seeking funding from the IFC. Some of the key issues identified during the AMR reviews include insufficient data quantification for parameters such as air quality, GHGs, noise monitoring, worker safety incidents, and non-compliace with some of IFC's Performance Standards (PS). Calculated environmental and Social Risk Rating (ESRR) for some of IFC's portfolio projects. The rating allows for a coincise, up-to-date assessment of client environmental and social risk throughout the life of the project. Recommended supervision missions/visits for facilities not meeting IFC PS and/or host country's requirements

Floridian Natural Gas Storage Project, Floridian Natural Gas Storage Company, FL. 2007-2008. As Project Engineer and 3rd Party EIS contractor with FERC, provided resource expertise and management for development of a 100 MMscf per day natural gas storage and liquefaction facility and a 4-mile pipeline in Martin County, Florida. Wrote noise and air quality sections of the EIS and provided quick responses to public and agency comments. Final EIS was approved by FERC in 2008 with some licensing conditions.

Refinery Modification and DRDA Expansion Project, Suralco Inc. (Alcoa), Suriname. 2007–2008. Project Engineer for evaluating the noise and air quality impacts for an ESIA for modifying an alumina refinery plant and expanding its dry residual disposal areas (DRDA) in

Suriname. Conducted ambient noise measurements and performed sound propagation modeling (ISO-9613-2 model) for major noise sources at the refinery and port area. Wrote noise and air quality sections of the ESIA in accordance with IFC Performace Standards and EHS guidelines.

Jaguar Thermal Electric Power Plant Project, AEI Inc., Guatemala. 2008. Author of the air quality and noise section of an ESIA for the development of a 300 MW thermal electric power plant in Guatemala in accordance with IFC Performance Standards. Reviewed and provided comments on applicant's ambient noise monitoring methodology. Coordinated the modeling of noise generated from over 1,200 identified major stationary and mobile noise sources at the site.

Technical Support for Licensing Two New Nuclear Power Plants, Areva, U.S. East Coast. 2008. Provided technical and environmental support for the preparation of combined license (COL) applications for two new 1600 MW nuclear reactors in PA and NY. Coordinated with other sub-contractors to address client's comments and ensured the applications were submitted to Nuclear Regulatory Commission within the scheduled time. Both applications were prepared in accordance with NRC's NUREG 1555 and Regulatory Guide 4.2.

Maniitsoq Aluminum Smelter, Transmission Line, Port, and Hydropower Project, Alcoa, Greenland. 2007. Author of the noise, climate, and air quality baseline assessment for an integrated hydropower, transmission line, aluminum smelter, and port complex in southwest Greenland.

New South Ocean Development (NSOD) Resort Project for NSOD Company Ltd, Nassau, Bahamas. 2007. As Project engineer, provided resource expertise and reporting for an EIA evaluating noise quality effects of developing a US$1 billion ocean-front resort including two hotels, casino, golf course, marina, and residential complex in Nassau, Bahamas. Conducted ambient noise measurements and modeled noise impacts from major noise sources such as an amphitheather, idling marina boats, and increased traffic volumes in the area.

Crown Landing LNG Project, Crown Landing LLC (a BP Energy Company), NJ. 2004-2007. Project Engineer and air and noise lead for the preparation of a FERC application for the development of a 1.2 Bscf per day onshore LNG facility in Logan Township, NJ, and associated pipeline extending under the Delaware River into PA. Performed a terminal system alternatives analysis and evaluated project impacts on noise, air quality, and water resources. Developed air emissions inventory and prepared an air conformity analysis report in accordance with NJ, DE, and PA State Implementation Plans.

Northeast Gateway Deepwater Port LNG Terminal and Pipeline Project, Excelerate Energy, Massachusetts Bay. 2006. As Project Engineer and 3rd Party EIS contractor with U.S Coast Guard, provided air quality and acoustic resource expertise and reporting for development of a 400 MMscfd per day LNG deepwater port with specially-designed regasification vessels and associated pipelines in Massachusetts Bay. Developed air emissions inventory and prepared an air conformity analysis report in accordance with MA State Implementation Plans. Conducted in-air and underwater sound propagation modeling for the marine vessels and determined impacts to sensitive receptors including marine mammals. The Maritime Administration issued a Record of Decision for the project in 2006. The deepwater port is currently in operation.

City of Buffalo Main Street Multi-Modal Access Project, Niagara Frontier Transportation Authority, NY. 2006. Acoustic Specialist for evaluating noise and vibration effects of improving an urban multi-modal transit system at Main Street, Buffalo, NY in accordance with USDOT's Transit Noise and Vibration Impact Assessment manual dated May 2006 and FHWA Traffic Noise Model (TNM), Version 2.5. Calculated existing noise and vibration levels from light rail vehicles in the Project's vicinity, estimated projected traffic noise levels on new road alignment, and wrote the noise section of the EA.

Field Supervisor, Shell Petroleum Development Company (SPDC), Port Harcourt, Nigeria. 2001. Working as a chemical engineer intern for SPDC, supervised oil well clean-ups for an oil production facility in Port Harcourt, Nigeria. Entered data regarding oil spillage sites and specific clean-up dates for various localities into a tracking database.

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Michael J. Fichera

Senior Project Engineer



Mr. Fichera is a senior project engineer with experience since 1993 in water quality and oil spill modeling, natural resource damage assessments (NRDA), risk assessment, and project management. He is skilled in modeling hydrodynamics, oil spills, dredge disposal / drill cutting transport, thermal plumes, water quality, eutrophication, toxicity, and food web simulations.

His oil spill modeling experience has been applied in response to major accidents for live trajectory predictions and injury estimations, for investigating potential origins of mysteriously oiled shorelines, and for predicting impacts due to hypothetical spills for environmental impact assessments. He has estimated impacts due to dredging in ship channels and from the release of mud and drill cuttings from offshore oil exploration.

Mr. Fichera has performed water quality modeling to estimate impacts due to nutrient runoff load increases from proposed residential development; establish nutrient TMDLs; characterize flushing improvements for stagnant water bodies; and aid permitting of a new discharge location for a phosphorus mine.

Modeling experience includes CORMIX, CE-QUAL-W2, EFDC, VPLUMES, QUAL-2k, and ERM's GEMSS model including expertise in its oil spill module COSIM and dredge / drill cutting module, GIFT. He has performed field measurements of water quality and designed a CSO stormwater sampling program.

Registration

- Professional Engineering License, Delaware, 1998
- Engineer in Training Certificate, New York, 1991

Fields of Competence

- Environmental Engineering
- Oil Spill Modeling
- Drilling Mud and Cuttings Modeling
- Water Quality Modeling
- Environmental Chemistry

Credentials

- M. E., Environmental Engineering, Manhattan College, 1993
- B. S., Civil Engineering, Manhattan College, 1991

Professional Affiliations

- Society of Environmental Toxicology and Chemistry (SETAC)
- Hudson Delaware Chapter of SETAC (HDC-SETAC)
- Inland Bays Scientific Technical Advisory Committee (STAC)
- Water Environment Federation (WEF)
- Chi Epsilon Civil Engineering Society
- Tau Beta Pi Engineering Society

Key Projects

For a strategic initiative to develop a model to estimate the exposure, duration, and potential toxicological impacts of oil and chemical spills, worked to construct the Chemical / Oil Spill Impact Module (COSIM). The module, a plug-in component of ERM's Generalized Environmental Modeling System for Surfacewaters (GEMSS), was designed for use for emergency response, emergency planning or hindcasting. Within the GEMSS framework, COSIM can produce simulations of the fate and transport of the various oil constituents and produce 3-D visualizations and animations.

Performed oil spill and drill cuttings deposition modeling for Environmental Impact Assessments (EIA) for over 50 projects around the world including Argentina, Colombia, Guyana, around the African coast (including Algeria, Morocco, Mauritania, Ghana, Nigeria, Gabon, the Democratic Republic of the Congo, Angola, and Mozambique), northern and western Australian coasts, Southeast Asia (including Malaysia, Brunei, Sulawesi, Vietnam), New Zealand, Italy, and in the Gulf of Mexico.

Provided marine oil spill models for BP's terminals and pipelines as part of regulatory compliance with Washington State Dept. of Ecology and internal Oil Spill Preparedness & Response plans.

Performed a baseline oil spill study for the Aleutian Islands Risk Assessment (AIRA). The goal of this study was to produce a comprehensive evaluation of the risk of vessel accidents and spills in the Aleutian Islands, with the ultimate goal of identifying risk reduction measures that can be implemented to improve the level of safety related to shipping operations in the region.

Assessed the fate, transport, and toxicity of oil during several major US oil spills for Natural Resource Damage Assessments (NRDA). Performed modeling processes concurrently with trustee-appointed modelers to facilitate the cooperative process. Assessed potential aquatic injuries associated with dissolved polyaromatic hydrocarbons (PAHs) in the water column. Designed and directed laboratory oil toxicity experiments. Major c NRDA projects include:

- September 1999 release of IFO-180 oil from the Dredge *M/V Stuyvesant* barge accident off the coast of Humboldt Bay, California
- April 2000 PEPCO Oil Spill, Chalk Point, Maryland approximately 140,000 gallons of a No. 2 / No. 6 fuel oil mixture into the Patuxent River
- April 2003 Bouchard B-120 accidental release of an estimated 98,000 gallons of No. 6 fuel oil into Buzzards Bay Massachusetts
- June 2006 Citgo Lake Charles pipeline rupture, releasing an estimated 53,000 barrels of waste oil into the Indian Marais and Calcasieu Rivers
- April 2010 BP MC-252 Gulf of Mexico blowout and oil spill

Performed NOAA NRDAM/CME ("Type A") oil spill modeling to assess fate, transport, and potential for natural resource damages and water column injury resulting from several oil spills, including the 1997 Texaco Lake Barre, LA oil spill, and the 2004 Bright State freighter vessel collision on the Mississippi River.

Utilized the NOAA Type A oil spill model for three oil releases resulting from Hurricane Katrina for a screening assessment of the magnitude of aquatic and wildlife injuries that may have resulted.

Performed rapid oil spill assessments of the fate, transport, and potential for natural resource damages during the Viking Lady Oil Spill, Casco Bay, Maine.

Provided emergency response site assessment for shoreline oiling and potential injury to local biota for the Port Mobil Explosion and Oil Spill, Staten Island, New York.

Managed hydrodynamic / water quality modeling of the Delaware Inland Bays for TMDL analysis upon impaired waters on the State of Delaware 303(d) list. Modeling included linkage to USGS HSPF model for model input of non-point source loads.

Utilized food chain modeling from sediments, plankton, fish, and birds to determine pesticide contamination liability.

Designed and managed a sediment chemistry survey / toxicity identification evaluation (TIE) for a U. S. Superfund site.

Created an acid attenuation model to estimate the fate and transport of an acidic leak into an aquifer.

Shwet Prakash

Senior Consultant, Water Resources and Modeling



Shwet Prakash is a senior consultant who has been managing and delivering water resources and modeling services to the oil & gas, power and manufacturing industry. He has been involved in developing state of the art chemical fate and transport models for a variety of water quality and transport applications. His experience over the last 10 years includes managing projects that include hydrodynamic studies, accidental oil spill studies, sediment transport and scour studies, TMDL development and regulatory permitting. Mr. Prakash has provided these services to most of the major oil & gas companies (ExxonMobil, BP, Shell, Chevron, Hess) and power companies (Exelon, PSE&G, Luminant, Progress Energy, Nebraska Public Power District) amongst others. The project site footprint includes Americas (US, Canada, Mexico, Brazil), Europe (Norway, Sweden, Turkey), Africa (Ghana, Angola, Sierra Leone, Uganda), Asia (Qatar, Saudi Arabia, Brunei, Malaysia, Indonesia, Thailand, China, Bangladesh) and Australia.

Fields of Competence

- Computational fluid dynamics
- 1-D, 2-D and 3-D numerical modeling of coastal and shelf processes including hydrodynamics and waves
- Chemical transport and fate and water quality modeling
- Ecological risk assessment
- Sediment transport modeling
- Particle tracking and entrainment modeling
- Groundwater modeling
- Programming in FORTRAN, C, Visual Basic and HTML
- Field data processing and analysis

Credentials

- M.S. (Civil Engineering), University at Buffalo, State University of New York, NY, February 2004
- B.S. (Civil Engineering), Indian Institute of Technology, Bombay, India, May 2001
- Watershed Management Training Certificate, The Watershed Academy, EPA
- Professional Development courses in Environmental Hydrodynamics and Sediment Transport Modeling with POM and ECOMSED, Stevens Institute of Technology, Hoboken, NJ

Key Industry Sectors

- Oil and Gas
- Electric Utility (fossil fuel, nuclear and hydropower)
- Harbors and Ports
- Industrial and Chemical
- Water supply and Wastewater Treatment
- Mining
- Marina design and water quality

Key Projects

Oil & Gas

Water Quality Impact Assessment from Onshore LNG Terminal Expansion, BP, Indonesia.
Managed a comprehensive modeling exercise to quantify environmental impacts related to expansion of an onshore LNG facility in Indonesia. Environmental risks associated to wastewater discharge, dredging, drill cuttings and mud discharge and pipeline hydrotesting were estimated using a 3-D hydrodynamic and transport model. Individual wastewater components were modeled and evaluated against relevant ambient water quality standards.

NRDA Computations, Gulf of Mexico, Confidential Client.

Oil Spill Response Planning and Impact Assessment for various clients and fields, offshore Malaysia.
Currently developing models to estimate the environmental impacts from accidental spills during the

operations of MOPUs and FSOs offshore Malaysia. Responsibilities include overall project management of these modeling projects that include three individual clusters.

Oil Spill Impact Assessment for confidential field development, offshore Western Australia.
Currently developing models to estimate the environmental impacts from accidental spills during the operations of MOPUs and FSOs offshore Australia. Responsibilities include overall project management of these modeling projects that include three individual clusters.

Sunrise Floating LNG Terminal, offshore Western Australia
Involved in modeling the environmental impacts from the operations associated with the proposed Sunrise floating LNG terminal located off the coast of Australia. Involvement included managing the modeling tasks that included thermal discharge modeling, oil spill modeling, PFW discharge modeling and water quality modeling. Findings of the modeling were submitted in a report for agency approval.

Prelude Floating LNG Terminal, offshore Western Australia
Involved in modeling the environmental impacts from the operations associated with the proposed Prelude floating LNG terminal located off the coast of Australia. Involvement included managing the modeling tasks that included thermal discharge modeling, oil spill modeling, PFW discharge modeling and water quality modeling. Findings of the modeling were submitted in a report for agency approval.

Keith Lake drilling fluid discharge model
Involved in the development of a near field Sediment Transport and Hydrodynamic model for Keith Lake, TX. The model application was aimed at analyzing the fate of drilling fluid released into the discharge pits as a result of Horizontal Directional Drilling (HDD) operation. The work included development of modeling cohesive sediment capabilities into GEMSS-STM. The analysis comprised of performing comparative study of the resulting turbidity plume for a varied set of lake flows, lake depths and material properties.

Entrainment Modeling for BP's Crown Landing Regassification Facility, New Jersey. BP proposed development of an LNG import terminal at Crown Landing on the Delaware River in Gloucester County, NJ. During vessel unloading while at berth, LNG carriers take on about 30,000 m^3 of water to maintain hydraulic stability when empty. Concerns exist regarding the entrainment effects and possible fishery losses due to this ballast water intake. Striped Bass, White Perch and Bay Anchovy are the species of concern since they consistently dominate the ichthyoplankton population in the Delaware River. ERM simulated intake effects using a high resolution hydrodynamic model to estimate entrainment rates for various life stages of these species of concern. These rates were used to estimate the loss of equivalent adults using a specialized module developed by ERM.

Buzzards Bay, MA Oil Spill modeling
Involved in development of an oil spill fate model for Buzzards Bay oil spill of April 27, 2003. The model was developed using GEMSS-COSIM (Chemical and Oil Spill Impact Module). The study required analysis of oil spill fate and its shoreline interaction under varying meteorological and hydrodynamic conditions.

Residual LNG Chlorine Study, ExxonMobil Research Qatar (EMRQ), Qatar. A residual chlorine discharge limit of 0.15 mg/L at the outfall was previously permitted by the Supreme Council for the Environment (SCE). At the edge of the mixing zone the residual chlorine concentration is not to exceed 0.01 mg/L limit. ERM was tasked to create a model simulating the chlorine plume discharged from the facility under these new conditions to verify compliance with standards and to modeling of residual chlorine and 15 chlorine by products discharged from the RasGas, Qatargas and RLCC outfalls into the Arabian Gulf. The chlorine model was successfully validated with an extensive field data set.

Mining

Water Quality Modeling for Diamond Mine Support in Snap Lake. ERM's Surfacewater Modeling Group developed hydrodynamic and water quality model for Snap Lake diamond mining operations. Modeling included past and future water quality impacts due to mining operations. Ice conditions were implemented to reproduce winter freeze and affects on the lake water quality.

Surfacewater Modeling for Support for Alberta Tar Sands Impact Assessment. ERM's Surfacewater

Modeling Group provided custom programming through its GEMSS modeling system to allow Cumulative Environmental Management Association (CEMA) estimate recovery time for tailings ponds. Key issues were rate of compaction, resulting morphodynamic changes and transfer of contaminants to surface waters.

Surfacewater Impacts for Marampa Iron Mine, Sierra Leone. ERM provided environmental impact assessment studies for the phased development planned for the Marampa iron ore mine proposed by London Mining. Project involved quantifying impacts due to dredging, minewater runoffs and accidental scenarios due to mining operations.

Water Quality

Lake Whatcom, Washington
ERM was tasked by Brown and Caldwell with evaluating the performance of the reservoir model component of the Lake Whatcom Nutrient Response Model (LWNRM). The LWNRM consists of the reservoir model (CE-QUAL-W2) and the watershed model (HSPF), which provides tributary flows and nutrient loads to the reservoir model. This model had been used to simulate nutrient water quality in the Lake for the two-year period 2002-2003, first to reproduce existing conditions (the calibration), then to simulate natural conditions, and finally to develop the Total Maximum Daily Load (TMDL). Because the TMDL process looks forward in time to predict improvements in water quality, ERM tested the model against field data for 2007-2008 and developed an alternative TMDL using loads for this two-year period. To do so, ERM developed new input files, made specific improvements in DO. It was desirable, therefore, to evaluate the model's performance against a dataset for another period. ERM performed the TMDL analysis for this new period to evaluate the projection capability of these TMDL estimates in to the future.

Budd Inlet Water Quality Modeling
Involved in the development of a carbon based water quality model for Budd Inlet and Capitol Lake, WA. ERM had done a similar study in 1998 for the Lacey, Olympia, Tumwater and Thurston County (LOTT) partnership for wastewater permitting. Current work includes improvement in the water quality calibration performed during the previous study along with the inclusion of Capitol Lake in the modeling domain.

Lower Passaic River Superfund Site Hydrodynamic and Contaminated Sediment Transport Modeling. This confidential study included analysis of current meter and water surface elevation data and modeling of the hydrodynamics and transport of sediments. The purpose of the study was to support our client, a PRP, in the interim allocation process and to help establish the magnitude of dispersal of material introduced into the prominent Newark Bay river-estuary system. This effort also included review of EPA- and Cooperating Parties Group-generated documents and datasets (particularly EPA's Framework Document and modeling reports), submission of comments, and attendance at Technical Committee meetings.

Delaware Bay TMDL
Developed and applied a hydrodynamic, transport and water quality model for Delaware Inland Bays. The objective of the study was to determine the TMDLs for the impaired waters on the State's 303(d) list for nitrogen, phosphorus, and DO within the Inland Bays of southern Delaware. These water bodies included Rehoboth Bay, Indian River, Little Assawoman Bay, and the surrounding tributaries and ponds. This analysis was accomplished using a hydrodynamic and water quality model GEMSS to verify the effectiveness of prescribed point and non-point source load reductions to meet the TMDL objectives.

Hydrodynamic Mixing Zone modeling of the confluence of the Nottawasaga River with Nottawasaga Bay
Involved in performing the hydrodynamic mixing analysis of Nottawasaga River with Nottawasaga Bay using GEMSS-HDM & GEMSS-WQM in support of developing future TMDL for the waterbodies. The work includes estimation of near field mixing zone and its effects on the local water quality. Study will also be done on estimating the extent of the Nottawasaga River mixing zone on various River loading conditions and the subsequent water quality in the near field Bay region.

Janey run mixing zone modeling
Involved in performing mixing zone analysis for a mine tailings discharge into Janey Run, MD. CORMIX was used to estimate the extent of the mixing zone during different tidal and non tidal conditions.

Charlotte Harbor water quality modeling

Involved in development of a Charlotte Harbor water quality model using GEMSS to analyze the relationship between physical and biochemical processes in the estuary. The analysis included study of phytoplankton effect on dissolved oxygen and investigation of the occurrence of hypoxia in the deeper regions of the harbor.

Roxboro power station thermal modeling
Involved in development of a hydrodynamic and thermal plume model for Lake Hyco, SC to analyze the thermal discharge from Progress Energy - Roxboro Generating Station. Updated GEMSS transport module with higher order transport schemes such as QUICKEST and QUICKEST+ULTIMATE to better estimate the stratification.

South Seas Marina Flushing Study
Modeled the South Seas marina for exchange of water with the open seas. It was found that the marina in its planned configurationdid not flush (replace) 90% of the water within 24 hours. Several improvements to the marina configuration were proposed and evaluated. It was found that a combination of widening and deepening of entry channel along with opening of one design breakwater will improve the flushing and increase the degree of exchange with the open sea.

Flushing and Water Quality Study for South Bethany
Assessed improvements to DO, nutrient levels, and other potential changes to the environment due to increasing ocean flushing into Delaware's Inland Bays (Indian River, Rehoboth Bay, and Little Assawoman Bay) using GEMSS HDM and WQM modules. Various methods of providing the flushing improvements and increasing the degree of exchange were examined including tidally driven inlets and pumping systems. Final recommendations were provided along with a cost-benefit analysis for the various options.

Monitoring of Harmful Algal Bloom (HAB) for Lake Ontario
Developed a three-dimensional free surface sigma co-ordinate hydrodynamic model for Lake Ontario based on Princeton Ocean Model (POM) for NOAA: MERHAB Lower Great Lakes. Also developed a Random walk particle-tracking model, to link with the hydrodynamic data to track the movement of algal blooms. Project also included analyzing the impact of Niagara River flow on the southern coastal region of the lake and on bloom movements. The overall goal was to setup a web page for real time simulations, where a user can specify the current bloom location and then monitor the trajectory.

Algae Transport & Water Quality model for Lake Ontario
Developed a FORTRAN based two-dimensional Dissolved Oxygen (DO) and algae transport model for Lake Ontario as a part of the Rochester Harbor project for the US Army Corps of Engineers (USACE) and URS Corporation. The models were developed to monitor the water quality and algae fate for analyzing the efficiency of "herd and pump" approach adopted to solve the algae accumulation at the Ontario beach. Also performed calibrations for the dispersion values in the lake using conductivity data. Submitted a final report on the analysis results to URS suggesting preferred pumping locations.

Sediment Transport

Purari Hydropower Sediment Transport Modeling.
Developed a hydrodynamic model in support of styding sediment transport in Purari River due to the construction of the hydropower facility. Modeling included assessment of net sediment fluxes, impacts on turbidity and evaluation of floodplain erosion.

Lower Passaic River Superfund Site Hydrodynamic and Contaminated Sediment Transport Modeling. This confidential study included analysis of current meter and water surface elevation data and modeling of the hydrodynamics and transport of sediments. The purpose of the study was to support our client, a PRP, in the interim allocation process and to help establish the magnitude of dispersal of material introduced into the prominent Newark Bay river-estuary system. This effort also included review of EPA- and Cooperating Parties Group-generated documents and datasets (particularly EPA's Framework Document and modeling reports), submission of comments, and attendance at Technical Committee meetings.

Thermal Modeling

Salem Generating Station Cooling Water Intake System improvements.
Salem Generating Station (SGS) withdraws water from Delaware Estuary its cooling water (CW) . Detrital material suspended in the Estuary is also drawn into the CW system. ERM's Surfacewater Modeling Group developed a high resolution hydrodynamic and particle

tracking model simulate the movement of detritus. It was found that approximately 40% of the grass collected at the intake structure comes from the grass disposed at the ends of the intake structure. Moving the disposal point from the ends of the intake structure to the CW outfall provided a large reduction in recirculation of grass. It was found that less than 5% of the disposed grass is recirculated to the intakes when it is disposed through the CW outfall. This result reflects an improvement of almost 90% compared to the current procedure (40% down to 5%).

Thermal Plume Modeling, RasGas LNG, Qatar. RasGas operates a liquefied natural gas (LNG) facility on the northeast coast of Qatar, discharging cooling water into the Arabian Gulf through an open canal. The RasGas facility originally consisted of a single LNG train that nominally circulates 27,500 m3/hr of seawater for heat exchanger cooling at a temperature rise of 10°C. RasGas subsequently added a second LNG train and proposed two additional trains. The objectives of this study were to model the thermal plume under existing and proposed operations including for model verification and mixing zone specification for the cooling water discharge plume. Model results showed that the thermal plume was vertically stratified, with a relatively large area on the surface and a relatively small bottom contact area. The advantage of the design was that it maximized heat exchange with the atmosphere, while protecting the benthic organisms from the temperature increase.

Susquehanna River hydrothermal modeling
Involved in the development of hydrodynamic model for Susquehanna River Brunner Island power plant using GEMSS-HDM in support of 316(a) renewal for the PPL Services Corporation, PA. Updated the GEMSS-HDM module for sigma stretching in vertical direction and model several connected waterbodies to accommodate for highly varying surface elevations. Also developed higher order turbulence closure schemes for vertical diffusion.

Ghana Thermal Modeling
Developed and applied a thermal discharge model, GEMSS®-TAM for the proposed TEMA Power Project located in an industrial area near Tema on the coast of Ghana. The Ghana Environmental Protection Agency (EPA) was imposes restrictions on the extent of the 3°C temperature rise isotherm which was modeled for three different plant configurations (two gas fired and one distillate fired). A probabilistic approach was applied to estimate the 3°C temperature rise isotherm under transient tidal conditions. Further model confirmation was done by setting up CORMIX in the near field. It was found that the maximum temperature rise at the surface was always less than 1°C. The 3°C temperature rise isotherm was found to be limited within the 8 m of the discharge port. Under all the proposed configurations, the plant did not violate the regulations imposed by the Ghana EPA.

Jobos Bay hydrothermal and entrainment modeling
Involved in development of a hydrodynamic model for Jobos Bay, Puerto Rico using GEMSS-HDM (Generalized Environmental Modeling System for Surface waters – HydroDynamic Module). The purpose of the modeling was to characterize the thermal plume from Aquirre Power station in support of <316(a)> study and to quantify entrainment rates of ichthyoplanktons in support of <316(b)> study. GEMSS-ENTM (Entrainment Module) was used for the 316(b) entrainment studies.

Temperature Forecasting System
Involved in the development of a temperature forecasting system for Nebraska Public Power District (NPPD), Sutherland, NE. NPPD has wells around its cooling water discharge canal that brings cold groundwater to reduce the heated cooling water used in power generating station. The temperature forecasting system was developed to help NPPD manage the operations of these wells based on the predicted temperature at the end of the canal. The forecasting system was an excel based software that takes waste heat load, flow, meteorological data and well flow data to predict temperatures.

Squaw Creek reservoir hydrothermal modeling
Involved in the development of hydrodynamic model for Comanche Peak Steam Electric Station located at Squaw Creek Reservoir, TX using GEMSS-HDM. The study was oriented towards evaluating the current and historical conditions during the plant full load and identifies different alternatives to decrease the intake water temperature. Several alternatives such as Spray modules, cooling towers and water garden steps were evaluated. Several enhancements to GEMSS were done to include modeling of such alternatives and analyzing their efficiency.

Hydropower

Purari Hydro Project, Papua New Guinea
Purari Hydro Project is a proposed hydroelectric power project aimed at providing electricity to Papua New Guinea, north and far north Queensland, and Australia's National Electricity Market. The project will have a capacity of 1,800 MW of baseload electricity. ERM is currently developing models to asses the impacts related to the development of reservoir on downstream water quality, sediment and hydrodynamic characteristics. The modeling work involves connecting in-reservoir models developed by Électricité de France and downstream impact models developed by ERM. The study is currently underway with models being developed in conjunction with field data collection.

World Bank, Trung Son Reservoir CE-QUAL-W2 Model Application and Software Training, Vietnam
Trung Son Reservoir is a proposed hydroelectric power project on the Trung Son River in central Vietnam for Vietnam Electric Utility (EVU). The client requested assistance with development and training with the 2-dimensional hydrodynamic and water quality model, CE-QUAL-W2. The goal was to assess the water quality of the proposed reservoir and the management options for clearing the flooded areas. The technology transfer took place as a 6-day intensive workshop presented in Nha Trang, Vietnam. The workshop achieved two objectives: the model was fully customized to the Tung Son Reservoir problem definition, and the client (fifteen engineers and scientists) were trained in the use and theory of the model.

Baynes Reservoir, Cunene River, Angola-Zambia
ERM applied two reservoir models to assess potential environmental impacts from the construction and operation of the Baynes Hydroelectric Reservoir on the Cunene River between Angola and Zambia. The primary impacts are (1) the change in the water temperatures in the reservoir and immediately downstream of the dam and (2) the potential for eutrophication in the reservoir. The U.S. Army Corps of Engineers CE-QUAL-W2 model was chosen to assess the impacts of the Project on the temperature structure of the Baynes Reservoir. The U.S. Army Corps of Engineers BATHTUB model was used to estimate its trophic status. Results of the models identified the range of surface water elevations through the year, vertical water temperature distribution and behavior, monthly average discharge water temperatures, and the effectiveness of discharge structure placement. The trophic status of the reservoir was projected to be oligotrophic due to the low level of nutrient loading.

Kalivaç Reservoir, Albania
ERM applied two reservoir models to assess potential environmental impacts from the construction and operation of the Kalivaç Hydroelectric Reservoir in Albania. The primary impacts are (1) the change in the water temperatures in the reservoir and immediately downstream of the dam and (2) the potential for eutrophication in the reservoir. The Generalized Environmental Modeling System for Surface Waters (GEMSS®) model was chosen to assess the impacts of the Project on the temperature structure of the Kalivaç Reservoir. The U.S. Army Corps of Engineers BATHTUB model was used to estimate the trophic status of Kalivaç Reservoir.

Publications

Prakash, S., Kolluru, V. and Young, C. "*Evaluation of the Zone of Influence and Entrainment Impacts for an Intake Using a 3-Dimensional Hydrodynamic and Transport Model*". Journal of Marine Science and Engineering 2014. Vol. 2, 306-325.

Febbo, E., Duggan, J., Kolluru, V. and Prakash, S. "*Integration of a Geospatial Framework with a Suite of Numerical Models for Operational, Environmental and Regulatory Aspects of Cooling Water Usage*". Proceedings of the 2014 International Petroleum Technology Conference, held January 20–22, 2014, in Doha, Qatar.

Mathur, Dilip, Royer, D.R., Long, K, Matty, R.M., Sullivan, T.J., Prakash, S. and Buchak, E.M. "*Retrospective analysis to quantify migration of American Shad in an impondment on the lower Susquehanna River*". Proceedings of the 2013 Georgia Water Resources Conference, held April 10–11, 2013, at the University of Georgia.

Saeed, S., Deb, N., Campbell, R., Prakash, S., Kolluru, V. and Febbo, E. "*Laboratory Experiments to Validate 3D Numerical Modeling of Chlorine Decay in Industrial Cooling Water Discharge*". SETAC Europe 23rd Annual Meeting. May 12th to May 16th, 2013. Glasgow, UK.

Prakash, S., Kolluru, V. and Tutton, P. "*Semi-Lagrangian Approach to Stydying Grassing Issue on a Nuclear Power*

Plant Cooling Water Intake". Proceedings of 10th International Conference on Hydroscence and Engineering. Nov. 4-7, 2012, Orlando, Florida.

Febbo, E.J., Kolluru, V.S. and S. Prakash. "*Numerical Modeling of Thermal Plume and Residual Chlorine Fate in Coastal Waters of the Arabian Gulf*". Society of Petroleum Engineering International Conference 2012. September 11-13. Perth, Australia.

Kolluru, V.S., S. Prakash and E. Febbo. 2012. "*Modeling the Fate and Transport of Residual Chlorine and Chlorine By-Products (CBP) in Coastal Waters of the Arabian Gulf*". The Sixth International Conference on Environmental Science and Technology 2012. June 25-29. Houston, Texas, USA.

Prakash, Shwet, J.A. Vandenberg and E. Buchak. 2012. "*CEMA Oil Sands Pit Lake Model*". CONRAD 2012 Water Conference. April 20-22. Edmonton, Alberta.

Kolluru, V.S. and S. Prakash. 2012. "*Source Water Protection: Protecting our drinking waters*". India Water Week 2012. April 10-14. New Delhi, India.

Long, K., R.M. Matty, D. Mathur, D. R. Royer, T. Sullivan, S. Prakash and E. Buchak. 2011. "*Assessment of effects of interaction of pumped storage station operations and thermal plume on migration of American Shad (Alosa Sapisissuma) in the Lower Susquehanna River*. EPRI 2011. Third Thermal Ecology and Regulation Workshop. October 11-12, 2011. Maple Grove, Minnesota.

Prakash, S., J.A. Vandenberg and E. Buchak. 2011. "*The Oil Sands Pit Lake Model - Sediment Diagenesis Module.*" MODSIM 2011. Modelling and Simulation Society of Australia and New Zealand, December 12-16, 2011. Perth, Australia.

Vandenberg, J.A., S. Prakash, N. Lauzon and K. Salzsauler. 2011. "*Use of water quality models for design and evaluation of pit lakes.*" Australian Center for Geomechanics. Mine Pit Lakes: Closure and Management. Page 63-81.

Prakash, Shwet, Atkinson, Joseph F. and Mark L. Green. "*A Semi-Lagrangian study of Circulation and Transport in Lake Ontario*". Journal of Great Lakes Research. Volume 33, Issue 4, 2007, Pages 774–790.

Kolluru, V.S., M.J. Fichera, S. Prakash. 2006. "*Multipurpose modeling tool for aquatic and sediment contaminant fate and effect assessments*". SETAC North America 27th Annual Meeting. Montreal, Canada. November 2006.

Prakash, Shwet and V.S. Kolluru, 2006. "*Implementation of higher order transport schemes with explicit and implicit formulations in a 3-D hydrodynamic and transport model*." published in the 7th International Conference on Hydroscience and Engineering (ICHE 2006), Sep 10 - Sep 13, Philadelphia, USA

Hubertz, J.M., Prakash, S., Krallis, G. and Venkat Kolluru. "*Relationship between Physical and Biochemical Processes in an Estuary*". 7th International Marine Environmental Modeling Seminar. 2004.

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Matthew W. Erbe, P.G.

Principal Consultant



Matt Erbe is a Principal Consultant within Environmental Resources Management, a global provider of environmental, health, safety, risk and social consulting services. He assists clients with implementing multi-disciplinary environmental projects across multiple client sectors and industries. Matt has a Master of Science in Hydrogeology from Syracuse University.

He has 19 years of comprehensive experience managing contaminated site investigations and remediation projects, environmental and social baseline studies, and impact assessments with project revenues exceeding of $26MM. He is recognized for his performance management capabilities to consistently meet and exceed client and stakeholder expectations and project deadlines, subcontractor management, budgets and specifications for ERM's largest projects.

Project work has included environmental reviews for power plant modifications, hydrogeological assessments to support coal combustion by-product (CCB) beneficial use assessments, CCB leachate impact analysis and fate & transport modeling, corrective measures evaluations for ground water and surface water impacts related to fly ash management and disposal, use of CCB grouts at underground abandoned coal mines for water quality stabilization, and ground water supply and impact analysis for proposed power plant withdrawals. He provides technical consulting for the characterization of impacts from chemical and manufactured gas plants, evaluation of corrective measures for soil and groundwater impacts, groundwater flow and contaminant transport modeling; coal combustion product beneficial use and leachate impact analysis; and groundwater resource and supply analysis.

Education & Training

- MS, Hydrogeology, Syracuse University, 1997
- BS, Natural Sciences - Geology, Towson State University, 1995
- Fundamentals of Ground Water Geochemistry, Geochemical Modeling of Aqueous Systems, Advanced Ground Water Modeling Workshop
- 40-Hour OSHA Health and Safety Training for Hazardous Material Operations and Emergency Response, Current on Annual 8-Hour Update

Professional Affiliations & Registrations

- Professional Geologist, State of Tennessee

Publications

- D. Aeiker, M. Erbe and L. Rafalko, V. Gardner and R. Cleary. "Mapping Preferential Groundwater Flow Pathways for Contaminant Migration within a Karst Aquifer System", **paper presented** at the Fifth International Symposium and Exhibition on the Redevelopment of Manufactured Gas Plant Sites, Destin, FL, 2014.
- Erbe, M., and J. Ryan, "Use of In-situ Bioventing to Mitigate Diesel Range Petroleum Hydrocarbons in Saprolite", **paper presented** at the Battelle Ninth International In-Situ and On-Site Bioremediation Symposium, Baltimore, MD, 2007.
- Erbe, M., "Evaluation of Water Quality Conditions Associated with the Use of Coal Combustion Products for Highway Embankments", **talk given at** the 2005 EPA Region III By-Products Symposium, Philadelphia, PA, 2005.
- Erbe, M., R. Keating, C. Travers, L. Norman, W. Cutler, and T. Martin, "Assessing the Role of Structural Elements in Aquifer Hydraulics and Plume Management", **talk and paper presented at** U.S. EPA/NGWA Fractured Rock Conference Proceedings, Portland, Maine, 2004.
- Erbe, M.W. and D.I. Siegel, "Using Ternary Diagrams to Characterize the Natural Attenuation of Chlorinated Ethenes in Ground Water", **published in** *Journal of Environmental Hydrology*, Vol. 9. March 2001.

Key Projects

Impact Assessment

Nicaragua Grand Canal. Project Manager for $26.5MM contract to complete an environmental and social impact assessment for the proposed 275 km interoceanic shipping canal in Nicaragua. Accountable for overseeing the physical, biological, cultural and social studies under an extremely challenging schedule utilizing more than 200 ERM engineers and scientists from Canada, China, Colombia, Mexico, Panama, Peru, and the US Northern, Southern and Western divisions. The work is also being conducted in partnership with international NGOs and Nicaraguan experts.

Hangar 21, San Juan, Puerto Rico. LANTDIV. Managed the environmental baseline study of a former a WW II era military base. Oversaw investigations of groundwater impacts relating to the historic fuel distribution system from a 1991 release of gasoline at an upgradient and off-site gasoline station. As a result, the Puerto Rico EQB has since identified additional responsible parties to the contamination. Current remediation includes AST removals, ground water monitoring and asbestos abatement of the hangar.

Municipal Landfill Evaluations

68th Street Landfill Superfund Site, Rosedale, Maryland. Remedial Investigation Task Manager overseeing the remedial investigation of a 270-acre area containing multiple former landfills and five USEPA-designated "source areas," as well as sensitive environmental features such as streams, wetlands, and floodplains. The investigation approach incorporates human health and ecological risk assessments as well as the future redevelopment of areas of site.

Millersville Landfill, Maryland. Anne Arundel County DPW. Project Manager and Hydrogeologist overseeing the development of the Assessment of Corrective Measures for impacts to ground water, replacement of residential supply wells, hydrogeologic investigation of seeps to support landfill cells design, and risk assessments.

Confidential Project, Maryland. Managed proposed landfill information review and fatal flaw analysis. Support included review of County's WMP, zoning requirements, environmental resources, design criteria, and estimation of landfill capacity.

Methane Gas Investigation, St. Mary's County, Maryland. Managed investigation of a methane gas plume migrating beneath a proposed housing development.

Corrective Measures

MFRI, Prince Georges County, Maryland. University of Maryland. Completed evaluation of corrective measures for impacts to ground water resulting from the release of gasoline from an UST. EPA Region III approved the use of monitored natural attenuation as the remedial alternative for cleanup of the non-potable aquifer.

CREO Manufacturing Plan, Middleway, West Virginia. Kodak. Evaluating remedial technologies to reduce source concentrations of trichloroethylene in the ground water within a karst aquifer system. Leading technologies being evaluated include electric resistance and radio frequency heating, bio augmentation, and dual-phase extraction with vapor extraction.

Anne Arundel County, Maryland. Alliant Techsystems. Completed a remedial alternatives analysis of measures to eliminate the potential for off-site migration of ground water plume and reduce the residual contaminant mass to reduce client's long-term liabilities and financial obligations associated with the site.

Sykesville Oil Site, Maryland. Managed the investigation and remediation of a 10,000-gallon diesel fuel spill that entered the saprolite and bedrock aquifers and discharged to surface water. Prepared the design and installation of an in-situ bioventing remedy to reduce hydrocarbon concentrations to a risk tolerable level. Work is being completed through a Consent Order with the EPA Region III.

Manufactured Gas Plant

Site Investigation, Hagerstown, Maryland. NiSource. Project Manager for the site characterization and ISCO pilot test to remediate residuals (BTEX and PAHs) at a former manufactured gas plant. Investigation activities included electrical resistivity survey to identify bedrock basins and ridges, direct-push and split-spoon sampling, soil gas sampling, overburden and bedrock well installation, implementation of a pilot test using sodium persulfate and calcium peroxide to reduce residual contamination.

Phase II ESA, Binghamton, New York. NYSEG. Geologist responsible for remedial investigation of ground water contaminated by coal tar at a former manufactured gas. Project included geologic site characterization and NAPL delineation, well installation, ground water sampling, aquifer testing, client and regulatory agency communication, and health and safety monitoring.

Groundwater Flow Model, Frankfort Indiana. NiSource. Project Manager for an investigation of the potential impacts to ground water related to a former MGP facility. Used analytical element models to simulate water table aquifer and capture zone for a City production well adjacent to the facility. Modeling indicated that the capture zone in the confined aquifer extends beneath the former MGP facility; however, ground water in the water table aquifer flows away from the City wells and is not hydraulically connected to the deeper aquifer.

Hydrogeologic Assessment

Fallstaff Property, Harford County, Maryland. Managed hydrogeologic investigation for ground water appropriations permit. The 23 lot parcel under development is adjacent to a fuel terminal which released gasoline to the saprolite and bedrock aquifers. Project included the use of an analytical element model to simulate future pumping conditions at the development and assess the migration and fate of BTEX and MTBE in ground water.

Groundwater Investigation, FMC Avtex Fibers Superfund Site in Front Royal, Virginia. Project Manager and Senior Hydrogeologist for a deep bedrock aquifer (DBA) investigation and closure of several former basins at the site. The project required installation of multiple deep groundwater monitoring wells using conventional and multi-level systems, ambient ground water and river level monitoring, conduct of single and multi-well pumping tests in fractured shale, and preparation of a dense aqueous phase liquid (DAPL) flow and transport model to evaluate the role of structural geologic elements in plume migration and aquifer hydraulics.

Site Characterizations, Parkersburg and Nitro, West Virginia. FMC Corporation. Managed the evaluation of environmental impacts at two former rayon manufacturing facilities under the West Virginia Voluntary Remediation Program. Primary contaminants included carbon disulfide and PAHs.

Gardiner Road, Charles County, Marylsn. Chaney Enterprises. Managed an assessment of hydraulic impacts relating to the proposed mineral extraction (i.e., sand and gravel mine). Assessment included a review of water quantity and quality impacts to first order streams and wetlands.

Piney Branch Bog, Charles County, Maryland. PPRP. Managed the hydrogeologic evaluation of the site to characterize the pre-development hydrology of the gravel bog and establish baseline hydrologic conditions prior to development in the region.

FIFRA Investigations. Carried out hydrogeologic investigations of agricultural chemicals under the EPA's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Responsibilities included: supervision of drilling, hydrogeologic characterization, vadose zone hydraulic conductivity analyses, installation of shallow soil lysimeters, test and control substances application rate verification, and sampling soil, ground water, soil water, and surface water for residue analysis.

CCP Use and Disposition

BBSS Mine Site, Crofton, Maryland. PPRP. Principal Investigator for the evaluation of impacts to groundwater quality resulting from the use of fly ash to reclaim a sand and gravel mine. Used statistical analysis of metals concentration data collected from monitoring wells and residential water supply wells both adjacent to the mine site and the surrounding communities. The investigation concluded that although natural soil conditions were contributing to elevated metal concentrations in the ground water, mining and reclamation activities had contributed to the deterioration of the shallow potable aquifer system.

Faulkner Fly Ash Storage Site, Charles County, Maryland. PPRP. Principal Investigator for evaluation of long-term surface water quality and the effectiveness of the wetland treatment systems to mitigate impacts to ground water from the ash fill. The studies provide stakeholders a basis for determining future requirements for monitoring and evaluating the effectiveness of preventive measures for sulfate reduction at existing and future CCP storage facilities and upgrading the treatment systems.

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Dusty Aeiker

Project Manager, Hydrogeologist



Ms. Aeiker is a project manager in ERM's Annapolis, Maryland office, with over five years of professional experience in environmental consulting. She is primarily active in the Site Investigation and Remediation practice at ERM.

Ms. Aeiker's professional experience includes Phase II Site Assessments of various types of active and inactive commercial and industrial facilities in Maryland, Virginia, and West Virginia. She has also worked on several sites that have been entered into the Maryland Voluntary Cleanup Program, West Virginia Voluntary Remediation Program, and RCRA program, both as a project geologist and as a project manager. Additional experience includes conducting, coordinating, and managing regular ground water monitoring events at various sites.

Ms. Aeiker is proficient in various types of sampling techniques for soil, ground water, and air (i.e., soil gas, sub-slab vapor and ambient indoor and outdoor air). Additionally, Ms. Aeiker holds extensive experience overseeing the installation of monitoring wells and piezometers using hollow stem auger, air rotary, wet rotary, mud rotary, and hydraulic direct-push drilling techniques. Ms. Aeiker also manages large volumes of chemical data in spreadsheet and database formats.

Registrations & Professional Affiliations

- National Ground Water Association

Fields of Competence

- Hydrogeology
- Geochemistry
- Environmental sampling (soil, surface water, ground water, soil vapor, sub-slab vapor, indoor air)

Key Industry Sectors

- Site Remediation and Investigation
- Mining and Minerals
- Oil and Gas
- Chemical Manufacturing

Education & Training

- B.S., Geology, Cum Laude, University of Maryland, 2006.
- 40-Hour OSHA Health and Safety Training for Hazardous Material Operations and Emergency Response, Current on Annual 8-Hour Update

Languages

- English, native speaker

Publications

Aeiker, D.M., Mansur, A.T., Rudnick, R.L., Piccoli, P.M., McDonough, W.F., *Deducing the depth of origin of granulite xenoliths from zircon-rutile thermometry: a case study from Tanzania*. Abstract V41A-03, 2006 AGU Joint Assembly, May 2006, Baltimore, MD.

Key Projects

Former CREO Manufacturing Plant Landfill Monitoring, Middleway, West Virginia. NPEC. Project Manager overseeing the semi-annual sampling of a closed industrial landfill under a West Virginia Landfill Permit and the semi-annual sampling of storm water outfalls under a West Virginia National Pollutant Discharge Elimination System (NPDES) Water Pollution Control Permit. Updates and maintains a DumpStat database for the landfill and generates statistical graphs of monitoring data in compliance with state reporting requirements. Completes NPDES monitoring reports and summary reports for landfill and storm water semi-annual sampling.

USEPA Region III RCRA Corrective Action Support, Winchester, Virginia. Federal-Mogul Corp. Oversaw the installation of injection, recovery, and monitoring wells. Collected ground water samples from wells utilizing low-flow sampling techniques and a multi-parameter probe. Conducted aquifer tests on injection and recovery wells to determine the hydraulic conductivity of the aquifer. Coordinated and conducted a dye trace study to determine ground water flow direction. Provides oversight during injection events, and completes quarterly reports in compliance with state reporting requirements.

USEPA Region III RCRA Corrective Action Support & Corrective Measures Study, Salisbury, Maryland. Dresser Industries, Inc. Coordinates and conducts soil and ground water sampling activities at a former manufacturing facility. Recent activities include coordinating the delineation of an LNAPL plume using direct-push technologies, coordinating a ground water quality vertical delineation using direct-push technologies, installing monitoring and injection wells as part of the *In Situ* Chemical Reduction (ISCR) Interim Corrective Measure (ICM) to address hexavalent chromium impacts in soil and ground water, and coordinating the sampling of all on-site monitoring wells. Assisted in the preparation of documents for submission to the U.S. Environmental Protection Agency (USEPA) as part of ongoing steps to complete the corrective action process for the facility.

Gardiner Road Water Level Monitoring, Charles County, Maryland. Chaney Enterprises. Project Manager overseeing the quarterly water level monitoring as part of the Charles County Board of Appeals approval for the mining operations. Updates and maintains water levels tables and generates quarterly isocontour maps of the water table surface in compliance with County reporting requirements.

Site Characterization at a Former Manufactured Gas Plant, Hagerstown, Maryland. NiSource. Coordinated and conducted field efforts for the site characterization of a former manufactured gas plant site and surrounding properties in Maryland. Investigation activities included electrical resistivity survey to identify an area in which MGP residual tar was placed, direct-push and split-spoon sampling, soil gas sampling, and overburden and bedrock well installation.

Former CREO Manufacturing Plant West Virginia Voluntary Remediation Program Application Support, Middleway, West Virginia. NPEC. Conducted a supplemental assessment of environmental media associated with an industrial site situated in a karst region in West Virginia. Assessment included the characterization of soil throughout the site, characterization of sediment and surface water in bordering streams, and installation of a deep bedrock well. Also collected indoor air samples using Summa® canisters to characterize the nature and extent of Volatile Organic Compounds (VOCs) in indoor air. Determined whether VOC sources in soil and ground water affect indoor air quality.

Ground Water Quality Evaluation, Crofton, Maryland. PPRP - BBSS Fly Ash Site. Assisted in the management and interpretation of geochemical data collected from compliance monitoring wells and residential supply wells surrounding the former mine sine. Used statistical analysis to demonstrate that heavy metals leached from the fly ash used to reclaim the mine were impacting water quality in the down-gradient vicinity of the mine.

Jonathan P. Connelly

Project Scientist/ESIA Specialist



Mr. Connelly is a Project Scientist within the Impact Assessment and Planning (IAP) Practice at ERM in Annapolis, Maryland. He has approximately 12 years of environmental consulting experience and has worked on numerous domestic and international projects. Since joining ERM in 2011, Mr. Connelly has been a member of the Biodiversity and Ecosystems Services Practice and is well versed in the principles of biology with a focus on terrestrial and wetlands ecologies, and impact assessments. Mr. Connelly has focused on conducting desktop and site reconnaissance for the preparation of Environmental Assessments, Environmental Impact Statements, Environmental and Social Impact Assessments, and permit preparation.

In addition to these roles, Mr. Connelly is skilled in geographic information systems (GIS) for spatial analysis, and database management, especially within the context of managing the receipt, organization, and response to stakeholder input on large scale, controversial projects.

Fields of Competence

- Environmental Impact Assessment
- Habitat and vegetation inventories
- Environmental Permitting
- Environmental regulations and policy research
- Biological Sampling including plant identification and collection; quantitative and qualitative fish community survey methods; fish shocking/netting/catching
- Water quality sampling
- Geographic Information System (GIS)
- Aerial photograph, landscape feature, and habitat interpretation
- Spreadsheet data management

Training & Certifications

- Qualified Professional in Maryland: Forest Stand Delineations and Forest Conservation Plans, 2013
- Pennsylvania State University College: Post-baccalaureate Certificate in Geographic Information Systems, Pennsylvania, 2015
- American Red Cross: Adult First Aid/CPR/AED, May 2016-2018
- 40-hour HAZWOPER, Compliance Solutions, 2016

Education

- Post-baccalaureate Certificate in Geographic Information Systems, PennState University, 2015
- University of Massachusetts – Graduate Course: Soil Sciences, Amherst, MA, 2009
- B.A. in Environmental Studies, Eastern University, PA, 2003

Key Projects

ExxonMobil Strategic Environmental Assessment (SEA) for Offshore Drilling, Guyana, 2014-2015.
Provided project and GIS support for the preparation of a Strategic Environmental Assessment (SEA) for the exploration of offshore petroleum resources along the Guyana coast. Assisted in the development of a Coastal Sensitivity and Spill Response Plan with use of digital and non-digital data in ArcGIS.

Preliminary Environmental Impact Assessment (PEIA) for a Gas-Powered Power Plant, Nigeria, 2015.
Provided project support for the preparation of a PEIA for a proposed Power Plant expansion project in Nigeria. Provided general GIS and spatial analytical support for noise sensitive receptors in and around the Project Site. Conducted research and review of applicable international, national, and local environmental rules

and regulations. Authored the ecological baseline and impact assessment sections.

Proton Energy Environmental and Social Impact Assessment (ESIA), Sapele, Nigeria, 2016. Provided general GIS and spatial analytical support for a proposed gas-fired open cycle power plant. Provided figures of surrounding noise sensitive areas and their approximate distances from the proposed Project.

Nassau Plateau Bauxite Mine, ESIA, Alcoa, 2011-2012. Assisted with the feasibility assessment for a proposed bauxite mine at a greenfield site in central Suriname. Supported development of biological resources chapters by assisting in report writing and fieldwork. Evaluated streams and rivers in the vicinity of the proposed project to collect fish, macroinvertebrate, and sediment samples for analysis of metals. Utilized ArcGIS to provide spatial analysis for the distribution of rare, threatened, and endemic fishes located within the concession boundary.

Alcoa and Rio Tinto Alcan (Alcoa-RTA), Kabata Alumina Refinery ESIA, Guinea, 2013. Assisted in the preparation of an ESIA for the construction of an Alumina Refinery Project in Guinea. Developed habitat and vegetation coverage GIS data within the project area based on a combination of remote data interpretation and biological data collected in the field. Conducted spatial analysis of project-related habitat conversions and mapped protected areas.

Nicaragua Canal Project ESIA, Nicaragua, 2013-2015. Collaborated with multiple GIS professionals across ERM Offices for the collection and organization of field data. Assisted with the integration of the data into GIS for biodiversity-related figures for an ESIA report. Created numerous rare and threatened species figures associated with the ESIA.

Fiat-Chrysler, Michigan, US, Biodiversity Study. Performed a Biodiversity Value Index Study within a 35 square mile radius of a Chrysler Engine Plant Site in Trenton, Michigan. Conducted a biodiversity characterization of the study area through seasonal field surveys of habitats and wildlife species.

NorthMet Mine EIS, Minnesota, US, Minnesota Department of Natural Resources, 2012-2013. Provided project support for preparation of an EIS and Supplemental EIS for construction and operation of a mining and processing operation in northeastern Minnesota (US). Verified water quality data and synthesized these data into a summary subsection of the water chapter in the EIS.

SEIS Keystone XL Pipeline, USA. 2012-September 2013. Assisted with the organization and categorization of stakeholder comments on the Keystone XL Pipeline during the scoping process. Utilized Microsoft Access to organize by topic area and content to enhance the accuracy and thoroughness of the comment review process. Utilized GIS to compile data on private land ownership and home locations along the Project's alternative routes. Supported the socioeconomic component of the alternatives analysis by analyzing the number and location of homes that would be affected by each location of the alternative alignments.

Environmental and Social Impact Assessment (ESIA), Wageningen, Suriname, 2012-2013. Utilized ArcGIS to organize data to depict field survey data during the baseline field studies. Created multiple GIS data of habitat- and vegetation-types within the Project area based on remote sensing data and biological data collected in the field. Provided spatial analysis of Project-related habitat conversions and mapped protected areas adjacent to the Project site. Assisted with writing of the baseline and impact assessment for terrestrial ecology and wildlife species for the ESIA.

ESIA, Mining Project, Weda Bay, Indonesia, 2012. Assisted in the preparation of an ESIA for construction and operation of a nickel and cobalt mining operations and an ore processing plant in Halmahera, North Maluku in Indonesia. Co-authored the vegetation impact assessment based on the spatial analysis of direct and indirect effects on vegetation coverage within the Project area. Supported development of the terrestrial resources chapters, ecosystems services report, conducted online literature reviews to support the impact assessment, and updated GIS figures.

Melinda K. Todorov

Project Scientist



Ms. Melinda Todorov is a Project Scientist within ERM based in Annapolis, Maryland. She has over nine years of experience in impact assessment and an additional four years experience in the field of aquatic ecology, including studies of marine invasive species. Ms. Todorov has a National Environmental Policy Act (NEPA) certificate from the Duke Environmental Leadership Program. Her responsibilities have included assisting in the preparation of Environmental Impact Statements, Environmental Assessments, and Integrated Natural Resources Management Plans under the National Environmental Policy Act (NEPA) and other U.S. and international regulations. She specializes in analysis of impacts on biological and water resources. As part of her NEPA experience, Ms. Todorov has assisted in the management of the collection and response to public comments.

Ms. Todorov has field experience with both marine and freshwater systems as well as wetlands. She has assisted in conducting wetland delineations and habitat assessments. In addition, she has provided support for planning and sustainability projects and studies as well as prepared wetland permits.

Fields of Competence

- NEPA implementation
- Environmental Impact Assessments
- Aquatic ecological studies including statistical analysis and macrozooplankton taxonomy and sampling

Education

- M.Sc. Aquatic Ecology (ISATEC), University of Bremen, Germany, 2001
- B.S. Biology, Central Michigan University, 1999

Certificates

- National Environmental Policy Act (NEPA) Certificate, Duke Environmental Leadership Program, Duke University, 2008 – 2012
- 40-hour HAZWOPER, Compliance Solutions, 2010

Languages

- English, native speaker
- German, conversational

Publications

Bednarski, M., Morales-Ramírez, A. 2004. Composition, abundance and distribution of macrozooplankton in Culebra Bay, Gulf of Papagayo, Pacific Coast of Costa Rica and their value as bioindicators of pollution. Revista de Biología Tropical 52 (3A): 105-120.

Cahill, M., K. Olsen, D. Blaha, J. Tims, A. Finio, M. Todorov, J. Ewald, J. Primo, L. Medley, D. Bigger, K. Skrupky, B. Hooker, B. Jordan and A. Dhanju. Atlantic Wind Energy Workshop Summary Report. U.S. Department of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement. Herndon, VA. OCS Study BOEMRE 049- 2011. 78 pp. + apps.

Key Projects

Atlantic Coast Pipeline, US, Dominion, 2015-present.
Provided Project support for the proposed interstate natural gas pipeline that will serve multiple public utilities and their energy needs in Virginia and North Carolina. Assisted in research of revegetation mixes and provide ongoing support to the biology team, including assisting with the Biological Evaluation and field data QA/QC.

LNG Re-gasification Plant Expansion Environmental Assessment, Barbados, Inter-American Development Bank, 2016.
Prepared several environmental setting sections (including Climate and Air Quality, Hydrology, Noise, Flora and Fauna, and Socioeconmics) of the Environmental Assessment (EA) for the Phase I strategy, which includes the expansion/upgrade of the existing LNG facility in Woodbourne, Barbados and the upgrade of natural gas transmission and distribution infrastructure.

NorthMet Mine Environmental Impact Statement, Minnesota, US, Minnesota, Department of Natural Resources, US Army Corps of Engineers, and US Forest Service, 2008-2016.
Provided project support for preparation of the Draft Environmental Impact Statement (EIS), Supplemental Draft EIS (SDEIS), and Final EIS (FEIS) for a 32,000 tpd open-pit polymetal sulfide mine in Minnesota. Co-authored and coordinated the preparation the water resources chapters of the Supplemental DEIS, including data verification and integration. Deputy task manager of SDEIS public comments process. Subject Matter Expert and lead for Aquatic Resouces chapters as well as Water Resources team coordinator for FEIS.

FirstNet Programmatic Environmental Impact Statement, AK, HI, and US Territories, 2015.
Assisted in the preparation of Land Use, Recreation, Visual Resources, Socioeconomics and Environmental Justice chapters for a programmatic EIS, evaluating the impacts of implementation of the federally-established First Responder Network Authority (FirstNet) projects in Alaska, Hawaii, and US overseas territories. FirstNet would build, operate and maintain a high-speed, nationwide wireless broadband network exclusively for public safety entities such as police, fire, and EMS.

Keystone XL Pipeline Supplemental Environmental Impact Statement, US, 2012-2014.
Assisted in preparation of the Supplemental Environmental Impact Statement (SEIS) as well as comment identification and comment response. This highly visible SEIS was completed at an accelerated pace for the U.S. State Department..

Nicaragua Canal Environmental and Social Impact Assessment, Nicaragua, HKND Nicaragua, 2013 – 2014.
Provided project support as needed, including coordination of the preparation of the Terms of Reference, Data Gaps report, and section on climate change impacts to biodiversity. Reviewed the Emergency Response Plan for field teams and created a database for worker health and safety survey.

Rosebel Gold Mines Tailing Storage Facility Expansion ESIA, Suriname, IAMGold, 2012.
Assisted in the preparation of Terms of Reference and Environmental and Social Impact Assessment (ESIA) for the gold mine tailings storage facility expansion project. Authored sections on Legal Framework and Impact Assessment Methodology.

Buckeye Wind Project Environmental Impact Statement, Ohio, US, Buckeye Wind L.L.C., 2011-2012.
Assisted in the preparation of the Draft EIS for construction and operation of a 250 MW wind facility in Ohio. Performed data analysis to update avian and bat fatality estimates for cumulative effects discussion.

Weda Bay ESHIA, Indonesia, Mining and Metals Sector Client, 2011 – 2012.
Assisted in the preparation of an Environmental Social and Health Impact Assessment (ESHIA) for construction and operation of a nickel and cobalt mining operation and an ore processing plant in Central and East Halmahera, North Maluku in the Indonesian archipelago. Supported development of the terrestrial resources chapters and ecosystems services report.

Columbia Gas Pipeline, Line MB Extension Environmental Assessment, Maryland, US, 2012.
Assisted in the preparation of an Environmental Assessment (EA) for construction and operation of a gas pipeline. Supported development of alternatives and cumulative effects chapters.

Nassau Plateau Bauxite Mine ESIA, Suriname, Suralco, 2008 -2012.
Assisted in the preparation of an Environmental and Social Impact Assessment (ESIA) for a new bauxite mine on the Nassua Plateau in Suriname. Supported development of biological resources and legislative chapters.

Suriname Bauxite Mine ESIAs, Suriname, Mining Sector Client, 2011 - 2012.
Assisted in the preparation of two ESIAs for bauxite mines in northeastern Suriname, one of which was approvedby the National Institute for Environment and Development in Suriname (NIMOS) in June 2012. Prepared legislative chapters and assisted in the development of biological resources and alternatives chapters.

Environmental Impact Statement, Massena, New York, US, Mining and Metals Sector Client, 2008, 2012.
Assisted in the preparation of the state-level Environmental Assessment to comply with the New York State Environmental Quality Review Act (SEQRA). Prepared the Socioeconomic and Transportation sections of the report.

Integrated Natural Resources Plan, Minot Air Force Base (AFB), North Dakota, US, 2011
Assisted in updating the Integrated Natural Resources Plan (INRMP) for the Minot AFB in North Dakota. The INRMP is a tool to help integrate natural resources management into Mission activities.

Environmental Impact Assessment Survey, Government (non-US) Client, 2009 - 2011.
Completed several surveys covering the National Environmental Policy Act (NEPA) process in the United States. Topics included public involvement, security of documents, mitigation and monitoring requirements, and the differences between programmatic and project EISs.

Natural Gas Pipeline Repair Permit, New Jersey, US, Sunoco, 2009-2010.
Assisted in the preparation of USACE Nationwide permit and NJDEP General Permit applications for the repair of a 8" natural gas pipeline. The pipeline is in an area that qualifies as wetlands and is below the natural water line of the tidal pond at all times.

Joint Land Use Study, Maryland, US, National Capital Park and Planning Commission, 2008 – 2009.
Assisted with the Joint Land Use Study between Andrews Air Force Base (AAFB) and Prince George's County, which seeks to ensure cooperative land use planning between AAFB and the surrounding communities so that future growth and development are compatible with the training and operational missions of the installation.

Crown Landing LNG Terminal, New Jersey, US, BP America, 2007 – 2008.
Assisted in the preparation of application materials for LNG terminal to the Federal Energy Regulatory Commission (FERC) and other government agencies. Supported project by updating resource reports, compiling application materials, and assisting in ichthyoplankton data interpretation.

Subregion 5 and 6 Master Plans, Maryland-National Capital Park and Planning Commission, 2008.
Assisted on environmental aspects of the 2008 environmental master plan updates for the Subregion 5 and 6 Master Plans in Prince George's County, Maryland. Researched water resources and land planning issues in the Subregion 5 portion of the Mattawoman Creek Watershed.

BP Alternative Energy, Mehoopany Wind Farm Northeast, Pennsylvania, US, 2008.
Assisted in wetlands surveys in support of state and federal wetlands and jurisdictional water body impacts associated with an approximately 90 MW proposed wind farm located across over 10,000 acres of mountainous forested terrain.

BP Alternative Energy, Cape Vincent Wind Farm Thousand Islands Region, New York, US, 2008.
Assisted in performing a wetland survey and habitat assessment of state and federal wetlandsto determine jurisdictional water body impacts associated with an approximately 90 MW proposed wind farm located across over 12,000 acres of rural farmland and forested terrain.

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Julia L. Tims

Technical Director Biodiversity and Ecosystem Services

Ms. Tims has twenty four years of experience in terrestrial ecology and natural resource management and environmental impact assessment. Ms. Tims specializes in terrestrial biodiversity and provides technical leadership for international Environmental and Social Impact Assessment (ESIA) projects around the world, primarily within the renewable energy, agricultural, mining, and transportation sectors. Ms. Tims has extensive experience in developing and leading biodiversity baseline and impact studies in accordance with best practice and international standards, including IFC Performance Standards, IDB Safeguard Policies, Equator Principals, and other lender standards. Ms. Tims specializes in application of the mitigation hierarchy and development of Biodiversity Action Plans, management and monitoring plans, restoration plans, and offset strategy development to address unavoidable residual impacts. Ms. Tims has been an active member of the Business and Biodiversity Offsets Program (BBOP) for over 5 years and is involved in numerous projects currently developing or considering the need for offsets.

Fields of Competence

- Environmental and Social Impact Assessment
- Biodiversity assessment, management, and monitoring
- International standards, including Equator Principles, IFC Performance Standards, and others
- Environmental and Social Due Diligence
- Application of mitigation hierarchy
- Biodiversity offsets
- Ecosystem services assessment
- Project permitting and documentation
- Endangered species conservation and management
- Terrestrial biodiversity baseline studies
- Stakeholder engagement related to biodiversity and biological/social interactions
- Interaction with environmental NGOs
- Habitat restoration and enhancement
- Conservation planning
- Alternatives analysis
- Cumulative impact assessment

Professional Affiliations

- American Ornithologist's Union
- The Wildlife Society
- Waterbird Society

Credentials

- M.Sc., Natural Resources Management/Ecology, Cornell University, 1999, With Distinction
- B.Sc., Entomology and Applied Ecology/Wildlife Conservation, University of Delaware, 1990
- Habitat Suitability Index Modeling, United States Fish and Wildlife Service
- Environmental Impact Assessment, Inter-American Development Bank
- Monitoring and Evaluation of Projects, Inter-American Development Bank
- OSHA 40-hr Hazardous Materials Handling and Safety Training

Key Industry Sectors

- Energy
- Mining
- Agriculture
- Transportation
- Infrastructure

Papers and Publications

- Tims, J.L., I.C.T Nisbet, J. Hatch, and C. Mostello. 2004. Characteristics and performance of Common Terns in Old and Newly-established colonies: implications for long term conservation. *Waterbirds*. 27(2):134-143.
- Tims, J.L. and K.M. Brown. 2001. Food Items Obtained by Gulls at and Around JFK International Airport: Relevance to Airport Management. *Waterbirds*. 24(1): 44-52.
- Tims. J.L. and K.M. Brown. 2001. Changes in the Nesting Populations of Colonial Waterbirds in Jamaica Bay Wildlife Refuge, New York, 1974-1998. *Northeastern Naturalist*. 45:17-28.

Julia L. Tims

Technical Director Biodiversity and Ecosystem Services

Representative Projects

Environmental and Social Impact Assessment, Nicaragua Canal Project, Nicaragua. Led the biodiversity component of the ESIA and preliminary offset strategy for the world's largest infrastructure project, the proposed Nicaragua Canal. The project consists of the canal and related infrastructure including two ports, a transmission line, roads, and reservoirs. Developed specialist team of over 100 Nicaraguan and international experts to conduct marine, terrestrial, and freshwater biodiversity studies across the country and led wet and dry season field surveys. Led the data analysis and terrestrial biodiversity impact assessment and prepared detailed biodiversity and protected areas management plans and offsetting proposals and developed the environmental and biodiversity components of the ESMS. Key issues included loss of primary rainforest, impacts to sea turtles, impacts to over 80 rare species, habitat fragmentation, impacts to protected areas and the Mesoamerican Biological Corridor, and impacts to critical habitat. All work on the project was conducted in alignment with international standards, particularly the IFC Performance Standards. The project was successfully conducted under an expedited timeframe and was subject to intense national and international scrutiny due to the high profile nature of the project.

Environmental and Social Impact Assessment for the Weda Bay Nickel Project, Indonesia. Lead biodiversity specialist for biodiversity baseline preparation and impact assessment for a nickel and cobalt mine and hydrometallurgical processing plant in Central Halmahera and East Halmahera Regencies, North Maluku Province, Indonesia. The island contains numerous endemic and red list flora and fauna and lies within the Northern Maluku Endemic Bird Area, which has the highest levels of bird endemism for its size anywhere in the world. Because of this high level of bird endemism, Halmehara and its neighboring isands rank number ten out of a total of 218 designated biological diversity hotspots in the world. Extensive baseline biodiversity studies were conducted over a ten year period and results were collated into a biodiversity baseline report. Ms. Tims conducted an ecosystem services review, IFC PS6 critical habitat assessment, and impact assessment and developed a robust Biodiversity Action Plan (BAP) and Biodiversity Management Strategy that focused on minimizing unavoidable impacts to critical habitats, endemic birds and other rare species, and important ecosystem services. Evaluated the feasibility of biodiversity offset options in accordance with Buisiness and Biodiversity Offet Program (BBOP) Principals.

Environmental and Social Due Diligence, Santander Sugarcane Operation, Belize. Currently leading the biodiversity and water aspects of an Environmental and Social Due Diligence (ESDD) of a sugarcane cultivation and processing mill for CIFI. The project is located in Belmopan District, Belize where rapid agricultural expansion is occurring. The greenfield site contained primary and secondary forest prior to clearing for project development and lies adjacent to a national protected area that was designated for the protection of jaguar and several sensitive water and wetland resources. Key issues facing the project include habitat loss, impacts to rare species, water quality, impacts of water abstraction on salinity and downstream water availability, maintenance of ecosystem services, cultural resources, resettlement, occupational health and safety, and induced and cumulative impacts from other sugarcane growers in the region that are growing sugarcane to supply the mill.

Environmental Impact Statement for an HCP and ITP for the Buckeye Wind Power Project, OH. Project Manager and avian/threatened and endangered species lead on an EIS for the United States Fish and Wildlife Service (USFWS) to assess the potential effects of the proposed 250 MW Buckeye Wind Power Project in west-central Ohio. The Project required an Incidental Take Permit (ITP) pursuant to the Endangered Species Act (ESA) to authorize the incidental take of Indiana bats, listed as federally endangered under the ESA, that would likely occur as a result of the Project. The EIS assessed the effects of issuance of the ITP on Indiana bats and other resources as required by the National Environmental Policy Act (NEPA) including migratory birds and compliance with the Migratory Bird Treaty Act and other applicable federal regulations and Executive Orders. The EIS included a robust cumulative impact assessment of numerous wind projects proposed for the region and their cumulative impact on Indiana bats and migratory birds. This high-

profile and precedent-setting project was the first ITP issued for Indiana bat related to a wind project in the US. ERM assisted the USFWS in preparing a robust EIS that withstood extensive public, NGO, and legal scrutiny on an expedited schedule. The final EIS was published in April 2013, and the USFWS approved the HCP in July 2013. The EIS was challenged in US Federal court and ultimately upheld, with the ITP issued in 2015.

Environmental and Social Impact Assessment, Bui Hydroelectric Project, Bui National Park, Ghana. Led the biodiversity and ecosystem services portions of the ESIA for the proposed Bui Hydroelectric Project, located within the Bui National Park in western Ghana. The project was highly controversial amongst Ghanaians and national and international NGOs for biodiversity and social reasons: the project area was located within a portion of Bui National Park, which has high biodiversity value. The area also contains roughly 2,000 villagers that would require resettlement if the project were to proceed. The ESIA was conducted in accordance with World Bank/IFC policies and guidelines. ERM conducted extensive stakeholder consultation throughout the ESIA process, a major focus of which was the effect of the project on the National Park and management options to balance project and park needs.

Environmental, Social, and Health Impact Assessment, Kabata Refinery, Guinea. Project manager and biodiversity and ecosystem services lead for the ESIA for Alcoa and RioTinto's proposed Kabata refinery and related port, railway, and related infrastructure located in Boka Prefecture Guinea. Collaborated with an expert local biodiversity field team to execute a rapid assessment, conducted in three seasonal survey missions, of terrestrial and aquatic biodiversity at the site and surrounding region. Two key species of concern identified were the IUCN-listed critically endangered marsh crab *Afrithelphusa monodosa* and the West African chimpanzee *Pan troglodytes verus***.** The project would have unavoidable direct and indirect impacts on the habitats for these species as well as sensitive coastal mangroves, local fishing grounds, and nursery habitat for commercially valuable marine species. Led the project team in application of the mitigation hierarchy and assessment of design and layout alternatives to reduce impacts on biodiversity and ecosystem services. Coordinated with the government of Guinea and local and international NGOs and other stakeholders regarding potential biodiversity offsets focused on chimpanzees. Supported Alcoa and Rio Tinto in consultations with Wildlife Chimpanzee Foundation regarding offsetting options and feasibility of offset implementation.

Environmental and Social Impact Assessment, Bekoko Transmission Line, Cameroon. Provided technical oversight on the biodiversity and ecosystem services aspects of an ESIA for a proposed 116 km, 225kV transmission line between Bekoko and Nkongsamba in western Cameroon. The proposed transmission line follows an existing line for much of its route; however, part of the line required clearing of relatively undisturbed rainforest habitat that is adjacent to the Mouyouka – Kombé Kompina Forest Reserve. Ecological issues addressed included habitat loss and fragmentation, endemic plant and wildlife species, loss of biodiversity, anthropogenic effects on wildlife populations, and erosion and associated increases in sediment loads to rivers and streams. The project involved extensive stakeholder consultation, including assessment of natural resource livelihoods and the interactions of social and ecological issues regarding the project.

Environmental and Social Impact Assessment, Baynes Hydroelectric Project, Angola. Led the biodiversity and ecosystem services portions of an ESIA for the proposed Baynes Hydropower Project located on the lower stretches of Kunene River, at the Angola-Namibia border. The project is located in a desert and mountainous region with high biodiversity and high species endemism. Provided technical oversight of five specialist studies (vegetation, avifauna, mammals, insects, and herptiles) that were conducted by local and international experts. Incorporated specialist input into the ESIA for the project and developed management recommendations in partnership with the specialists and the project proponent in order to minimize adverse biodiversity impacts and to maximize potential benefits of the project (e.g., access to stable water source, etc.).

Environmental and Social Impact Assessment, Suralco Aluminum Refinery, Suriname. Led the biodiversity aspects of the ESIA related to a proposed expansion of Alcoa's aluminium refinery in northeastern Suriname. Led an international team of biodiversity experts to conduct a rapid assessment biodiversity survey of the

undeveloped area surrounding the refinery. The survey assessed the biological condition and value of the site based on: 1) habitat heterogeneity; 2) a preliminary survey of the organisms that characterize each of the habitats; and 3) the intactness of the habitats, and their capacity to support important biological resources and ecological processes. The results of the survey were used to evaluate the impact of the proposed refinery expansion on the local ecology and to recommend ways to minimize adverse effects on sensitive habitats and species.

Environmental and Social Impact Assessment, Staatsolie Sugarcane to Ethanol Project, Suriname. Project manager and lead biodiversity specialist for the ESIA for Staatsolie's proposed sugarcane to ethanol project located in Wageningen, northwestern Suriname. The 15,000 hectare site is bordered to the north, east, and south by nature reserves and undeveloped land, and to the west by rice fields. The project contains agricultural (sugarcane plantation) and industrial (ethanol and sugar processing and production facility) components. A combined raw sugar/ethanol plant and power exportation plant is planned to allow for flexibility to vary ethanol versus sugar production depending on market demands and to export power to the national grid. ERM developed the ESIA to conform with Suriname National Institute for Environmental and Development Standards (NIMOS) standards. Key issues addressed in the ESIA included impacts to biodiversity, forest loss, water quality, water use/demands from the project and other users, impacts to nationally registered historic sites, impacts to protected areas, maintenance of ecosystem services, land use management and ownership, and greenhouse gas (GHG) production. ERM developed a GHG emissions inventory and assessed GHG impacts based on minimum GHG savings in terms of the project's GHG intensity against a fossil fuel comparator using the methodology and rules defined in the European Union Renewable Energy Directive (EU RED). ERM was able to predict GHG savings of 60 to 85 percent depending on the amount of electricity sold to the national grid.

Environmental and Social Impact Assessment, Alcoa Greenland Aluminium Smelter and Hydroelectric Project, West Greenland. Project manager and biodiversity lead for the ESIA for Alcoa's Greenland Aluminium and Hydroelectric Project, which consisted of an aluminium smelter, marine port, two hydroelectric projects, and electric transmission lines. This project constituted the largest industrial development in Greenlandic history. Issues identified during ESIA scoping included smelter air and water emissions and waste management; effects of the hydroelectric development on caribou migration, birds and internationally recognized Important Bird Areas, Arctic char, and cultural resources; and social and health effects related to immigration of foreign workers, housing, infrastructure, and social and health services. Collaborated with local and international experts to conduct baseline environmental, human health, and social studies. The impact assessment is currently on hold pending government negotiations relative to project development.

Environmental and Social Impact Assessment, Staatsolie Sugarcane to Ethanol Project, Suriname. Project manager and lead biodiversity specialist for the ESIA for Staatsolie's proposed sugarcane to ethanol project located in Wageningen, northwestern Suriname. The 15,000 hectare site is bordered to the north, east, and south by nature reserves and undeveloped land, and to the west by rice fields. The project contains agricultural (sugarcane plantation) and industrial (ethanol and sugar processing and production facility) components. A combined raw sugar/ethanol plant and power exportation plant is planned to allow for flexibility to vary ethanol versus sugar production depending on market demands and to export power to the national grid. ERM developed the ESIA to conform with Suriname National Institute for Environmental and Development Standards (NIMOS) and IFC Performance Standards. Key issues addressed in the ESIA included impacts to biodiversity, forest loss, water quality, water use/demands from the project and other users, impacts to nationally registered historic sites, impacts to protected areas, maintenance of ecosystem services, land use management and ownership, and greenhouse gas (GHG) production. ERM developed a GHG emissions inventory and assessed GHG impacts based on minimum GHG savings in terms of the project's GHG intensity against a fossil fuel comparator using the methodology and rules defined in the European Union Renewable Energy Directive (EU RED). ERM was able to predict GHG savings of 60 to 85 percent depending on the amount of electricity sold to the national grid.

Julia L. Tims

Technical Director Biodiversity and Ecosystem Services

Biodiversity Baseline Studies and Impact Assessment, Pascua Lama Mine and Related Infrastructure, Argentina and Chile. Led the analysis and reporting for a Rapid Biodiversity Assessment and Ecosystem Services Review to fill baseline data gaps for Barrick Gold's Pascua-Lama gold mine and related infrastructure located on the border of Chile and Argentina. The project has been under construction for over a decade and is now operational. Used the Valued Environmental Components (VEC) approach to assess the project's historic construction-related impacts and predicted future operational impacts on biodiversity. VEC's included rare flora, several rare terrestrial fauna species, migratory ungulates, *vegas* (i.e., wetlands), aquatic and riparian habitats, species known to provide important ecosystem services to local communities, and a internationally recognized Biosphere Reserve that is located just outside the Project's area of influence. Ms. Tims used the information generated during the baseline and impact assessment to update the project's Biodiversity Management Plan to define measures that will minimize and manage ongoing impacts to VECs during project operation and closure. Also prepared a Critical Habitat Assessment relative to IFC Performance Standard 6 and advised client on PS6 conformance.

Cumulative Impact Assessment for the Camisea Gas Project, International Development Bank and Pluspetrol Peru Corporation, Peru. As part of the ESIA for the Camisea Gas Project in Peru, Ms. Tims conducted a comprehensive cumulative impacts assessment on biological resources that could result from the planned oil and gas developments and expansion of the Malvinas Gas Separation Plant, combined with other past and reasonably foreseeable future activities within the lower Urubamba watershed. The assessment identified the probability and magnitude of cumulative effects on biodiversity, habitat quality, rare species, ecosystem services, and indigenous communities that rely on biological resources for sustenance fishing and hunting.

Environmental Impact Statement for the Clackamas Hydroelectric Project Relicensing. Portland, OR. Project manager for the EIS and technical leader for terrestrial ecological issues for relicensing the Clackamas River hydroelectric project. Managed the NEPA process for the project, including preparation of the Draft and Final EIS as third-party contractor to the Federal Energy Regulatory Commission and facilitated interactions with PGE and the FERC regarding relicensing issues. Led the interaction among cooperating agencies in the NEPA process including US Forest Service and BLM. Provided technical expertise within working groups and facilitated coordination among natural resource trustees on ecological issues. Key issues included the effects of the project on wildlife and habitat, threatened and endangered plant and animal species, habitat loss, habitat connectivity/ fragmentation and wildlife movement, and establishment and spread of exotic species. Collaborated on preparation of a Vegetation Management Plan, Invasive and Exotic Species Management Plan, and Threatened and Endangered Species Management Plan.

Environmental Impact Statement for the New York Power Authority-FDR Power Project. Massena, NY. Technical leader for terrestrial vegetation and wildlife sections of the EIS related to the proposed relicensing of the FDR hydroelectric power project. The EIS was prepared to meet federal NEPA and New York SEQRA standards and requirements. During the five year relicensing process, Ms. Tims provided technical expertise within working groups and facilitated coordination among natural resource trustees on ecological issues. Key issues includes the effects of the project on wildlife and habitat, threatened and endangered plant and animal species, habitat loss, habitat connectivity/ fragmentation and wildlife movement, and establishment and spread of exotic species. Facilitated interactions with NYPA, NYSDEC, and USACE.

Business and Biodiversity Offsets Program (BBOP). Ms. Tims is currently providing biodiversity expertise in an advisory group that is developing a standardized approach for identifying, developing, and implementing biodiversity offsets for projects with unavoidable adverse impacts on biodiversity. Advisory group members include corporate representatives, academic scientists, representatives of environmental NGOs, US state and federal regulators, and international government representatives. The group is currently developing a protocol and a set of tools for determining when an offset is appropriate and defining the scope and nature of appropriate offsets. Efforts are also focused on implementation and long term management and protection strategies for biodiversity offsets and the possibility of aggregating offsets into national or global protected areas management system aimed at specific conservation priorities.

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Benjamin Sussman, AICP



Mr. Ben Sussman is a consultant with ERM based in Annapolis, Maryland, US. He has more than seventeen years' experience in impact assessment and transportation planning for local and state governments across the United States, as well as mines, pipelines, and other major infrastructure projects in Africa, Europe, and North and South America.

As a transportation planner, Mr. Sussman has also evaluated vehicular and rail transportation corridor options for industrial, commercial, and residential land uses using quantitative measures such as Highway Capacity Software (HCS), combined with qualitative measures such as internal and external stakeholder interviews.

As an impact assessment specialist, Mr. Sussman also evaluates the transportation, socioeconomic, land use, recreation, and visual impacts of proposed energy, mining, and other industrial projects. His experience in the United States includes third-party analyses to meet NEPA, CEQA, and other state-equivalent requirments. Mr. Sussman also oversees large public comment management processes for these projects. His international experience focues on IFC-compliant Environmental and Social Impact Assessments in Africa and South America.

As a land use planner, Mr. Sussman has prepared comprehensive land use plans and community plans for small and large cities and unincorporated communities, with emphasis on the linkages between land use, growth, and water resources.

Professional Affiliations & Registrations

- American Institute of Certified Planners (2003)
- American Planning Association

Fields of Competence

- Transportation planning
- NEPA, CEQA, and other state-equivalents
- IFC-compliant Environmental and Social Impact Assessments (ESIA, ESHIA, EIS)
- Socioeconomics
- Comprehensive planning/land use planning
- Public Scoping and public information management
- Visual impact assessment

Education

- MCRP (City and Regional Planning)
  Georgia Tech, 2002
- B.S., Science, Technology, and Society
  Stanford University, 1998

Languages

- English, native speaker
- French, proficient
- Spanish, basic

Key Industry Sectors

- Government
- Mining
- Oil and Gas
- Transportation
- Government

Key Projects

Land Use, Transportation, and Visual Resources Analysis, Various Suralco Mines, Suriname, 2014.
Author of land use, transportation, and visual resources sections of IFC-compliant ESIAs (including baseline conditions, impacts, mitigation, and design of data collection procedures) for the Nassau Plateau, Lelydorp Mine, and Para and Kankantrie bauxite mines.

Skagit County, Washington, Environmental Impact Statement for Tesoro Anacortes Clean Projects Upgrade Project, Anacortes, WA, Ongoing.
Marine Transportation subject matter expert for a State Environmental Policy Act-compliant EIS, evaluating the impacts of the proposed upgrades to Tesoro's existing refinery near Anacortes. The project would add new vessel traffic to the heavily-used Puget Sound region, and could also increase the risk of spills and other marine casualty events.

ESIA, St. Vincent Geothermal Project (Phase 1), St. Vincent and the Grenadines. IDB, 2016.
Prepared the transportation and visual impacts sections of an IFC-compliant ESIA, evaluating the exploratory drilling phase of proposed geothermal energy development on the slopes of St. Vincent Island's *La Soufrière* volcano. Evaluated baseline traffic/road and aesthetic conditions, as well as the likely impacts from drilling activity, including vessel-delivered materials and heavy truck activity on the island's Windward Highway.

ESMP Review, Lekki Port, Nigeria. 2016.
Reviewed the Traffic and Safety Management Plan—a component of the Master Environmental and Social Management Plan for the proposed Lekki container port in Nigeria. Ensured that the plan met lender standards and adhered to international best practice for traffic operations and transportation safety practices.

Transportation Study for Proposed Mine, Confidential Client, Sierra Leone, 2015.
Responsible for development of a traffic study (to be incorporated into an IFC-compliant ESIA) documenting existing and likely future traffic condtions associated with a proposed iron mine in Sierra Leone. The study will evaluate the impact of the project's 45 km haul road, barge port, and barge traffic on transportation facilities and activities. Developed traffic study procedures and supervised traffic data collection and analysis.

Transportation Study, Confidential Oil and Gas Client, Albania, 2015.
Responsible for development of a traffic study (to be incorporated into an IFC-compliant ESIA) documenting existing and likely future traffic and transport safety condtions associated with construction and development of a proposed petroleum field in the central portion of the country.

ESIA Review for Lima Metro System Expansion, Interamerican Development Bank, Peru, 2014.
Conducted a review of the ESIA for an expansion of the Lima metro (mass transit) system (construction of Lines 2 and 4), to identify potential gaps related to traffic, transportation, and safety. Provided recommendations for additional analysis and mitigation measures.

Transportation Study, Confidential Mining Client, Dominican Republic, 2014.
Developed a traffic study (to be incorporated into an IFC-compliant supplement to an existing ESIA) for a proposed ferro-nickel mine in the central Dominican Republic. The document focuses on updating baseline conditions from a 2012 ESIA, as well as identification and analysis of a large set of transportation alternatives. Conducted an in-country evaluation of the haul route, and interviewed internal stakeholders.

Traffic Rapid Assessment, Pascua-Lama Mine, Barrick, Chile and Argentina, 2012.
Prepared a comprehensive evaluation of background transportation and traffic conditions affecting haul routes to and from the Pascua-Lama mine, existing and anticipated mine-related traffic, and recommended strategies to minimize and avoid delays and safety concerns for mine traffic. Conducted an in-country evaluation of the haul route, and interviewed internal stakeholders.

Draft ESHIA, Confidential Client, New Providence Island, Bahamas, 2008.
Evaluated transportation impacts of a planned resort on New Providence Island. Designed and managed traffic data collection and analysis for the existing and future road network. prepared the ESIA section documenting level of service, safety concerns, and other transportation impacts. Conducted consultations with public agencies.

Noam Raffel



Noam recently joined ERM after completing his Master's degree in GIS at Clark University. Noam is a GIS specialist for the Impact Assessment team in the Washington dc office.

Noam has 5 years of experience in the field of GIS in various different sectors. In the public sector, Noam managed geodatabases for the City of Worcester GIS Department. In the private sector Noam interned for the GIS consulting company iMapdata helping manage fast response online maps, and digitizing and updating databases for the media company New England Fiber. He also worked for the GIS software company Idrisi. Noam also interned at the nonprofit organization Groundwork London creating and managing a crime database for the whole of England and developed methods for managing surveying related GIS databases.

Noam's work at ERM is focused on helping the Impact Assessment team collect, manage, and analyze data from various projects. He focuses on organizing geospatial data for ESIA reports on a variety of large international and domestic projects.

Fields of Competence

- Esri ArcGIS
- Clark Labs IDRISI
- CrimeStatIII
- Windows VBA
- Python coding language

Key Industry Sectors

- Cultural Heritage
- Social
- Urban Planning

Education

- Master of Arts in Geographic Information Systems, Clark University, Worcester, MA, 2014
- Bachelor of the Arts in Geography, Clark University, Worcester, MA, 2013

Languages

- English, native speaker
- Hebrew, semi fluent

Relevant Experience:

In his short time at ERM Noam has helped in various projects whether it has been the creation of data intensive suitability and sensitivity models, on the fly maps, georeferencing maps, developing efficient methods for data collection, or working on greater projects listed below.

Nicaragua Canal Project (HKND) – Nicaragua October 2014-ongoing

ERM has been tasked to assess the impact of a potential canal through Nicaragua. Noam was responsible for managing the data of the archeological and built heritage data that may be potentially affected by the canal. He assisted in the development of a sensitivity model to assess high risk location of archeology. Noam modeled and mapped the cumulative impact assessment of the project.

Guinea Alumina Corporation, Mine, Guinea, Jan 2015 – Feb 2015

The Guinea Alumina Corporation tasked ERM to find potential cultural heritage sites in the location of a potential mine in Guinea. Noam created sensitivity model from LIDAR imagery to assess where potential sites are located. The model was tested against to known sites and proved to be highly accurate.

Confidential Client, Manufacturing Plant, March 2015 -ongoing

A Confidential Client plan on building a manufacturing plant in rural West Virginia. Noam was responsible for reviewing LIDAR data and satellite imagery to inspect for potential cultural heritage finds. He is also tasked for on the ground data collection to assist with both archeology and built heritage.

Shell Appalachia, Pennsylvania, March 2015- Ongoing

Noam has been tasked to create and manage a database of all cultural heritage finds in Pennsylvania. The sites are managed in a geographical database which has been manipulated to display areas of higher sensitivity.

Ascent, Unconventional Gas Project, West Virginia Nov 2014

Noam was responsible for developing a method for surveying and collecting archeological data from a potential unconventional gas site in West Virginia. Noam developed a mapping survey using Arcpad to improve the efficiency of archeological monitoring the site.

City of Worcester, GIS Department, Massachusetts Summer 2013

In 2013 Noam interned for the City of Worcester, Massachusetts, GIS department organizing GIS databases used by different departments to manage city resources. His main tasks was the development of a SDE database for the roads file that would be used by all city departments for online maps.

Idrisi Clark Labs, Worcester Massachusetts Summer 2013

Noam worked for the GIS software company Clarklabs testing for bugs in the software Idrisi and the Earth Change Modeler plugin for ArcGIS 10.1 .

Erin Rykken



Ms. Erin Rykken is a Senior Technical Editor with ERM based in Livingston, Montana. She has 12 years of technical editing and writing experience and has spent the last 6 years with ERM performing a wide array of document editing, formatting, and publishing duties.

Ms. Rykken's specialized training includes reference librarianship, with an emphasis on academic research and government information. This background affords her a strong understanding of research methodologies and the best practices for assuring relevant and comprehensive information retrieval from a variety of resources.

While a majority of Ms. Rykken's time is spent on large document production, such as the Keystone XL SEIS, she also supports numerous smaller projects by applying her skills to report documents, letters and memos, data QA/QC, proposals, and SOQs.

Professional Affiliations & Registrations

- American Library Association

Fields of Competence

- Technical writing and editing
- Research and reporting
- Document formatting and print production

Education

- Master of Library Science, Indiana University, 2009
- M.A. English Literature, Boise State University, 2004
- B.A. English, University of Wisconsin—Green Bay, 2000

Languages

- English, native speaker

Key Industry Sectors

- Government
- Mining
- Oil and Gas
- Power

Key Projects

Draft Programmatic Environmental Impact Statement, Confidential Client, 2015-2016.
The multi-volume EIS was developed for a nationwide wireless broadband network dedicated to public safety. In addition to document editing and production, developed reference tracking, verification, and coordination procedures for all authors across all resource areas and geographical locations.

Canal de Nicaragua Environmental and Social Impact Assessment, HKND Group, 2014-2015.
Developed extensive reference tracking, verification, and coordination procedures for a large team developing an ESIA for the construction and operation of the Nicaragua Canal in Central America.

NorthMet Mining Project and Land Exchange Environmental Impact Statement Public Comment Processing, Minnesota Department of Natural Resources, 2014-2015.
Assisted with the processing of lengthy, substantive comments. Tasks involved reading full submittals,—some as long as 80 pages--and retrieving the most substantive and representative comments, entering and coding comments within the master database, and providing QA/QC of the data entry to ensure consistency/accuracy.

NorthMet Mining Project and Land Exchange Environmental Impact Statement, Minnesota Department of Natural Resources, 2012-2016.
In addition to editing, formatting, and production support, managed all aspects of author-cited materials in support of a large team developing an EIS for the construction and operation of the mine. Worked with project management and the client to coordinate the delivery of the 1,500-page impact assessment.

Keystone Pipeline National Interest Determination - Comment Processing, U.S. Department of State, 2014.
Assisted with the processing of over 2 million comments. Tasks involved reading full submittals and retrieving substantive comments, entering and coding comments within the master database, and providing QA/QC of the data entry to ensure consistency/ accuracy.

Keystone Supplemental Environmental Impact Statement Technical Editing and Production, U.S. Department of State, 2012-2013.
Provided document coordination services, including technical editing and formatting. Improved the SEIS document template to ensure consistency throughout the document writing process, which involved 40+ contributors writing from offices across the United States and culminating in a multi-volume final product. Ensured text was readable/appropriately written for the general public and that all data and general information was presented with appropriately cited sources of information.

Environmental and Social Impact Assessment (ESIA) - Stage 1 and 2, Confidential Mining Company, 2012-2013.
Provided document editing and formatting services for company involved in a high profile and highly controversial new mine site development. Conducted professional reference/citation verification, sentence-level edits for audience readability, and final document print layout/pdf production.

Sampling and Analysis Plan & Baseline Assessment and Monitoring Plan Development, Confidential Oil and Gas Client, Wyoming, 2010.
Provided document coordination and editorial review for two 500+ page documents. Coordinated the writing and research efforts of 10+ staff from five different office locations. Ensured readability and uniform presentation of the documents' numerous sections, figures, tables, and corresponding appendices.

EMS Training Manual Development Support, Confidential Mining Client, 2011-2013.
Responsible for editing and formatting two Environmental Management System training guides. Ensured consistency between User Guide and Administrator Guide for both language use and overall visual aesthetics. Ensured documents met client-specific training template guidelines and provided quality review for Spanish translations.

Operations, Safety, and Maintenance (OSM) Manual Updates, Confidential Mining Company, 2012-2016.
Developed a document template that adhered to the Mining Association of Canada's (MAC) OSM Manual Guidelines for use at all client facilities going forward. Tasks included updating, editing, and reformatting existing manuals, and writing/creating manuals for new facilities.

NPS CSM Work Plan, and Report Editing and Formatting, National Park Service, 2010-2013.
Collaborated with numerous staff to compile, edit, and format a variety of Contaminated Site Management (CSM) work plans and reports for the National Park Service (NPS) in Alaska.

Culvert Inspection and Fish Passage Assessment Training Manual, BPXA, 2011-2013.
Assisted in the development of "accessible" text for a culvert inspection and fish passage assessment training manual whose intended audience was not necessarily familiar with scientific terminology or methods. Provided formatting and editing services, in addition to overseeing and ensuring quality of final electronic and print production.

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HANCE THOMPSON

EDUCATION

M.Sc. in Environmental and Earth Resources Management, Kingston University, London **2006/07**
B.Sc. Biology, University of Guyana **1998-2002**

PROFESSIONAL BODIES

Graduate Member of the Institute of Environmental Management and Assessment **(IEMA)- London**

EXPERIENCE

2010 to Present: GROUND STRUCTURES ENGINEERING CONSULTANTS INC

Environmental/Biological Specialist; Responsibilities include; Coordinating and conducting Environmental and Social Impact Assessments (ESIAs); Writing ESIAs and Environmental Management Plans (EMPs); Conducting/coordinating Bio-physical Baseline Surveys; Conducting/coordinating Environmental Site Assessments. Co-coordinated and managed the following projects ; ETK ESIA at Toroparu, Strata Gold ESIA at Tassawini, Guyana Goldfields Inc. (GGI) updated ESIA baseline survey at Aurora and Sulphur Rose, GGI Rapid Biodiversity Assessment at Julian Ross Itabu, Mulgravian Inc. Environmental Liability Assessment at Five Star.

April –October 2010: SYNERGY HOLDINGS (GUYANA) INC.
(AMAILA FALLS HYDRO ACCESS ROAD PROJECT)

Environment, Health and Safety Manager; Duties included; Overall Environmental Management and Monitoring of the Project; Specific Duties included; prioritize risk management strategies with the objective of achieving acceptable environmental and health practices; enforce policy and procedures on health and safety; plan and implement training programmes; liaise with the Project Manager of the Government of Guyana, the EPA, and other regulatory bodies on environment, and health and safety management.

2003 – 2010: ENVIRONMENTAL PROTECTION AGENCY, GUYANA

Post: Senior Environmental Officer (SEO) within the Environmental Management Division (EMD) with responsibilities for Managing and Coordinating activities under the Authorisation and Research and Development Programme Areas of the Environmental Management Programme; Duties included:

SEO of Authorisation - Coordinate and manage the Environmental Authorisation Process including the Environmental Impact Assessment (EIA) Process; Conduct and coordinate the review of EIAs and EMPs; Facilitate/chair public scoping meetings; Develop and review

environmental authorisation; Coordinate and manage the screening of applications for environmental authorization; Coordinate and assist in the development and revision of guidelines, standards and procedures for environmental authorisation;

SEO Research and Development (R&D) – Developed Environmental Standards, Regulations, and Guidelines for Industry; Identify areas for development in Environmental Management in Guyana and formulated proposals for projects; Coordinated and managed the implementation of projects under the Environmental Management Programme of the EPA. These projects included; The development of a National Hazardous Waste Inventory (for year 2007) and Management Strategy for Guyana; An assessment of Marine Litter Management in Guyana; The development of a project to link National Programmes of Action (NPAs) for the Protection of Marine and Coastal Ecosystems and Water Safety Plans (WSPs), developed for the Demerara Watershed and the community of Linden. Other **R&D** duties included; Coordinated and managed the implementation of the Basel Convention on the Control of the Transboundry Movement of Hazardous Waste and their Disposal; Coordinated the preparation of EPA's Recommendation on Guyana's Ratification of the Cartegena Convention.

February, 2003 – October, 2003: GUYANA RICE DEVELOPMENT BOARD (RESEARCH STATION)

Post: Research Assistant to Chief Scientist. Duties included: Managing and planning activities of the plant pathology department; screening new rice plant varieties for resistance against major rice fungus; testing and screening new fungicides for effectiveness against major rice fungus; conducting field and laboratory diagnosis of diseased rice plants for causal pathogens.

CURRICULUM VITAE

Arq. NOELIA ARISPE ARISPE

Mayo 2016

INFORMACIÓN PERSONAL

Noelia C. Arispe Arispe
Cédula de Identidad Nº: V-3.885.344
Estado civil: Casada
Nacionalidad: Venezolana
Lugar de nacimiento: Barquisimeto – Estado Lara
Dirección: Calle Sta. Isabel, Qta. Curarí, Sta. Fe Norte. Caracas 1080.
Teléfonos 0212--979.53.25 / 0414--8132385
Correo electrónico: naa1011@yahoo.es / naa1011@gmail.com

FORMACIÓN PROFESIONAL

ESTUDIOS DE POST- GRADO

1978 – 80: Architectural Association School of Architecture, University of London - Londres – Inglaterra

Curso: Planificación del Desarrollo Nacional, Regional y Urbano

Título obtenido: Diploma Honnus y Master

ESTUDIOS DE PRE-GRADO

1969 – 1975: -Universidad Central de Venezuela – Facultad de Arquitectura y Urbanismo - Caracas – Venezuela

Título obtenido: Arquitecto

ALGUNOS CURSOS REALIZADOS

- Introductorio del Desarrollo Urbano y Regional / Centro de estudios del Desarrollo, CENDES-UCV / 1976.
- Idioma Inglés / Instituto Venezolano-Británico /1977-1978.
- Idioma Inglés / International House - Londres Inglaterra / 1978.
- Formación de Instructores / Instituto Nacional de la Vivienda INAVI / Caracas, 1981.
- Curso General de Planificación /CORDIPLAN, Programa RH-Sinaplan / 1982.
- Idioma Italiano / centro Cultural Venezolano-Italiano/ 1982.
- Idioma Italiano / Escuela de Idiomas de la F.F.A.A. / 1986 – 1987

- Vialidad y Terraceo en Desarrollos Habitacionales / Instituto Nacional de la Vivienda INAVI /Caracas, 1986.
- Revisión y Evaluación de Estudios de Impacto Ambiental /MARN-CIARA/ 1992.
- Organización, Planificación y Marketing de los Atractivos Turísticos Naturales / CORPOTURISMO – OEA /Caracas, 1993.
- Desarrollo Sustentable / MARN /Caracas, 1994.
- Informática a Nivel Gerencial /Instit. Hispano de Informática / Caracas, 1996.
- Auditorias Ambientales / MARN /Caracas, 2000.
- Sistemas de Gestión Ambiental Bajo Stand ISO 14.000 / MARN / 2000.

EXPERIENCIA PROFESIONAL

- **2014 - Gecoplan, S.A.**
  Consultoría Ambiental y Urbana

- **2013 FII-CPDI**
  Asesoría Ambiental

- **2009—2013 Proconsult C.A.**
  Consultoría Ambiental

- **2007-- 2010 Ecodipla Consultores, C.A.**
  Consultoría Ambiental y Urbana

- **2006-- 2007 Gecoplan, S.A.**
  Consultoría Ambiental y Urbana

- **2002-- 2007 Ecology and Environment, S.A.**
  Consultoría Ambiental

- **2000 ARMO Estudios y Proyectos, C. A.**
  Desarrollo Urbano y Regional, Planificación Ambiental y Planificación en general

- **1998 –2000 Ministerio del Ambiente y de los Recursos Naturales (MARN)**
  Dirección General de Planificación y Ordenación del Ambiente (DGPOA)

  Cargo desempeñado: Directora de la Oficina de Coordinación de Proyectos Especiales

- **1988 – 1998 MARN - Dirección General de Planificación y Ordenación del Ambiente (DGPOA)**

Dirección de Ordenación del Territorio

Cargo desempeñado: Planificador Jefe

- **1981 - 1988 Instituto Nacional de la Vivienda (INAVI)**
  Gerencia de Planificación y Presupuesto

  Cargo desempeñado: Arquitecto Jefe III

- **1977 – 1978 MINDUR - Dirección General de Planificación Urbanística**
  Dirección de Estudios Urbanos

  Cargo desempeñado: Arquitecto III

- **1975 – 1977 MOP - Dirección de Planeamiento Urbano**

  División Región Los Andes
  Cargo desempeñado: Arquitecto I

ACTIVIDADES MAS IMPORTANTES A NIVEL PROFESIONAL

- Coordinación del Estudio: **"Desarrollo Urbano Regional de la Región Sur-Oeste Andina"**, trabajo realizado en la Dirección de Planeamiento Urbano del Ministerio de Desarrollo Urbano (MINDUR) durante los años 1977–1978

- Participación en la elaboración de los **planes de Desarrollo Urbano**, para las ciudades de la Fría, San Antonio, Aguas Calientes y San Juan de Colón realizado en la Dirección de Planeamiento Urbano del Ministerio del Desarrollo Urbano (MINDUR), durante los años 1975 – 1978.

- Elaboración de los **Programas de áreas, para Viviendas de Interés Social**, localizadas en las ciudades de Guasdualito, Santa Rosalía, Barbacoas, Altagracia de Orituco, Cantaura, Cumaná, Ciudad Losada, San Cristóbal, Clarines, Trujillo, Barinas, entre otras. Trabajo realizado para la Gerencia de Planificación y Presupuesto del Instituto Nacional de la Vivienda (INAVI) - años1981 – 1988.

- Participación en la elaboración del Proyecto de **“Normas para las Variables Ambientales Urbanas”**, para la Dirección de Planificación y Ordenación del Ambiente - Ministerio del Ambiente y de los Recursos Naturales, años 1988 a 1989.

- Participación en la elaboración del Documento Base para **las “Normas Ambientales aplicables en el Medio Rural”**, para la Dirección de Planificación y Ordenación del Ambiente - Ministerio del Ambiente y de los Recursos Naturales, durante los años 1989 – 1990.

- Coordinación Técnica en la elaboración del “**Plan de Ordenación del Territorio del Área Anaco-Maturín-Caripito”** bajo el Convenio MARNR-LAGOVEN-CORPOVEN, durante los años 1990 – 1991.

- Participación en la elaboración e implementación de diversos **Planes estadales de Ordenación del Territorio y de Áreas Bajo Régimen de Administración especial (ABRAE)**, en la Dirección de Planificación y Ordenación del Ambiente - Ministerio del Ambiente y de los Recursos Naturales, durante los años 1988 – 1998.

- **Revisión de Estudios de Impacto Ambiental (EIA) y Evaluaciones Ambientales Específicas (EAE) de proyectos de importancia nacional y regional** a ser ejecutados por empresas tales como CADAFE, EDELCA, PDVSA, SINCOR, PETROZUATA, AMERIVEN, CERRO NEGRO, BP, CANTV, entre otros, quienes tramitan la Autorización para la Ocupación del Territorio (AOT) y/o la Autorización para la Afectación de Recursos Naturales (AARN) ante el Ministerio del Ambiente y de los Recursos Naturales. Actividades realizadas en ese ministerio. Durante los años 1987 – 2000.

- **Coordinación y control de tramitaciones administrativas requeridas para obtener las autorizaciones para la ocupación del Territorio (AOT) y de Afectación de los Recursos Naturales (AARN)**. Solicitudes presentadas ante el Ministerio del Ambiente y de los Recursos Naturales para desarrollar proyectos caracterizados como de importancia nacional y de importancia regional. Actividades realizadas en la Oficina de Proyectos Especiales adscrita a la Dirección General de Planificación y Ordenación del Ambiente (DGPOA) - Ministerio del Ambiente y de los Recursos Naturales (MARN). Durante los años 1998 – 2000.

- Realización de los **“Aspectos Ambientales correspondientes al Plan de Manejo del Parque Metropolitano Vicente Emilio Sójo en Caracas”,** para FUNDACOMUN. Mayo-Agosto 2001.

- Realización de los **“Aspectos de Dinámica Espacial, Sistema de ciudades y Jerarquización de Centros Poblados”**, como apoyo al Proyecto Planta de Generación Térmica para la Empresa Termoyaracuy C.A. en la Consultora Ingeniería Piasa - Mayo 2002.

- Participación en la elaboración del Estudio de Impacto Ambiental del Proyecto: **“Campo de Desarrollo Pedernales**”, en la Empresa Ecology and Environment, S.A., para la Empresa PERENCO PETROLEOS, Año 2002.

- Elaboración del **“Documento Síntesis Estudio de Impacto Ambiental del Proyecto Complejo Criogénico de Occidente, ULE”,** Estado Zulia, en la Empresa Ecology and Environment S.A., para PDVSA, Años 2002-2003.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) del **“Proyecto Plataforma Deltana, Bloque 4”,** en la Empresa Ecology and Environment, S.A. para la Empresa petrolera STATOIL Venezuela, Año 2003-2004.

- Participación en **el “Estudio de Prefactibilidad para la Localización de una Planta Turbogas”** en el Estado Anzoátegui con la Empresa INELMECA, C.A. para EDELCA, Año 2.004.

- Participación en la formulación del Proyecto **“Desarrollo Sustentable de la Actividad Pesquera en el Nororiente de Venezuela”,** elaborado en la Empresa Ecology and Environment, S.A. para la Empresa Petrolera STATOIL Venezuela, Años 2004-2005.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) del Proyecto **“Autopista de los Llanos Centrales”,** en la Empresa Ecology and Environment, S.A. para la Fundación Fondo de Transporte Urbano (FONTUR), adscrito al Ministerio de Infraestructura (MINFRA) Años 2005-2006.

- Elaboración del estudio **“Plan Específico de Permisos Ambientales” en el contexto del desarrollo del Proyecto Libertador a ubicarse en el Complejo Jose**, estado Anzoátegui, en la Empresa Ecology and Environment, S.A. para, para Pequiven, S.A. - Año 2006
- Participación en la elaboración de la **“Auditoria Ambiental Fase I de la parcela Fertilizantes II, Proyecto Libertador”,** en la Empresa Ecology and Environment, S.A. para , para Pequiven, S.A. - Año 2006.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) del Proyecto**: “Acondicionamiento de las parcelas Jose norte y Jose sur, Urbanismo industrial en el Complejo Petroquímico Anzoátegui”** en la Empresa Ecology and Environment, S.A., para Pequiven, S.A. - Año 2007.

- Coordinación de la elaboración de tres Estudios de Impacto Ambiental y Socio Cultural (EIASC) para los Proyectos: **“Perforación de Pozos estratigráficos en el Bloque 1”, “Perforación de Pozos estratigráficos en el Bloque 2” y “Perforación de Pozos estratigráficos en el Bloque 3”,** todos ubicados en el Área Junín de la Magna Reserva, elaborados en la Empresa Ecology and Environment, S.A. para PDVSA-CVP, bajo Convenio CPDI, Años 2006-2008.

- Participación en la elaboración del Estudio **“Identificación de la Estructura actual del Sistema de Centros Poblados, comandados por Ciudad Guayana, Estado Bolívar “**, en la Empresa GECOPLAN, & Asociados, C.A, para el MINFRA, año 2006.

- Participación en la elaboración de los **Estudios Preliminares correspondientes al Environmental, Social and Health Impacts Assessment (ESHIA) del “Proyecto Delta Caribe”,** en Ecology and Environment, S.A, para la empresa CHEVRON, Año 2007.
- Participación en la elaboración del Estudio **“Identificación de la Estructura Actual del Sistema de Centros Poblados, comandados por el eje urbano Barcelona-Puerto La Cruz, Estado Anzoátegui**“, en la Empresa GECOPLAN, & Asociados, C.A, para el MINFRA, año 2007.

- Participación en la elaboración del **Estudio "Visualización preliminar de la Planificación y Gestión del Territorio de la Faja Petrolífera del Orinoco"** en la empresa Ecodipla Consultores C.A. para PDVSA-CVP. Año 2008.

- Participación en la elaboración del Estudio **"Plan de Ordenamiento y Reglamento de Uso (PORU) de la Zona de Interés Turístico, Estado Vargas y Estado Miranda", en la empresa** Grupo CONAHOL, S.C. para el MINTUR. Años 2008-2009.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) del Proyecto: **"Sistema de Recolección de Aguas Residuales en el eje El Consejo-Sabaneta, estado Aragua",** en la Empresa Proconsult, C.A, para HIDROVEN - Año 2009-2010.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) del Proyecto**: "II Etapa para Educación Básica y Diversificado del Liceo Agroecologico, Escuela Canaima"**, en la Empresa Proconsult, C.A, para la Fundación CANAIMA - Año 2009-2010.

- Participación en la elaboración de la Evaluación Ambiental del Proyecto **"Ola Cruises",** específicamente en los Aspectos Socio-Económicos y Culturales, en la empresa Ecodipla Consultores C.A. para la empresa Servicios Acuáticos de Venezuela Saveca C.A. Año 2009.

- Participación en "**Estudio de Opciones de Localización y Evaluación Socio-Ambiental preliminar de los sitios preseleccionados para desarrollar una refinería en Haití"**, en la empresa PCI Ingenieros Consultores S.A, para PDV Caribe – Año 2009-2010.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) para el **Proyecto diseño y construcción de arquitectura preliminar y avanzada de un conjunto de unidades habitacionales y sus servicios complementarios, infraestructura, urbanismo y demás obras civiles**, ubicado en el sector Yucatán parroquia Tamaca, municipio Iribarren del estado Lara, en la Empresa Proconsult, C.A, para la empresa Kayson C.A, año 2012.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) para el **Proyecto diseño y construcción de arquitectura preliminar y avanzada de un conjunto de unidades habitacionales y sus servicios complementarios, infraestructura, urbanismo y demás obras civiles**, ubicado al sur de la ciudad de Valencia, en el municipio Valencia del estado Carabobo, en la Empresa Proconsult, C.A, para la empresa Kayson C.A, año 2012.

- Elaboración del Estudio de Impacto Ambiental y Sociocultural para el **Proyecto Construcción de Vivienda Unifamiliar Casa Velasco**, ubicado en la Urb. La Lagunita Country Club, municipio El Hatillo, Estado Miranda, para la empresa Desarrollos VINCIPEOPLE C.A, año 2012.

- Participación como asesora y control de calidad en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) del proyecto denominado **"Modificación del Segmento 2 del Sistema del Cable de Fibra Optica Atlántica I/ Globenet (Segmento 2.3)",** para la empresa Brasil Telecom de Venezuela, S.A.- Mayo 2013.

- Participación como asesora en el **Proyecto "Servicios Profesionales en la elaboración de estudios ambientales correspondientes a la fase de Producción Temprana en la Faja Petrolífera del Orinoco"**, en el Instituto de Ingeniería, Centro de Procesamiento de Imágenes Satelitales (FII-CPDI) – desde el Año 2011.

- Participación y asesoramiento en el Estudio de Impacto Ambiental y Sociocultural (EIASC) para el **Proyecto Sistema Metrocable Mariche Tramo Local, Línea LB2",** elaborado en la **Empresa Gecoplan C.A para C.A. Metro de Caracas / Constructora Odebrecht, S.A.** desde Abril 2014.

- Participación en la en la elaboración de la **Caracterización y Diagnóstico de la situación actual en las ubicaciones de ocho (8) almacenes de CORPOELEC**, localizados en diversos estados del país, en la **Empresa ADR3 C.A.-VITAAMBIENTE C.A. para la empresa Corpoelec,** desde Octubre 2014 a Mayo 2015.

- Elaboración de la **Actualización de los Costos de las Medidas Ambientales propuestas en el Estudio de Impacto Ambiental y Socio Cultural del año 2008,** correspondiente al Proyecto **"Mantenimiento Correctivo del Sistema de Cable Submarino Internacional de Fibra Optica "Atlántica I" en Aguas Territoriales**

Venezolanas". Addendum preparado para la empresa **Globenet Cabos Submarinos Vzla, S.A,** Noviembre 2015.

- Participación en la elaboración del Estudio de Impacto Ambiental y Socio Cultural (EIASC) para el **Proyecto Perforación Direccional para Cable Submarino**, localizado en el estado Vargas, en la Empresa Proconsult, C.A, para la empresa **Globenet Cabos Submarinos Vzla, S.A,** años 2015-2016.

- Servicios Profesionales para desarrollar actividades inherentes al proceso de obtención **de Permisos y Autorizaciones No Ambientales para el Proyecto Perforación Direccional y Sustitución de Tramos en Segmentos 2 y 3 del Cable Submarino Atlantica-1 (Venezuela), con** la empresa **Globenet Cabos Submarinos Vzla, S.A,** desde Febrero 2016.

- **Elaboración, coordinación, evaluación y asesorías de Proyectos de planificación y desarrollo a escala urbana, regional y nacional, Planificación ambiental y evaluaciones ambientales.** Actividades permanentes de Consultoría y Asesoría Individual.

ALGUNOS TRABAJOS REALIZADOS EN EL ÁMBITO ACADÉMICO

"Diseño Urbano en el Sector de Sabana Grande – El Rosal"

UCV, años 1973 a 1974 Tesis para optar al Título de **Arquitecto** en la Universidad Central de Venezuela.

"Polos de Desarrollo en Venezuela"

Londres, Inglaterra, Architectural Association (A.A), años 1978 a 1979, para optar al **Diploma Honus.**

"Desequilibrios Regionales en Venezuela"

Londres, Architectural Association, (A.A) años 1971 a 1980, para optar al Título de **Maestría en Planificación Nacional, Regional y Urbana**

IDIOMAS

INGLÉS E ITALIANO

Respaldos a disposición

HEMA DAVID

Date of Birth: June 24, 1982

Nationality: Citizen of Trinidad and Tobago

Current Post: Environmental Scientist
Ecoengineering Consultants Limited

Ms. Hema David is an Environmental Scientist and holds a Master of Science Degree in Biodiversity Conservation and Sustainable Development in the Caribbean from the University of the West Indies. She has in preparing Certificate of Environmental Clearance (CEC) Applications for various projects, including industrial projects. She also has experience in monitoring the Health, Safety and Environmental (HSE) performance of contractors during the construction phase of a highway extension, road rehabilitation works and an industrial estates. She has conducted noise, air quality , water quality and soil contamination monitoring, as well as worked on several Environmental Impact Assessments (EIAs), Environmental Management Plans, Environmental Audits and other Environmental Studies. In addition to her work in Trinidad and Tobago, Hema has undertaken assignments in Grenada, St. Vincent, St. Lucia, St. Kitts and Nevis, Dominica, Guyana and Suriname.

EDUCATION

M.Sc. Biodiversity Conservation and Sustainable Development in the Caribbean, University of the West Indies, St. Augustine (2014)

B.Sc. Environmental and Natural Resource Management, University of West Indies, St. Augustine (2009)

Associate Degree Environmental Management, College of Science, Technology and Applied Arts of Trinidad and Tobago (2004),

COMPUTER LITERACY

Working knowledge of Microsoft Office, Word Perfect, and Adobe Acrobat

TRAINING

- Point Lisas Energy Association (PLEA) of Upstream Operators Safety Training (2015)
- Standard Workplace First-Aid / C.P.R / A.E.D. (16hr) (2015)
- Tropical Further Offshore Emergency Training (2014)
- Accident Investigation (2013)
- Defensive Driving (2010)
- Supervisory Management (2009)
- Open Water Diver (PADI) (2007)
- Occupational Health and Safety for General Industry (30 hr) (2005)

EMPLOYMENT RECORD

Jan 2009 - Present	Environmental Scientist, Ecoengineering Consultants Limited
June 2008 - Jan 2009	Environmental Scientist (Trainee), Ecoengineering Consultants Limited
June 2007 - August 2007	Health and Safety Technician, Ecoengineering Consultants Limited
June 2005 - August 2006	Health and Safety Technician, Ecoengineering Consultants Limited.

WORK EXPERIENCE

Certificates of Environmental Clearance

2016	Environmental Scientist, Establishment of a Housing Development in Maracas, St. Joseph
2014	Environmental Scientist, Expansion of a Golf Course in Chaguaramas
2013	Study Manager, The Establishment of a Methanol Tank in Point Lisas
2013	Environmental Scientist/Assistant Study Manager, Proposed Residential Development in Endeavour, Chaguanas
2012	Environmental Scientist, Development of an Ammonia/Urea Facility in Point Lisas
2012	Environmental Scientist, CEC Application for the Establishment of a Town Centre in Sangre Grande
2011	Environmental Scientist, CEC Application for Site Preparation Works for a 45 ha site in Point Lisas
2008	Environmental Scientist, CEC Application for Reconditioning of Berth 3 and Change in Pipeline Route for an Ethanol Dehydration Plant at Petrotrin, Pointe-a-Pierre
2008	Environmental Scientist, CEC Application for expansion of an Ethanol Dehydration Plant at Petrotrin
2005	Technician, CEC Application for Proposed Housing Development at Felicity, Chaguanas

Environmental Monitoring

2016	Environmental Scientist, Salinity Profiling (Water and Soil) as part of a Drainage Study in South Oropouche
2016	Environmental Scientist, River Water Quality Monitoring and Benthic Ecology as part of a Limestone Quarry in Maracas, St. Joseph
2016	Environmental Scientist, Vegetation Survey at a Quarry in Matura
2013-2016	Environmental Scientist, Compliance Water Quality Monitoring and Benthic Sampling (offshore) for a Desalination Plant, Point Fortin
2015	Environmental Scientist, Air Quality Monitoring and River Quality Monitoring for a Proposed Steel Plant in La Brea
2015	Environmental Scientist, Water Quality and Sediment Sampling as part of a Port Expansion project in La Brea
2015	Environmental Scientist, Air Quality, Noise and Water Quality Monitoring as part of a Feasibility Study for Road Improvement Works in Diego Martin
2013-2014	Environmental Scientist, Compliance Water Quality Monitoring and Benthic Sampling for a Desalination Plant, Point Fortin
2014	Environmental Scientist, Sediment Sampling as part of Maintenance Dredging of a harbor in Point Lisas
2013	Environmental Scientist, Baseline Noise Monitoring for a proposed Industrial and Commercial Park in Paranam, Suriname
2007 - 2013	Environmental Scientist, Flow Characteristics of a site stream in the Point Lisas Industrial Estate
2007 - 2013	Environmental Scientist, Assessments of a Mangrove Wetland System, south-west of an Ammonia Facility in the Point Lisas Industrial Estate
2013	Marine Water Quality Monitoring near the Cooling Water Discharge Outfall of an Ammonia Complex, Point Lisas
2011-2012	Environmental Scientist, Ecological Assessments (Wetland and Terrestrial) south-west Tobago.
2012	Environmental Scientist, Monitoring of Thermal Effluent from a Power Station into Invaders Bay, Port of Spain.

2011	Environmental Scientist, Floral and Faunal Studies in the Guayaguayare Block
2011	Environmental Scientist, Ecology Survey for Site Preparation Works at a 41.5 ha Site in Point Lisas
2010	Environmental Scientist, Marine Baseline Monitoring in the Guayaguayare Block (Water and Sediment Quality and Benthic Macrofauna)
2009-2010	Environmental Scientist, Air and Noise Monitoring for a Rail System
2008 - 2010	Environmental Scientist, Compliance Monitoring for a Technology Park, Wallerfield
2008 -2010	Environmental Scientist, Particulate Matter (PM10) Monitoring at an Ammonia Complex, Point Lisas
2008	Environmental Scientist, Noise Monitoring at a Heliport, Couva
2007	Technician, Environmental Investigation (sub surface contamination survey) at three Service Stations in Tobago
2006	Technician, Air and Noise Monitoring at a Proposed Mall Complex in Sangre Grande

Health and Safety Inspections

2015-2016	Environmental Scientist, Undertaking HSE Inspections as part of Slope Stabilization Works, South Oropouche.
2008 - 2010	Environmental Scientist / Health and Safety Technician, undertaking inspections at Tamana Intech Park, Wallerfield
2005 - 2009	Health and Safety Technician, undertaking inspections on National Highways Program - Year III Roads Rehabilitation Packages 1 & 2
2005 - 2006	Health and Safety Technician, undertaking inspections on the extension of the Diego Martin Highway

Environmental Management and Related Plans

Present	Environmental Scientist, Best Management Practices Plan as part of a Water Pollution Permit for an Ammonia Facility in Point Lisas
Present	Environmental Scientist, Rehabilitation Plan for a Quarry in Matura
2015	Environmental Scientist, Environmental Management Plan for Improvement Works to the Diego Martin Highway / Western Main Road Intersection and Related Improvements
2014	Environmental Scientist, Environmental Management Plan, Erosion & Sediment Management Plan and Stormwater Management Plan for the establishment of a Fruit and Vegetable Crop Farm and Energy Services Facility at the Picton IV Estate, Debe
2013	Environmental Scientist, Environmental and Social Management Plan for the establishment of an Industrial and Commercial Park, Paranam, Suriname
2013	Assistant Study Manager, Environmental Management Plan for the Establishment of a Dam/Reservoir in Cumuto, Trinidad
2013	Environmental Scientist, Environmental Management Plan for the Establishment of a Port in Montserrat
2013	Environmental Scientist, Conceptual Erosion and Sediment Management Plan for the Establishment of a Science City, Couva
2012	Environmental Scientist, Dredge Spoil Sampling Plan as part of maintenance dredging of a harbor in Point Lisas
2012	Environmental Scientist, Air Quality Monitoring Plan for an Ammonia/Urea Complex in Point Lisas
2012	Environmental Scientist, Mangrove Replanting Plan for the development of an Ammonia/Urea Complex in Point Lisas
2012	Environmental Scientist, Stormwater, Sediment and Erosion Management Plan for the development of a Town Centre in Sangre Grande
2012	Environmental Scientist, Conceptual Environmental Management Plan for a Hotel and Residential Development at Londonderry, Dominica
2012	Air and Noise Monitoring Plans for various segments of the Point Fortin Highway Extension

2011-2012	Environmental Scientist, Flood, Water Quality and Sediment Management Plans for various segments of the Point Fortin Highway Extension
2010	Environmental Scientist, Conceptual Acquisition Plan for the Upgrade and Development of the Southern Main Road, from Paria Suites to St. Mary's Junction
2009	Environmental Scientist, Emergency Response Plan for the Community Roads Improvement Project for Regions 3, 4, 5 and 6, Guyana

Environmental Audits

2012	Environmental Scientist / Health and Safety Technician, Environmental Health and Safety Compliance Audit for Air Quality Monitoring at an Ammonia Facility in Point Lisas
2010	Environmental Scientist, Environmental, Health and Safety Compliance Audit at Lowman's Bay Power Station, St. Vincent and the Grenadines

Environmental Impact Assessments

Present	Environmental Scientist, EIA for a proposed Limestone Quarry at Cuarita Estate, Maracas, St. Joseph
2015	Environmental Scientist, Draft EIA for Proposed Slope Stabilization Works at Belle Isle and Coull's Hill, St. Vincent.
2014-2015	Environmental Scientist, Draft EIA for Proposed Slope Stabilization works at Nine Sites in St. Vincent.
2014	Assistant Study Manager, EIA for the Establishment of a Fruit and Vegetable Crop Farm and Energy Service Facility in Debe.
2013	Assistant Study Manager, EIA for the Establishment of an Ammonia/Urea/Melamine Complex in Point Lisas
2012	Environmental Scientist, EIA for the drilling of Exploratory Wells in the Mayaro/Guayaguayare Block (Onshore)
2012	Environmental Scientist, EIA for the Mining of 209 acres of Sand and Gravel at Pine Road, Matura

2012	Environmental Scientist, EIA for the Drilling of Seven (7) Exploratory Wells (Onshore and Offshore) in the Guayaguayare Block
2010	Environmental Scientist, EIA for Exploratory Drilling of Three (3) Wells in Block 2(ab) Offshore the East Coast of Trinidad
2010	Environmental Scientist, EIA for Upgrade and Development of the Southern Main Road from Paria Suites to St. Mary's Junction
2010	Environmental Scientist, EIA for a Wind Turbine at Rosalie Bay Nature Resort, Dominica
2008	Environmental Scientist, EIA for a Road Tank Wagon Loading Facility at Pointe-a-Pierre
2008	Environmental Scientist, EIA for the Clearing and Grading of 7.5 ha of Land at Acono Road in Maracas Valley, St. Joseph
2007	Technician, EIA for 8" Natural Gas Pipeline to Diamond Vale Industrial Estate
2007	Technician, EIA for Establishment of a 152 mm Diameter Gas Pipeline to the Tamana In-Tech Park, Cumuto Along With Upgrade of a 50mm Diameter Gas Pipeline to the Unicell Plant, O'Meara Industrial Estate, Arima.
2007	Technician, EIA for the Extraction and Processing of Sand from Quarry Operations at Toco Main Road, Matura
2007	Technician, EIA for a Sulphuric Acid Regeneration Unit, Road Tank Wagon Loading Faciltiy, Off site Feed and Production Systems, Propylene / Butylene Alkalation Unit and Continuous Catalyst Regeneration Platforming Unit
2006	Technician, EIA for Science and Technology Park at Wallerfield
2006	Technician, EIA for Gas to Liquids Plant at Point-a-Pierre
2006	Technician, EIA for Princes Town to Mayaro Highway
2006	Technician, EIA for various segments of the Point Fortin Highway - Golconda to Debe, Debe to Mon Desir Segment and St. Mary's to Point Fortin Segments
2005 - 2006	Technician, EIA for HFO Power Plant in Suriname

Other Environmental Studies

Present	Environmental Scientist, Detailed Assessment of Impacts to the Natural Environment as part of a Flood Mitigation and Integrated Watershed Management Project in the South Oropouche River Basin
2016	Environmental Scientist, Coastal Mapping of the Southern, Eastern and Northeastern Coastline of Trinidad and Southern and Northeastern Coastline of Tobago
2016	Environmental Scientist, Desktop Survey and Reconnaissance of Baseline Vegetation Types and Associated Fauna within the South Oropouche Drainage Basin
2015	Environmental Scientist, Environmental Evaluation Report for Improvement Works to the Diego Martin Highway / Western Main Road Intersection and Related Improvements
2014	Environmental Scientist, Environmental Advisory Services for the Expansion of a Golf Course in Tucker Valley
2013	Study Manager, Environmental Scoping Report for the Establishment of a Methanol Tank at Point Lisas
2012	Peer Reviewer, Preliminary EIA for the Caroni River Basin Study
2012	Environmental Scientist, Environmental Scoping Report for the Rehabilitation of several Bridges in Trinidad.
2012	Environmental Scientist. Preliminary EIA for a Hotel and Residential Development at Londonderry, Dominica
2011	Environmental Scientist, Environmental Scoping Report, for Site Preparation Works at a 41.5 ha Parcel of Land in Point Lisas
2011	Environmental Scientist, Initial Environmental Impact Assessment for the Halls of Justice Project in OECS Member Countries (Grenada, St. Vincent and the Grenadines, St. Lucia, Dominica, Antigua, Anguilla, St. Kitts, Nevis and British Virgin Islands)
2010	Environmental Scientist, Noise Abatement Study for the Yara Trinidad Ammonia Plant, Point Lisas
2010	Environmental Scientist, Social Baseline Study for the Drilling of an Offshore Exploratory Well, Suriname

2010	Environmental Scientist, Preliminary Environmental Impact Assessment for the North Oropouche Drainage Improvement Works
2009 / 2010	Environmental Scientist, Preliminary Environmental Impact Assessment for Coastal Protection Works at Four Zones along the North Coast of Trinidad
2009	Environmental Scientist, Environmental Context Report for Consultancy Services to Assist the Siparia Regional Corporation in Preparing its Spatial Development Plan
2009	Environmental Scientist, Environmental Management Plan for the Guyana Community Roads Improvement Project, Regions 3, 4, 5 & 6
2009	Environmental Scientist, Environmental Scoping Report for a Proposed Port at LABIDCO Estate, La Brea
2009	Environmental Scientist, Protected Areas System Plan for St. Kitts and Nevis
2009	Environmental Scientist, Initial Environmental Evaluation for Telesur Submarine Fibre Optic Cable, Suriname
2008	Environmental Scientist, Environmental Scoping Report for Tamana Park North Area
2008	Environmental Scientist, Soil Contamination Study at the Lube Oil Tank Farm, Petrotrin Refinery, Pointe-a-Pierre
2008	Environmental Scientist, Environmental Scoping Report for Augmentation of WA - 1 Water Supply System, Dominica
2007	Technician, Baseline Environmental and Regulatory Framework Assessment for Barbados Offshore and Coastal Areas
2007	Technician, Environmental Scoping Report - Community Development Works at Felicity, Preysal and Spring Village.
2006	Technician, Development and Regulation of Hazardous Material Road Transport System
2006	Technician, Master Plan for Southwest Peninsula
2006	Technician, Environmental Scoping Report for Aluminum Smelter at Cap-de-Ville
2005	Technician, Modelling of Hydrotest Water Discharge From Dolphin A Platform

APPENDIX C – EIA Review Checklist

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Environmental Protection Act Checklist

Environmental Protection Act Citation	Text from Environmental Protection Act	Corresponding EIA Reference
Schedule IV, Section 11, Paragraph 1	*(1) A developer of any project listed in the Fourth Schedule, or any other project which may significantly affect the environment shall apply to the Agency for an environmental permit and shall submit with such application the fee prescribed and a summary of the project including information on:-* *(i) the site, design and size of the project;* *(ii) possible effects on the environment* *(iii) the duration of the project; and* *(iv) a non-technical explanation of the project.*	• All information required in 1. (i-iv) is contained in permit application and attachment to application July 5 2016, as well as in summary posted by the EPA on January 14 2017.
Schedule IV, Section 11, Paragraph 2	*(2) Where it is not clear whether a project will significantly affect the environment, the developer shall submit to the Agency a summary of the project which shall contain the information as required by subsection (1) and the Agency shall within a reasonable period publish in at least one daily newspaper a decision with reasons as to whether the project:* *(a) will not significantly affect the environment, and thereof exempt from the requirement for an environmental impact assessment; or* *(b) may significantly affect the environment and will require and environmental impact assessment.*	• Project summary posted by the EPA on January 14 2017, and EPA issued several notices of requirement to conduct EIA and public scoping meetings in fourth quarter 2016.
Schedule IV, Section 11, Paragraph 4	*(4) Every environmental impact assessment shall be carried out by an independent and suitably qualified person approved by the Agency and shall:* *(a) identify, describe and evaluate the direct and indirect effects of the proposed project on the environmental including:* *(i) human beings;* *(ii) flora and fauna and species habitats;* *(iii) water;* *(iv) soil;* *(v) air and climatic factors;* *(vi) material assets, the cultural heritage and the landscape;* *(vii) natural resources, including how much of a particular resource is degraded or eliminated, and how quickly the natural system may deteriorate;* *(viii) the ecological balance and ecosystems;* *(ix) the interaction between the factors listed above;* *(x) any other environmental factor which needs to be taken into account or which the Agency may reasonably require to be included; and* *(b) assess every project with a view to the need to protect and improve human health and living conditions and the need to preserve the stability of ecosystems as well as the diversity of species.*	• Impacts on human beings required under 4(a)(i) of the EP Act contained in multiple subsections of Section 7.3 of EIA. • Impacts on flora/fauna, water, air and climate, cultural heritage, and ecological balance/ecosystems required under 4(a)(ii, iii, and v) of the EP Act included as subsections of Chapter 7 of EIA. • Impacts on soil and landscape required under 4(a)(iv) of the EP Act mentioned but scoped out of detailed analysis in Table 5.2 of EIA • "Material assets" addressed as required under 4(a)(vi) of the EP Act under "Economic Conditions" in Section 7.3 of EIA. • Temporal aspect of impacts impacts addressed by categorizing impacts as short term/long term and temporary/permanent as required under 4(a)(vii)of the EP Act. • Impacts on "Natural Resources" required under 4(a)(vii) of the Act assessed throughout Sections 7.1 and 7.2 of EIA • Impacts on ecological stability addressed in Section 7.2.9 as required under 4(a)(viii) of the Act. • Interaction between factors required under 4(a)(ix) of the Act assessed as indirect impacts throughout Section 7 of EIA • "Other environmental factors" not specifically required to be assessed under 4(a) of the EP Act but assessed in the EIA include oceanographic conditions, sound, and protected areas (in accordance with 4(x) of the EP Act)aspect. • Impacts on "human health" and aspects of "living conditions" required under 4(b) of the Act assessed throughout Section 7.3 of EIA • Impacts on biodiversity required under 4(b) of the Act assessed by major taxonomic group in Section 7.2 of EIA

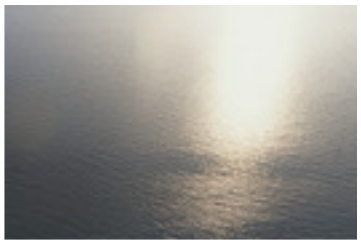
Environmental Protection Act Citation	Text from Environmental Protection Act	Corresponding EIA Reference
Schedule IV, Section 11, Paragraph 5	*(5) Every environmental impact assessment shall contain the following information:-* *(a) a description of the project, including in particular:-* *(i) the geographical area involved, the physical characteristics of the whole project and the land-use requirements during the construction and operational phases, including plans, drawings, and models;* *(ii) the main characteristics of the production process, including the nature and quantity of the materials used, plans, drawings and models;* *(iii) and estimate, by type and quantity, of expected contaminants, residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation) resulting from the operation of the proposed project;* *(iv) the length of time of the project.* *(b) an outline of the main alternatives studied by the developer and an indication of the main reasons for his choice, taking into account the environmental factors;* *(c) a description of the likely significant effects of the proposed project on the environment resulting from:-* *(i) the existence of the project;* *(ii) the use of natural resources;* *(iii) the emission of contaminants, the creation of nuisances and the elimination of waste, and a description by the developer of the forecasting methods used to assess the effects on the environment.* *(d) an indication of any difficulties (technical deficiencies or lack of knowledge or expertise) encountered by the developer in compiling the required information;* *(e) a description of the best available technology;* *(f) a description of any hazards or dangers which may arise from the project and an assessment of the risk to the environment;* *(g) a description of the measures which the proposed developer intends to use to mitigate any adverse effects and a statement of reasonable alternatives (if any) and reasons for their rejection;* *(h) a statement of the degree of irreversible damage, and an explanation of how it is assessed;* *(i) an emergency response plan for containing and cleaning up any pollution or spill of any contaminant;* *(j) the developer's programme for rehabilitation and restoration of the environment;* *(k) a non-technical summary of the information provided under the preceding paragraphs.*	• Discussion of AOIs in Section 5.1 of EIA describe the geographical area involved as required in 5(a)(i) of the EP Act. • Project Description in Section 2 describes physical characteristics of the Project and production processes as required in 5(a)(ii), and Project schedule as required in 5(a)(iv) of the EP Act. • Section 2.10.3 of EIA discusses wastes, contamination, etc. as required in 5(a)(iii) of the EP Act; potential impacts from radiation scoped out in Table 5.2 of the EIA. • Section 2.15 of EIA discusses alternatives as required in 5(b) of the EP Act. • Section 7 of EIA discusses significant impacts from all aspects of the Project as required in 5(c) of the EP Act. • Data gaps and studies designed to address "technical deficiencies" and "lack of knowledge" are discussed in the TOR as required in 5(d) of the EP Act, and the information provided by these studies (including the Environmental Baseline Studies, Air Quality monitoring study, and Metocean Study) is included in the appropriate subsection of Chapter 6 of the EIA. • Technology to be used on the Project is discussed broadly in terms of having been proven effective in the industry as required in 5(e) of the EP Act. • Natural hazards discussed briefly in Section 5.3 of EIA as required in 5(f) of the EP Act but scoped out of further analysis. • ESMP framework (Section 9 of EIA) and actual ESMP document discuss measures required in 5(g) of the EP Act. • Irreversibility addressed for every impact as required in 5(h) of Act as part of the impact rating process described in Section 4 of the EP EIA. • Emergency response procedures are contained within the ESMP as required in 5(i) of the EP Act. • EIA concludes that disturbed habitats (primarily seafloor habitats) will recover naturally over time as required in 5(j) of the EP Act. ESMP addresses monitoring / mitigations for ensuring residual impacts of significance that could not be mitigated are remedied, where feasible. • EIS is provided as preface to EIA provides non-technical summary as required in 5(k) of the EP Act.
Schedule IV, Section 11, Paragraph 6	*(6) Before any environmental impact assessment is begun the Agency shall at the developer's cost publish in at least one daily newspaper a notice of the project and make available to members of the public the project summary referred to in subsection (1).*	• Summary posted by the EPA on January 14 2017, and EPA issued several notices of requirement to conduct EIA and public scoping meetings in fourth quarter 2016.
Schedule IV, Section 11, Paragraph 7	*(7) Members of the public shall have twenty-eight days from the date of publication referred to in subsection (6) to make written submission to the Agency setting out those questions and matters which they require to be answered or considered in the environmental impact assessment.*	• 28 day review period for the project summary currently being administered, expires on February 10 2017.
Schedule IV, Section 11, Paragraph 8	*(8) The Agency shall after consultation with the person chosen to carry out the environmental impact assessment, set the terms and scope of the environmental impact assessment taking into account any submissions made under subsection (7)*	• EPA accepted the final TOR for the EIA on February 17, 2017 as required in paragraph 8 of the EP Act.

Environmental Protection Act Citation	Text from Environmental Protection Act	Corresponding EIA Reference
Schedule IV, Section 11, Paragraph 9	*(9) During the course of the environmental impact assessment the developer and the person carrying out the environmental impact assessment shall:* *(a) consult members of the public, interested bodies and organizations;* *(b) provide to members of the public on request, and at no more than the reasonable cost of photocopying, copies of information obtained for the purpose of the environmental impact assessment.*	• ERM conducted regional and agency sector scoping meetings during preparation of the TOR and will ensure stakeholders are appropriately engaged / consulted during the EIA process as required in paragraph 9 of the EP Act.
Schedule IV, Section 11, Paragraph 10	*(10) The developer and the person carrying out the environmental impact assessment shall submit the environmental impact assessment together with an environmental impact statement to the Agency for evaluation and recommendations and publish a notice in at least one daily newspaper confirming that the environmental impact assessment and environmental impact statement have been submitted to the agency and members of the public shall have sixty days from the date of publication of such notice to make such submissions to the Agency as they consider appropriate.*	• Notice of availability to be completed and public review period to be administered once the EIA is submitted.
Schedule IV, Section 11, Paragraph 11	*(11) The environmental impact assessment and the environmental impact statement shall be public documents and the developer and the Agency shall have such documents available for the duration of the project and five years thereafter for inspection, subject to the deletion therefrom of such information as may disclose intellectual property rights, during normal working hours at their respective offices and shall supply on request and on payment of cost of photocopying copies of such documents.*	• To be completed once the EIA is submitted.
Schedule IV, Section 11, Paragraph 12	*(12) All expenses of the environmental impact assessment process (including the preparation of the preliminary and full environmental impact assessments, the environmental impact statements, and the conduct of public hearings) shall be borne by the developer.*	• EEPGL paying required costs for EIA process.
Schedule IV, Section 11, Paragraph 13	*(13) The Agency shall submit the environmental impact assessment together with the environmental impact statement to the Environmental Assessment Board for its consideration and recommendation as to whether the environmental impact assessment and the environmental impact statement are acceptable.*	• EPA to complete once the EIA is submitted.
Schedule IV, Section 12, Paragraph 1	*(1) The Agency shall approve or reject the project after taking into account:-* *(a) the submissions made under section 11 (10) and the recommendations of the Environmental Assessment Board made under section 18 (2); and* *(b) the views expressed during the consultations under section 11 (9); and (c) the environmental impact assessment and environmental impact statement.*	• EPA to complete once the EIA is submitted.
Schedule IV, Section 12, Paragraph 2	*(2) The Agency shall publish its decision and the grounds on which it is made.*	• EPA to complete once the EIA is submitted.
Schedule IV, Section 13, Paragraph 1	*(1) A decision by the Agency to issue an environmental permit for a project shall be subject to conditions which are reasonably necessary to protect human health and the environment and each environmental permit shall contain the following implied conditions:* *(a) the Agency shall have the right to cancel or suspend the environmental permit if any of the terms or conditions of the environmental permit are breached;* *(b) the developer shall have an obligation to use the most appropriate technology;* *(c) the developer shall have an obligation to comply with any directions by the Agency where compliance with such directions are necessary for the implementation of any obligations of Guyana under any treaty or international law relating to environmental protection; and* *(d) the developer shall have an obligation to restore and rehabilitate the environment.*	• Technological alternatives are discussed in Section 2.15 and technology to be used on the Project is discussed broadly in terms of having been proven effective in the industry.
Schedule IV, Section 13, Paragraph 2	*(2) The Agency shall not issue an environmental permit unless the Agency is satisfied that:-* *(a) the developer can comply with the terms and conditions of the environmental permit; and* *(b) the developer can pay compensation for any loss or damage which may arise from the project or breach of any term or condition of the environmental permit.*	• Environmental permit, determination of compliance with terms of the permit, and determination of the ability of developer to pay compensation for loss or damage arising from the project or breach of the permit to be completed following submission of the EIA (subject to EPA's review and acceptance of the EIA).

Environmental Protection Act Citation	Text from Environmental Protection Act	Corresponding EIA Reference
Schedule IV, Section 17 Paragraph 1	*(1) Where any activity by itself does not have a significant effect on the environment but the same activity or similar activities are carried out by any person in any place and cumulatively may significantly affect the environment, the Agency shall require to be carried out an environmental impact assessment of the cumulative effects of such activities by such persons.*	• Section 8 of the EIA addresses cumulative impacts
Schedule IV, Section 17 Paragraph 2	*(3) Where an environmental impact assessment is required under this section, the procedure set out in this Part shall be followed in so far as such procedure is applicable.*	• Section 8 of the EIA addresses cumulative impacts

APPENDIX D – Air Quality Monitoring Report

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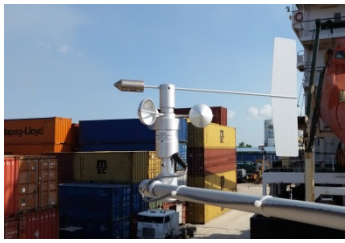


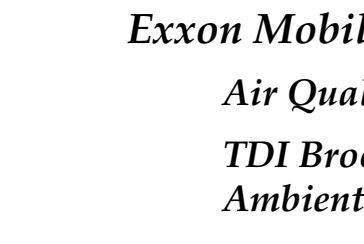
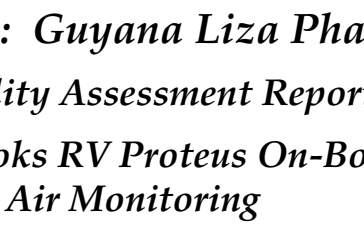
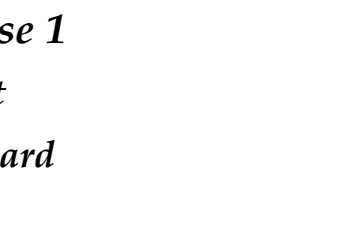










Exxon Mobil: Guyana Liza Phase 1

Air Quality Assessment Report

TDI Brooks RV Proteus On-Board Ambient Air Monitoring

December 3, 2016

TABLE OF CONTENTS

I. EXECUTIVE SUMMARY.....I

II. ACRONYMS AND ABBREVIATIONS.....2

III. MONITORING APPROACH.....3

IV. INSTRUMENTATION.....5

V. QUALTIY CONTROL/QUALITY ASSURANCE.....9

VI. RESULTS.....10

A. SULFUR DIOXIDE.....10

B. HYDROGEN SULFIDE.....10

C. NITROGEN DIOXIDE.....10

D. CARBON MONOXIDE.....11

E. VOLATILE ORGANIC COMPOUNDS.....11

F. INHALABLE PARTICULATE MATTER.....12

G. METEOROLOGICAL PARAMETERS.....12

LIST OF FIGURES

FIGURE IV-1 INSTRUMENTATION CONFIGURATION

LIST OF APPENDICES

A Training Class Roster

I. EXECUTIVE SUMMARY

ERM performed ambient air quality monitoring of the Liza Phase 1 area, by instrumenting the research vessel Proteus to measure inhalable particulate matter (PM_{10}), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), nitrogen dioxide (NO_2), carbon monoxide (CO), and volatile organic compounds (VOC). To mitigate the challenges posed by shipboard monitoring, multiple measurement methods, duplicate sampling, and concurrent meteorological and geographic position measurements were employed.

The program was carried out in general conformance with the October 1, 2016 Air Quality Assessment Protocol prepared for ExxonMobil, by Environmental Resources Management, Inc. (ERM).

During the 20 day survey period, 50 discrete, integrated samples were collected, in addition to continuous PM_{10}, SO_2, H_2S, NO_2, CO, and VOC sensor measurements. Geographic position, relative wind direction, wind speed, ambient temperature, and relative humidity were also measured on a continuous basis.

In general, these measurements documented that ambient concentrations of the monitored air pollutants in the Liza Phase 1 area are very low, usually below the quantification level of the measurement systems.

Inhalable particulate matter was the only air pollutant consistently above the minimum reporting levels. The maximum 24 hour average PM_{10} concentration measured was 32 microgram per cubic meter—approximately sixty percent of the World Health Organization's Guideline concentration. Supplemental chemical analyses demonstrated that the primary constituent of sampled particulate matter was sea salt.

The continuous air quality sensors were a valuable supplement to the time-integrated samples that required post-survey laboratory analysis. However, it was essential that these units' measurements be compared to more established methods. The Liza Phase 1 results demonstrated that the sensor responses varied from the collocated reference method by as much as a factor of 16.

II. ACRONYMS AND ABBREVIATIONS

CO	Carbon Monoxide
H_2S	Hydrogen Sulfide
NO_2	Nitrogen Dioxide
PM_{10}	Inhalable Particulate Matter with an aerodynamic diameter of < 10 micrometer
ppb(v)	Parts Per Billion by Volume
ppm(v)	Parts Per Million by Volume
QA	Quality Assurance
QC	Quality Control
SO_2	Sulfur Dioxide
SOP	Standard Operating Procedure
VOC	Volatile Organic Compounds

III. MONITORING APPROACH

In order to confirm the validity of the background pollutant concentration assumptions upon which the air quality modeling was based, ERM assessed the ambient air quality in the Liza Phase 1 area, offshore Guyana. This was a verification exercise and was not intended as the basis for an ongoing monitoring program.

Monitoring and sampling equipment was mounted on the TDI Brooks research vessel Proteus and air was sampled during its 20-day deployment, from October 3 through 23, 2016. During the course of the air monitoring program, the TDI Brooks helmsman endeavored to maintain the bow of the Proteus in the upwind direction to the extent possible, in order to minimize the potential bias of the air samples by on-board emission sources.

This report presents the results of the monitoring effort. Six air pollutants (or class of pollutants) were selected for monitoring:

- Sulfur Dioxide (SO_2) ,
- Hydrogen Sulfide (H_2S);
- Nitrogen Dioxide (NO_2),
- Volatile Organic Compounds (VOC)
- Carbon Monoxide (CO), and
- Inhalable Particulate Matter, less than 10 micrometer in aerodynamic diameter (PM_{10}).

These are air contaminants that may be associated with oil and gas exploration and/or production. This assessment was performed to document baseline offshore air quality conditions.

Primary reliance was on a set of real-time sensors whose calibration was correlated to laboratory analysis results of collocated passive samplers and collected samples. In addition to air quality parameters, the following meteorological parameters were measured:

- Relative Wind Speed and Direction,
- Temperature, and
- Relative humidity.

Finally, the location of the air quality instrumentation package was continuously tracked by a GPS logger.

A few periods of potential continuous sensor bias from on-board emission sources have been designated as "suspect" or "invalid", based on concurrent measurement of wind direction, relative to the air sampling package and records of ship-board emission source operations. While all data have been retained in the raw data record, only validated data are reported herein.

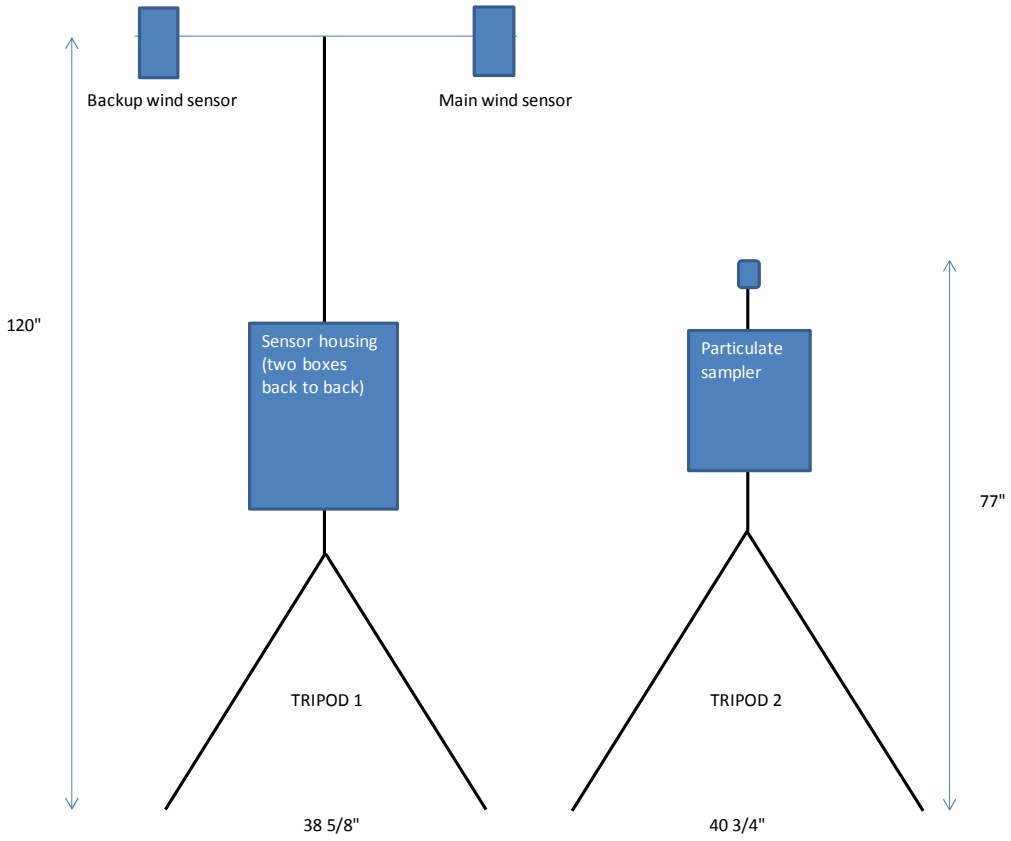
Upon the survey's conclusion, air samples were retrieved and shipped for laboratory analysis. The real-time air quality, meteorological, and GPS data were downloaded from the instruments either at the dock site or, subsequently, in ERM's Rolling Meadows, Illinois air quality laboratory.

Data processing consisted of using the laboratory data to validate and adjust the raw air quality sensor data. This report uses the validated laboratory results and the adjusted sensor data to characterize the baseline ambient air quality in the Liza Phase 1 area.

IV. INSTRUMENTATION

Air quality, meteorological, and miscellaneous instrumentation used for the Liza Phase 1 background ambient air quality assessment are described below. Figure IV-1 illustrates the physical configuration of the instruments.

Figure IV-1. Instrumentation Configuration



1. Air Quality Parameters

The program measured ambient concentrations of SO_2, H_2S, NO_2, CO, VOC, and PM_{10}. Each air contaminant was measured with a passive sampler or collected air sample that required laboratory analysis, as well as a continuously monitoring sensor. The laboratory results are considered more reliable, so they were used to validate and adjust the sensor data, as appropriate.

a. **SO_2 –** SKC passive sampling badges (SKC UMEx 200), as well as an Aeroqual Model 500 monitor equipped with a 0 to

10 ppm SO_2 sensor, were used to measure ambient concentrations during the study.

The Aeroqual monitor collected and recorded data throughout the duration of the field survey.

Sample badges were exposed for approximately 24 hours, prior to being sealed for subsequent analysis and replaced with a fresh badge. This continued throughout the survey period, with each badge exposed, sequentially. Duplicate badges were employed for the first few sample periods to provide insight into the method's measurement precision.

b. **H_2S –** Radiello passive sampling tubes (Sigma Aldrich RAD1236), as well as an Aeroqual Model 500 monitor equipped with a 0 to 10 ppm H_2S sensor, were used to measure ambient concentrations during the study.

   The Aeroqual monitor collected and recorded data throughout the duration of the field survey.

   Each sample tube was exposed for approximately 24 hours, prior to being sealed for subsequent analysis and replaced with a fresh tube. This continued throughout the survey period, with each tube exposed, sequentially. Duplicate samples were collected for the first few sampling periods in order to provide an estimate of measurement precision.

c. **NO_2 – T**he same SKC passive sampling badge was employed to measure SO_2 concentrations during the study. The badge was analyzed so that both SO_2 and NO_2 exposure was measured. Thus, sample badges were exposed for approximately 24 hours, prior to being sealed for subsequent analysis and replaced with a fresh badge. This continued throughout the survey period, with each badge exposed, sequentially. Duplicate badges were employed for the first few sample periods to provide insight into the method's precision.

   In addition, an Aeroqual Model 500 monitor equipped with a 0 to 1 ppm NO_2 sensor provided a continuous reading of ambient concentrations throughout the duration of the field survey.

d. **VOC –** Passivated stainless steel ("Summa") canisters, as well as an Aeroqual Model 500 monitor equipped with a 0 to 25 ppm VOC sensor, were employed to measure ambient concentrations during the study.

   Two-day integrated ambient air samples were collected using pairs of flow controlled evacuated passivated stainless steel ("Summa") canisters. One Summa was configured to draw its sample from within the enclosure housing an Aeroqual Model 500 VOC monitor. The other Summa drew a direct ambient air sample. This permitted assessment of whether the enclosure biased the VOC measurement, and facilitated interpretation of the continuous Aeroqual results. At the conclusion of each two-day sampling period, the canisters were capped and stored for subsequent laboratory analysis, a fresh pair of canisters installed, and another sample collection initiated.

   At the laboratory, each canister was analyzed for total and speciated VOC by GC/MS, in accordance with US EPA Method TO-15.

   The Aeroqual monitor continuously collected and recorded data throughout the duration of the field survey.

e. **CO –** The same pairs of 48-hour integrated Summa canister samples were analyzed in the laboratory for CO concentration.

   The Aeroqual monitor collected and recorded data throughout the duration of the field survey.

f. PM_{10} **–** A Met One Instruments E-Sampler measured PM_{10} using two methods. First, multi-day integrated ambient concentrations were determined by laboratory gravimetric analysis of pre-weighed Teflon filters. The filter samples were also analyzed using U.S. EPA Metho IO 3.3 (X-ray fluorescence) to assess their composition.

   Second, the E-Sampler also contains a nephelometer. This provided a continuous signal, proportional to ambient PM_{10} concentrations. Due to the nature of the optical system employed, the continuous readings had to be adjusted for the nature of the specific particulate matter being measured.

ERM used the laboratory gravimetric results to perform this adjustment.

2. Meteorological Parameters

Wind speed and wind direction (relative to the ship's axis) were continuously monitored by cup and vane sensors and the resultant data logged by the E-Sampler's internal data logger.

Sample relative humidity and temperature were measured by a sensor attached to one of the Model 500 monitors and recorded by its internal data logger. These data were used to identify any periods during which the air quality sensors operated outside their control limits. Data were invalidated as necessary.

3. Miscellaneous Parameters

A Garmin GPS logger was used to identify the location of the instrument package at each point in time, throughout the survey.

V. QUALTIY CONTROL/QUALITY ASSURANCE

Air monitoring on board a working research vessel introduces numerous challenges to obtaining reliable ambient air quality monitoring measurements. These include:

- Potential uncertainty regarding the location at which a measurement is made;
- Exposure to weather that may damage instruments or bias their measurements;
- Potential measurement bias due to impacts from on-board emission sources; and
- Reliability of electrical power with which to operate the monitoring instruments.

The Liza Phase 1 ambient air quality monitoring program's equipment proved to be relatively resilient to the challenges encountered at sea. The only significant aberrations were the failure of the CO sensor, 12 days into the survey and the NO_2 sensor malfunctioning, starting at 0300 on October 12, 2016. Summa canisters continued to provide 48 hour integrated CO samples for the duration of the survey but the loss of the CO sensor resulted in reduction of temporal resolution for this parameter. Similarly, the NO_2 passive samplers continued to provide 24 hour integrated values.

The E-Sampler's continuous data could not be downloaded dockside. These data were subsequently successfully retrieved in ERM's air quality laboratory and found to be valid.

The project's primary quality assurance mechanism was the teaming of passive samplers (and laboratory analyses) of known reliability with the real-time measurements of electrochemical air quality sensors whose performance quality is less certain. As noted above, TDI Brooks' helmsman endeavored to maintain the bow of the Proteus in the upwind direction to the extent possible, in order to minimize the potential bias of the air samples by on-board emission sources.

The program also relied on traditional quality control/quality assurance (QA/QC) measures such as the use of field and laboratory blanks, chain of custody documentation, and periodic calibrations against certified standards. Staff training and reliance on Standard Operating Procedures (SOPs) round out the overall QA/QC program. Appendix A contains the training class roster.

VI. RESULTS

In general, concentrations of the monitored air contaminants in the vicinity of the Liza Phase 1 area were found to be very low when compared with levels typically found in terrestrial environments, and with national and international ambient air quality standards.

The monitored values are summarized below. The entire valid data record is contained in Appendix B.

A. SULFUR DIOXIDE

The passive samplers yielded 24-hour (nominal) integrated sample values that were all below the 31 part per billion by volume [ppb(v)] Minimum Reporting Limit. Since the passive sampler results were all below the reporting limit, it was not possible to adjust the sensor data to align with the reference method. The maximum continuous SO_2 sensor recorded raw one hour concentrations of approximately 70 ppb(v). Daily average values were all less than 20 ppb(v), qualitatively consistent with the passive samplers (i.e., below their level of quantification). For comparative purposes, the World Health Organization (WHO) 10 minute average Guideline Concentration is 191 ppb(v) and the 24 hour Guideline is 7.6 ppb(v). Since the passive sampler results were all below the reporting limit, it is not possible to determine how accurate the sensor data are.

B. HYDROGEN SULFIDE

The passive samplers yielded 24-hour integrated sample values that were all below the Minimum Reporting Limit, which ranged from 5.9 to 7.1 ppb(v). The continuous H_2S sensor recorded a maximum one hour average concentration of approximately 50 ppb(v). Daily average values were all less than 10 ppb(v), qualitatively consistent with the passive samplers. For comparison purposes, the WHO 30 minute Guideline Concentration is equal to 14 ppb(v). Since the passive sampler results were all below the reporting limit, it is not possible to determine how accurate the sensor data are.

C. NITROGEN DIOXIDE

The passive samplers yielded 24-hour integrated sample values that were all below the 53 ppb(v) Minimum Reporting Limit. The continuous NO_2 sensor recorded raw maximum one hour average concentrations of approximately 70 ppb(v). Daily average values were all 53 ppb(v) or less, qualitatively consistent with the passive samplers.

For comparison, the WHO Guideline Concentrations are 106 ppb(v) for one hour and 21 for annual averages. Since the passive sampler results were all below the reporting limit, it is not possible to determine how accurate the sensor data are.

D. CARBON MONOXIDE

The Summa canisters were analyzed for CO using US EPA Method 25C (modified). Of the 18 valid (nominally) 48-hour composite samples, only one, a 7.1 ppm(v) measured value, was above its Minimum Reporting Limit (6.4 ppm(v), for this sample). It is notable that the duplicate value for this sample period was below its Minimum Reporting Limit. The Minimum Reporting Limits ranged from 4.6 to 13 ppm(v), depending on the specific sample.

The continuous CO sensor recorded a maximum one hour average concentration of 1.5 ppm(v). Daily average values were all less than 0.4 ppm(v), qualitatively consistent with the passive samplers. Given the single sample above the reporting limit, it was not possible to determine how accurate the sensor data are.

For comparison purposes, the WHO Guideline concentrations are 26.2 and 8.7 ppm(v) for one and eight hour averages, respectively.

E. VOLATILE ORGANIC COMPOUNDS

The Summa canisters were analyzed for volatile organic compounds and total volatile organic compounds calculated as toluene in accordance with United States EPA Method TO-15. The analytical system was comprised of a gas chromatography/mass spectrometer interfaced to a whole-air pre-concentrator. Over 70 discrete VOC species, and total VOCs, were quantified for each sample.

Total non-methane VOC concentrations ranged from 30 to 290 ppb(v) for these 48-hour (nominal) integrated samples. In most samples, most of the individual VOC species were below the Minimum Reporting Limits. The only individual compounds measured above 25 ppb(v) were ethyl acetate, ethanol, propene, acetone, and toluene. Ethanol was the most commonly found constituent at concentrations exceeding 25 ppb(v).

While all but three of the duplicate sample pairs agreed within 25%, there was little correlation between individual species identified in the sample pairs. This is probably due to the relatively low concentrations of the individual species, and the long hold times necessitated by the survey's

duration—allowing transformation of some sampled species into secondary compounds.

The average of the raw one hour concentrations recorded by the continuous VOC sensor was 1,400 ppb(v). The concurrent Summa canister results suggested a sensor correction factor of 0.096. This value was used to adjust the hourly sensor results, yielding corrected values that agree with the Summa results.

WHO has not promulgated a Guideline Concentration for VOC.

F. INHALABLE PARTICULATE MATTER

Two integrated filter PM_{10} samples were collected—both yielding calculated concentrations of 11 $\mu g/m^3$. The continuous nephelometer-based measurement were corrected based on these filter gravimetric results. The resultant "k factor" (ratio of nephelometer value to filter value) was 1.8.

The maximum and average corrected nephelometer 24 hour average PM_{10} concentration measurement were 33 and 12 $\mu g/m^3$, respectively. For comparison purposes, the WHO Guideline Concentrations are 50 and 20 $\mu g/m^3$ for 24 hour and annual averages.

Based upon elemental analysis, sea salt (sodium chloride) constituted the largest component (approximately 30%) of the measured PM_{10}.

G. METEOROLOGICAL PARAMETERS

Data recovery of wind speed and relative wind direction was 100% over the duration of the survey. The relative wind direction results document that the helmsman was generally successful in orienting the vessel so as to minimize potential measurement interference from onboard emission sources. The relative wind direction was only from astern during 28 of the 480 hours the vessel was at sea.

The temperature and humidity measurements documented that these parameters were within the air quality sensors' acceptable use range throughout the survey period.

APPENDIX A: TRAINING CLASS ROSTER

ExxonMobil

Liza Phase I Ambient Air Quality Monitoring Program

Proteus Staff Training Record

October 3, 2016

Instructor: Richard H. Osa, QEP (ERM)

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APPENDIX E – 2014 EBS

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ENVIRONMENTAL BASELINE STUDY

GUYANA STABROEK BLOCK

Prepared for

Esso Exploration and Production Guyana Ltd.

Prepared by

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San Diego, CA 92122

With

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July 2014
Report

ENVIRONMENTAL BASELINE STUDY
GUYANA – STABROEK BLOCK

Report

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July 2014

TABLE OF CONTENTS

LIST OF FIGURES ..... **iii**
LIST OF TABLES ..... **iii**
LIST OF ACRONYMS ..... **iv**
EXECUTIVE SUMMARY **ES-1**

1 INTRODUCTION AND EBS OBJECTIVES **1-1**
1.1 Environmental Baseline Study Objectives 1-1
1.2 Sampling Design 1-2
1.3 Report Organization 1-4

2 FIELD AND ANAYLICAL METHODS **2-1**
2.1 Field Methods 2-1
2.1.1 Water Sampling and Profiling 2-1
2.1.2 Sediment Sampling 2-1
2.2 Analytical Methods 2-2
2.2.1 TSS, TOC, and Sediment Particle Size 2-3
2.2.2 Metals 2-3
2.2.3 Hydrocarbons 2-4
2.2.4 Benthic Macrofauna 2-5
2.2.5 Sample Archival 2-6
2.3 Quality Control (QC) 2-6
2.4 Data Management and Analysis 2-6
2.4.1 Descriptive Statistics 2-7
2.4.2 Correlation Analysis 2-7
2.4.3 Graphical Presentations of Data 2-7
2.4.4 Analysis of Hydrocarbon Source 2-8

3 WATER COLUMN RESULTS **3-1**
3.1 Background 3-1
3.2 Water Column Profiles 3-1
3.3 Discrete Water Sample Results 3-6
3.3.1 Total Suspended Solids (TSS) and Total Organic Carbon (TOC) 3-6
3.3.2 Heavy Metals and Other Elements 3-7
3.3.3 Hydrocarbons 3-7

4 SEDIMENT PHYSICAL AND CHEMICAL RESULTS **4-1**
4.1 Background 4-1
4.2 Sediment Grain Size and Total Organic Carbon 4-1
4.3 Metals 4-3
4.4 Hydrocarbons 4-6

5 BENTHIC MACROFAUNA RESULTS 5-1
5.1 Background 5-1
5.2 Liza – Abundance and Diversity 5-2
5.2.1 Abundance 5-2
5.2.2 Diversity and Dominance 5-5
5.3 Sorubim – Abundance and Diversity 5-5
5.3.1 Abundance 5-5
5.3.2 Diversity and Dominance 5-8

6 EVALUATION OF DATA QUALITY 6-1
6.1 Evaluation of EBS Objectives 6-1
6.1.1 Study Objective 1 6-1
6.1.2 Study Objective 2 6-3
6.2 Analytical Chemistry Data Quality 6-3
6.2.1 Hydrocarbons 6-3
6.2.2 Metals 6-5
6.3 Benthic Infauna 6-7
6.3.1 Collection of Benthic Infaunal Sediment Samples 6-7
6.3.2 Laboratory Removal and Sorting of Organisms 6-7
6.3.3 Identification and Enumeration of Benthic Macrofauna 6-7

7 DISCUSSION AND CONCLUSIONS 7-1

8 REFERENCES 8-1

LIST OF FIGURES

Figure 1-1 Stabroek Block with locations of Liza and Sorubim EBS project areas 1-2
Figure 1-2 Locations of water and sediment sampling stations at Liza and Sorubim 1-3
Figure 3-1 Depth profiles for temperature, salinity, and density at Liza. 3-2
Figure 3-2 Profiles of dissolved oxygen and percent light transmission at Liza 3-3
Figure 3-3 Profiles of salinity, temperature, and water density at Sorubim 3-4
Figure 3-4 Profiles of salinity, temperature, and water density at Liza 3-5
Figure 4-1 Spatial distribution of percent fines and TOC at Liza 4-3
Figure 4-2 Spatial distribution of percent fines and TOC at Sorubim 4-3
Figure 4-3 Spatial distribution of aluminum and barium at Liza 4-6
Figure 4-4 Spatial distribution of aluminum and barium at Sorubim 4-6
Figure 4-5 Spatial distribution of total PAH and total SHC at Liza 4-8
Figure 4-6 Representative distributions of individual PAH and SHC analytes 4-11
Figure 5-1 Spatial distribution of macrofauna total abundance and family diversity at Liza 5-3
Figure 5-2 Spatial distribution of macrofauna total abundance and family diversity at Sorubim 5-7

LIST OF TABLES

Table 1-1 Sediment and water station names, locations and sampling inventory 1-4
Table 2-1 Analytical methods, laboratory, and number and type of EBS samples. 2-2
Table 2-2 EBS key parameters used in statistical analyses 2-7
Table 2-3 Diagnostic ratios and parameters of SHC and PAH 2-8
Table 3-1 Summary statistics for water physical structure data 3-6
Table 3-2 Summary results TOC and TSS for Liza and Sorubim discrete water samples 3-6
Table 3-3 Summary results for metals in Liza and Sorubim. 3-7
Table 3-4 Summary results for hydrocarbons in Liza and Sorubim 3-8
Table 4-1 Sediment grain size descriptions. 4-2
Table 4-2 Summary results for sediment grain size and TOC 4-2
Table 4-3 Summary results for sediment metals. 4-4
Table 4-4 Pearson correlation results for key chemical and selected physical parameters. 4-5
Table 4-5 Summary results for hydrocarbons 4-7
Table 4-6 Pearson correlation results for key hydrocarbon parameters 4-8
Table 4-7 Values for key diagnostic parameters indicating hydrocarbon source. 4-9
Table 5-1 Summary statistics for benthic macrofauna Liza 5-2
Table 5-2 Dominant families of macrofauna Liza 5-3
Table 5-3 Summary statistics for benthic macrofauna Sorubim 5-6
Table 5-4 Dominant families of macrofauna Sorubim 5-6
Table 6-1 Coefficients of variation for mean results reported for selected key parameters 6-2
Table 6-2 Summary results for QC surrogate recovery for hydrocarbons. 6-4
Table 6-3 QC summary results for hydrocarbons (PAH and SHC) analyzed in water and sediment 6-5
Table 6-4 Data quality objectives for metals analyzed by ICP with mass detector 6-6
Table 6-5 QC summary results for metals analyzed in water and sediment 6-6

ACRONYMS AND ABBREVIATIONS

α	parametric probability
µg	microgram
µg L^{-1}	microgram per liter (parts per billion)
µg g^{-1}	microgram per gram (parts per million)
µm	micron (micrometer)
<	less than
>	greater than
≥	greater than or equal to
≤	less than or equal to
/	divider
%	percent
‰	parts per thousand
°	degrees
±	plus or minus
®	registered trade mark
amu	atomic mass unit
As	arsenic
ASE	accelerated solvent extractor
ASTM	American Society for Testing and Materials
ca.	approximately
C	centigrade
cm	centimeter
CPI	carbon preference index
CTD	conductivity, temperature and depth
CV	coefficient of variation
DRC	dynamic reaction cell
DGPS	Differential Global Positioning System
DO	dissolved oxygen
EBS	Environmental Baseline Study
g	gram
GC-FID	gas chromatography/flame ionization detection
GC-MS	gas chromatography/mass spectrometry
GGMC	Guyana Geology and Mines Commission
Hz	hertz
ICP-MS	inductively-coupled plasma/mass spectrometry (ICP)
ID	identifier
km	kilometer
km^2	square kilometer
L	liter
m	meter
m^2	square meter
MDL	method detection limit
mg	milligram
mg L^{-1}	milligram per liter
mL	milliliter

mm	millimeter
m/z	mass to charge ratio
n	number or count
N	North
na	not applicable
NASA	US National Aeronautics and Space Administration
ng g^{-1}	nanogram per gram (parts per billion)
ng L^{-1}	nanogram per liter (parts per trillion)
p	Pearson's Correlation Coefficient
PAH	polycyclic aromatic hydrocarbons
QA/QC	Quality Assurance/Quality Control
RPD	relative percent difference
RSD	relative standard deviation
RTG	Real Time Gypsy
RV	Research Vessel
s^{-1}	records per second
SHC	saturated and aliphatic hydrocarbons, and selected isoprenoids
SIM	selected ion monitoring
SIO	Scripps Institute of Oceanography
SOP	standard operating procedure
TM	Trade mark
TOC	total organic carbon
TSS	total suspended solids
USA	United States of America
USEPA	United States Environmental Protection Agency
W	west
WGS	World Geodetic System
x	multiplier
z	non-parametric probability

EXECUTIVE SUMMARY

This report presents the background, approach, and results of an environmental baseline study (EBS) conducted in April and May 2014 in the Stabroek Block located approximately 130 to 240 km offshore central Guyana. The report describes the characteristics of physical, chemical, and biological properties of sediment and the water column to document baseline conditions prior to planned petroleum exploration and potential development in Liza and Sorubim, two areas located within Stabroek. Profiling of the water column was conducted to provide general information on water quality and physical structure at the time of the survey and to compare results to available regional information.

Background

The EBS emphasized water and sediment because they are a major repository for introduced environmental substances to the marine environment. Sediments can provide an integrated view of historical and contemporary contaminant inputs and depositional events. Benthic infauna (macrofauna) communities are a useful indicator of environmental health, due to their relative sensitivity to changes in sediment physical and chemical conditions. The study documents current concentrations of hydrocarbons and metals in offshore sediments, as these are the main contaminants potentially introduced from petroleum exploration and development.

EBS Objectives

The primary objective of the study was to define the range of sediment habitat conditions at Liza and Sorubim, and to examine chemical and biological patterns of variability in relation to sediment physical characteristics and water depth. To meet this objective, sediments were collected at 18 sampling stations: ten at Liza and eight at Sorubim.

A second objective was to evaluate water column physical structure (salinity, temperature, density, dissolved oxygen, turbidity), general water quality (suspended solids, total organic carbon), and selected chemical concentrations in near-surface, mixed layer, and near-bottom waters. Water data were collected at seven of the sediment station locations: four at Liza and three at Sorubim, effectively covering the area of interest.

Results

Water Physical Structure and Quality. Water column profiling depicted a steep halocline, reaching a maximum salinity of 37‰ at 100 m depth. Water temperature dropped monotonically from 28^{o} C at the surface to 3^{o} C around 2000 m. The water column was highly stratified, likely limiting nutrient flux into surface waters from below the mixed layer. The permanent (non-seasonal) pycnocline extends down to approximately 200 m, below which density increases slowly with depth. The water column was relatively clear, with light transmittance through the 25 cm path length typically greater than 95%. Dissolved oxygen was consistently high, ranging from roughly 6 mg L-1 near the surface to greater than 8 mg L-1 in near-bottom waters, although concentrations dropped as low as 4 mg L-1 at one station.

Water Chemical Results. Petroleum hydrocarbons (PAH and SHC) and ten pollutant-indicator metals were measured at three depths at each station. Concentrations of all metals, including barium, were well below those considered harmful to aquatic organisms in marine waters. Barium was the only metal detected in all samples, also displaying the highest concentrations in all samples (6.04-9.21 [illegible]g L-1). Copper, mercury, and zinc were the only other metals detected, with all mercury concentrations <1 ng L-1 (part-per-trillion). Arsenic, cadmium, chromium, copper, and lead were not detected in any sample at the low part-per-billion level (<4 µg L-1).

Total PAH (for 43 compounds) concentrations were extremely low in all samples (≤50 ng L-1). The majority of detected PAH compounds were naphthalene, and C1- and C2-naphthalenes, suggesting potential ultra-trace level introduction from the analytical laboratory. These compounds are ubiquitous laboratory contaminants, commonly found in floor wax, tubing, and other laboratory equipment. Total SHC concentrations were below detection limits (<12 µg L-1) in all but one sample, with a result of 109 µg L-1.
Sediment Particle Size and Chemistry. EBS samples consisted primarily of fine-grained material (avg. 77.3%) (<0.063 mm diameter), averaging 77.3%, with roughly equal portions of silts and clays. Sand comprised the remaining minor fraction in all samples. Concentrations of total organic carbon (TOC) were very low (<1%) in all samples. In general, the highest organic carbon concentrations were observed in sediments closest to shore, and increased with increasing percentage fine-grained sediments.

All of the ten pollutant-indicator metals had concentrations similar to those reported for clean coastal environments, except for arsenic, which was slightly enriched. Arsenic can become elevated from arsenic oxides, a byproduct of gold-mining, which is an established industry in Guyana. Most metals increased significantly with increasing fine-grained sediment and TOC, but either the opposite or no significant relationship was observed with water depth.

Extremely low concentrations of hydrocarbons were measured in sediments at Liza and Sorubim. Total PAH concentrations ranged from 16.48 to 53.36 ng g-1 dry weight in all samples. Concentrations of total SHC ranged from 2.6 to 14 µg g-1. Relative distributions of hydrocarbon compounds indicated biogenic sources opposed to petroleum or combustion-related sources, which typically dominate the offshore hydrocarbon signature from atmospheric fallout. Biogenic hydrocarbon sources most likely consist of terrestrial plant and humic material transported downslope from river inputs. Both total PAH and total SHC exhibited strong, positive correlations with TOC, also indicating biogenic origins of these trace level hydrocarbons. The dominance of naphthalenes and phenanthrenes (2- and 3-ring PAH) was observed in the majority of samples, suggesting plant biogenesis. In particular, low concentrations of phenanthrene have been measured in bark and twigs of Vismia trees, of which the species Vismia guyana and Vismia baccifera are native to Guyana.

Benthic Infauna. Total abundance was low, averaging 116 organisms m-2. This organism density is below the range of typical abundances reported from other continental slopes. The most abundant major taxonomic groups were polychaete worms, mollusks, and crustaceans. Polychaetes were the numerically dominant group at Liza (41%, avg. 47 m-2), while mollusks were dominant at Sorubim (37.5%, avg. 37.5 m-2). The overall prevalence of these three groups is typical for marine sediments. Polychaetes typically comprise about half of the numbers and a third of the macrofaunal species from deep-water marine habitats worldwide. No other individual major taxa were abundant, and collectively comprised less than 14% of total abundance. The observed impoverished macrofauna is likely ascribed to limited organic food sources, indicated by the extremely low organic carbon content in Liza and Sorubim sediment.

A total of 50 distinct families were identified, with approximately half represented by either one or two individuals. This is a relatively high level of diversity considering the low abundance of the macrofauna. Dominant families were typical cosmopolitan inhabitants of shelf and slope sediments worldwide. These included oweniid polychaetes, pericarid crustaceans, and tindariid and nuculanid (bivalve) mollusks. The relatively low percent coefficient of variation (mean=36) between sampling stations indicates that this is a conservative parameter and a potentially effective index for monitoring potential change induced from oil and gas exploration and development.

Conclusions

Offshore sediments collected from Liza and Sorubim areas of Stabroek Block have metal and hydrocarbon concentrations lower than those reported for undeveloped coastal environments, except for arsenic, which may be slightly enriched through mineral deposits. Biological results indicated a low abundance but relatively diverse macrofauna relative to offshore marine habitats of similar water depth and latitude.

Potential impacts to the macrofauna from petroleum development offshore are unlikely to be significant and restricted to the immediate area, and a steep species accumulation curve should be realized as conditions return to normal. However, there is the potential for pollutant transport from drilling and operations into more sensitive areas of nearshore shallow zones from the dominant longshore current.

1 INTRODUCTION AND EBS OBJECTIVES

This executive summary report presents the results of an environmental baseline study (EBS) conducted offshore Guyana by TDI-Brooks International (TDI) and reported by Maxon Consulting on behalf of Esso Exploration and Production Guyana Ltd. Sampling was conducted in April and May 2014 in the Liza and Sorubim areas slated for oil and gas exploration within the Stabroek Block. Analyses of sediment and water samples were conducted by B&B Laboratory and Albion, located in College Station, Texas, USA. Benthic macrofauna samples were analyzed by Lovell Taxonomic Services with oversight from Maxon Consulting (both located in San Diego, California, USA).

This report focuses on general environmental characteristics of marine sediment and oceanic water in the area of planned exploration. The report objective is to provide information that can be used to support environmental decision making through the evaluation of chemical, physical, and biological properties of sediment and the water column within the Liza and Sorubim sites. Emphasis was placed upon sampling and analysis of the sedimentary environment because sediment and their biota are relatively immobile and integrate the effects of depositional processes, including physical disturbances and potential introduction of contaminants (Boesch and Rabalais 1987). The benthic environment can be a depositional area for discharged drilling cuttings and adhered muds, and is recognized as a sensitive and reliable monitoring indicator for measuring potential impacts from exploration drilling. This report presents survey data and summarizes key environmental features in support of EBS objectives.

1.1 Environmental Baseline Study Objectives

Study objectives were formulated for the successful completion and interpretation of EBS data and are listed below. The objectives are directed toward documenting background environmental conditions in the vicinity of potential sites prior to oil and gas exploration drilling.

1. *Provide comprehensive, descriptive, and quantitative documentation of environmental conditions at Liza and Sorubim sites of potential exploration and development.*

The EBS was designed to cover the estimated range of potential impacts to the environment from exploration drilling and potential well development. The location of offshore sites, Liza and Sorubim, and associated sampling stations are shown in **Figures 1-1** and **1-2**, respectively. Sediment station locations were selected to provide the range of existing environmental conditions prior to future planned exploration and development.

2. *Gain information to assess the significance of environmental impacts to offshore Guyana sediment from potential existing sources, such as atmospheric deposition and hydrodynamic transport.*

Trace level hydrocarbon chemical analyses were conducted to distinguish types and potential sources of petroleum related compounds measured in sediments and water. Biological samples were analyzed using a 0.5 millimeter (mm) screen to describe benthic macrofaunal community structure.

3. *Identify potential confounding factors that may interfere with the interpretation of sediment chemical and biological data to aid sampling design and interpretation of future environmental data.*

Correlation analyses were performed to identify statistically significant co-varying environmental parameters (confounding factors) to help interpret key chemical and biological results. Common confounding factors include sediment particle size, water depth, total organic carbon (TOC), and dissolved oxygen, which can influence hydrocarbon, metal, and/or benthic macrofauna results.

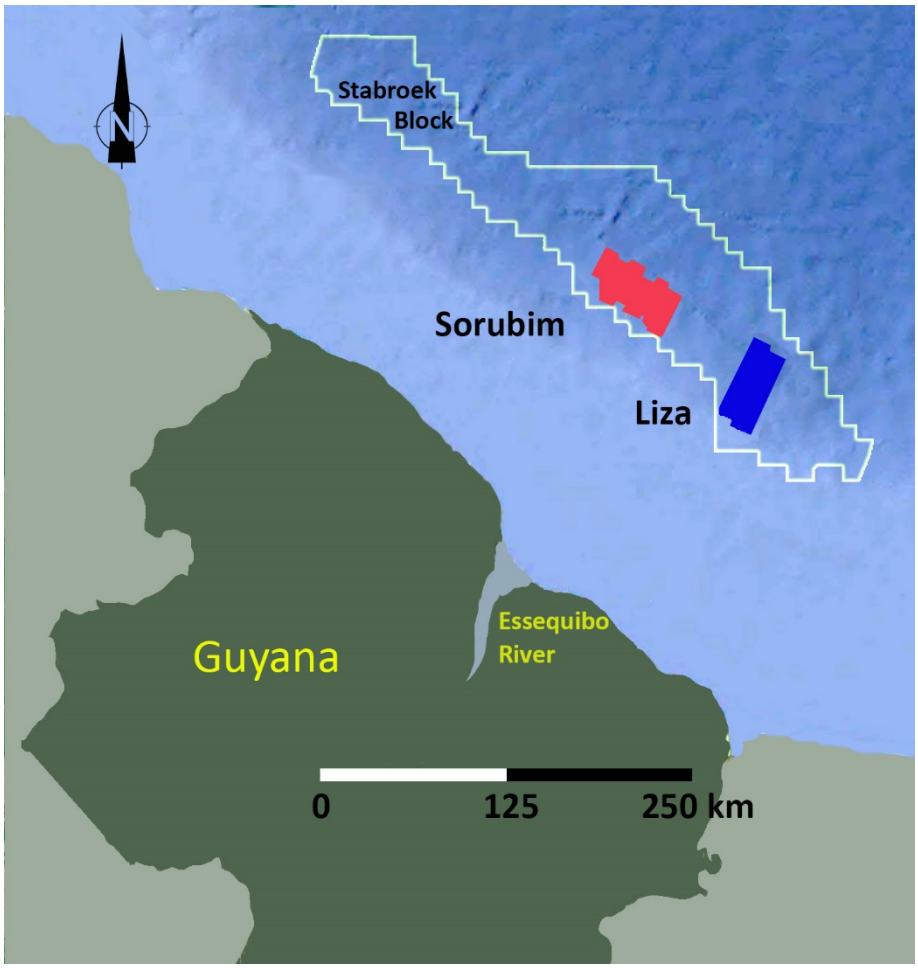


Figure 1-1. Stabroek Block with locations of Liza and Sorubim EBS project areas.

1.2 Sampling Design

Sampling locations (stations), shown in **Figure 1-2**, were selected to encompass the water depth and spatial range of existing conditions over an area of planned exploration drilling. **Table 1-1** presents station names, geographic coordinates, water depths, and types and numbers of samples collected. The sampling areas ranged from approximately 130 to 240 kilometers (km) offshore in water depths of 860 to 2400 meters (m), with Liza slightly shallower than Sorubim (see Table 1-1). Sediment samples were collected at a total of 18 stations (10 at Liza and 8 at Sorubim) using a single 0.25 square meter (m^2) box core.

The physical structure of the water column was electronically profiled at seven stations, four at Sorubim and five at Liza. In addition, three discrete water samples were collected at each station, resulting in a total of 21 discrete water samples. The sampling design supports the following methods of data interpretation to meet the previously stated EBS objectives:

- Describe central tendencies and range of key physical, chemical, and biological data throughout potential areas of oil and gas exploration and development.
- Identify potential confounding factors, such as water depth, sediment grain size, organic carbon content, dissolved solids, and dissolved oxygen that may affect interpretation of important project-related parameters, such as benthic macrofauna abundance/diversity, and concentrations of hydrocarbons and metals in sediment.
- Summarize results for water column key variables to depict existing contaminant concentrations and evaluate potential sources prior to exploration drilling.

Sediment samples were analyzed for benthic macrofauna community structure, grain size, total organic carbon (TOC), petroleum-related hydrocarbons (including polycyclic aromatic hydrocarbons [PAH] and saturated aliphatic hydrocarbons [SHC]), and 12 metals (including barium). Chemical and physical samples were collected from the top 10 cm of sediment. Benthic macrofauna were collected from the top 15 centimeters (cm) of a 0.1 m^2 sample area and retained on a 0.5-mm diameter screen. Discrete water samples were collected near the surface (10 m depth), mid-water, and near-bottom. Samples were analyzed for total organic carbon, total suspended solids, nine metals (including barium), and hydrocarbons (SHC and PAH). Continuous water column profiles were obtained for conductivity/salinity, temperature, density, light transmission (an indicator of water clarity), and dissolved oxygen at each of the seven water stations.

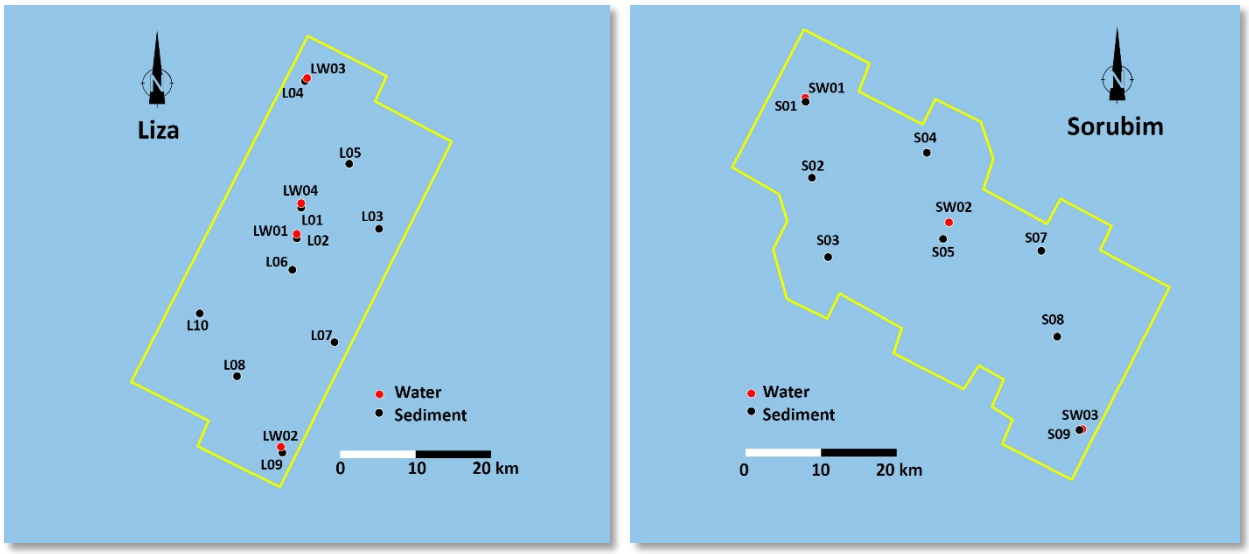


Figure 1-2. Locations of water and sediment sampling stations at Liza and Sorubim.

Table 1-1. Sediment and water station names, locations, and sampling inventory.

Sample ID	Station	Bottom Depth (m)	Latitude[1] (North)	Longitude[1] (West)	Sediment Samples	Water Samples[2]	Water Profiles[3]
Liza							
L-EBC01	L01	1831	8.1109	56.94940	1		
L-EBC02	L02	1741	8.0758	56.95319	1		
L-EBC03	L03	1853	8.0859	56.85493	1		
L-EBC04	L04	2074	8.2560	56.94463	1		
L-EBC05	L05	1931	8.1594	56.89383	1		
L-EBC06	L06	1649	8.0366	56.95963	1		
L-EBC07	L07	1478	7.9527	56.91102	1		
L-EBC08	L08	1106	7.9104	57.02392	1		
L-EBC09	L09	877	7.8214	56.97025	1		
L-EBC10	L10	1328	7.9855	57.06931	1		
L-WAT01	LW01	1216	8.0781	56.95367		1	1
L-WAT02	LW02	1741	7.8273	56.97295		1	1
L-WAT03	LW03	2004	8.2565	56.94205		1	1
L-WAT04	LW04	1772	8.1172	56.94806		1	1
Sorubim							
S-EBC01	S01	2327	8.7627	57.84372	1		
S-EBC02	S02	2171	8.6761	57.82443	1		
S-EBC03	S03	1962	8.5832	57.80321	1		
S-EBC04	S04	2238	8.7077	57.69202	1		
S-EBC05	S05	2038	8.6057	57.66938	1		
S-EBC06	S06	1857	8.4945	57.64313	not collected[4]		
S-EBC07	S07	2204	8.5910	57.55337	1		
S-EBC08	S08	2030	8.4919	57.53158	1		
S-EBC09	S09	1737	8.3840	57.50826	1		
S-WAT01	SW01	2014	8.7736	57.83698		1	1
S-WAT02	SW02	1859	8.6250	57.66557		1	1
S-WAT03	SW03	1491	8.3826	57.50786		1	1

[1]Reported in WGS 84 decimal degrees; [2]Discrete chemistry samples collected at surface, mid-water, and near-bottom depths; [3]Water column profiles of conductivity (salinity), temperature, density, and dissolved oxygen; [4]unable to collect acceptable sediment sample after several attempts.

1.3 Report Organization

This report is organized into two parts, the main report body and Appendices A-C. The main report body is organized into eight sections.

Section 1 – Introduction and EBS Objectives presents the purpose of the environmental baseline survey, the study design and sample inventories for sediment and water, and the site location.

Section 2 – Methods presents field, laboratory, and data analysis procedures. Field methods are presented for navigation and station positioning, and sample collection, processing and transfer to laboratories. Laboratory analytical methods are summarized for chemical, biological and physical samples, including sample preparation, instrumentation, quality control, and reporting. This section includes methods of data analysis, including brief descriptions of statistics used to support interpretation of results.

Section 3 – Water Physical Structure and Discrete Sample Results presents results for seven vertical profiles of conductivity/salinity, water density, temperature, turbidity, and dissolved oxygen. Water structure is discussed in relation to published studies of the region. Summary statistics are presented for discrete water column samples collected at each of three depths for total organic carbon (TOC), total suspended solids (TSS), metals and hydrocarbons.

Section 4 – Sediment Physical and Chemical Results presents results for grain size, total organic carbon, metals and hydrocarbons. Effects of sediment physical characteristics on chemical and biological parameters are emphasized. Statistical results are summarized, presenting central tendencies, range and variation in parameters for each of the two exploration sites. Spatial distributions of key physical and chemical parameters are graphically presented and evaluated.

Section 5 – Biological Characteristics of Sediment discusses patterns of diversity and abundance for benthic macrofauna. Statistical results are presented for central tendencies, range and variation in total abundance, number of distinct taxa, and distributions of selected major family-level taxa for each of the two exploration sites. Statistically significant relationships between key biological parameters and selected sediment physical parameters are reported.

Section 6 – Evaluation of Data Quality for chemical and biological analyses is presented in this section. Study objectives, presented in Section 1, are evaluated with respect to the sampling design and data collected. Laboratory quality control results are assessed for precision and accuracy for key chemical and biological data and the corresponding analytical methods used.

Section 7 - Discussion and Conclusions are presented regarding chemical and biological data for the two combined sites, and the use of these data to assess future potential impacts from oil and gas exploration drilling and development.

Section 8 – References provides full citations for referenced works. Complete results for each sample are presented in the appendices.

2 FIELD AND ANALYITICAL METHODS

Field and laboratory methods describing the collection and analysis of sediment and water data are described in this section. Additionally, statistical and graphical methods used to interpret and present EBS results are discussed.

2.1. Field Methods

Field operations were conducted from the Research Vessel (RV) GYRE, a 55.5-m vessel, outfitted with two hydraulic winches, respectively operating stern and port mounted A-frames. The vessel is equipped with wet and dry laboratories, and storage rooms containing sample freezers and dry storage areas.

A C&C Technologies™ C-Nav 2050 full Differential Global Positioning System (DGPS) and a Winfrog navigation package were used to position and navigate the vessel. C-Nav is based on Real Time Gypsy (RTG) technology developed by the US National Aeronautics and Space Administration (NASA) to achieve position accuracies of ≤0.1m to 2m. Geographical locations of sampling stations were recorded in latitude/longitude decimal degrees (WGS 84 datum). Locations were recorded electronically with station identification and date/time of sample collection and stored on an onboard computer until subsequent transfer to the project database.

Standard operating procedures governing all field operations were reviewed by the scientific team members and included establishing shift assignments, maintaining effective communications, preparing for sampling activities while in transit, recording field data, storing and tracking of samples, and packing and shipping of samples upon cruise completion.

2.1.1 Water Sampling and Profiling

Discrete water samples were collected from the near-surface (5–10 m depth), at the mixed layer (ca. 25-m below surface), and from approximately 5-10 m above the seafloor at each of seven stations. All samples were analyzed for total suspended solids, total organic carbon (TOC), metals, saturated hydrocarbons (SHC), and polycyclic aromatic hydrocarbons (PAH).

Samples were collected using 3- to 5-liter (L) polyvinyl chloride Niskin bottles deployed from a rosette at the targeted depth. Sample bottles were deployed open at both ends, and closed at the targeted depth. Bottles were washed before sampling and between each station with a non-phosphate detergent, then rinsed with de-ionized water and filtered seawater. For hydrocarbon analysis, a 1-L subsample was transferred from the Niskin bottle into a pre-cleaned borosilicate glass jar, containing 1 milliliter (mL) of 50% hydrochloric acid preservative to prevent bacterial degradation of hydrocarbons. For metals, a 500-mL aliquot was collected from the Niskin bottle directly into a pre-cleaned polyethylene jar containing 0.5 mL of 50% hydrochloric acid preservative. All chemistry water samples were refrigerated at 4^{o}celcius (C) while on board ship.

The water column was electronically profiled with the CTD, augmented with additional sensors for dissolved oxygen and percent light transmission (turbidity). Water column data were collected at a rate of 2 records per second (s^{-1}) throughout the water column.

2.1.2 Sediment Sampling

Sediments were sampled with a 50 x 50 centimeter (cm) steel box corer, providing a sediment surface area of 0.25 m^2.

Benthic Macrofauna. A 0.1 m^2 square, stainless steel sleeve was used to subsample the box core. The sleeve was inserted into one corner of the box core to a depth of 15 cm. The entire volume of sediment was collected (including overlying water) from the sleeve and placed into a plastic bucket. The sediment and collected water were transferred within 30 minutes of collection to a flow-through sieve with a 0.5-mm mesh. After sieving, macrofauna samples and retained sediments were transferred to plastic containers and preserved with approximately 50% volume of 10% buffered formalin and rose bengal dye. The preservative was sufficient to cover the entire sample, and exceeded the retained material volume by at least 10%. Rose bengal, which is a vital stain, stained living biological material red, facilitating the efficient removal of biological material during subsequent laboratory sample sorting. If necessary, high-volume samples were stored in more than one sample container, and labeled accordingly. Each sample was inverted several times to ensure thorough mixing of the preservative. Preserved samples were stored in plastic coolers at ambient temperature.

2.2 Analytical Methods

The environmental baseline analytical program was designed to provide high quality, detailed chemical and biological data to meet program objectives. **Table 2-1** lists the physical, chemical and biological tests, corresponding matrices, analytical methods, and processing laboratories.

Table 2-1. Analytical methods, laboratory, and number and type of EBS samples.

Parameter	Sediment Samples	Water Samples	Analytical Method
B&B Laboratories, College Station, Texas, USA			
Total Suspended Solids	-	21	Filtration and gravimetric determination
Total Organic Carbon	18	21	Combustion with infra-red detection
Polycyclic Aromatic Hydrocarbons (PAH)	18	21	GC-MS SIM, USEPA 8270-modified
Saturated Hydrocarbons (SHC)	18	21	GC-FID, USEPA 8015-modified
Albion Laboratory, College Station, Texas, USA			
Metals (except mercury)	18	21	ICP-MS, USEPA Methods 1638 & 200.8
Mercury	18	21	Cold vapor with atomic fluorescence
Lovell Benthic Laboratory, San Pedro, California, USA			
Benthic macrofauna	18	-	0.5mm sieve; identification and enumeration at family level, 4 major taxonomic groups

ICP=inductively coupled plasma spectroscopy detector
ICP-MS= ICP with mass detector
GC-FID = gas chromatography with flame ionization
GC-MS = gas chromatography with mass detector

2.2.1 TSS, TOC, and Sediment Particle Size

Total suspended solids (TSS) in water samples were analyzed using a standard filtration and gravimetric method following USEPA Method 160.3. In summary, a 1-L sample obtained from the Niskin sampler at each depth was volumetrically determined using a graduated cylinder and then passed through a 0.45 micron (µm) filter in the vessel laboratory. The filter was then wrapped in foil, labeled, and stored refrigerated until shipment back to B&B Laboratory for analysis. In the laboratory, the sample was dried in a desiccator and weighed to the nearest 0.01 milligram (mg). Results were reported in mg L^{-1} for each sample.

Total organic carbon (TOC) was analyzed using a persulfate digestion of carbon at 100° C followed with detection of organic carbon using an O.I. Analytical Model 700 TOC Analyzer based on USEPA methods 9060 and 415.1. Water samples were acidified to a pH of <2 and analyzed unfiltered. The reported TOC results are the total of dissolved and particulate organic carbon.

Sediment TOC samples were digested with a 50% by volume phosphoric acid solution. The acid-sediment slurry was oven dried at 105° C, weighed. The resulting moisture-free sample was combusted at 1350° C and TOC was quantified using a Leco CR-412 Total Carbon Analyzer to remove chlorine interferences in marine samples by filtering gases through a magnesium perchlorate, halogen trap column.

Sediment particle size was determined for the four major size classes: gravel, sand, silt, clay using a sieve and hydrometer technique. Sediment samples analyzed for grain size were thoroughly mixed. Approximately 100 to 150 g of each sample was weighed into receiving containers. Ten (10) mL of deflocculent solution (1% solution of sodium hexametaphosphate in deionized water) was added to the jar and shaken until the sample was totally disaggregated. The disaggregated sample was poured through a number 230 sieve into a 1000-mL graduated cylinder. The sieved sample is washed with deionized water. Sediment retained on the number 230 sieve was transferred into a pre-weighed beaker and oven dried (70-90° C) for at least 24 hours. Dried sediment was transferred to a series of stacked sieves, shaken and the contents of each weighed. Sediment passing through the smallest sieve was added to the 1000-mL graduated cylinder and further processed using the hydrometer settling method ASTM D-422. Percent gravel, sand, silt, clay and several graphic sediment parameters were calculated from initial weights and retained fractions.

2.2.2 Metals

Water samples were analyzed for nine metals and sediment samples were analyzed for 12 metals (see Appendices A and B for respective metals).

Water samples (except those analyzed for mercury) were preserved under clean room conditions to a pH of <2 using ultrapure nitric acid. Preserved samples were allowed to equilibrate for at least 24 hours to insure all metals adsorbed to the container walls were re-solubilized. A near-total (≥90%) recoverable digest was then performed on the preserved total recoverable samples. Additional acid was added and the samples were heated for at least two hours at 85° C, and allowed to cool prior to analysis. In addition, all samples were subjected to an additional 48 hour ultraviolet digestion procedure. The ultraviolet procedure insured that all dissolved organic chelates that could interfere with extraction efficiency were decomposed, prior to pre-concentration.

Mercury water samples were preserved under clean room conditions with bromine monochloride (BrCl) and digested (equilibrated) for at least 24 hours prior to analysis. The composite was analyzed under clean room conditions by dual gold amalgam trap cold vapor atomic fluorescence, following USEPA method 1631 revision E.

Sediment samples were analyzed for the same nine metals analyzed in water samples plus aluminum, cadmium, and iron. Except for mercury, sediment metals were analyzed using either standard inductively coupled plasma spectrometry (ICP) with mass detector (ICP-MS) (USEPA method 200.8), or in the case of chromium and iron, ICP-MS modified to use an ammonia gas dynamic reaction cell (DRC)-ICP-MS. Prior to ICP analysis, sediment samples were homogenized, sub-sampled and freeze-dried to a constant weight. The dried sediment was then ground to a fine powder. For USEPA method 200.8, approximately 0.2 g of the dried and powdered sediment samples were subjected to a strong acid leaching digestion at 95^{o} C for 4 hours. Ultra-pure deionized water was then added to the acid leachate to achieve a final volume of approximately 20 mL. The leachate (digestate) was then diluted further to keep the solution concentration within the calibration range of the ICP-MS instrument, and to adjust the acid strength for analysis. Sediment mercury samples also were analyzed using USEPA method 1631 revision E.

2.2.3 Hydrocarbons

Extraction of Hydrocarbons. A sediment aliquot was dried in a convection oven at 40^{o} C, and then thoroughly homogenized using a ceramic mortar and pestle. An additional aliquot of approximately 1 g of wet sediment was removed and dried in an oven at 105^{o} C to a constant weight for percent moisture determination. Samples were extracted using a Dionex ASE200 Accelerated Solvent Extractor (ASE). The dried sample was loaded into 22- or 33-mL stainless steel ASE extraction tubes. The extractions were performed using 100% dicholormethane at 100^{o} C and 2000 psi. The extracted organics dissolved in the solvent were collected in 60-mL glass vials. The extract was concentrated to approximately 10 mL in the collection vials and then transferred to 25-mL Kurdena-Danish concentrator tubes. The sample extract was concentrated to 3 mL in a water bath at 55 to 60^{o} C. Additional cleanup procedures were used for sediments including high-pressure liquid chromatography fractionation followed by silica gel and alumina-column cleanup. Cleanup procedures were performed to remove potentially interfering non-target compounds.

The sample extract was loaded on top of 300 mm x 19 mm glass liquid chromatography columns packed with 10 g of deactivated alumina and 20 g of deactivated silica gel. The columns were loaded in 100% dichloromethane. The dichloromethane was replaced by adding 40 mL of pentane. The extract was carefully added to the top of the chromatography column. The column was flushed at a rate of 1 to 2 mL per minute using 200 mL of 50:50 pentane/dichloromethane and collected into 250-mL flasks. The eluent collected in the 250-mL flask was evaporated to 2 mL using a water bath at 55 to 60^{o} C. The samples were transferred into 2 mL amber vials. The concentrated extract was then analyzed by GC-MS for polycyclic aromatic hydrocarbons (PAHs) or by GC-FID for saturated hydrocarbons and selected isoprenoids.

If the extract was colored it was processed through silica gel/alumina chromatography columns. The sample extract was then loaded on top of 300 mm x 19 mm glass liquid chromatography columns packed with 10 g of deactivated alumina and 20 g of deactivated silica gel. The columns were loaded in 100% dichloromethane. The dichloromethane was replaced by adding 40 mL of pentane. The extract was carefully added to the top of the chromatography column. The column was flushed at a rate of 1 to 2 mL per minute using 200 mL of 50:50 pentane/dichloromethane and collected into 250-mL flasks. The eluent collected in the 250-mL flask was evaporated to 2 mL using a water bath at 55 to 60^{o} C. The samples were transferred into 2-mL amber vials. The concentrated extract was then analyzed by GC-MS with selected ion monitoring (SIM) for polycyclic aromatic hydrocarbons or GC-FID for saturated hydrocarbons.

***Polycyclic aromatic hydrocarbon (PAH) analysis*.** Parent PAHs and their alkylated homologues were analyzed in sample extracts by a HewlettPackard model 5890 GS and model 5972 MS, operated in SIM mode, using a capillary column. A list of analyzed compounds is provided in Appendices A1 and B1 for water and sediment samples. The GC was operated in splitless mode and the capillary column was an Agilent Technologies HP-5MS (60 m x 0.25 mm ID and 0.25 mm film thickness). The carrier gas was helium at a flow rate of 1 mL min^{-1}. The temperature of the injection port was 300^{o} C and transfer line was 290^{o} C. The initial oven temperature was 60^{o} C and the ramp rate was 7^{o} C per minute to a final oven temperature of 310^{o} C, held for 20 minutes. For analyte identification, the extracted ion current profiles of the primary m/z and the confirmatory ion for each analyte must be at a maximum in the same scan or within one scan of each other and the retention time must fall with 5 seconds of the retention time of the authentic standard or alkyl homologue grouping. The pattern of alkylated PAH homologue groupings was established by analysis of reference oil standards. The relative peak heights of the primary mass ion compared to the confirmation or secondary mass ion must fall within 30% of the relative intensities of these masses in a reference mass spectrum.

Saturated hydrocarbons (SHC) analysis. Saturated hydrocarbons are defined as a group of straight- and branched-chained (saturated) as well as cyclic hydrocarbons that are typically found in petroleum related products and crude oil. In sediments, a complete range of these "saturated" hydrocarbons were analyzed that encompass light and heavy fractions of petroleum (e.g., Nc_9-nC_{40}) and selected isoprenoids, including pristine and phytane. A list of analyzed compounds is provided in Appendices A1 and B1 for water and sediment samples. Target analytes were extracted with PAH compounds and analyzed using gas chromatography with flame ionization detection (GC-FID). Measured concentrations were calculated against the surrogate compounds (e.g., tetracosane-d50) added prior to the extraction.

2.2.4 Benthic Macrofauna

Benthic macrofaunal samples were sorted in order to remove the fauna from the sediment and separate them into major taxonomic groups for taxonomic analysis by specialty taxonomists. Sorting was performed under dissecting microscopes with fiber optic lighting. Small volumes of sediment were spread out in sorting trays and systematically inspected. Animals were removed from each sample and separated into vials representing five major sorting groups: polychaetes, crustaceans, mollusks, echinoderms, and miscellaneous phyla. Borosilicate glass vials with poly-seal lids were used for sorted fractions. Each vial was labeled with sample ID and taxonomic group. Labels were written on rag paper using India ink pen. Each tray of sediment was inspected until the sorter was confident that all animals were removed. The sorted sediments were placed into a separate labeled jar and the process continued until the entire sample was sorted.

Prior to sorting, samples collected for identification and enumeration of benthic infauna were sieved again and separated into three size fractions that were examined separately under a dissecting scope: 1) easily suspended material (e.g., light bodied/typically non-shell bearing specimens and detritus; 2) large heavy material (e.g., shell hash, large shell bearing mollusks and large worm tubes); and 3) coarse sediments (i.e., aggregated clay). Easily suspended material was washed under a fume hood into a 2-L beaker. Sample material was thoroughly suspended/agitated with freshwater dispensed from a ½ inch Tygon hose attached to a municipal water line. Suspended material was allowed to settle for a few seconds before decanting supernatant onto an ASTM Standard 35 (500 µm) sieve.

The process was repeated 5 to 10 times, until the wash water was visibly clear. Material retained on the sieve was washed into a labeled 50-mL beaker. Large heavy material retained in the 2-L beaker was washed on an ASTM Standard 10 (2 mm) sieve fitted above an ASTM Standard 35 (500 µm) sieve. Material retained on the 2-mm screen was washed with fresh water dispensed from a spray wand attached to a municipal water line to remove any residual fine materials. Retained coarse material was washed into a labeled 100-mL beaker. Coarse sediment was pre-sieved on the 2-mm sieve and retained on the underlying 500-µm sieve, and washed with freshwater dispensed from a 1-cm diameter Tygon hose and fine spray wand attached to a municipal water line to remove any residual sand and silt. Material retained on the 500-µm sieve was washed into a labeled 500-mL beaker. All material retained on sieves was examined under a fluorescent magnifier to ensure that all organisms had been removed.

The three sieved fractions were consolidated during the picking (sorting) process. Picked specimens were transferred to labeled glass vials containing 70% ethanol. Dissecting and compound microscopes with standard magnifications of 6x-50x and 40x-1000x were used to examine the specimens. Fiber optic lighting was used to illuminate specimens under the dissecting microscope.

Infauna were separated into four major taxonomic groups: polychaeta, mollusca, crustacea, and combined other taxa. Abundances were recorded to the family level, with names reported for the taxonomic categories of annelids, crustaceans, echinoderms, mollusks, and miscellaneous grouped phyla. The number of organisms reported accounted for all organisms in a sample that were alive at the time of collection. Empty mollusk shells or crustacean molts were not counted. Limitations that effect the level of identification are lack of published literature for the area; condition of the specimens (fragmented, poorly preserved); and juvenile, reproductive, or other poorly documented life stage.

Specialty taxonomists used taxonomic literature pertinent to the region from which the samples were collected. Additional literature from other regions or literature of a general nature was used as necessary. When possible, specimens not attributable to a described family were given a unique provisional name and notes on its unique taxonomic characteristics were made to facilitate subsequent identifications. Damaged or juvenile specimens were identified to the family level whenever possible.

Quality control included two forms of oversight. First, all material processed by each of two pickers was reexamined by the taxonomist for each benthic category. Second, instruction and guidance from the lead taxonomist was available and frequently provided to pickers throughout the analysis. To maintain consistent standards resulting taxonomic lists from provided to an alternative taxonomist for verification. Any discrepancies in identification were corrected by the lead taxonomist and standardized in the taxonomic database.

2.2.5 Sample Archival

Sediment not consumed by analyses is stored frozen for up to one year under strict chain-of-custody procedures at B&B Laboratory, College Station, Texas.

Representative organisms from processed macrofauna samples were preserved in 70% ethanol and submitted for archival at Scripps Institute of Oceanography (SIO), Benthic Invertebrate Collection, La Jolla, California (http://collections.ucsd.edu/bi/index.cfm). The SIO Benthic Invertebrate Collection contains over 750,000 specimens, with approximately 20,000 identified to genus level and 14,500 to species level. The collection supports scientific research by providing specimens for study on the taxonomy, evolution, and ecology of benthic invertebrates. Archived specimens are available for examination at SIO and for loan to researchers at academic institutions.

2.3 Quality Control (QC)

Details on the type, quantity, and performance results specific to each method are presented in Section 6 (Evaluation of Data Quality). A complete suite of laboratory QC samples was run with sediment and water chemistry samples to confirm method performance and control. Method-specific required laboratory QA/QC samples included a control blank, duplicate samples, performance validation samples, standard reference materials, and various recovery and check standards, depending on the analysis.

Results that were collected using electronic or remotely deployed instruments were checked for accuracy and precision by the equipment manufacturer (e.g., Seabird Electronics, Winfrog Navigation) or by the scientific team, following guidance from the manufacturer.

2.4 Data Management and Analysis

All data management and analysis tasks were performed using the SAS™ Software System (version 9.4) in batch programming mode. SAS™ is a data management, statistical, and graphical system that is widely used and is the recognized standard by many academic, government and medical/health industries worldwide. Graphical presentations of data were performed using Surfer® (version 10, Golden Software, Inc.) and Grapher (version 9, Golden Software, Inc.) software. Data were translated from Microsoft Excel files to SAS™ data sets, and all analyses were performed within the SAS™ system. Statistical results were output as text, rich text format and Microsoft Excel files. Key parameters used in statistical analyses are shown in **Table 2-2**.

Table 2-2. EBS key parameters used in statistical analyses.

Chemical Parameters	***Benthic Macrofauna***	***Water Quality Parameters***
Barium	Total Abundance	Total Suspended Solids
Cadmium	Polychaeta Abundance	Total Organic Carbon
Chromium	Crustacea Abundance	pH
Copper	Echinodermata Abundance	Dissolved Oxygen
Iron	Family Diversity	Turbidity
Lead	Mollusca Abundance	Salinity
Mercury	Other Grouped Phyla Abundance	Density
Nickel	***Sediment Physical Parameters***	Temperature
Vanadium	Sediment particle size (various)	Depth
Zinc	Total Organic Carbon	
Total PAH	Depth	
Total Resolved SHC		
Total Unresolved SHC		
Total SHC		

2.4.1 Descriptive Statistics

Descriptive statistics were performed for key variables of the physical, chemical, and biological data sets. Summary statistics included computations for sample mean, mean standard deviation, range of values, and where appropriate, frequencies of detectable concentrations. Average results were used in cases where duplicate samples were analyzed by the laboratory. These results were then used to generate statistical results (e.g., central tendencies) for the entire data set. Values equal to one-half of the method detection limit were used for non-detect chemistry results in statistical calculations. Computations were performed on final results that passed data quality objectives.

2.4.2 Correlation Analysis

Correlation analysis provides insight into the relationship between two analysis variables. Pearson Product-Moment correlation coefficients were calculated for pair-wise variables of interest within the data set. The significance of correlations between meaningful pairs of environmental variables (e.g., depth and total abundance) is discussed in Sections 3 through 5, providing results for the correlation coefficient and probability level of statistical significance.

2.4.3 Graphical Presentations of Data

Bar plots showing concentrations of hydrocarbon compounds at selected individual stations were produced in Excel (Microsoft Office, Version 2013). Contour maps were produced by the rectangular grid-based contouring program, Surfer® (Golden Software, Version 10). This program interpolates irregularly spaced data into a regularly spaced grid, and places interpolated data in a grid file. Original data included station coordinates and selected chemical and biological parameters for each station.

2.4.4 Analysis of Hydrocarbon Source

General sources of hydrocarbons were identified by evaluation of selected diagnostic ratios and parameters (Douglas et al. 1996; Steinhauer and Boehm 1992). Indices and parameters used to identify hydrocarbon source are shown in **Table 2-3**. Characteristics based on PAH compounds provide information on the source of hydrocarbon contaminants, whereas SHC-based parameters are used primarily to distinguish between biogenic and petroleum-derived sources. Parameters based on both PAH and SHC compounds were used to discern hydrocarbon sources in offshore Guyana sediment (see Section 4).

Table 2-3. Diagnostic ratios and parameters of SHC and PAH used to identify hydrocarbon source.

Parameter or Ratio	Relevance in Environmental Samples
Saturated Hydrocarbons (SHC)	
Pristane/Phytane	Source of phytane is mainly petroleum, whereas pristane is derived from both biological matter and oil. In "clean" environmental samples, this ratio is > 1.0 and decreases as oil is added.
nC16/(nC15 + nC17)	The ratio of hexadecane (nC16) over pentadecane (nC15) plus heptadecane (nC17). At "background" levels, hydrocarbon nC15 and nC17 can be used as indicators of plankton (algae) hydrocarbon inputs. As plankton productivity increases the ratio decreases.
Carbon Preference Index (CPI)	The total odd-chain hydrocarbons divided by the total even-chain HC. A value of 2-4 indicates input from plants, as oil is added the value decreases, approaching 1.0
Polycyclic Aromatic Hydrocarbons (PAH)	
N/P	The ratio of summed naphthalene alkylated homologues (C1-C4) over summed phenanthrene-anthracene alkylated homologues (C1-C4); this ratio decreases with increased weathering of oil.
Perylene	A biogenic compound formed during early diagenesis in marine and lacustrine sediments; usually associated with terrestrial plants.
Total PAH	The sum of all PAH target analytes including 2- through 6-ring parent PAH and C1 - C4 alkyl substituted PAH. General indicator of petroleum hydrocarbon sources.
Pyrogenic	The sum of combustion PAH compounds (4-, 5-, and 6-ring PAHs): fluoranthene, pyrene, chrysene, B(a)A, B(b)F, B(k)F, B(a)P, D(a,h)A, B(g,h,i)P
Petrogenic	The sum of petrogenic PAH compounds (2-, 3-, and 4 -ring PAHs): naphthalenes, acenaphthene, acenaphthylene, fluorene, phenanthrenes, dibenzothiophenes, chrysenes, and fluoranthenes/pyrenes
Petrogenic/Pyrogenic	Useful to determine relative contributions of pyrogenic and petrogenic hydrocarbons in differentiating sources. The ratio increases as inputs from petroleum increase.

adapted from Steinhauer and Boehm (1992).

3 WATER COLUMN RESULTS

This section presents results for water column profiles and chemical/physical analyses of collected (discrete) water samples. Four profiles and 12 samples (4 stations x 3 depths) were collected at Liza; and three profiles and nine samples (3 stations x 3 depths) were collected at Sorubim.

3.1 Background

Guyana's Atlantic Ocean coastline is approximately 430 kilometers (km) in length, bounded by Suriname on the east and Venezuela on the west. Guyana has a land area of approximately 214,970 km^2, and also shares a border with Brazil on the west and south. The country is situated between 1 and 9 north latitude and between 56 and 62 west longitude. The offshore region, including Liza and Sorubim, located 130 to 240 km offshore and along a combined total of 120 km of coastline, is primarily under the influence of large scale oceanic processes overlying the upper continental slope, and are generally beyond the immediate influence of coastal shore processes of localized runoff, sedimentation, and thermal structuring. Guyana generally has an equatorial climate with year-round rainfall; however, variations in rainfall affect surface water features accordingly, both locally and through runoff from its four major rivers, including the Essequibo River delta (see Figure 1-1, Section 1).

3.2 Water Column Profiles

Depth profiles of salinity, temperature, density, dissolved oxygen, and percent light transmittance (as an indicator of turbidity) are shown in **Figures 3-1** through **3-4** for each of seven water stations. Summary statistics for profiled data collected at the same station depth as discrete samples are presented in **Table 3-1.** Results indicate a consistent water column structure over the survey period and sampling area. A lens of relatively low salinity (~ 33‰) water gives way to a steep halocline, reaching a maximum salinity of 37‰ at 100 m at both sites. Water temperature drops monotonically from 28° C at the surface to 3° C around 2000m. The resulting density profiles indicate a highly stratified water column, which likely limits nutrient flux into surface waters from below the mixed layer. There is a sharp increase (step) in density at the 100m salinity maximum in most profiles. The permanent (non-seasonal) pycnocline extends down to approximately 200m, below which density increases slowly with depth. The water column is relatively clear, with light transmittance through the 25 cm path length typically greater than 95%. A minor accumulation of material appears to rest on the 100 m step in the density profile, where transmittance drops to 92% in several profiles. Dissolved oxygen profiles show high levels (ca. 6 mg L^{-1}) near the surface and even higher levels (>8 mg L^{-1}) below 1000 m. The water column properties are quite reasonable, given the local oceanography. The profiles were collected approximately 175 km offshore of the delta of the Essequibo River, Guyana's largest river. Guyana annual precipitation is very high, averaging between 250–350 cm. The lower salinity surface layer is most likely maintained by river and rainfall input. The wind-driven coastal North Brazil Current and Guyana Current (Lumpkin and Garzoli 2005), resulting from the North Equatorial Current from the east (Tomczak and Godfrey 2003), determine water conditions above the permanent pycnocline. Salinities range from 36 to 37‰ and temperatures range from 22° to 28.5° C

(http://oceancurrents.rsmas.miami.edu/atlantic/guiana.html).

The conditions below the permanent pycnocline are maintained by Antarctic Intermediate Water down to approximately 1000m, and below that by North Atlantic Deep Water (Tomczak and Godfrey 2003). The Antarctic water is characterized as relatively fresh (34.3‰) and cold (2° C). The underlying North Atlantic Deep Water, formed when the salty Gulf Stream is cooled off Labrador, sinks and moves southward. It is more salty (35‰), has high oxygen concentrations (6–8 mg L^{-1}) and is identifiable down to 4000 m. The coincident increase in salinity and dissolved oxygen below 1200m can be seen in nearly every one of the corresponding profiles.

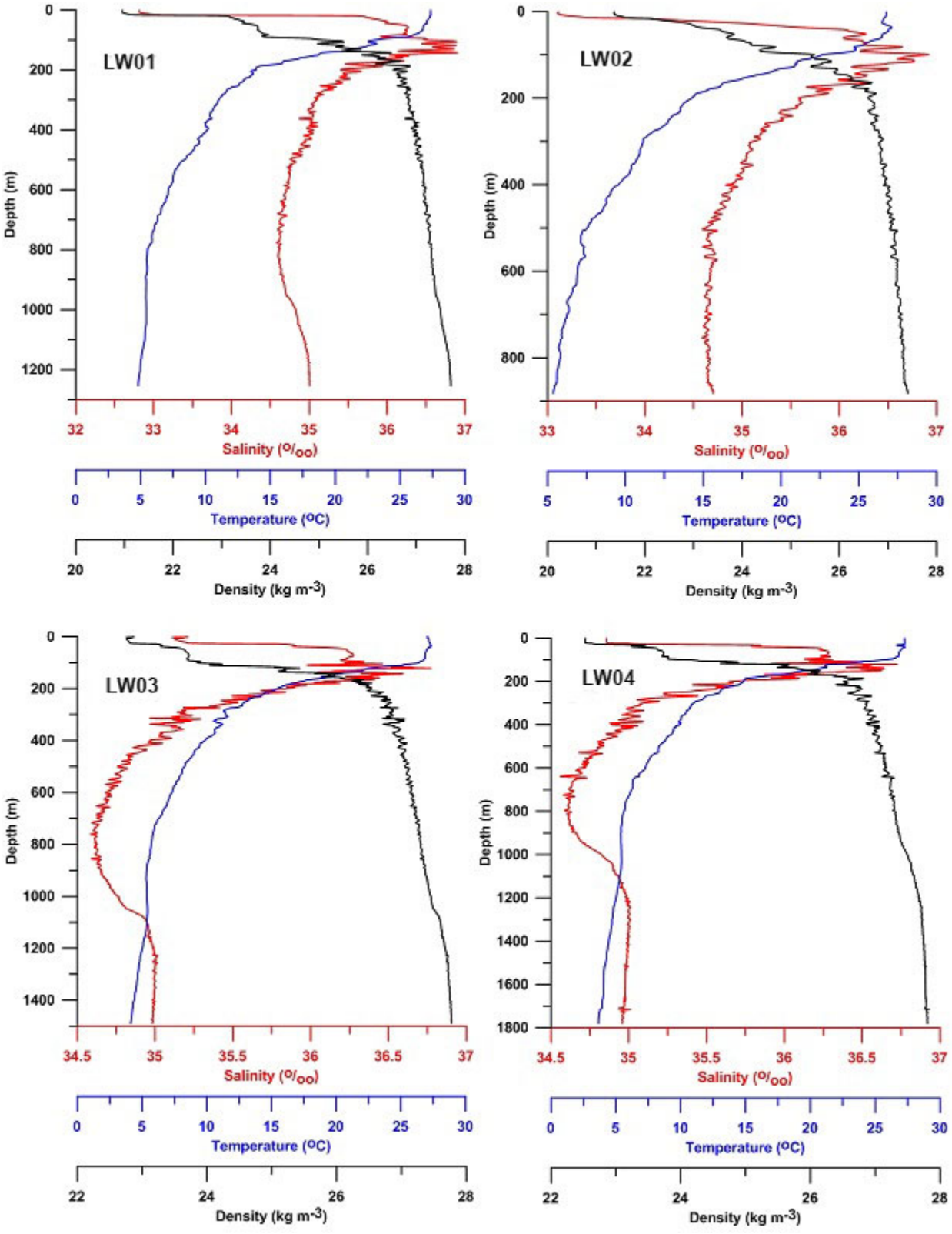


Figure 3-1. Profiles of salinity, temperature, and water density at each of four stations at Liza.

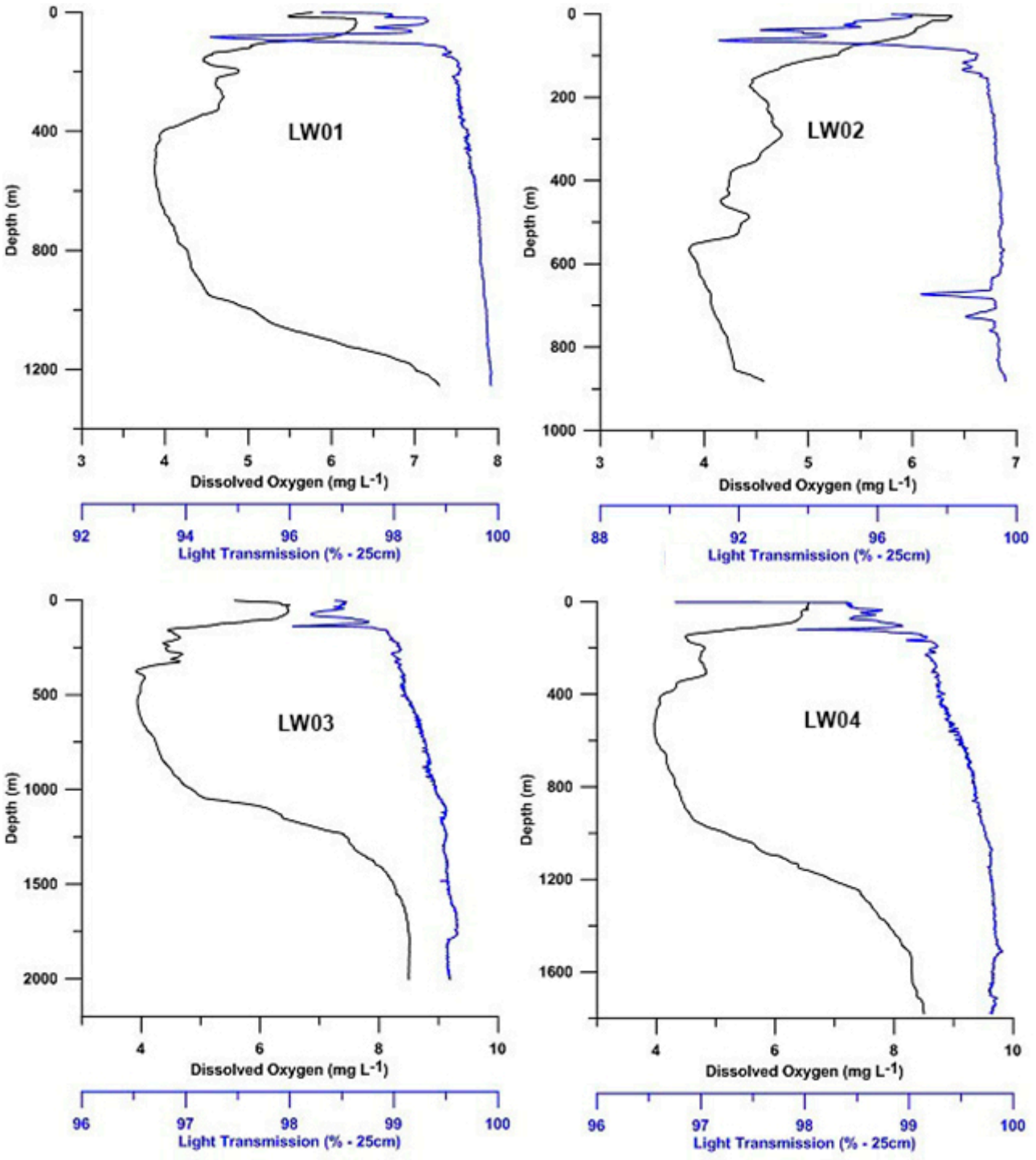


Figure 3-2. Profiles of dissolved oxygen and percent light transmission at each of four stations at Liza.

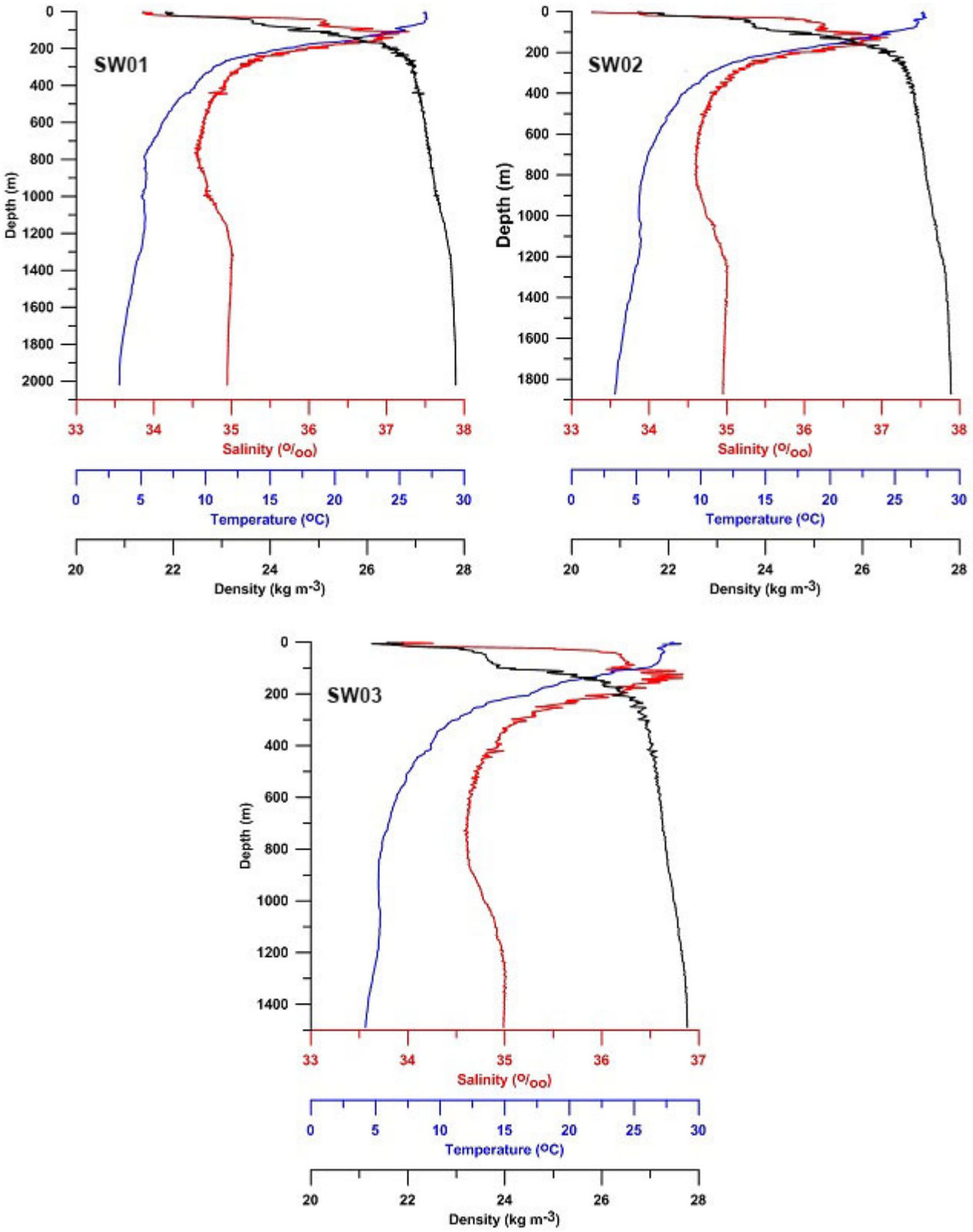


Figure 3-3. Profiles of salinity, temperature, and water density at each of three stations at Sorubim.

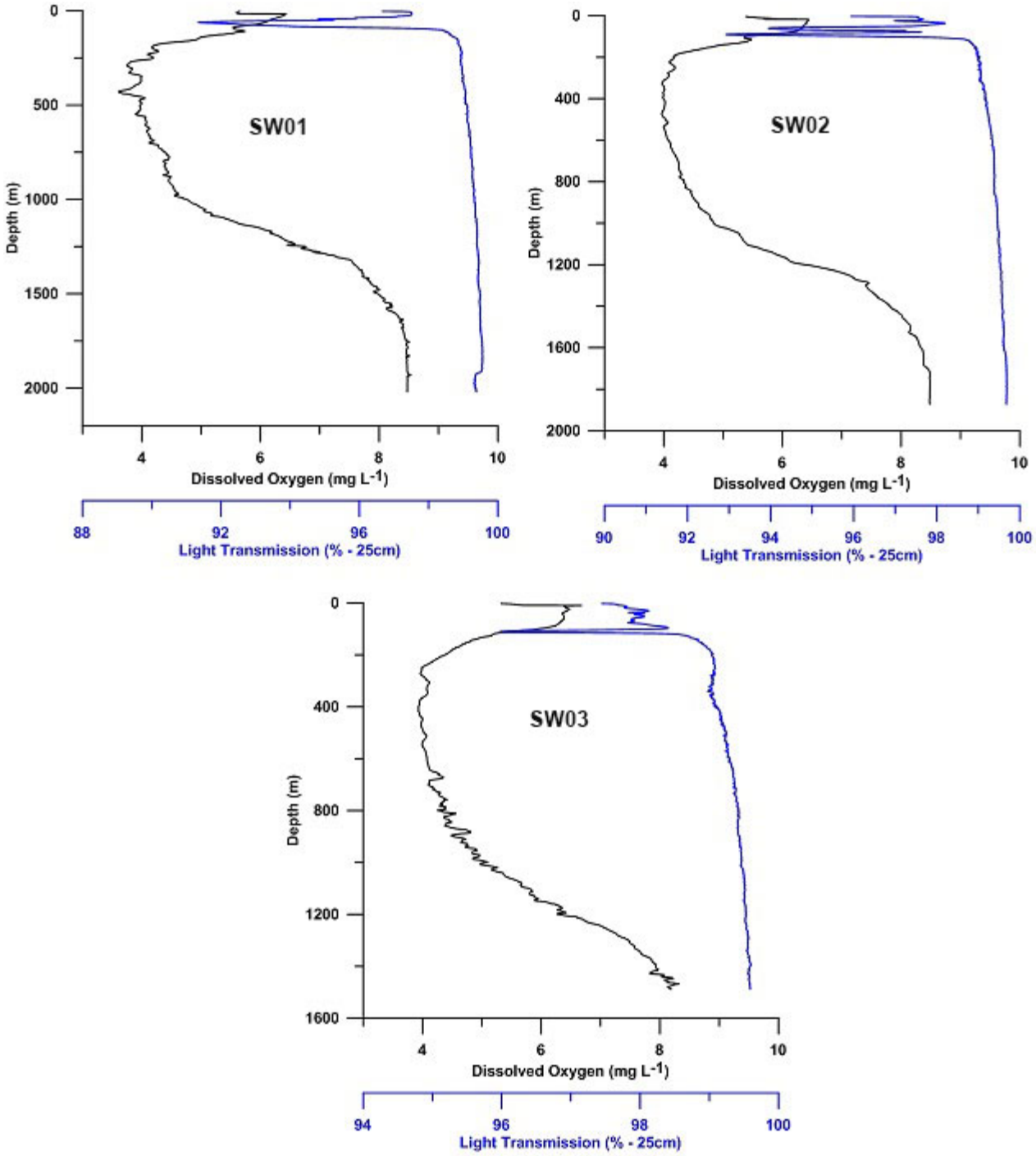


Figure 3-4. Profiles of dissolved oxygen and percent light transmission at each of three stations at Sorubim.

Table 3-1. Summary statistics for water physical structure data.

Parameter	Units	Mean	Standard Deviation	Minimum	Maximum
		Liza (n=12)			
Temperature[1]	°C	19.67	11	3.42	27.36
pH[2]	pH units	8.1	0.13	7.84	8.19
Salinity[1]	‰	34.74	0.79	32.9	35.7
Dissolved Oxygen[1]	mg L^{-1}	5.47	0.76	3.86	8.39
		Sorubim (n=9)			
Temperature[1]	°C	19.37	11.79	3.34	27.47
pH[2]	Unit	8.11	0.1	7.94	8.19
Salinity[1]	‰	34.56	0.63	33.7	35.2
Dissolved Oxygen[1]	mg L^{-1}	5.99	0.67	5.52	8.48

[1]profile results measured at discrete sample water depth; [2]results for discrete samples

3.3 Discrete Water Sample Results

Summary statistics for water physical parameters, metals, and hydrocarbons are shown in **Tables 3-2** through **3-4**.

3.3.1 Total Suspended Solids (TSS) and Total Organic Carbon (TOC)

Total suspended solids can be an important water quality parameter with respect to sediment transport and discharges to the water column from exploration or development drilling. There were no significant trends between depths, with results ranging from very clear (<1 mg L^{-1}) to moderately turbid (8.85 mg L^{-1}) water. Unlike turbidity, there was no clear trend in TSS with water depth. Although the limited number of depth strata sampled may not have been sufficient to detect depth-related trends, it appears to have adequately captured the range of results for the water column. Although collected over a limited time period, these results are assumed to represent seasonal background conditions for the study area. Background concentrations during heavy rain may be significantly higher due to suspended material broadcast from the Essequibo River.

Total organic carbon (particulate + dissolved organic carbon) concentrations provide rough estimations of productivity in ocean water when not confounded by anthropogenic inputs, such as treated sewage, agricultural runoff, or other organic inputs. Results for all samples were low, at ≤1.2 mg L^{-1}, with mean concentrations of 0.42 and 0.46 mg L^{-1}, respectively, for Liza and Sorubim samples. These results are comparable to a concentration of 0.83 mg L^{-1} TOC for an open ocean surface water sample collected from the Gulf of Mexico that was analyzed for quality control purposes. There were no significant differences (α=0.05) in mean TOC concentrations between sample depths at either site.

Table 3-2. Summary results TOC and TSS for Liza and Sorubim discrete water samples.

Parameter (mg L^{-1})	Mean	Standard Deviation	Minimum	Maximum
Liza (n=12)				
Total Organic Carbon (TOC)	0.81	0.26	0.42	1.13
Total Suspended Sediment (TSS)	4.3	1.92	1.4	7.25
Sorubim (n=9)				
Total Organic Carbon (TOC)	0.81	0.24	0.46	1.04
Total Suspended Sediment (TSS)	4.77	2.38	0.35	8.95

3.3.2 Heavy Metals and Other Elements

Except for barium, nearly all results were below laboratory detection limits (**Table 3-3**). Barium was detected in all samples, with concentrations well within the natural range for ocean water (Morel et al. 2006). An ultra-trace method used to analyze mercury produced detectable concentrations of sub-part-per-trillion (<1 ng L^{-1}) in only two samples, both collected at Liza. All reported concentrations were well below those considered harmful to aquatic organisms in marine receiving waters (Buchman 2008).

Table 3-3. Summary results for metals in Liza and Sorubim water samples. Results reported in µg L^{-1}.

Parameter	No. of Detects	Mean	Standard Deviation	Minimum	Maximum
Liza (n=12)					
Arsenic	0	<2	NA	<2	<2
Barium	12	7.5	0.83	6.4	9.21
Cadmium	0	<2	NA	<2	<2
Chromium	0	<5	NA	<5	<5
Copper	1	1.68	0.63	<3	3.68
Lead	0	<0.6	NA	<0.6	<0.6
Mercury	2	0.000124	0.000057	<0.0002	0.000254
Nickel	0	<4	NA	<4	<4
Vanadium	0	<4	NA	<4	<4
Sorubim (n=9)					
Arsenic	0	<2	NA	<2	<2
Barium	9	7.62	0.93	6.04	8.81
Cadmium	0	<2	NA	<2	<2
Chromium	0	<5	NA	<5	<5
Copper	0	<3	NA	<3	<3
Lead	0	<0.6	NA	<0.6	<0.6
Mercury	0	<0.0002	NA	<0.0002	<0.0002
Nickel	0	<4	NA	<4	<4
Vanadium	0	<4	NA	<4	<4
Zinc	1	2.38	1.13	<4	5.38

Note: ½ of the detection limit was used for non-detect results in all statistical calculations; NA=not applicable

3.3.3 Hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) and saturated aliphatic hydrocarbons (SHC) were measured as general indicators of petroleum-related contamination. Although hydrocarbons are fairly hydrophobic, trace concentrations of dissolved and adsorbed (to suspended material) compounds persist in many offshore water bodies throughout the world's oceans, with the highest concentrations typically reported for waters near populated industrial areas with nearby rivers (Kennish 1992).

Most hydrocarbons attain peak concentrations in rivers, and estuarine and coastal environments, as there is a strong tendency to adsorb to suspended particles that settle before being carried offshore. Hydrocarbons enter the ocean environment from various sources including natural oil seeps, spills from vessels and drilling rigs, incorporation of airborne particulate matter and down-slope transport of contaminated sediment. Ultimately, they degrade, are taken up by biota in the water column, or are sequestered in sediment.

Summary results for total PAH and total SHC are shown in **Table 3-4** for Liza and Sorubim water samples. Total PAH concentrations (based on the sum of 43 analytes) were extremely low in all samples (≤50 ng L^{-1}). The only PAH compounds detected were naphthalene, C_1 and C_2 alkylated homologues of naphthalene, fluorene, and phenanthrene. These low molecular weight PAHs are ubiquitous trace-level laboratory contaminants. Naphthalene contamination is often introduced from floor waxes, polyvinyl chloride tubing, and other laboratory equipment. Evidence of ultra-trace naphthalene contamination from the laboratory also is derived from the fact that all samples were affected and similar concentrations were detected in the corresponding method blanks. Fluorene and phenanthrene are ubiquitous PAHs found in all petroleum and its products, and in combusted fuels. Ultra-trace concentrations detected in otherwise uncontaminated samples, such as those collected at Liza and Sorubim, are often introduced from laboratory analytical equipment (i.e., cross-contamination).

Table 3-4. Summary results for hydrocarbons in Liza and Sorubim water samples. Results reported in µg L^{-1}, except where noted.

Analyte	No. of Detects	Mean	Standard Deviation	Minimum	Maximum
Liza (n=12)					
Total PAH (ng L^{-1})	12	31.56	6.44	18.0	43.32
Total SHC	3	36.38	66.42	<13	230
Total Unresolved SHC	3	21.3	27.87	<13	87
Total Resolved SHC	3	20.05	39.1	<13	143
Sorubim (n=9)					
Total PAH (ng L^{-1})	9	40.42	5.27	31.39	47.82
Total SHC	1	17.89	34.17	<13	109
Total Unresolved SHC	1	16.89	31.17	<13	100
Total Resolved SHC	1	6.78	0.83	<13	9

Note: ½ of the detection limit was used for non-detect results in all statistical calculations

4 SEDIMENT PHYSICAL AND CHEMICAL RESULTS

Analytical results, consisting of total organic carbon, particle size, hydrocarbons, and metals are presented for ten Liza and eight Sorubim sediment samples. Results for key chemical parameters were evaluated for spatial distribution at Liza and Sorubim, and for variability in relation to water depth and sediment physical characteristics. Results from diagnostic tools to identify potential hydrocarbon sources also are discussed. All results are reported on a dry weight basis.

4.1 Background

Sediment particle size characteristics are emphasized for their controlling influence upon sedimentary community dynamics, and because they often correlate with biologically meaningful variables such as sediment porosity, compaction, oxygen tension, water content and retention of organic matter. Particle size can be equally important in controlling sediment chemical concentrations due to the increase in adsorptive capacity with finer-grained particles. Because many contaminants co-occur with fine-grained particles, there is a potential for contaminant accumulation in deep-water areas, including the continental slope depths of the Stabroek Block.

Guyana coastal sediment is characterized by very thick deposits of transported Amazon mud and high volumes of fluvial mud from erosion in its coastal waters. These ultra-fined grained sediments move down the shelf edge towards the seaward basins, including the area of Liza and Sorubim. In the study area, sediments also are broadcast offshore by the Essequibo River, which empties southwest of the two exploration sites. Although the Guyana coastline has four major rivers that flow through a region of high terrestrial biodiversity, associated rates of detrital carbon flux to the deep seabed (> 1000m) from coastal and overlying water column sources are low, typical of low-productivity tropical habitats.

4.2 Sediment Grain Size and Total Organic Carbon

Sediment particle size (grain size) was reported for four major classes: gravel, sand, silt, and clay based on the percent composition of each class. Fines are the sum of silt and clay fractions, and represent the proportion of particles with diameters <0.0625 mm. Descriptions and corresponding ranges in size (based on the Wentworth scale, Folk 1980) are summarized in **Table 4-1**.

Particle size characteristics are summarized in **Table 4-2**. The majority of sediment samples are categorized as poorly to moderately sorted fine-grained material, comprised of approximately equal portions of silt and clay. All 18 stations had sediment containing greater than 59% fines, with gravel-sized particles absent from all samples and sand contributing no more than 40% in any sample. Results indicate fairly uniform, primarily fine-grained sediment comprised of a fairly narrow range of class sizes based on the Wentworth scale, typical of offshore depositional areas.

In general, significant relationships between key particle size parameters and sample depth were observed at Liza, but not at Sorubim. At Liza, percent fines (p= -0.85, z = 0.021) and TOC (p = -0.93, z = 0.0001) decreased significantly with water depth, but no such relationships were observed at Sorubim (z > 0.05). These results are likely due to the wider range of water depths at Liza compared with Sorubim, rather than differences in bottom sediment physical conditions. Concentrations of TOC were much lower than those of typical depositional sediments, with results less than 1% at all stations.

The respective distributions of percent fines and TOC at Liza and Sorubim are illustrated in **Figures 4-1** and **4-2**, in which both parameters display trends of higher concentrations in the southwest portion of the site, which is closer to shore.

Table 4-1. Sediment particle size descriptions (adapted from Folk 1980).

Sediment Type	Wentworth Scale (mm diameter)	Description
Gravel	>2 to 64	Very Fine Gravel to Gravel
Sand	>0.0625 to 2	Very Fine Sand to Very Coarse Sand
Silt	>0.0039 to 0.0625	Very Fine Silt to Coarse Silt
Clay	>0.00098 to 0.0039	Medium Clay to Coarse Clay

Table 4-2. Summary results for sediment particle size class and TOC. Results reported as percent (%) dry weight.

Parameter	Mean	Minimum	Maximum	Standard Deviation	Station with Minimum	Station with Maximum
Liza (n=10)						
Gravel	0	0	0	0	NA	NA
Sand	17.83	2.09	40.50	12.81	L10	L05
Silt	39.34	20.42	55.56	11.86	L05	L08
Clay	42.83	32.36	57.96	7.11	L07	L06
Fines	82.17	59.5	97.91	12.81	L05	L10
Graphic Sorting (Phi)	2.78	1.47	3.59	0.69	L10	L05
TOC	0.52	0.3147	0.8685	0.16	L05	L09
Sorubim (n=8)						
Gravel	0	0	0	0	NA	NA
Sand	28.88	14.63	38.92	8.92	S03	S09
Silt	31.97	24.17	37.30	4.78	S02	S08
Clay	39.15	24.74	56.37	11.36	S09	S03
Fines	71.12	61.08	85.37	8.92	S09	S03
Graphic Sorting (Phi)	3.37	2.69	3.77	0.39	S03	S02
TOC	0.37	0.2333	0.4939	0.08	S09	S03

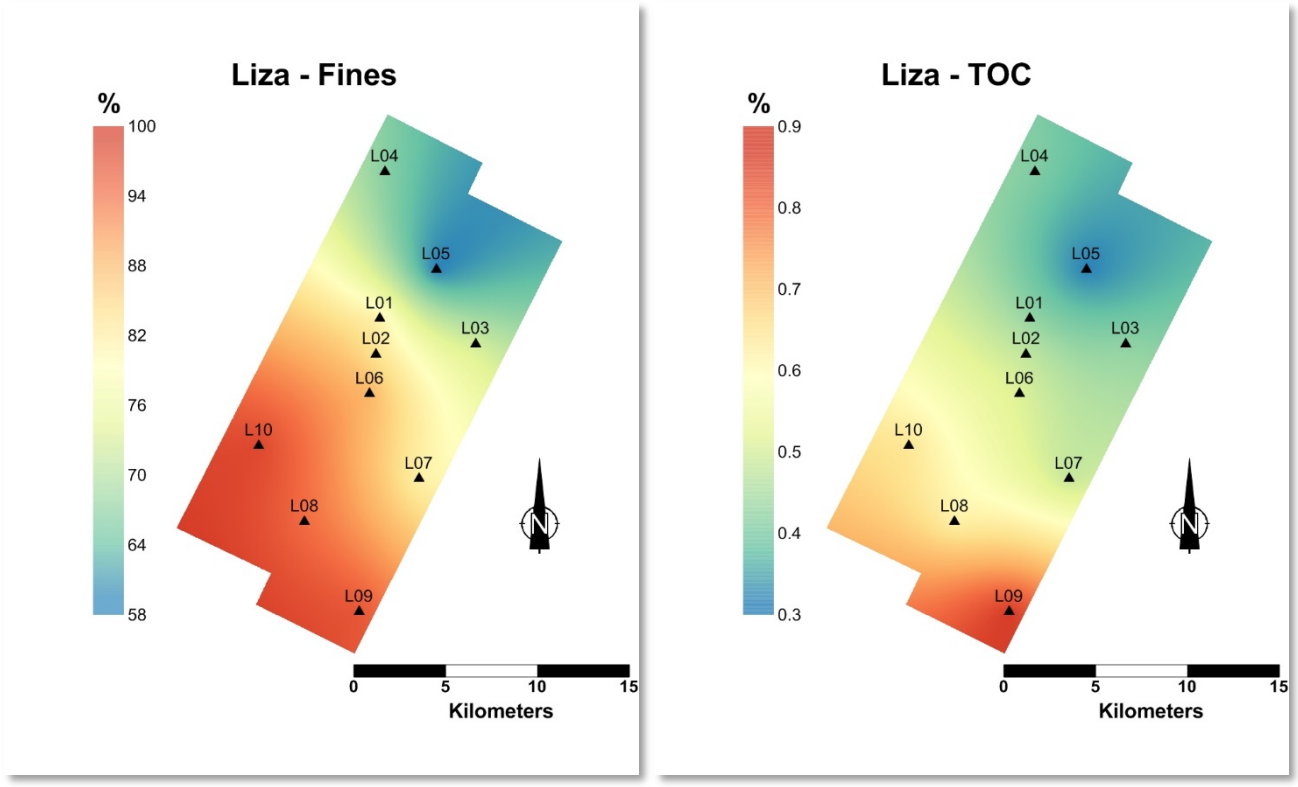


Figure 4-2. Spatial distribution of percent fines (silt + clay) and total organic carbon (TOC) at Liza.

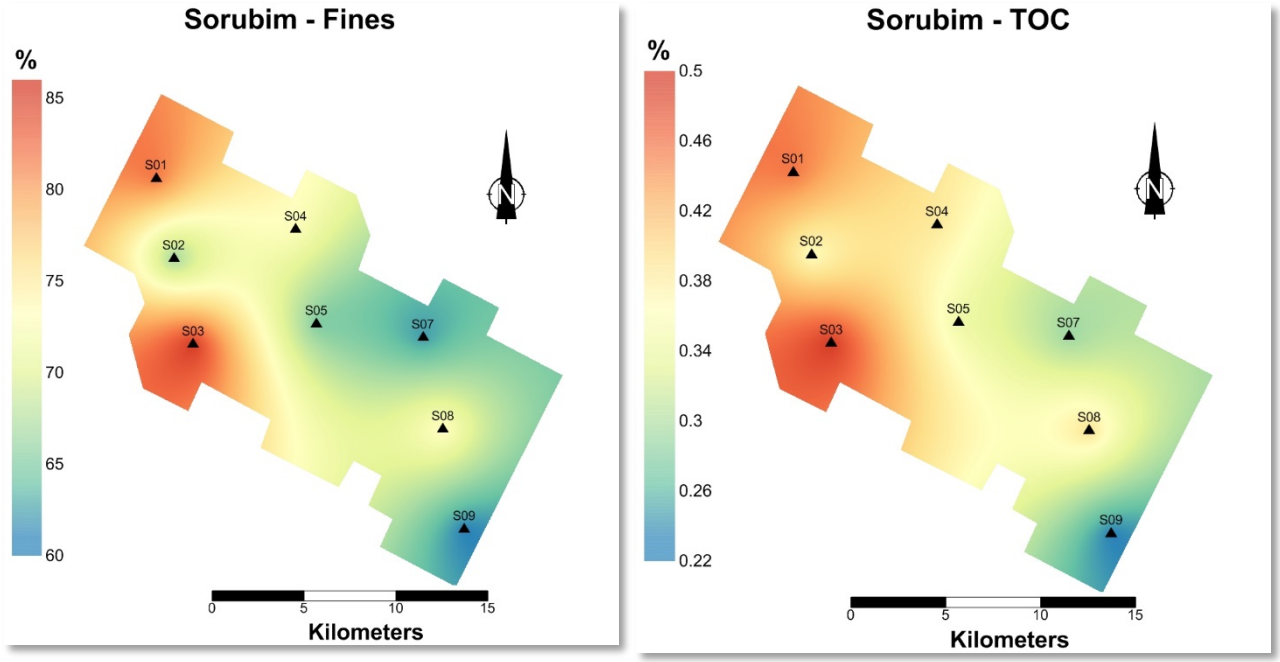


Figure 4-2. Spatial distribution of percent fines (silt + clay) and total organic carbon (TOC) at Sorubim.

4.3 Metals

Twelve metals were measured to determine general patterns of distribution within each site and to assess potential contamination from any nearby pollution sources. Ten metals commonly associated with anthropogenic sources, consisting of arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, vanadium and zinc were analyzed. Two additional metals, aluminum and iron, were analyzed to provide geological source information. Mean metal concentrations and associated statistics for Liza and Sorubim sediments are shown in **Table 4-3**. In general, concentrations of all metals were slightly lower at Sorubim compared with Liza; however, there were no statistically significant differences ($\alpha = 0.05$) between mean concentrations of any metal between the two sites. Concentrations of most metals were similar to or less than mean concentrations reported for the upper continental crust, except for arsenic, which had mean concentrations more than three times higher. Arsenic can become naturally enriched from arsenic-rich igneous and sedimentary rocks, and arsenic-bearing minerals, including arsenopyrite (AsFeS), realgar (AsS) and orpiment (As_2S_3). Elevated arsenic also is a byproduct of gold-mining, a staple of Guyana's economy. The Guyana Geology and Mines Commission (GGMC) oversees the mining industry and has implemented modern mining practices and codes of operation.

Table 4-3. Summary results for sediment metals for Liza and Sorubim. Reported in µg g^{-1} dry weight.

Parameter	Mean	Minimum	Maximum	Standard Deviation	Station with Minimum	Station with Maximum	Mean Background[1]
			Liza (n=10)				
Aluminum	11495	8100	15000	2322	L05	L10	77440
Arsenic	6.06	4.51	11.4	2.07	L01	L09	2.0
Barium	98.92	57.4	159	27.5	L05	L10	668
Cadmium	0.13	0.102	0.165	0.02	L05	L09	0.102
Chromium	14.95	8.57	21.1	4.34	L05	L09	35
Copper	13.11	9.86	16.5	1.84	L05	L10	14.3
Iron	19130	13500	25300	3879	L05	L09	30890
Lead	11.55	8.33	15.6	2.21	L05	L10	17
Mercury	0.042	0.0263	0.0624	0.012	L05	L10	0.056
Nickel	21.44	14.1	32.3	4.9	L05	L10	18.6
Vanadium	23.54	18.1	28.3	3.8	L05	L09	53
Zinc	45.51	26.9	63.7	12.5	L05	L10	52
			Sorubim (n=8)				
Aluminum	8779	7040	11800	1767	S05	S03	77440
Arsenic	6.78	3.86	14.1	3.17	S07	S02	2.0
Barium	76.53	37.8	119	25.8	S09	S01	668
Cadmium	0.13	0.0872	0.15	0.02	S09	S04	0.102
Chromium	12.44	8.38	16.9	2.63	S07	S03	35
Copper	14.53	9.63	19.6	3.12	S09	S01	14.3
Iron	14825	11300	19700	3092	S07	S02	30890
Lead	10.52	8.42	12.3	1.32	S09	S03	17
Mercury	0.034	0.022	0.0457	0.008	S09	S01	0.056
Nickel	18.29	13.8	22.9	2.9	S09	S01	18.6
Vanadium	25.03	17.4	35.8	5.3	S07	S02	53
Zinc	37.14	30.6	46.3	6.4	S07	S03	52

[1]Mean concentration in upper continental crust (Wedepohl 1995)

Pearson correlation coefficients for metals with water depth, percent fines, and/or TOC are shown in **Table 4-4** for Liza and Sorubim sediments. Barium, which can be introduced to the marine environment as barite in drilling muds, increased significantly with percent fines (z<0.001) at both sites. Most metal concentrations increased significantly with increasing TOC and fine-grained sediment (percent fines). Significant changes in these relationships along with increased concentrations of certain metals may be used as an indication of anthropogenic activities. For example, post-exploration changes in the strong positive correlation between percent fines and barium may indicate effects from drilling. In addition to TOC, barium also was strongly correlated with aluminum (p = 0.83, z = 0.003 at Liza; p = 0.82, z = 0.01 at Sorubim), which is apparent in **Figure 4-3**.

Table 4-4. Pearson correlation results (p) for key chemical and selected physical parameters at Liza and Sorubim. Significant correlations (z < 0.05) are shown in **bold.**

Metal	Water Depth	Percent Fines	Percent TOC
	Liza (n = 10)		
Aluminum	**-0.79**	**0.91**	**0.80**
Arsenic	**-0.82**	**0.64**	**0.91**
Barium	-0.57	**0.83**	0.55
Cadmium	-0.61	**0.65**	**0.79**
Chromium	**-0.94**	**0.95**	**0.91**
Copper	-0.17	0.59	0.29
Iron	**-0.84**	**0.94**	**0.90**
Lead	**-0.81**	**0.94**	**0.86**
Mercury	**-0.86**	**0.93**	**0.84**
Nickel	-0.54	**0.82**	0.56
Vanadium	**-0.90**	**0.90**	**0.87**
Zinc	**-0.88**	**0.96**	**0.89**
	Sorubim (n = 8)		
Aluminum	0.29	**0.90**	**0.86**
Arsenic	-0.02	-0.07	0.09
Barium	0.57	**0.93**	**0.93**
Cadmium	0.64	0.68	0.68
Chromium	0.01	**0.87**	**0.83**
Copper	0.69	**0.83**	**0.88**
Iron	-0.02	0.41	0.43
Lead	0.51	**0.71**	**0.83**
Mercury	0.60	**0.93**	**0.96**
Nickel	0.56	**0.92**	**0.93**
Vanadium	-0.09	0.18	0.26
Zinc	0.34	**0.85**	**0.87**

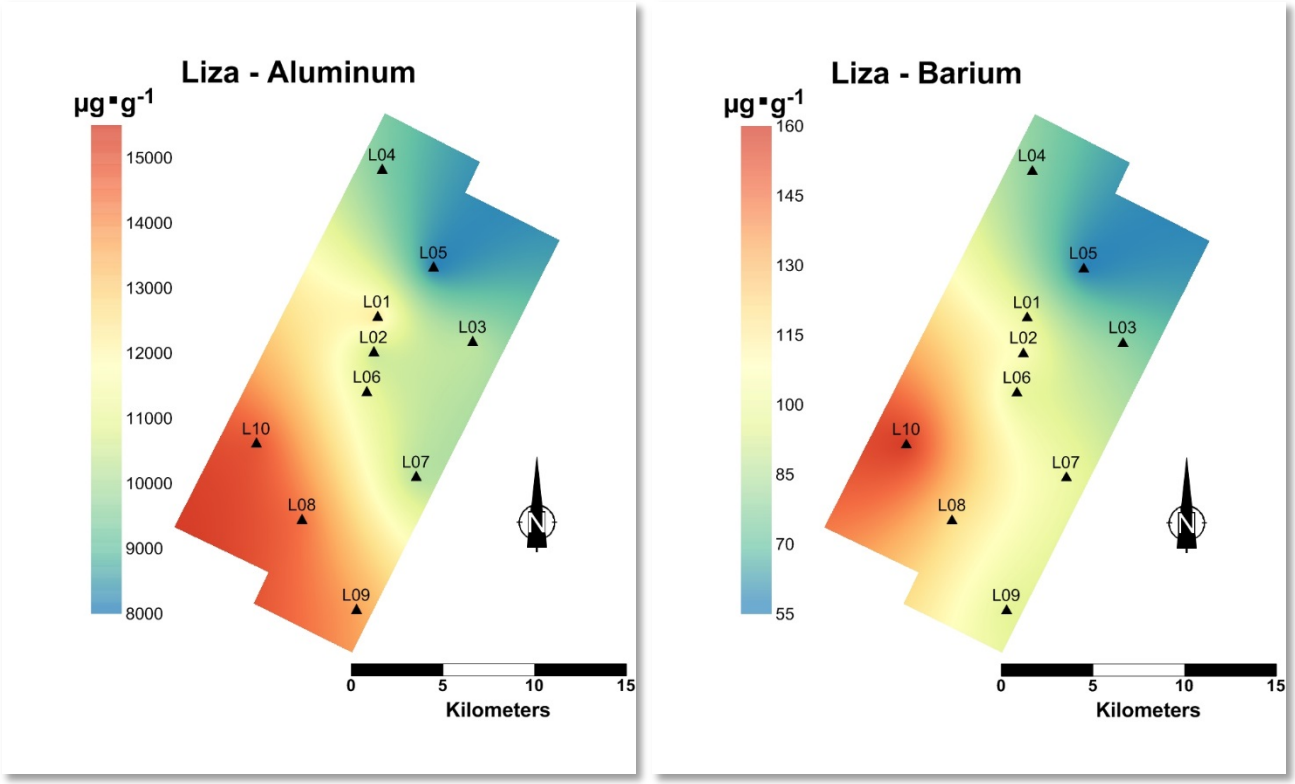


Figure 4-3. Spatial distribution of aluminum and barium in surface sediment at Liza.

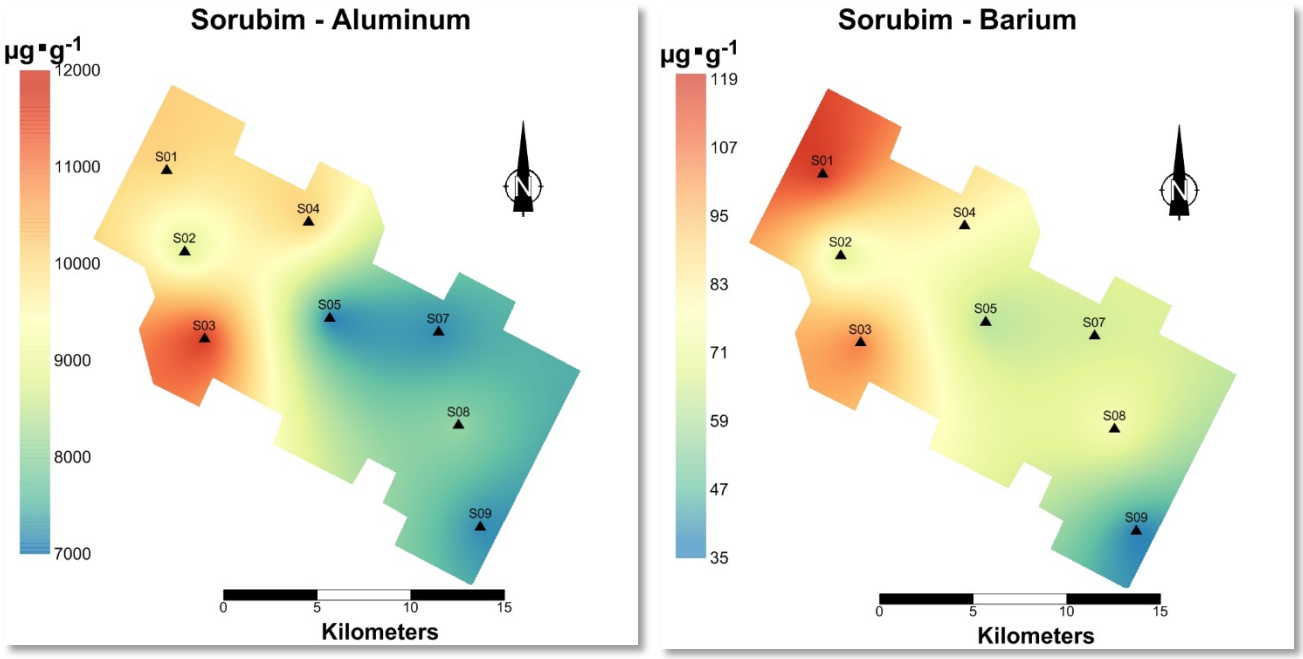


Figure 4-4. Spatial distribution of aluminum and barium in surface sediment at Sorubim.

4.4 Hydrocarbons

Hydrocarbon data describe background conditions as a precursor to future oil and gas development, with the objective of establishing a statistically reliable database for assessment of potential impacts and predictive capacity for projected environmental perturbations. Specifically, the EBS study objectives focus on defining existing chemical concentrations in sediment within the Liza and Sorubim exploration sites. Two classes of organic chemicals consisting of polycyclic aromatic hydrocarbons (PAH) and saturated hydrocarbons (SHC) were emphasized since they are important indicators of age and source of petroleum-related hydrocarbons in sediments. Polycyclic aromatic hydrocarbons analyzed included 20 parent (unalkylated) compounds and 23 alkylated homologues, consisting of two- to six-ring PAH compounds and dibenzothiophenes (sulfur containing compounds). Laboratory data also included results for biphenyl, several hopanes, and several furans, which were not included or interpreted in the EBS. These compounds are rarely addressed in published studies of environmental hydrocarbons, and are not required for the interpretation of hydrocarbon type and potential source in offshore Guyana sediment.

Extremely low concentrations of hydrocarbons were measured in sediments collected at both sites. Total PAH (43 analytes) concentrations ranged from 16.48 to 53.36 ng g^{-1} (nanograms per gram; parts-per-billion) dry weight. Concentrations of total SHC (39 nC_9-nC_{40} analytes, including 7 isoprenoids) also were extremely low, ranging from 1.2 to 14 µg g^{-1} (micrograms per gram; parts-per-million) (mean=9.5 µg g^{-1}), with resolved hydrocarbons comprising the majority of SHC in most samples. There was no significant correlation between total PAH and total SHC (apparent in **Figure 4-5** for Liza), indicating non-petroleum related sources for these extremely low hydrocarbon concentrations.

Hydrocarbon concentrations measured at both sites were lower than those reported for coastal sediments adjacent to relatively unpopulated or non-industrialized regions that receive minor hydrocarbon inputs, such as undeveloped coastal California, the south Baltic Sea, the North Atlantic continental slope and the Gulf of Finland, which all have total aliphatic hydrocarbon (SHC) concentrations ranging from 70 to 500 µg g^{-1} and total PAH concentrations <1 µg g^{-1} (i.e., 1000 ng g^{-1}) (Kennish 1997).

Table 4-5. Summary results for hydrocarbons. Reported in dry weight.

Analyte	Mean	Minimum	Maximum	Standard Deviation	Minimum at Station	Maximum at Station
Liza (n=10)						
Total PAH (ng g^{-1})	38.61	24.58	53.36	10.99	L05	L08
Total SHC (µg g^{-1})	10.64	8	14	1.92	L06	L05
Total Unresolved SHC (µg g^{-1})	6.97	3	12	2.87	L09	L05
Total Resolved SHC (µg g^{-1})	3.68	2	8.9	2.07	L01	L09
Sorubim (n=8)						
Total PAH (ng g^{-1})	31.50	16.48	48.05	11.05	S09	S01
Total SHC (µg g^{-1})	8.05	2.6	9.4	2.28	S09	S05
Total Unresolved SHC (µg g^{-1})	5.93	1.2	8.5	2.44	S09	S05
Total Resolved SHC (µg g^{-1})	2.11	0.9	4	1.23	S05	S02

Several key hydrocarbon parameters displayed significant correlations with water depth, grain size parameters, and/or TOC (see **Table 4-6)**; however, results were inconsistent between sites, likely due to the extremely low concentrations measured and the relatively narrow depth range sampled. The positive correlations between total PAH and TOC for both sites is due almost entirely to perylene, a biogenic PAH, which comprised >80% of total PAH concentration in most samples.

Table 4-6. Pearson correlation results (*p*) for key hydrocarbon parameters at Liza and Sorubim. Significant correlations ($z < 0.05$) are shown in **bold.**

Hydrocarbon	Water Depth	Percent Fines	Percent TOC
	Liza (n = 10)		
Total PAH	**-0.86**	**0.82**	**0.71**
Total SHC	0.13	-0.52	-0.14
Total Unresolved SHC	**0.65**	**-0.77**	**-0.71**
Total Resolved SHC	**-0.81**	0.60	**0.88**
	Sorubim (n = 8)		
Total PAH	0.46	**0.89**	**0.93**
Total SHC	**0.78**	0.24	0.46
Total Unresolved SHC	0.48	0.01	0.19
Total Resolved SHC	0.53	0.42	0.47

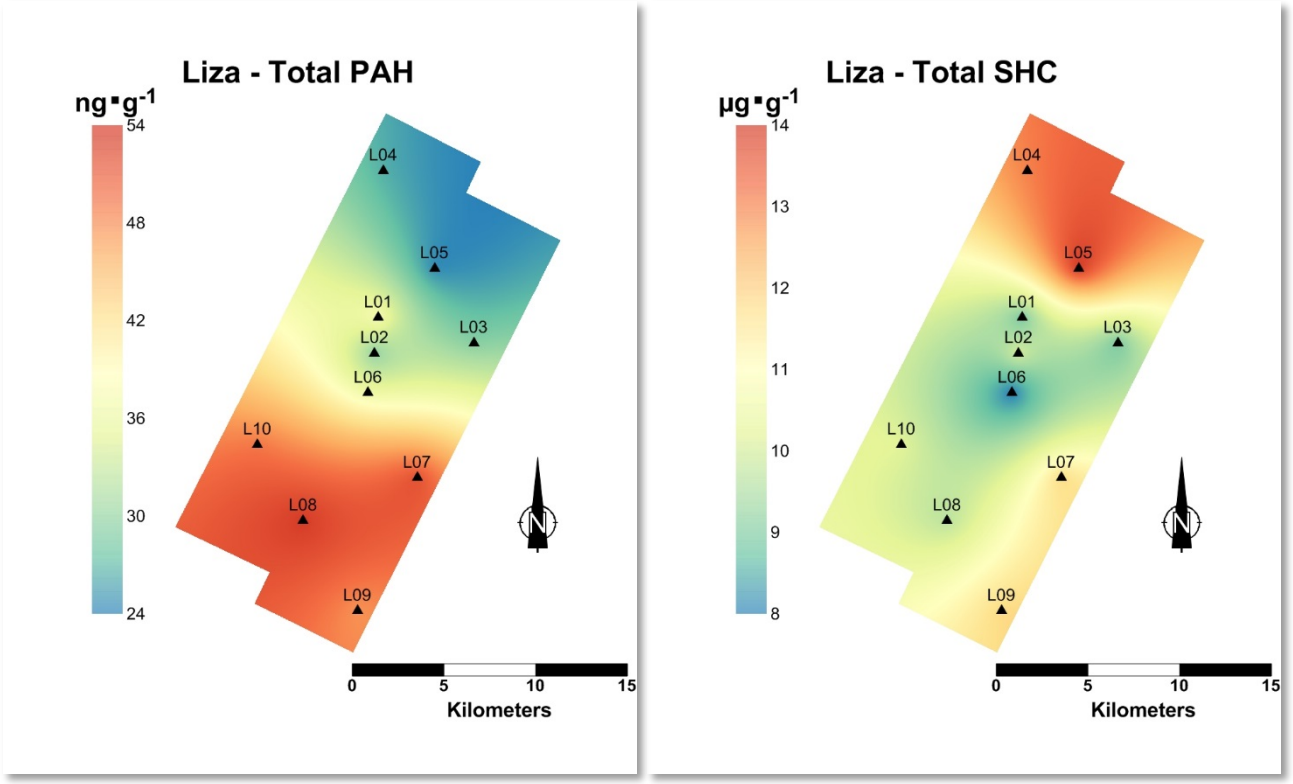


Figure 4-5. Spatial distribution of total PAH and total SHC in surface sediment at Liza.

4.4.1 Hydrocarbon Source

The within sample distribution of individual PAH compounds provides information for a range of hydrocarbon sources, whereas SHC compounds are used primarily to distinguish between biogenic and petroleum-derived sources. Relatively high concentrations of low molecular weight PAH (2-, 3-, and several 4-ring PAH) are typically associated with petrogenic (petroleum-derived) sources. Increased concentrations of high molecular weight PAH (4-, 5- and 6-ring PAH) indicate either pyrogenic (fossil fuel combustion) sources or possibly heavier, more degraded crude oils, depending on their relative distributions. Pyrogenic sources typically display increased concentrations of fluoranthene and pyrene relative to their corresponding alkylated homologues, while heavier crude oils generally display a fuller suite of alkylated compounds that are elevated relative to their parent compounds. The degree of hydrocarbon weathering generally increases as the ratio of naphthalene homologues to phenanthrene/anthracene homologues decreases. Interpretation of values for this ratio (i.e., N/P) and other diagnostic indices used to identify hydrocarbon source and degree of weathering are shown in **Table 2-3** (Section 2); results for diagnostic parameters for the 18 EBS sediment samples are shown in **Table 4-7**.

The distribution of n-alkanes in mature crude oil and distillates typically does not exhibit odd-even carbon preference. Terrestrial plants synthesize n-alkanes almost exclusively with an odd number of carbon atoms in the nC_{25} to nC_{37} range, whereas marine plants synthesize odd-numbered carbon chains in the nC_{15} to nC_{21} range (Hunt 1995). The ratio of pristane to phytane concentrations in sediment also is a useful diagnostic parameter, because phytane is mainly derived from petroleum, whereas both petroleum and biological sources typically contribute pristane to marine sediment. In addition, reduction in concentrations of low molecular weight alkanes (i.e., nC_9 to nC_{20}) and the ratio of heptadecane (nC_{17}) to pristane are commonly related to evaporative and biological weathering of hydrocarbons in sediment.

Table 4-7. Values for key diagnostic parameters indicating hydrocarbon source.

Analyte	Mean	Minimum	Maximum	Standard Deviation	Minimum at Station	Maximum at Station
			Liza (n=10)			
Petrogenic/Pyrogenic	3.36	2.14	4.65	0.97	L04	L07
CPI	1.97	1.47	3.27	0.50	L10	L09
C16/(C15+C17)	0.40	0.24	0.51	0.10	L09	L05
Pristane/Phytane:	1.34	0.67	1.8	0.42	L01	L09
			Sorubim (n=8)			
Petrogenic/Pyrogenic	2.66	1.94	3.37	0.60	S04	S02
CPI	1.99	1.24	3.22	0.59	S07	S02
C16/(C15+C17)	0.36	0.25	0.54	0.09	S08	S09
Pristane/Phytane:	1.05	0.33	2.0	0.51	S03	S01

*see Section 2.3.4 for a description of diagnostic parameters; CPI=carbon preference index

Chromatograms for all 18 sediment samples exhibited a noticeable predominance of odd-carbon-number over even-carbon-number n-alkanes, with a Carbon Preference Index (CPI) value >2 in most samples, indicating primarily biogenic sources of these low concentration hydrocarbons. A strong odd-carbon-number preference in the nC_{25} to nC_{37} range also was observed, indicating that the majority of hydrocarbons in sediment are derived primarily from plant (biogenic) material. Similarly, the low ratio (<1) of nC_{16} over the sum of nC_{15} + nC_{17} for all samples, indicates relatively low inputs of marine algae to these sediments, consistent with the low observed organic carbon content.

Analysis of the aromatic fractions revealed the presence of a full suite of 2-, 3-, 4-, 5- and 6-ring PAH compounds in most samples, with a notable absence of the sulfur-containing benzofurans. In general, sample distributions were dominated by the low molecular weight PAHs, naphthalenes and anthracene-phenanthrenes. High concentrations of perylene relative to other PAH compounds also were observed for all samples. Perylene is a biogenic compound formed during early diagenesis in marine and lacustrine sediments, usually associated with terrestrial plants (Tan and Heit 1981; LaFlamme and Hites 1978), and has been reported as the dominant PAH in clean sediments sampled offshore Brazil. A study by Krauss et al. (2005) indicated that naphthalenes and phenanthrenes (2- and 3-ring PAH) from plant biogenesis provided the majority of PAH measured in sediments and soils in a Brazilian rainforest with low overall PAH concentrations (i.e., <1 µg g^{-1}). In particular, phenanthrene had elevated concentrations (12-60 ng g^{-1}) in bark and twigs of Vismia trees, of which several species (e.g., *Vismia guyana, Vismia baccifera)* are native to Guyana.

The relative absence of combustion-related PAH in all sediment samples, as evidenced in petrogenic/pyrogenic ratios greater than 1 (**Table 4-7**), further indicates that biogenic or natural material, rather than combustion-related compounds, are the primary source of low level hydrocarbons measured in Guyana offshore sediment.

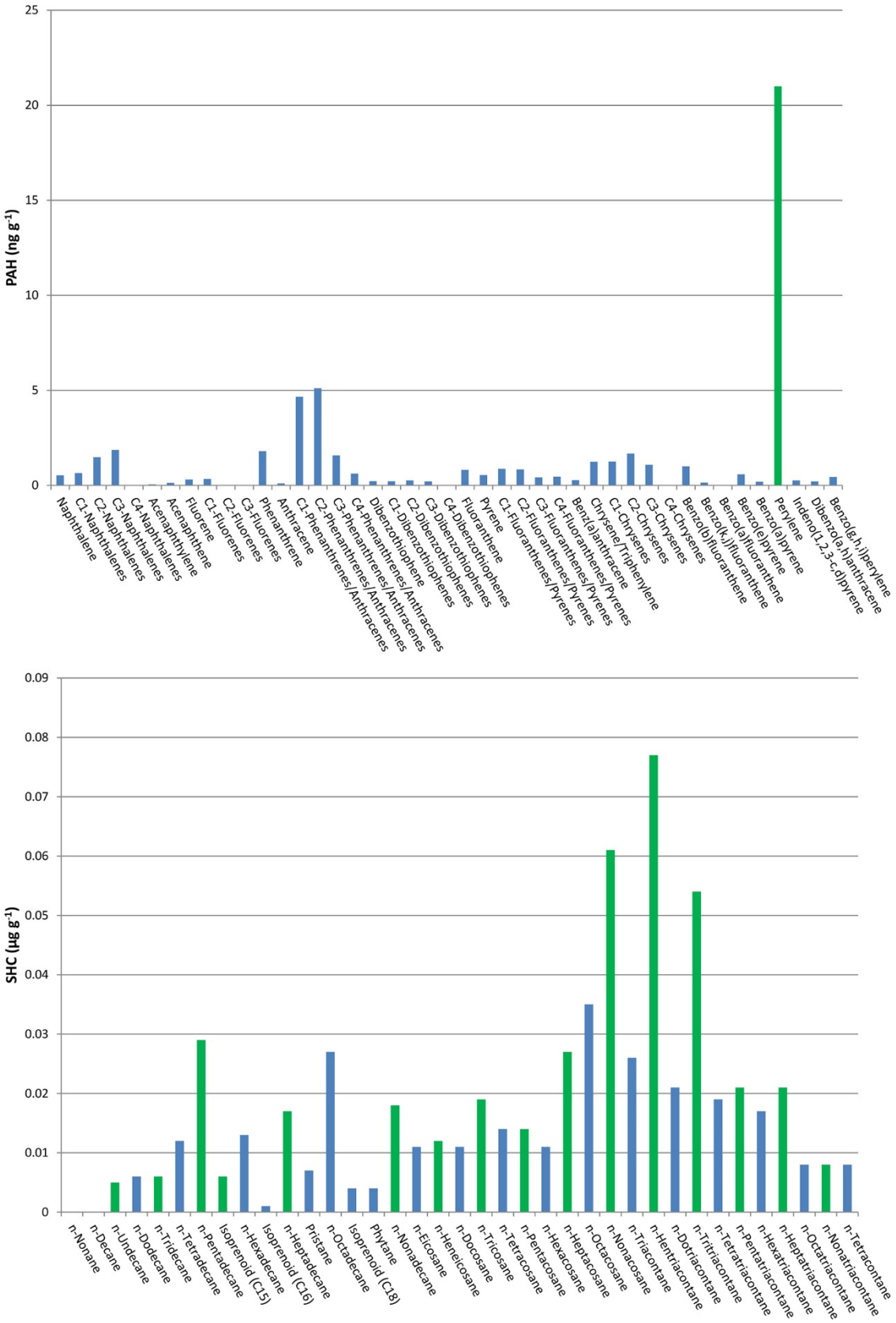


Figure 4-6. Distributions of individual PAH (top) and SHC (bottom) analytes in a representative sediment sample (station L08).

5 BENTHIC MACROFAUNA RESULTS

Benthic macrofauna results are presented for ten Liza and eight Sorubim sediment samples, consisting of patterns of total abundance, abundance of major taxonomic groups, taxonomic diversity, and taxonomic dominance. Presented results include mean values, maxima and minima, and coefficients of variation of data for each of the two sites. Correlations of the biota with depth, sediment grain size and organic content also are examined, spanning the entire range of sediment conditions and depth (877–2327m).

The two sites were sampled at mid- to outer continental slope depths (see Section 1). A stainless steel box corer insert with a sampling surface area of 0.1 m² was used to collect the samples, which were sieved through a 0.5 mm screen and preserved for analysis. Abundance data were respectively transformed and reported as the number of organisms per square meter, which is consistent with conventionally reported benthic literature. Complete field sampling procedures and analytical methods are described in Section 2.

Information on species diversity is constrained by the lack of taxonomic refinement in identification of organisms from deep sediments in general, and particularly from areas such as offshore Guyana (see Levin et al. 2001). Due to the relatively unknown nature of the deep-water biota from this region, taxonomic diversity is discussed in a broader context that is not directly related to the species concept of diversity. Instead, discussion is focused on biological diversity at the family level, which has been shown to be effective in delineating pollution impacts upon the diversity of benthic macrofauna (Ferraro and Cole 1990; Dauvin et al. 2003; Gomez Gesteira et al. 2003).

5.1 Background

The benthic boundary layer serves as a repository for sinking particles containing both organic and inorganic matter, hosting a biologically active and complex trophic food web in continental slope sediments. Benthic infaunal organisms are described as those residing on and in the sediments. They are collected by grab or core sampling, and have conventionally been designated as macrofauna at sizes larger than 0.5 mm (Holme and McIntyre 1971). Most macrofauna live within the upper 10 cm of sediment and are small, averaging only a few milligrams in weight and usually numbering from several hundred to several thousand per m^2 (m^{-2}). Peak values may reach several tens of thousands m^{-2} when a smaller sieve screen (e.g., 0.3mm) is utilized. Many of the increased numbers retained on the smaller screen are isopod and tanaid crustaceans.

The most common invertebrate macrofaunal groups found in marine shelf and continental slope sediments are polychaetous annelid worms, peracarid crustaceans and mollusks (Rex 1981; Grassle et al. 1990; Gage and Tyler 1991). Polychaetes typically comprise about half of the numbers and a third of the macrofaunal species from deep-water marine habitats. Beyond the continental shelf, conventionally defined as exceeding 150 m in depth, macrofaunal biomass and average body size typically decrease with depth, usually ascribed to decreasing food availability and reduced temperature (Rowe et al. 1991; Levin et al. 2000).

Macrofauna communities are known to be strongly influenced by bathymetric gradients in factors such as temperature, dissolved oxygen, and food availability, with depth strongly correlated to shifts of benthic community composition. Relationships of these environmental factors with macrofaunal benthic diversity have been summarized by Levin and Gage (1998) from 40 sites ranging from shelf to abyssal depths of the Atlantic, Pacific and Indian Oceans. Depth, latitude, sediment total organic carbon content (TOC) and bottom water oxygen concentration were determined to be the most significant factors affecting four indices of diversity and community structure, accounting for 52% to 87% of observed variation. Sediment grain size factors were relatively insignificant. When depth and latitude effects were removed, oxygen and organic carbon accounted for 32% to 67% of variation in the four indices.

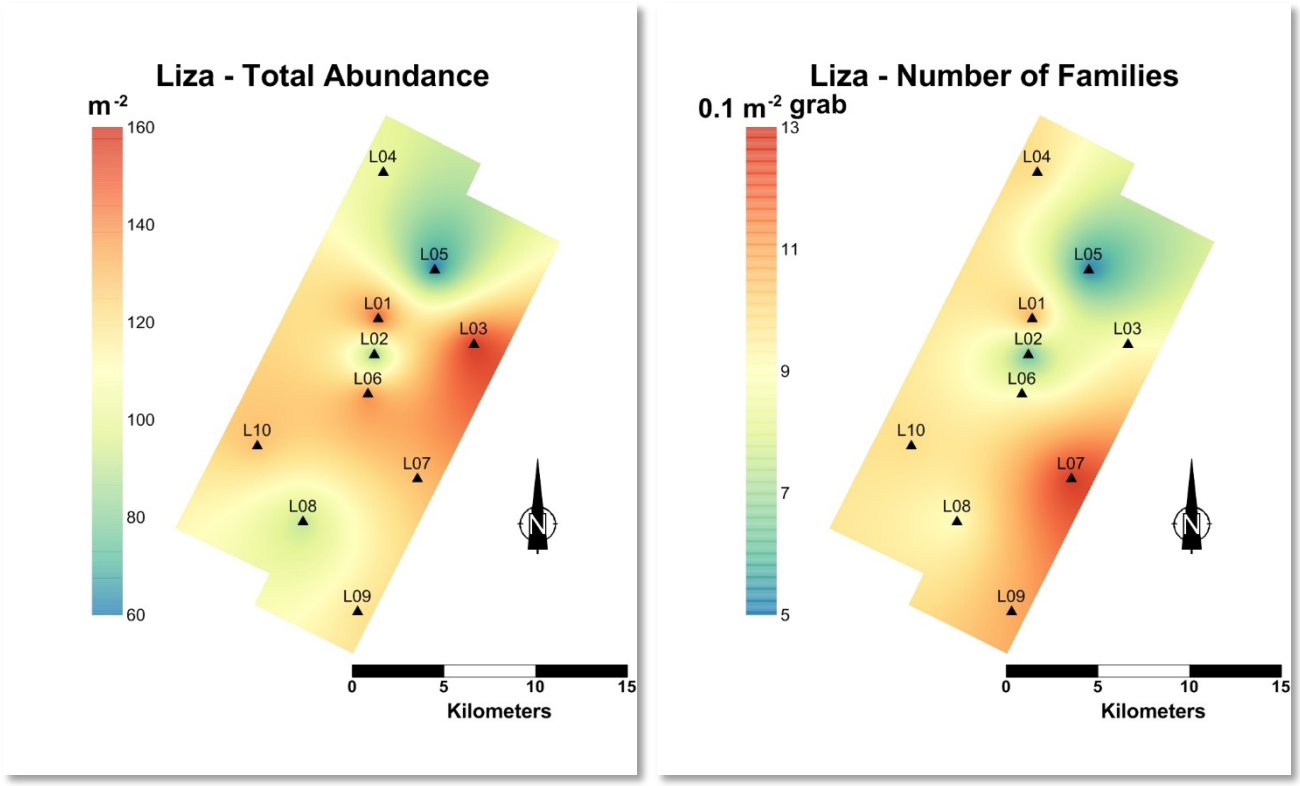


Figure 5-1. Spatial distribution of macrofauna total abundance and family diversity at Liza.

At depths greater than 500 m, seasonal variation in physical parameters (e.g. temperature, salinity) is minimal (Thistle 2003). The absence of significant upwelling phenomena offshore Guyana and little or no seasonal variation in surface productivity in offshore tropical waters suggest that no, or minimal, seasonal variation would be predicted for the benthos in the Liza and Sorubim sampling areas.

Studies of macrofaunal community diversity and abundance have not been conducted on the continental slope offshore Guyana, nor from adjacent areas within several hundred kilometers. This reflects the dearth of information from deep water sites in the southern hemisphere, especially from the western Atlantic Ocean (see Levin and Gooday 2003). From the broader region, studies in the Venezuelan Basin have indicated a macrofaunal abundance of 678 organisms m^{-2} and biomass carbon levels of less than 0.01 grams m^{-2} (Tietjen 1992). Sediments from this region may contain high levels of biogenic carbonate (up to 75%) from Foraminifera tests and may harbor distinctive faunal elements (Briggs 1985).

5.2 Liza – Abundance and Diversity

Ten stations, with a total sampling area of 1.0 m^2, contained 116 organisms, represented by 50 distinct families. General patterns of abundance and diversity, and correlations with sediment parameters and depth follow.

5.2.1 Abundance

Average total macrofaunal abundance was 116 m^{-2}, ranging from 60 to 160 m^{-2}. This population density is at the lower end of macrofaunal densities reported from continental slope sediments around the world (see Rowe et al. 1982; Gage and Tyler 1991). Levels of sediment organic carbon were extremely low in Liza sediments, averaging only 0.52% of sediment dry weight (see Section 4.1). Low sediment TOC suggests limited input of organic food sources sinking to the bottom and does not appear to be sufficient to maintain an abundant macrofauna. Abundance statistics are summarized in **Table 5-1**. Spatial distribution of the abundance of all organisms is illustrated in **Figure 5-1**. Total abundance was not significantly correlated with water depth or sediment physical parameters.

Table 5-1. Summary statistics for benthic macrofauna at Liza (*n*=10). Reported as organisms m^{-2} except where noted.

Parameter	Mean	Standard Deviation	CV	Minimum	Maximum	Station with Minimum	Station with Maximum
Number of Families[1]	9.3	2.4	25.4	5	13	L05	L07
Total Abundance	116	32.4	27.9	60	160	L05	L03
Crustacea	20	14.9	74.5	0	50	L10	L01
Mollusca	29	20.2	69.8	0	60	L05	L03
Polychaeta	47	22.6	48.2	20	90	L04	L01
Other Minor Phyla	11	11	100	0	30	L01	L10

[1]reported as distinct taxa per 0.1 m^2 grab sample; CV=coefficient of variation

The most abundant major taxonomic group was polychaete worms, averaging 47 m^{-2}, comprising 41% of total abundance, followed by mollusks (29 m^{-2}, 25%) and crustaceans (20 m^{-2}, 16%). Collectively they comprised 83% of total macrofaunal numbers. These major taxa are the predominant macrofaunal components of continental slope sediments worldwide. Several other taxonomic groups made up the remaining 18%, including four of the five major classes of echinoderms (brittle stars, starfish, sea-cucumbers, sea urchins), along with nemerteans (ribbon worms), nematodes (round worms), sponges, pycnogonids (sea-spiders) and sipunculids (peanut worms). Dominant families, collectively exceeding 50% of total macrofaunal abundance, are listed in **Table 5-2**.

Table 5-2. Dominant families of macrofauna collectively comprising >50% of total abundance at Liza (*n*=10).

Family	Major Taxon	Percent of total abundance	Frequency of Occurrence (%)
Oweniidae	Polychaete	14.7	70
Tindariidae	Bivalve Mollusk	7.8	40
Apseudidae	Tanaid Crustacean	4.3	50
Arcidae	Bivalve Mollusk	4.3	30
Maldanidae	Polychaete	3.4	30
Golfingiidae	Sipunculid	3.4	30
Phyllodocidae	Polychaete	2.6	30
Chaetopteridae	Polychaete	2.6	20
Ampharetidae	Polychaete	2.6	20
Eusiridae	Amphipod Crustacean	2.6	30
Bairdiidae	Ostracod Crustacean	2.6	20

Polychaete worms were present in all 10 samples and were the numerically dominant taxonomic group, comprising 41% of total abundance (47 m^{-2}), varying by a factor 4.5 between samples.

Predominance of polychaetes is characteristic of continental slope sediments (Knox 1977; Gage and Tyler 1991). Nineteen polychaete families were identified, of which five collectively comprised more than 75% of total polychaete abundance (Oweniidae, 17 m^{-2}; Maldanidae, 4 m^{-2}; Chaetopteridae, 3 m^{-2}; Phyllodocidae, 3 m^{-2}; Ampharetidae, 3 m^{-2}). These families are common and cosmopolitan in distribution from continental slope sediments.

Oweniid polychaetes were the most abundant family of macrofauna, comprising 14.7% of total organisms sampled. These sedentary tube dwelling polychaetes feed on surface deposits and filter suspended particulate matter. Other families such as Capitellidae, Spionidae and Cirratulidae which typify deep sediments with higher organic content (see Pearson and Rosenberg 1978; Bellan 1984) were present, but in lower numbers. Polychaete abundance was not significantly correlated with depth, mean grain size or TOC.

Mollusks were collected at nine of the ten stations. Abundance averaged 29 m^{-2}, comprising 25% of the total macrofauna. Eleven families were collected, of which eight were pelecypods (bivalves). Other molluscan taxa included gastropods (snails), scaphopods (tusk shells) and chaetodermatids. Mollusk abundance was not significantly correlated with depth, TOC or sediment grain size parameters.

Pelecypods had an average abundance of 25 m^{-2}, comprising 86% of mollusk numbers and 22% of total macrofaunal abundance. Tindariids (9 m^{-2}) and Arcids (5 m^{-2}) were the most abundant pelecypod families. Only a single gastropod (snail) was collected (from station L07). Scaphopods of the family Dentaliidae were represented by single specimens from Stations L08 and L10. A single chaetodermatid was collected at station L10.

Crustaceans were present in nine of the ten samples. Abundance averaged 20 m^{-2}, comprising 16% of the total macrofauna. The coefficient of variation between stations (74.5) was the highest of the major taxonomic groups. Crustacean abundance was not significantly correlated with depth, TOC, or sediment grain size parameters.

The most abundant crustaceans were amphipods and tanaidaceans (6 and 5 m^{-2}, respectively). Cumaceans, ostracods, and isopods comprised the remaining crustacean fauna (collectively 5 m^{-2}). Typically, tanaidaceans and isopods are the numerically dominant crustacean groups in slope sediments.

Crustaceans were represented by 10 families, each typically absent from the majority stations or represented by a single individual. Only the tanaidacean family Apseudidae was present at the majority of stations, from which only single individuals were collected. With the exception of three ostracod specimens, all crustaceans (amphipods, isopods, cumaceans, tanaidaceans) were members of the Pericarida super-order, a group of crustaceans that brood their young, generally are of small body size, and are highly successful in deep marine sediments (Sanders 1977; Brandt 1997).

Grouped Minor Phyla, the remaining Liza macrofauna, consisting of a variety of major taxa, collectively comprised 18% of total abundance. Of these, echinoderms (9 m^{-2}) and sipunculids (6 m^{-2}) were most abundant. None of the remaining major taxa exceeded 2 m^{-2} in average abundance.

5.2.2 Diversity and Dominance

The number of families per sample (also referred to as family diversity) can provide an assessment of species habitat suitability. A diversity of families indicates relatively unstressed conditions, with habitat factors that are central to the tolerance ranges of a relatively high number of potential recruits. Low family diversity may reflect environmentally stressed or marginal conditions unsuitable for successful settlement and subsequent growth of recruits. Dominance is defined as the number of species comprising 50% or more of total infaunal abundance. Herein, it is applied to the number of families.

Fifty families of marine organisms were identified from the 10 boxcore samples. Areal (spatial) distribution of family diversity is shown in **Figure 5-1**. The average number of families per grab was 9.3, ranging from 5 to 13, with a CV of 25.4. This is a high number of families given the low total number (n = 116) of organisms retrieved from ten samples. The average number of organisms per family was only 2.3, indicating a low level of dominance by any specific family. This indicates conditions of low physical-chemical stress at the sediment boundary, thereby providing adequate habitat for a diverse biota, but with low flux of detrital food material reaching the bottom to support a larger population.

It is noteworthy that over half of the 50 families were represented by either one or two individuals from the ten samples. This proportion of families represented by few individuals indicates that much more sampling is required to adequately represent the family diversity either locally or regionally (see Grassle and Maciolek 1992).

5.3 Sorubim – Abundance and Diversity

Eight stations from the Sorubim site, with a total sampling area of 0.8 m^2 contained 80 organisms, represented by a 41 families. General patterns of abundance, diversity and their correlations with sediment parameters and depth are discussed below.

5.3.1 Abundance

Average total macrofaunal abundance was 100 m^{-2}. This population density is at the lower end, but within the range, of macrofaunal densities reported from continental slope sediments around the world (see Rowe et al. 1982; Gage and Tyler 1991). Levels of sediment organic carbon were low in sediments, averaging only 0.37% of sediment dry weight (Section 3.3.1), indicating a general limitation of organic food sources reaching bottom sediments to maintain an abundant macrofauna. The only significant correlation (z < 0.05) between abundance and depth, TOC or sediment grain size parameters was a positive correlation between bivalve abundance and percent fines.

Abundance statistics are summarized in **Table 5-3**. Dominant families, collectively exceeding 50% of total macrofaunal abundance, are listed in Table 5-4. Spatial distribution is illustrated in **Figure 5-2**.

Table 5-3. Summary statistics for benthic macrofauna at Sorubim (*n*=8). Reported as organisms m^{-2} except where noted.

Parameter	Mean	Standard Deviation	CV	Minimum	Maximum	Station with Minimum	Station with Maximum
Number of Families[1]	8	3.4	42.8	4	14	S01	S05
Total Abundance	100	40	40	40	150	S01	S03
Crustacea	15	20	133.3	0	50	S01	S05
Mollusca	37.5	29.2	77.7	0	100	S01	S03
Polychaeta	28.8	27	93.8	0	90	S09	S07
Other Minor Phyla	13.8	14.1	102.4	0	40	S01	S08

[1]reported as distinct taxa per 0.1 m^2 grab sample; CV=coefficient of variation

Table 5-4. Dominant families of macrofauna collectively comprising >50% of total abundance at Sorubim (*n*=8).

Family	Major Taxon	Percent of total abundance	Frequency of Occurrence (%)
Tindariidae	Bivalve Mollusk	12.5	37.5
Oweniidae	Polychaete	7.5	20
Nuculidae	Bivalve Mollusk	7.5	27.5
Silicea*	Sponge	3.8	12.5
Chrysopetalidae	Polychaete	3.8	12.5
Spionidae	Polychaete	3.8	25
Cirratulidae	Polychaete	3.8	37.5
Nematoda*	Round Worm	3.8	37.5
Eusiridae	Amphipod Crustacean	2.5	25

*Unidentified family

Mollusks were the most abundant major taxonomic group, averaging 37.5 m^{-2}, comprising 37.5% of total abundance, followed by polychaete worms (28.8 m^{-2}, 29%) and crustaceans (15 m^{-2}, 15%). Collectively they comprised 81% of total macrofaunal numbers. These major taxa are the predominant macrofaunal components of continental slope sediments, worldwide. Several other taxonomic groups made up the remaining 18.5%, including four of the five major classes of echinoderms (brittle stars, starfish, sea-cucumbers, sea urchins), along with hydrozoans, sea-anemones, nemerteans, nematodes and sponges.

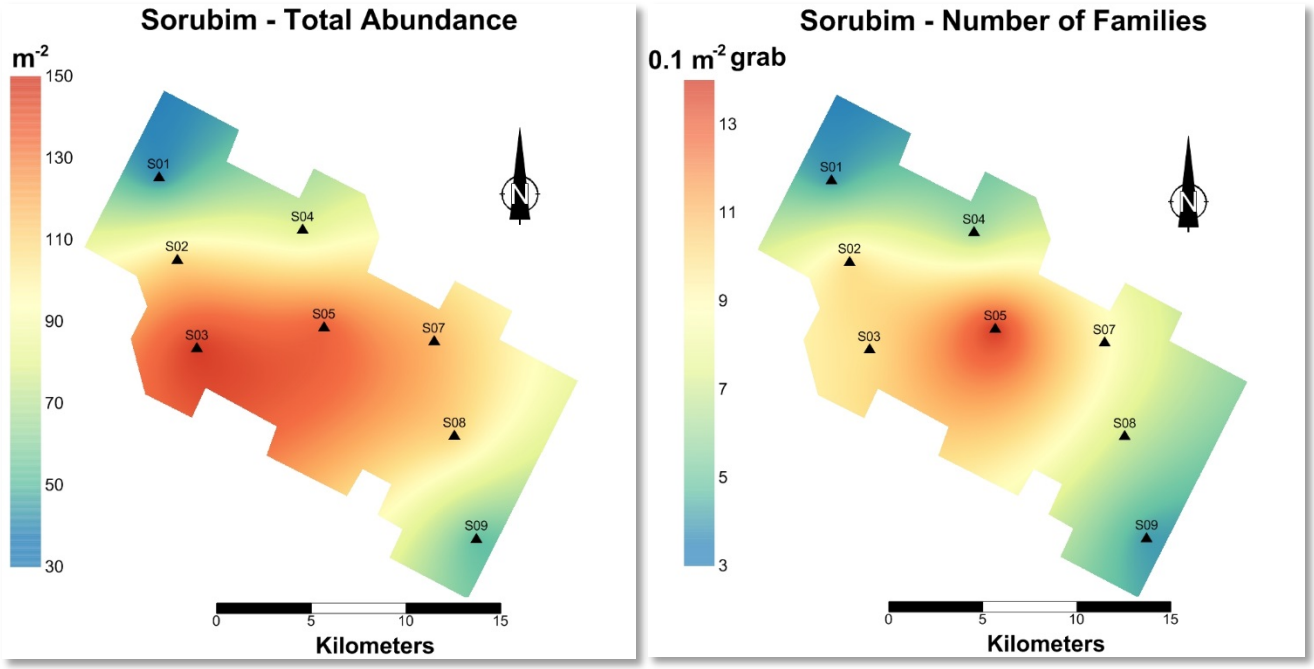


Figure 5-2. Spatial distribution of macrofauna total abundance and family diversity at Sorubim.

Mollusks were collected at seven of the eight sampling stations. Abundance averaged 37.5 m^{-2}, comprising 37.5% of the total macrofauna. Eleven families were collected, of which nine were pelecypods (bivalves). Other molluscan taxa included gastropods (snails) and scaphopods (tusk shells).

Pelecypods had an average abundance of 32.5 m^{-2}, comprising 87% of mollusk numbers and 32.5% of total macrofaunal abundance. Tindariidae (12.5 %) and Nuculidae (7.5 %) were the most abundant pelecypod families (**Table 5-4**). Both of these families are members of the bivalve Order Nuculoida, which contains several families that are dominant members of continental slope macrofaunal communities. Only two gastropods (snails) were collected (from stations S05 and S07). Scaphopods of the family Laevidentaliidae were represented by single specimen from station S03.

Pelecypod abundance exhibited a positive correlation with fine (silt + clay) sediments ($p = 0.837$, $z = 0.019$). Correspondingly, they had a significant negative correlation with the larger sand fraction. Correlations with depth and TOC were insignificant.

Polychaete worms were present in seven of the eight samples, with an average abundance of 28.8 m^{-2}, comprising 29% of total abundance, with a CV of 93.8 between samples. Polychaetes typically represent a higher fraction of total abundance in slope sediments.

Eleven polychaete families were identified, of which oweniids (7.5 m^{-2}) were the most abundant. Other representative families (see **Table 5-4**) are common and cosmopolitan in distribution from continental slope sediments. These sedentary tube dwelling polychaetes feed on surface deposits and filter suspended particulate matter. Other families such as Capitellidae, Spionidae and Cirratulidae which typify deep sediments with higher organic content (see Pearson and Rosenberg 1978; Bellan 1984) were present, but in lower numbers. Polychaete abundance was not significantly correlated with depth, mean grain size or TOC.

Crustaceans were present at four of the eight stations. Abundance averaged 15 m^{-2}, comprising 15% of the total macrofauna. The coefficient of variation between stations (133.5) was the highest of the major taxonomic groups. Crustacean abundance was not significantly correlated with depth, TOC or sediment grain size parameters.

The most abundant crustaceans were amphipods (10 m^{-2}). Tanaidaceans and isopods each averaged 2.5 m^{-2}. They are typically found at higher population densities in slope sediments. Crustaceans were absent from half of the eight stations. Only a single crustacean family (Eusiridae), an amphipod, exceeded 2% of total macrofaunal abundance. All crustaceans were pericarids, which brood their young.

Grouped Minor Phyla; the remaining Sorubim macrofauna, consisting of a variety of major taxa collectively comprised 19% of total abundance. Of these, echinoderms (5 m^{-2}) and sponges (5 m^{-2}) were most abundant.

5.3.2 Diversity and Dominance

Forty-one families of marine organisms were identified from the eight stations. Spatial distribution of family diversity is shown in **Figure 5-2**. The average number of families per grab was 8.0, ranging from 4 to 14, with a CV of 42.8. This is a high number of families given the low total number of organisms (*n* = 80) obtained from the eight samples. The average number of organisms per family was only 1.95, indicating a low level of dominance by any specific family, suggesting conditions of low physical-chemical stress at the sediment boundary. While a diversity of families was present, none had large populations due to an apparent lack of food source as indicated by low TOC values, which averaged less than 0.4% of sediment dry weight.

6 EVALUATION OF DATA QUALITY

This section evaluates the quality of the collected and analyzed data to determine whether relevant program objectives identified in Section 1.1 were met. Specifically, elements of the study design, critical to meeting program objectives (restated below) were evaluated using EBS results (Section 6.1). Sections 6.2 and 6.3 evaluate quality control data for key chemical and biological parameters provided by the laboratories to ensure that data quality objectives, specified in method-specific Standard Operating Procedures (SOPs), were met. Detailed descriptions of analytical methods are presented in Section 2.

6.1 Evaluation of EBS Objectives

Results for key parameters were examined to determine whether the following program objectives (see Section 1) were met.

1. *Provide comprehensive, descriptive, and quantitative documentation of environmental conditions in the area of potential exploration within Liza and Sorubim exploration sites.*

2. *Gain information to assess the significance of environmental impacts to offshore Guyana sediment from potential existing sources such as atmospheric deposition.*

3. *Identify potential confounding factors that may interfere with the interpretation of sediment chemical and biological data to aid sampling design and interpretation of future environmental data.*

To meet the above objectives, sediment and water were sampled in Liza and Sorubim areas of planned petroleum exploration to determine environmental conditions prior to future drilling (see Figure 1-1, Section 1). A total of 18 sediment samples were collected: ten at Liza and eight at Sorubim. Water samples were collected at seven of the sediment stations: four at Liza and three at Sorubim. Samples were collected at three discrete depths (near-surface, at 25m depth, and near-bottom) to capture representative samples from the stratified water column. Water depths ranged from 877m to 2327m for the sampling area, which was located primarily downslope off the central coast of Guyana.

Results for key physical, biological, and chemical parameters (identified in Table 2-2, Section 2) were evaluated to provide estimates of variability and identify physical factors that may impact monitoring results. Potential physical confounding factors, including sediment particle size, water depth, and total organic carbon (TOC), also were measured. These factors are recognized for their strong influence on benthic community structure and sediment chemical characteristics, and can be important in the interpretation of data.

6.1.1 Study Objective 1

Variation within the data set, presented as coefficients of variation (CV), is shown for selected key parameters in **Table 6-1**. Coefficients of variation indicate the relative spread in population data, where the CV = standard deviation ⁄ the population mean x 100. The mean value ± 2 x CV (expressed as percent of mean) provides an approximation of the data envelope containing 95% of the individual data points. With the exception of percent sand at Liza, all key physical and chemical parameters had CV's <50 for sediment samples collected from each site, consistent with physically uniform, uncontaminated sediment. Echinodermata and Amphipoda abundance CV's were relatively high (>100) compared with other macrofauna results, likely due to very low numbers of individuals and patchy distribution. In general, variability is expected to decrease with decreasing distance between stations in future surveys.

Benthic macrofauna community results with CV's >100 are often reported in the literature, typically due to factors such as recruitment, availability of food, predation, environmental contamination, and organic enrichment.

Table 6-1. Coefficients of variation (CV) for mean results reported for selected key parameters for Liza and Sorubim.

Parameter	Liza (*n*=10)	Sorubim (*n*=8)
Sand	71.9	30.9
Silt	30.1	15.0
Clay	16.6	29.0
Fines	15.6	12.5
TOC	30.4	22.6
Depth	24.2	9.0
Aluminum	20.2	20.1
Arsenic	34.2	46.8
Barium	27.8	33.7
Cadmium	19.4	18.3
Chromium	29.0	21.1
Copper	14.0	21.5
Iron	20.3	20.9
Lead	19.1	12.5
Mercury	27.9	21.9
Nickel	23.0	15.9
Vanadium	16.0	21.2
Zinc	27.5	17.3
Total PAH(43)	28.5	35.1
Total SHC	18.0	28.3
Total Unresolved SHC	41.2	41.2
Total Resolved SHC	56.1	58.3
Total Abundance	27.9	40.0
Number of Families	25.4	42.8
Annelida	48.2	93.8
Crustacea	74.5	133.3
Mollusca	69.8	77.7
Other	100.0	102.4
Echinodermata	143.0	151.2
Amphipoda	161.0	141.4
Pelecypoda	76.0	73.1
Polychaeta	48.2	80.0

Low variability in key physical and chemical measurements indicates that post-exploration environmental impacts to study area sediments will be relatively easy to discern from existing conditions. For example, drilling-related discharges to the seafloor, including barium, cuttings (via grain size measurements), or hydrocarbons (e.g., adhered non-aqueous drilling mud), should produce significant differences from background at concentrations of approximately two times higher than EBS concentrations, which are very low based on results from this study. A prospective (a priori) power analysis should be performed prior to designing a post-drilling program to provide information on the number of samples needed to determine a defined difference between mean values for different areas (e.g., well site, reference), which is a standard approach used to quantify changes from drilling-related discharges.

6.1.2 Study Objective 2

Potential confounding factors were evaluated to satisfy Study Objective 2, and to aid sampling design of future studies. Pearson correlations were performed on measured parameters to identify physical characteristics that were significantly correlated with key chemical and biological results, and could therefore, potentially confound interpretation of results. Correlation results for physical parameters with key chemical and macrofauna parameters are presented in Sections 4 and 5, respectively.

Most metals (including barium) and several key hydrocarbon parameters displayed significant correlations with percent fines and TOC (z <0.05) at both sites. These results indicate that sediment grain size and/or TOC should be taken into account in the interpretation of chemical results in future studies.

There were no significant correlations between major macrofauna group abundances with sediment physical parameters or water depth for either site. This is an unusual situation that is likely due to the limited water depth range and consistently low levels of TOC observed at each site.

6.2 Analytical Chemistry Data Quality

Laboratory quality control results were evaluated to ensure that data of sufficient quality were produced to meet program objectives. Quality control objectives for batch analysis (≤20 field samples) are shown in **Table 6-2** for analysis of hydrocarbons and in **Table 6-4** for metals. Quality control results for PAH, SHC and metals data follow.

6.2.1 Hydrocarbons

B&B Analytical Laboratory quality control data packages demonstrated that initial calibration, continuing calibration and procedural blank data for polycyclic aromatic hydrocarbons (PAH) and saturated (aliphatic) hydrocarbons (SHC) met or exceeded data quality objectives listed in **Table 6-2**. Continuing calibration, procedural blanks, duplicate samples, and blank spike/blank spike duplicate pairs were analyzed with every batch of field samples.

PAH. Trace levels of several target compounds (primarily naphthalene, and C_1- and C_2-napthalenes) were detected in the procedural blanks for both sediment and water samples. All concentrations were below five times the corresponding method detection limits, and therefore, met quality control criteria for the method.

Surrogate standards were added to every field sample to monitor extraction efficiency. Surrogate standard recoveries were within the quality control limits specified in **Table 6-3** for all sediment and water samples.

Differences in analyte concentrations (>10x method detection limit) for duplicate samples, as well as concentrations of 100% of matrix spike/matrix spike duplicate analytes and all of the reference standard analytes were within acceptable limits (results not shown).

SHC. Initial calibration, continuing calibration, and procedural blank data for SHC analysis performed by B&B Analytical Laboratory met or exceeded data quality objectives for the method (US EPA 8015-modified). Continuing calibration, procedural blank, duplicate sample, blank spike/blank spike duplicate and standard reference material were analyzed with every batch of field samples. Surrogate standards were added to every field sample to monitor extraction efficiency. Differences in analyte concentrations (>10 x method detection limit) of duplicate samples were within acceptable limits, as were matrix spike and matrix spike duplicate analyte concentrations. Based on these results, SHC analysis satisfied the data quality objectives established for the program. Quality control results for surrogate spike recoveries for 18 sediment and 21 water samples for PAH and SHC are summarized in **Table 6-3**. All surrogate recoveries were within acceptable ranges for each method.

Table 6-2. Summary results for QC surrogate recovery for hydrocarbons (PAH and SHC) in sediment and water. Results reported as percent recoveries (%).

QC Parameter	QC Frequency	Acceptance Criteria	Corrective Action
Instrument Check	1 per analytical run	±15% recovery	Reanalyze or document justification.
Surrogate recovery	2-3 per sample	50-120% recovery	Reanalyze or document justification. Flag impacted data.
Procedural blank	1 per batch of 20 samples	No target analytes > 5X MDL	Reanalyze or document justification. Flag impacted data.
Laboratory Control Sample (Blank Spike)	1 per batch of 20 samples	70-120% recovery	Reanalyze or document justification. Flag impacted data.
Laboratory Sample Duplicate	1 per batch of 20 samples	±30% RPD for 90% of the target analytes that are present at concentrations >10x MDL	Review data to assess impact of matrix. Reanalyze or document justification. Flag impacted data.
Instrument Calibration – Initial Calibration	Initial 5-point prior to sample analysis	±25% RSD single compound average of 15%	Re-calibration or document justification.

MDL=method detection limit; RPD=relative percent difference; RSD=relative standard deviation.

Table 6-3. QC summary results for hydrocarbons (PAH and SHC) analyzed in water and sediment. Results reported as percent (%).

Surrogate	Mean	Minimum	Maximum	Standard Deviation	Acceptable
Sediment PAH (n=18)					
Acenaphthene-d10	86.66	83.67	91.64	2.44	Yes
Chrysene-d12	82.63	79.95	85.15	1.44	Yes
Naphthalene-d8	79.88	74.57	87.36	3.65	Yes
Perylene-d12	62.59	31.71	81.61	14.38	Yes
Phenanthrene-d10	84.30	81.49	87.84	1.67	Yes
Sediment SHC (n=18)					
n-Dodecane-d26	80.56	74.70	89.60	5.50	Yes
n-Eicosane-d42	90.44	83.30	97.20	4.81	Yes
n-Triacontane-d6	94.08	86.40	101.40	5.27	Yes
Water PAH (n=21)					
Naphthalene-d8	83.18	69.32	92.00	6.46	Yes
Acenaphthene-d10	90.41	80.65	105.00	6.64	Yes
Phenanthrene-d10	82.35	66.66	99.00	8.46	Yes
Chrysene-d12	86.74	74.00	94.00	6.01	Yes
Perylene-d12	86.05	74.00	92.00	5.78	Yes
Water SHC (n=21)					
n-Dodecane-d26	56.95	29.90	73.80	11.17	Yes
n-Eicosane-d42	92.11	78.80	98.00	5.51	Yes
n-Triacontane-d6	86.85	71.70	97.10	5.07	Yes

6.2.2 Metals

Quality control criteria and corresponding results for metals analysis are presented in **Tables 6-4** and **6-5,** respectively. Analysis of procedural blanks, matrix spikes, and sample duplicates performed by Albion Environmental Laboratory met all data quality objectives. A procedural blank was analyzed with each batch in order to monitor potential contamination resulting from laboratory reagents and processing procedures. A matrix spike sample (method of additions analysis) was analyzed to provide information on the extent of any signal suppression or enhancement due to the sample matrix. A sample duplicate was analyzed every 10 samples to verify method precision. Based on these results, analysis of metals satisfied the data quality objectives established for the program.

The heated, strong acid leach digestion used to extract metals is NOT a total digestion quantifying all of a given element present in the sediment matrix. The percentage of metal leached into solution for analysis varies by element. For example, for the more refractory metals (e.g., chromium, vanadium), only a relatively small percentage is extracted. For many other elements (including many pollutant metals) that are largely adsorbed onto the sediment particles, a much higher percentage is extracted. A sediment reference material (MESS-3) was used to estimate the percentage of each element leached into solution for analysis. The percentage released is compared to a historical percentage that is typically observed for such a heated strong acid leach. Results for the batch analysis of MESS-3 were within the normal range of historical data, indicating acceptable accuracy for the EBS metals analyzed (historical data not shown).

6-4. Data quality objectives for metals analyzed by ICP with mass detector.

QC Parameter	Acceptance Criteria	Corrective Actions
Mass Calibration	Must not differ by more than 0.1 amu from true value	Perform Instrument Maintenance. Re-calibrate
Resolution Checks	Less than 0.9 amu at full width at 10% peak height	Perform Instrument Maintenance. Re-check
Method Blank	< reporting limit	Notify project manager. Re-extract samples. Evaluate impact to data, discuss with manager, determine if corrective action is necessary
Laboratory Control Sample	80-120% recovery for aqueous and 75-125% recovery for solid	Evaluate impact to data, discuss with manager, determine if corrective action is necessary
Matrix Spike Duplicate (if requested)	75-125% recovery for solid and aqueous; and 20% RPD	Evaluate impact to data, discuss with manager, determine if corrective action is necessary
Initial and Continuing Calibration Verification	90-110% recovery	Perform Instrument Maintenance. Re-analyze affected samples. Notify project manager and justify.
Initial and Continuing Calibration Blank	< reporting limit	Perform Instrument Maintenance. Re-analyze affected samples. Notify project manager and justify.
ICSA and ICSAB Solution	80-120% recovery for spiked analytes	Evaluate impact to data, discuss with manager, determine if corrective action is necessary

amu=atomic mass unit; MDL=method detection limit; RPD=relative percent difference; RSD=relative standard deviation.

6-5. QC summary results for metals analyzed in water and sediment. Results reported as percent (%) unless noted.

QC Sample	Total QC Batch Samples	Minimum	Maximum	Acceptable
Sediment Samples (n=18)				
Matrix Spike Recovery	2	89 (V)	116 (Ba)	Yes
Laboratory Duplicate RPD	2	0.9 (V)	24 (Pb)	Yes
Reference Material Recovery	2	91 (V)	104 (Al, Fe)	Yes
Blank Spike Recovery	2	81 (Pb, Zn)	115 (As)	Yes
Method Blank (µg L^{-1})	2	<0.002 (Hg)	<20 (Al, Fe)	Yes
Water Samples (n=21)				
Matrix Spike Recovery	3	92 (Cd, Cu)	107 (As)	Yes
Reference Material Recovery	3	92 (V)	102 (Zn)	Yes
Blank Spike Recovery	3	95 (Zn)	115 (Ni)	Yes
Method Blank (µg L^{-1})	2	<0.0002 (Hg)	<0.5 (Pb, Zn, Ni, Cr)	Yes
Field Blank (µg L^{-1})	3	<0.0002 (Hg)	<0.5 (Pb, Zn, Ni, Cr)	Yes

6.3 Benthic Infauna

There are three major processes that affect the quality of benthic infaunal data: 1) field collection of samples, 2) laboratory removal and sorting of organisms, and 3) taxonomic identification. Quality control procedures and results used for each of these three major processes follow.

6.3.1 Collection of Benthic Infaunal Sediment Samples

Sample quality was controlled through a process of observation and measurement during the acquisition of sediments destined for infaunal analysis. All 18 EBS sediment samples collected met the following criteria:

1. Sampling device (e.g., 0.1-m^2 box core insert) was not overfilled with sediment
2. Sampling device was fully closed upon sample retrieval
3. Overlying water was not excessively turbid
4. Sampling device contained greater than 15 cm of sediment
5. Sieving/screening device was without tears and punctures for all samples

Infaunal sediment samples collected during the investigation that did not meet the above criteria were rejected and the station was re-sampled. Review of station occupation data taken from the field logs indicated that of the 21 stations sampled, two required more than one grab due to washed out, slumped, or disturbed sediment.

6.3.2 Laboratory Removal and Sorting of Organisms

Ten percent of all samples (i.e., 2 random samples) were re-sorted to provide assurance that >90% of infaunal organisms were removed from sample debris. Resorting was conducted by a quality control technician that did not perform the initial sorting task. The quality control technician sorted through previously processed material following procedures used during the initial removal/sorting process. The total number of newly discovered organisms from the second sorting effort was compared to the total number of organisms obtained from the initial processing task. If the resorted sample contained greater than 10 percent additional organisms, all samples processed by the initial processing technician were completely reprocessed.

Sorting QC results for two randomly selected samples follow. Sample S-EBC02 (station S02) passed, scoring 100%. Sample L-EBC07 (station L07) failed at 90%. An additional QC sample for the initial sorter was randomly chosen from their remaining eight samples. That sample (L-EBC03, station L03) passed, scoring 100%. Final QC results were 95% average sorting efficiency.

6.3.3 Identification and Enumeration of Benthic Macrofauna

Randomly selected 10% of all identifications were reviewed by a second taxonomist. Individual taxa were compared to an extensive in-house reference collection and a voucher collection of identified species was established. Additionally, names of identified species were compared to species reported from other investigations of Caribbean / southwest Atlantic macrofauna, and with the scientific literature for similar latitudes and water depths.

7 DISCUSSION AND CONCLUSIONS

The offshore Guyana EBS area is relatively isolated from coastal activities, and at present is removed from other offshore oil and gas operations. Potential impacts to the marine environment from offshore petroleum development are unlikely to be significant if they are restricted to the immediate development area. However, there is the potential for transport of drilling and operation-related substances into sensitive areas of nearshore shallow zones from the longshore North Brazil Current (NBC) that flows north along the northeastern coast of South America, as it passes Guyana. In addition, the environment may be vulnerable to offshore transport of substances from the Essequibo River, which could project a freshwater lens to Stabroek Block surface waters during periods of heavy flow. Metal and hydrocarbon concentrations in offshore sediments and water are some of the lowest reported worldwide. However, increased industrialization of onshore areas, or localized activities associated with oil and gas exploration and production could contribute to pollutants offshore.

The observed patterns of variance in key physical, chemical, and biological parameters have general implications for environmental monitoring design. Under observed conditions, minor chemical perturbations to the seafloor from drilling operations will be discerned in the local environment within Liza and Sorubim areas of the Stabroek Block. Based upon the current set of data, hydrocarbons (i.e., total PAH and total resolved SHC) are the best indicators of chemical impact. This is due to their potential source from drilling activities as well as their extremely low concentrations and strong positive correlations with fine-grained sediment and organic carbon content.

Benthic macrofauna at Liza and Sorubim are characterized by low abundances combined with high diversity, and low dominance by specific groups. Numerically prevalent groups include polychaete worms, pelecypod molluscs and pericarid crustaceans, as is typical of slope-depth sediments worldwide. The respective average abundances of 116 m^{-2} and 100 m^{-2} are amongst the lowest values reported from continental slope sediments. This result indicates low primary productivity in overlying surface waters, as indicated by corresponding sediment total organic carbon concentrations of approximately 0.5%.

While total abundances were similar between the sites, polychaetes were relatively more abundant at Liza, while mollusks prevailed at Sorubim. Crustaceans were more common and abundant at Liza. The 51 and 41 respective families identified at Liza and Sorubim are typical of continental slope habitats over wide geographic ranges of the world's oceans that are not limited by oxygen depletion, organic loading, or other unique conditions.

The majority of families were represented by no more than two individuals per station, suggesting a low level of group dominance, and indicating that higher sampling density would be required to adequately characterize local or regional diversity.

The results of the Liza and Sorubim site surveys did not indicate the presence of any unique or atypical habitat for the region under consideration. Thus, should any localized potential impact from drilling activities occur, they are unlikely to pose a significant threat to overall population maintenance of the resident biota in the region.

Based upon the current set of data, while abundances of major taxonomic and selected indicator species may be sensitive to drilling-related impacts, taxonomic diversity (e.g., family diversity) would likely provide the best indicator due to its conservative nature (low variability) and responsiveness to environmental perturbations.

Little information concerning temporal variability in macrofauna from this region is available. Therefore, direct comparison of pre- and post-drilling conditions to quantify impacts from exploration activities should be avoided. Instead, inference of drilling-related effects should be based on statistically-based gradient analysis between point sources and references sites that are removed from potential impacts.

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APPENDIX F – 2016 EBS

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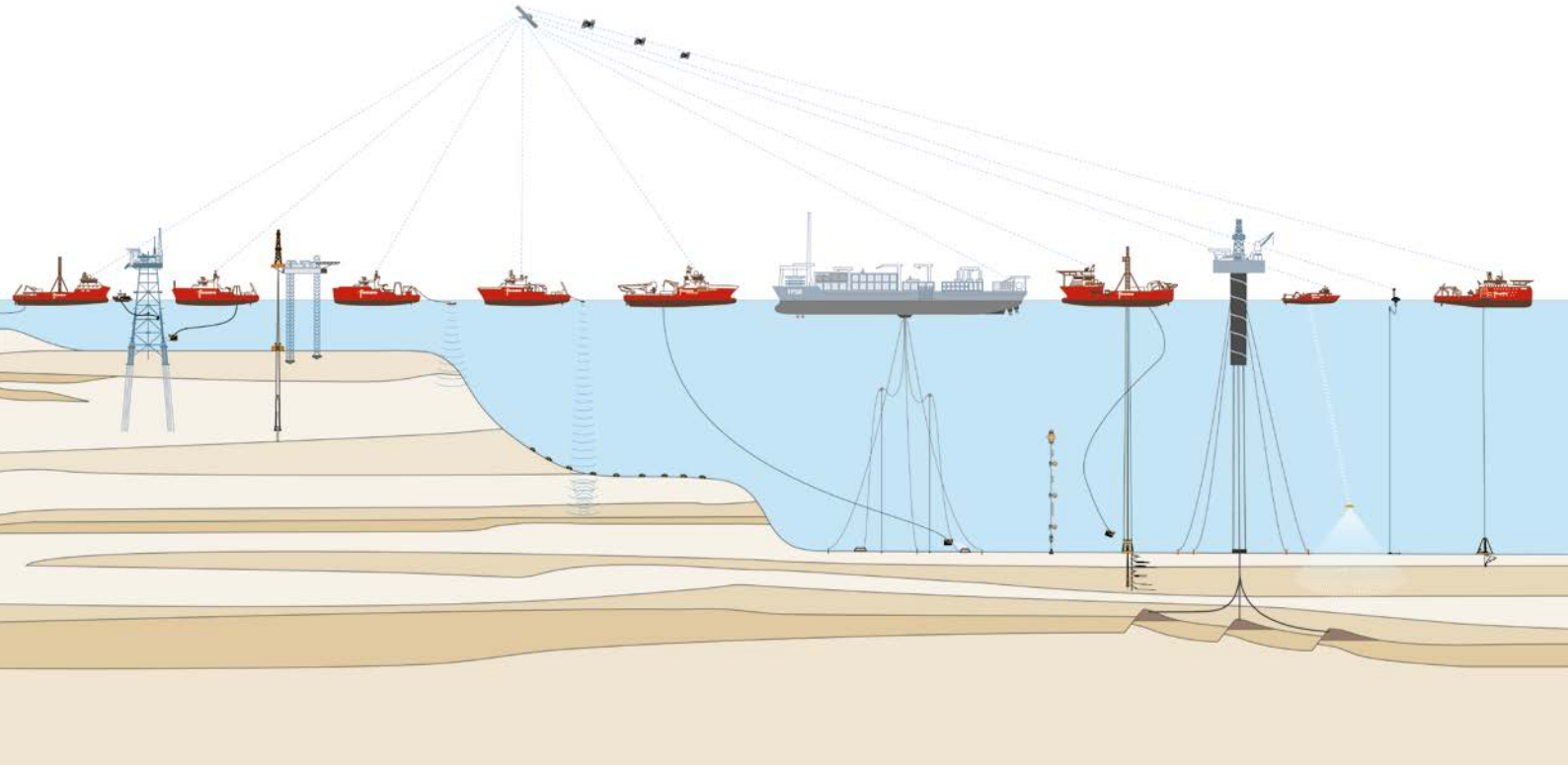
Environmental Baseline Survey Report
Liza Development, Offshore Guyana
4 March to 19 March 2016

Environmental Baseline Survey Report

Fugro Job No. 2415-3066-EBS
Esso Exploration and Production Guyana Limited

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Environmental Baseline Survey Report
Liza Development, Offshore Guyana

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Environmental Baseline Survey Report

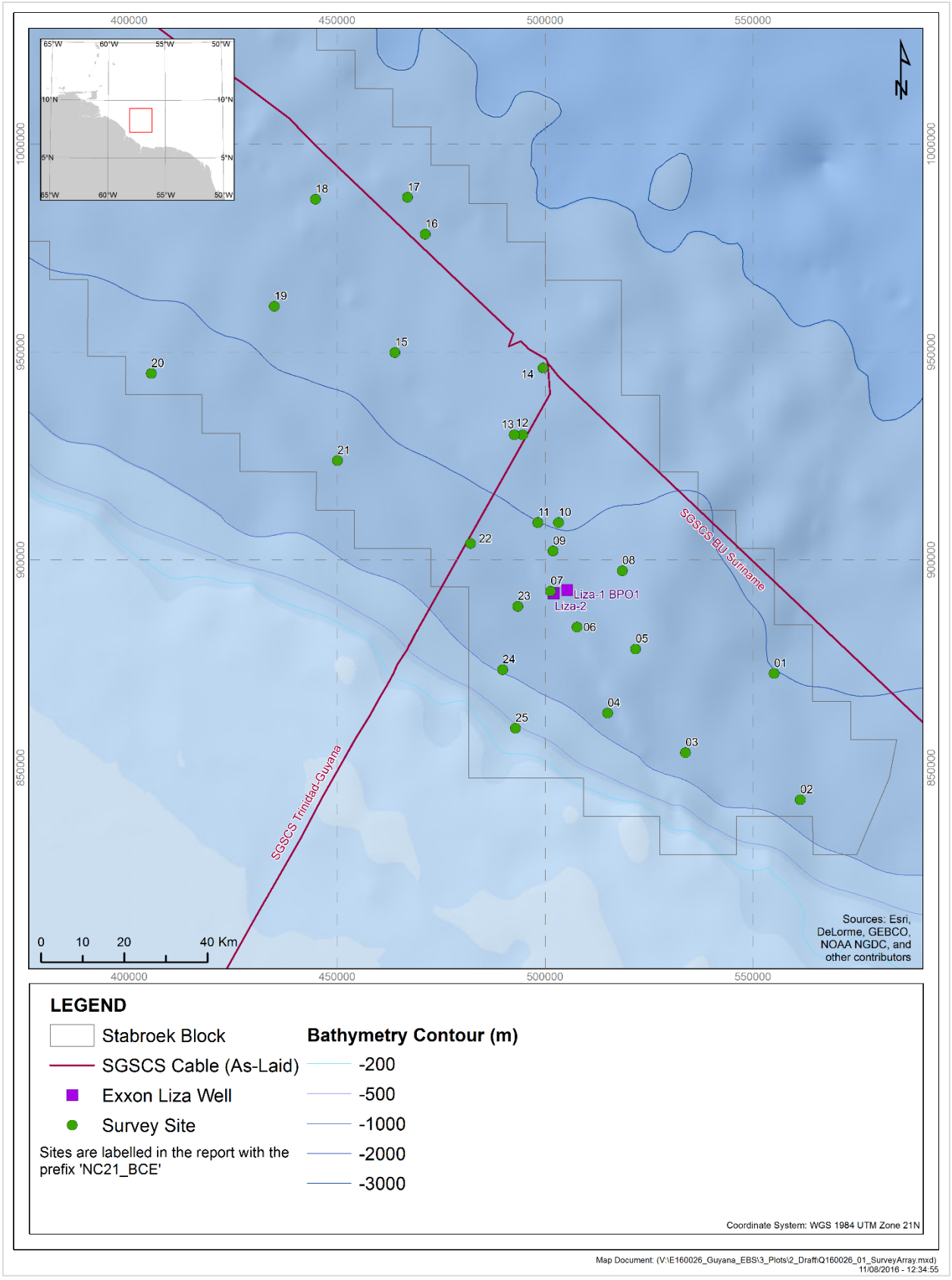
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EXECUTIVE SUMMARY

On the instruction of Esso Exploration and Production Guyana Limited (EEPGL), Fugro GeoServices Incorporated (FGSI) and Fugro EMU Limited (Fugro EMU) performed a detailed integrated site investigation program covering the Liza-1 Deepwater Field within the Stabroek area, offshore of Georgetown, Guyana.

The main objective of the Environmental Baseline Survey (EBS) was to acquire sufficient environmental data so as to describe all habitats recorded within the Stabroek Block and to identify and delineate the extent of any potentially sensitive habitats or species, if present. The results of the survey will act as a basis for comparison with subsequent data from environmental monitoring programs, and highlight potential sensitive areas. The EBS aim was fulfilled through the acquisition of water and seabed sediment samples, which were subsequently analysed with respect to physico-chemical and biological characteristics. Sediment grab sampling was performed at 25 locations to establish the physico-chemical and biological properties of the sediment at pre-determined locations. Water quality was also assessed through in-situ monitoring of water column profiles at 15 locations, which provided information on a range of physico-chemical parameters of the seawater.

Seabed sediments across the survey area comprised predominantly of sandy mud, muddy sand and, to a lesser extent, mud, one station also consisted of slightly gravelly sandy mud. Mud content was high, averaging 60.8% across the survey area. Sand content averaged 39.1% across the survey area, and gravel was absent except at one station (NC21_BCE025). Organic content in the form of Total Organic Carbon was low and no pattern of spatial distribution was identified.

Total hydrocarbon concentrations (THC) were considered to be at low levels across the survey area. Higher levels of THC were associated with finer sediments. Concentrations of THC were below 5 $\mu g g^{-1}$ at all stations and were consistent with background concentrations reported in other studies.

Of the seabed sediment metals analysed in this study, aluminium was dominant, and its concentration consistently higher than that of iron. Mean metal concentrations across the survey area were generally at low levels. Individual metal concentration at each sampling station were also generally below the comparative standards used in this study (NOAA ERL's and Canadian Sediment Quality Guidelines). However, arsenic, nickel, copper and lead all exceeded NOAA ERL values at some of the stations within the survey area (10, 2 and 1 stations respectively for each metal).

Analysis of the photographic data collected by the SPI camera identified one biotope complex as defined by the European Union nature information service habitat classification system (EUNIS, 2015), 'circalittoral sandy mud' (A5.35) with aspects of 'Deep sea mud' (A6.5). No potentially sensitive habitats were identified in the current survey.

Results from the seabed sediment samples showed macrofaunal communities within the survey area to be rich and diverse, with abundances fairly evenly distributed across the taxa recorded. Of the environmental parameters assessed, there were no strong correlations between any parameter and macrofaunal communities.

Macrofauna were dominated by polychaete worms, followed by crustaceans, whereas molluscs were poorly represented and comprised mainly bivalves. Results of the multivariate analysis identified four clusters of stations and two unclassified stations across the entire survey area.

Results of the water profiles showed a stratified water column, with similar profiles being seen at all stations, however the depth of the thermocline, halocline and oxygen boundary layer increase proportionally with water depth. Values of dissolved oxygen at shallower depths are near oxygen saturation, with oxygen levels decreasing with increasing depth across the survey area.

SUMMARY OF SURVEY RESULTS

Location:

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W				
Location	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**
Liza-1	505 213.49	892 693.82	08° 04′ 33.40″ N	056° 57′ 09.65″ W
Liza-2	501 965.60	891 960.90	08° 04′ 09.54″ N	056° 58′ 55.78″ W

Study Area: Environmental surveys were completed over the 640 km2 Liza field development area, located offshore of Georgetown, Guyana.

Survey Strategy: Box coring and sediment profile imaging (SPI) were proposed at 25 stations. Conductivity, temperature and depth (CTD) data and water samples were also proposed at 15 of these stations. All box core, CTD and water samples were successfully collected. The SPI camera was required to collect plan view and profile images from each station. Plan view images were successfully collected from nine stations and profile images were successfully collected from 11 stations.

All stations were selected by the client, taking into consideration stations previously sampled for an EBS prepared by Maxon Consulting and TDI Brooks in 2014, planned areas of the block associated with current and future exploration, appraisal and potential development activities, with the desire to further characterize the marine environment within the block.

Bathymetry: Depths in the EBS area ranged from 200 m below lowest astronomical tide (LAT) in the south-west to 2800 m below LAT in the north-west. Depths of the geophysical survey ranged from 105 m to 1875 m.

Seabed Features: Depressions were observed sporadically across the site. The majority of the seabed was found to comprise muddy sands or sandy muds with varying quantities of shell material.

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ABBREVIATIONS

Al	Aluminium
ARPD	Apparent Redox Potential Discontinuity
AUV	Autonomous Underwater Vehicle
BAC	Background Assessment Concentration
BC	Background Concentration
BHQ	Benthic Health Quality
CCC	Criterion Continuous Concentration
CEMP	Coordinated Environmental Monitoring Programme
CMC	Criterion Maximum Concentration
CPI	Carbon Preference Index
CM	Central Meridian
CTD	Conductivity, Temperature and Depth
CV-AFS	Cold Vapour Atomic Fluorescence Spectroscopy
DCM	Dichloromethane
DNA	Deoxyribonucleic acid
DO	Dissolved oxygen
DTI	Department of Trade and Industry
EBS	Environmental Baseline Survey
EPA	United States Environmental Protection Agency
ERL	Effects Range Low
ERM	Effects Range Median
EUNIS	European Nature Information Service
FA/FB	Fauna Sample A/Fauna Sample B
FGSI	Fugro GeoServices Incorporated
FTU	Formazin Turbidity Unit
GC	Gas Chromatography
GC-MS	Gas Chromatography - Mass Spectrometry
GC-FID	Gas Chromatography - Flame Ionisation Detection
H'(log_2)	Shannon-Wiener Diversity Index
GNSS	Global Navigation Satellite System
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICP-OES	Inductively Coupled Plasma Optical Emission Spectroscopy
J'	Pielou's Evenness
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LOI	Loss on Ignition
MBES	Multibeam Echosounder
MDS	Multi-dimensional Scaling
Min	Minimum
max	Maximum
mV	Millivolts
N	Total Individuals

nC_{12-20}	Alkanes ranging from carbon numbers 12 to 20
nC_{21-36}	Alkanes ranging from carbon numbers 21 to 36
nC_{12-36}	Alkanes ranging from carbon numbers 12 to 36
ngg^{-1}	Nanograms per gram
nMDS	Non-metric Multidimensional Scaling
NMBAQC	National Marine Biological Analytical Control Scheme
NOAA	United States National Oceanic and Atmospheric Administration
NPD	Naphthalene, Phenanthrene, Anthracene and Dibenziothene
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polycyclic Aromatic Hydrocarbons
PC	Physico-chemical (grab sub-sample)
PCA	Principal Components Analysis
PSD	Particle Size Distribution
Ph	Phytane
pH	Measure of acidity (Power of Hydrogen)
ppt	Parts per thousand
PRIMER	Plymouth Routines in Multivariate Ecological Research
Pr	Pristane
QA	Quality Assurance
QC	Quality Control
SBP	Sub-bottom Profiler
SBR	Sediment Boundary Roughness
SD	Standard Deviation
SIMPER	Similarity Percentage Index
SPI	Sediment Profile Imaging
SSS	Sidescan sonar
stdev	Standard Deviation
TEL	Total Exposure Limits
THC	Total Hydrocarbon Concentration
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UCM	Unresolved Complex Mixture
UHF	Ultra High Frequency
UKAS	United Kingdom Accreditation Service
UTM	Universal Transverse Mercator
WAS	Wilson Auto-Siever
WGS84	World Geodetic System 1984
λ	Simpson's Dominance Index

CONTENTS

1.	**INTRODUCTION AND SCOPE OF WORK**	**1**
1.1	Scope of Work	1
1.1.1	Geophysical Survey	1
1.1.2	Environmental Survey	1
1.2	Geodetic Parameters	2
2.	**METHODS**	**4**
2.1	Environmental Survey Strategy	4
2.2	Survey Methods	7
2.2.1	Combined Water Sampling and Profiling	7
2.2.2	Deployment and Recovery	7
2.2.3	Water Profile Processing	7
2.2.4	Water Sample Processing	8
2.3	Seabed Video/Photography	8
2.4	Sediment Grab Sampling	10
2.5	Physico-chemical Sample Processing	11
2.6	Macrofauna Sample Processing	11
2.7	Laboratory and Analytical Methods	12
2.7.1	Particle Size Analysis	12
2.7.2	Organic Carbon Content	13
2.7.3	Hydrocarbon Analysis	13
2.7.4	Heavy and Trace Metals	13
2.7.5	Macrofauna	14
3.	**RESULTS**	**17**
3.1	Field Operations	17
3.2	Bathymetry	22
3.2.1	Seabed Features	22
3.3	Sediment Particle Size Distribution and Organic Content	25
3.3.1	Particle Size	25
3.3.2	Total Organic Carbon	25
3.3.3	In Situ Sediment Parameters	25
3.4	SPI Results	30
3.5	Sediment Hydrocarbons	31
3.6	Sediment Heavy and Trace Metals	45
3.6.1	Sediment Heavy Metals	45
3.7	Seabed Habitats and Epifauna	50
3.7.1	Potentially Sensitive Habitats	50
3.8	Macrofauna	52
3.8.1	General Description of Phyletic Composition	52
3.8.2	Ranked Abundance and Dominance	53
3.8.3	Species Accumulation and Richness Estimation	54

3.8.4 Primary Variables and Diversity 55
3.9 Water Samples 59
3.9.1 Water Profiling 59
3.9.2 Water Total Organic Carbon (TOC) 62
3.9.3 Total Suspended Solids (TSS) 63
3.9.4 Water Hydrocarbons 63
3.9.5 Water Heavy and Trace Metals 77

4. DISCUSSION 80

5. REFERENCES 84

APPENDICES

A. PERSONNEL

B. METHODS

C. LOGS

D. PARTICLE SIZE ANALYSIS AND GRAB PHOTOGRAPHS FOR SEDIMENTS

E. SPI REPORT

F. HYDROCARBON ANALYSIS FOR SEDIMENTS

G. MACROFAUNA ANALYSIS FOR SEDIMENTS

H. CORRELATIONS FOR SEDIMENTS

I. WATER PROFILES

J. HYDROCARBONS FOR WATERS

TABLES IN THE MAIN TEXT

Table 1.1: Proposed Well Locations 1
Table 1.2: Project Geodetic Parameters 3
Table 2.1: Proposed Environmental Survey Stations 4
Table 3.1: Overview of all Completed Sampling 17
Table 3.2: Summary of Sediment Particle Size Distribution Data 26
Table 3.5: Summary of Hydrocarbon Results [µgg^{-1} dry weight] 32
Table 3.6:Polycyclic Aromatic Hydrocarbons (PAH) Concentrations [ngg^{-1}] 35
Table 3.9: Individual PAH Concentrations [ngg^{-1} dry weight] 38
Table 3.10: USEPA Specified PAH Concentrations [ngg^{-1} dry weight] 42
Table 3.11: Heavy and Trace Metal Concentrations [µgg^{-1} dry weight] 48
Table 3.12: Heavy and Trace Metal Concentrations Normalised to 5% Al [µgg^{-1} dry weight] 49
Table 3.13: Abundance of Major Taxonomic Groups 53
Table 3.14: Dominant Taxa and Dominance Rank for Stations [0.1m^2] 54
Table 3.15: Primary Variables and Diversity Indices by Sample [0.1 m^2] 56
Table 3.17: Summary of Water Physical Parameters Recorded by Water Column Profiles 61
Table 3.18: Summary of Water Total Organic Carbon 62
Table 3.19: Summary of Water Total Suspended Solids 63
Table 3.20. Total Hydrocarbon in water samples 64
Table 3.21: Summary of the Organic Compounds Concentrations in the Water Samples 65
Table 3.22: Individual n-Alkanes Average Concentrations at Each Site [ngl^{-1} of Water] 67
Table 3.23: Concentrations of all 16 PAHs (ng/l Water) 71
Table 3.24: Individual PAH Concentrations [per Station ngl^{-1}] 73
Table 3.25: Summary of Water Sample Heavy Metal Analysis 78

FIGURES IN THE MAIN TEXT

Figure 2.1: Survey array for the Stabroek area (provided by EEPGL) 6
Figure 3.1: Survey area bathymetry and environmental survey stations 24
Figure 3.2: Spatial distribution of sediment characteristics 28
Figure 3.3: Spatial distribution of total organic carbon 29
Figure 3.8: Spatial distribution of total hydrocarbon (THC) concentrations [ugg^{-1}] 34
Figure 3.11: Example of parent/alkyl distribution - station NC21_BCE001 40
Figure 3.12: Example of parent/alkyl distribution - station NC21_BCE019 40
Figure 3.14: Spatial distribution of barium concentrations [ugg^{-1}] 46
Figure 3.15: Spatial distribution of arsenic concentrations [ugg^{-1}] 47
Figure 3.16: Abundance of major taxonomic groups 53
Figure 3.18: Spatial distribution of number of taxa (S) [0.1 m^2] 57
Figure 3.19: Spatial distribution of number of individuals (N) [0.1 m^2] 58
Figure 3.22: Water column profile at sampling station NC21_16WC002 60

PLATES IN MAIN TEXT

Plate 3.1: Example seabed photographs 51

1. INTRODUCTION AND SCOPE OF WORK

On the instruction of Esso Exploration and Production Guyana Limited (EEPGL), Fugro GeoServices Incorporated (FGSI) and Fugro EMU Limited (Fugro EMU) performed a detailed integrated site investigation program covering the Liza Field Development Area within the Stabroek area, offshore of Georgetown, Guyana.

The coordinates for the proposed well locations Liza-1 and Liza-2 are displayed in Table 1.1. The survey involved geophysical autonomous underwater vehicle (AUV) data acquisition, a geohazard/geotechnical survey, and an Environmental Baseline Survey (EBS). Each of these activities was undertaken separately, the EBS was conducted onboard the RV Fugro Americas between 4 March and 19 March 2016.

This report provides details of environmental operations and presents a detailed analysis and interpretation of all data collected.

Table 1.1: Proposed Well Locations

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W				
Location	**Easting [m]**	**Northing [m]**	**Latitude**	**Longitude**
Liza-1	505 213.49	892 693.82	08° 04′ 33.40″ N	056° 57′ 09.65″ W
Liza-2	501 965.60	891 960.90	08° 04′ 09.54″ N	056° 58′ 55.78″ W

1.1 Scope of Work

1.1.1 Geophysical Survey

The geophysical survey was undertaken to provide information on seafloor and near-seafloor geological conditions within the Liza Field Development survey area. Geophysical data are used to identify any potential hazards, constraints and cultural resources that may impact the design and placement of the planned subsea installations and flowlines.

The geophysical data were collected using a high-resolution Autonomous Underwater Vehicle (AUV) including multibeam echo sounder (MBES), sidescan sonar (SSS) and chirp sub-bottom profiler (SBP), and a hull-mounted MBES and SBP.

1.1.2 Environmental Survey

The main objective of the environmental survey was to acquire environmental data in order to describe all the habitats and characteristic species recorded within the study area. The information recorded was used to: identify and delineate the extent of any potentially sensitive habitats and/or species, if present; to describe baseline conditions of the physico-chemical and biological properties of the sediment and water column at key locations and to expand and build on the knowledge gained from sampled stations in the previous EBS prepared by Maxon Consulting and TDI Brooks in 2014, which focused on the Liza and Sorbium Areas.

The EBS survey was designed to assess a broader range of the Stabroek Block covering a variety of water depths and corresponding potential marine habitats, to further characterize these as well as the Liza Area of Interest. This report presents the results of the environmental baseline survey.

1.2 Geodetic Parameters

All coordinates detailed in this report are referenced to the World Geodetic System 1984 (WGS84) datum and Universal Transverse Mercator (UTM) Projection Zone 21 North, Central Meridian (CM 57ºW). Detailed geodetic and projection parameters are provided in Table 1.2.

Table 1.2: Project Geodetic Parameters

Global Positioning System Geodetic Parameters [1]							
Datum:	World Geodetic System 1984 (WGS84)						
Spheroid:	World Geodetic System 1984						
Semi major axis:	a = 6 378 137.000 m						
Reciprocal flattening:	1/f = 298.257 223 563						
Local Geodetic Datum Parameters							
Datum:	World Geodetic System 1984 (WGS84)						
Spheroid:	World Geodetic System 1984						
Semi major axis:	a = 6378137.00000m						
Reciprocal flattening:	1/f = 298.2572236						
Datum Transformation Parameters from WGS84 to WGS84 [2]							
Shift dX:	0.00	m	Rotation rX:	0.00	arc sec	Scale Factor:	-1.200 ppm
Shift dY:	0.00	m	Rotation rY:	0.00	arc sec		
Shift dZ:	0.00	m	Rotation rZ:	0.00	arc sec		
Project Projection Parameters							
Grid Projection:	Universal Transverse Mercator, Northern Hemisphere						
UTM Zone:	21 N						
Central Meridian:	57° 00′ 00″ West						
Latitude of Origin:	00° 00′ 00″ North						
False Easting:	500 000 m						
False Northing:	0 m						
Scale factor on Central Meridian:	0.9996						
Units:	metre						

Notes:
1. Fugro Starfix navigation software always uses WGS84 geodetic parameters as a primary datum for any geodetic calculations
2. This is the right-hand coordinate frame rotation used by the Fugro Starfix navigation software

2. METHODS

The following section provides an overview of survey, analysis, and interpretation methods.

2.1 Environmental Survey Strategy

Box coring and sediment profile imaging (SPI) were proposed at 25 stations, of which 15 were selected for conductivity temperature and depth (CTD) data and water samples. Collection of water samples was proposed at the surface, below the thermocline and at the bottom of the water column, close to the sediment surface. The coordinates, data to be acquired and rationale for each location are provided in Table 2.1, and displayed spatially in Figure 2.1. Acceptable sampling accuracy was agreed with the client representative to be within ≤ 50 m of the target location for box cores and ≤100 m for CTD/water samples given the currents and counter currents that can be experienced in the Stabroek Block, Offshore Guyana. The survey array for the Stabroek area, including all sampling undertaken, well locations and boundaries, is illustrated in Figure 2.1. At each station water and sediment samples were also collected to support potential environmental DNA analysis that was being planned by the client.

Table 2.1: Proposed Environmental Survey Stations

Stations	Easting [m]	Northing [m]	Sample Acquisition
NC21_16BCE001	555 087.5	872 666.7	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE002	561 362.9	842 298.1	PC, FA, FB, DNA, plan and profile view photographs, CTD, water column samples
NC21_16BCE003	533 722.2	853 586.9	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE004	515 005.1	863 106.6	
NC21_16BCE005	521 741.0	878 532.9	PC, FA, FB, DNA, plan and profile view photographs, CTD, water column samples
NC21_16BCE006	507 683.0	883 790.0	
NC21_16BCE007	501 316.1	892 438.6	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE008	518 555.0	897 354.7	PC, FA, FB, DNA, plan and profile view photographs, CTD, water column samples
NC21_16BCE009	501 900.3	902 086.7	
NC21_16BCE010	503 234.0	908 943.0	
NC21_16BCE011	498 234.0	908 950.9	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE012	494 587.2	930 071.3	PC, FA, FB, DNA, plan and profile view photographs, CTD, water column samples
NC21_16BCE013	492 587.2	930 071.3	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE014	499 542.0	946 110.0	
NC21_16BCE015	463 847.9	949 827.0	PC, FA, FB, DNA, plan and profile view photographs, CTD, water column samples
NC21_16BCE016	471 156.5	978 303.6	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE017	466 847.0	987 164.0	PC, FA, FB, DNA, plan and profile view photographs, CTD, water column samples
NC21_16BCE018	444 776.4	986 730.1	PC, FA, FB, DNA, plan and profile view photographs
NC21_16BCE019	434 883.5	960 957.7	
NC21_16BCE020	405 291.3	944 807.2	PC, FA, FB, DNA, plan and profile view photographs, CTD, water

Stations	Easting [m]	Northing [m]	Sample Acquisition
NC21_16BCE021	450 032.4	923 884.0	column samples
NC21_16BCE022	482 055.8	903 906.1	
NC21_16BCE023	493 428.0	888 781.0	
NC21_16BCE024	489 763.6	873 528.2	
NC21_16BCE025	492 834.0	859 481.8	

Notes:
PC = Physico-chemical sample
FA = Fauna sample A
FB = Fauna sample B
DNA = Deoxyribonucleic acid sample

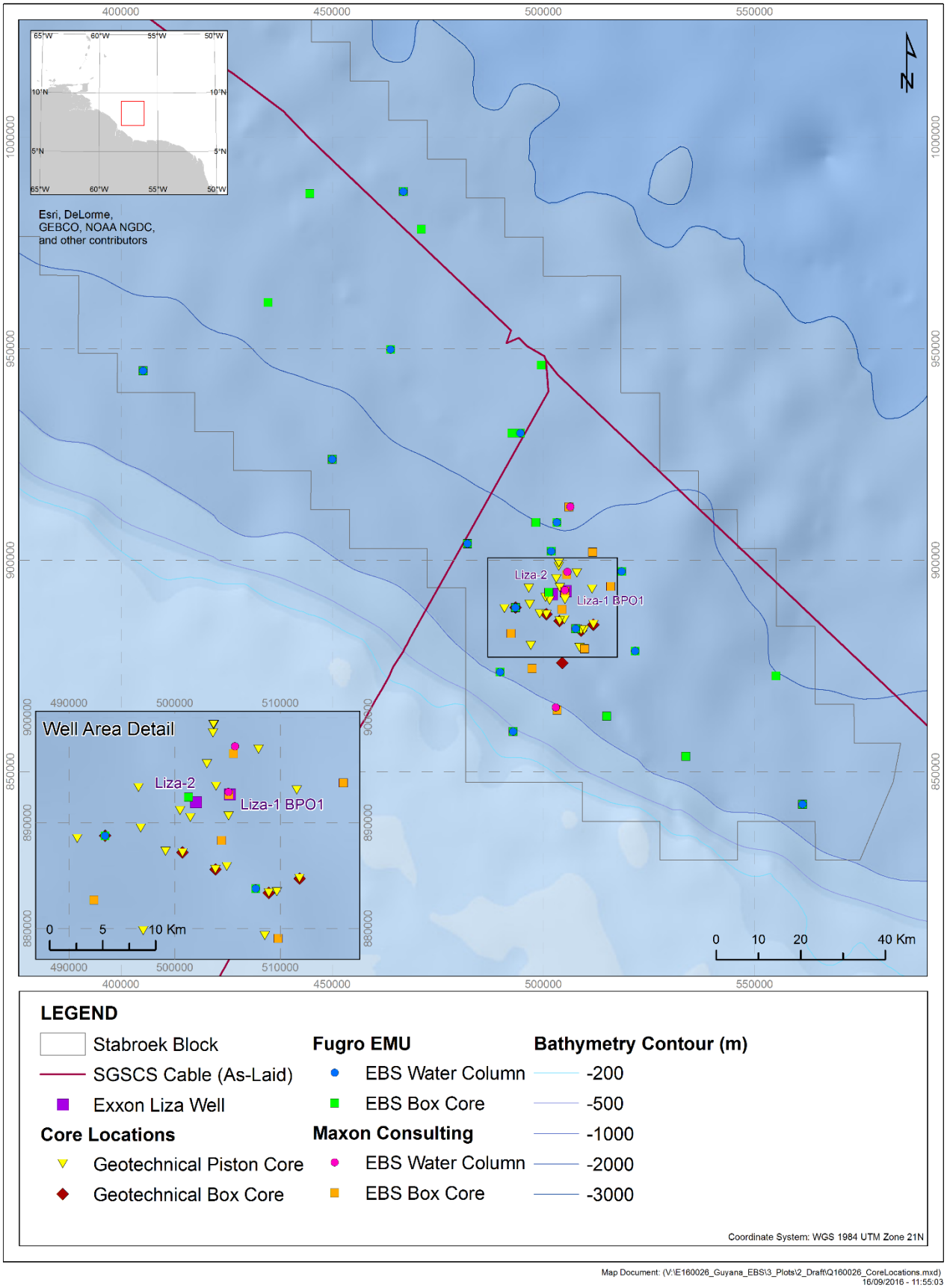


Figure 2.1: Survey array for the Stabroek area (provided by EEPGL)

2.2 Survey Methods

2.2.1 Combined Water Sampling and Profiling

The following procedure describes the deployment and recovery of the Valeport 606+ deepwater CTD and simultaneous deployment and recovery of 5 litre Niskin water samplers. This section also describes the subsequent uploading and processing of water profile data and handling of water samples.

2.2.2 Deployment and Recovery

The CTD and Niskin water samplers were deployed using the following methodology:

- The CTD was set up to record conductivity, temperature, depth, turbidity, pH and dissolved oxygen (DO). Both the pH and DO sensors were calibrated onboard prior to survey operations;
- After calibration the data output from the CTD underwent a visual check to ensure that the readings were accurate and the pH and DO sensors had not drifted after calibration;
- At each station the initial drop had a clump weight, beacon, CTD and six 5 litre Niskin water samplers attached to the lifting wire at intervals coinciding with the bottom three sampling depths;
- The Niskin bottles were armed and a messenger weight suspended under each sampler except the bottom one. The messenger weights were rigged so that once the first Niskin was triggered a domino effect would take place triggering those suspended below;
- The equipment was deployed over the stern using the A-frame;
- Once deployed the CTD was held at the surface for a period of approximately five minutes to allow the profiler to acclimatise to environmental conditions;
- The equipment was then lowered to the desired depth at a rate of 0.5 m s^{-1} to 1.0 m s^{-1}. When at the desired depth deployment stopped and a messenger weight was attached to the lift wire. The weight was then released to trigger the samplers;
- A conservative fall rate was used to determine release time after which a positional fix for the bottom sample was taken by the surveyor;
- The equipment was then recovered to deck with each item of equipment being removed from the wire as it paid in;
- The Niskin samplers were set to sample at three depths the surface (10 m), below the thermocline and 20 m above the seabed.

2.2.3 Water Profile Processing

The CTD was rinsed with clean water immediately after deployment – the plug area was dried after rinsing. Data were uploaded from the unit (.dat format) and translated into a text file (.000 format) with the pressure tare applied. These raw data were backed up to hard drive immediately.

The translated data were copied into Water Profile QA.xls and data quality checked. The following acceptance criteria applied:

- All data must be within expected values for seawater (e.g. pH = 7.8 to 8.5; DO = approximately 100 % at surface and declines with depth);
- Data should be collected for the duration of both the down and up casts;
- Data should be consistent between down and up casts.

Occasional spikes in data (due to sensor interference) are acceptable as is some variation in readings at depths where profiler is stationary (i.e. where Niskin water samplers fitted or samples taken); this occurs due to mixing effects, which the fast response DO meter is particularly susceptible to.

2.2.4 Water Sample Processing

The Niskin water samplers were cleaned after each deployment, after the following subsamples were collected:

- Nutrient samples A and B were collected at each depth and stored in 1 litre plastic bottles at – 20 ºC;
- Heavy metal samples A and B were collected at each depth and stored in 125 ml plastic bottles at between 4 ºC and 6 ºC;
- Two total suspended solid (TSS) sample was collected at each depth and stored in 1 litre plastic bottles at – 20 ºC;
- Samples to be tested for Mercury (A and B) were collected at each depth and stored in 100 ml glass bottles at between 4 ºC and 6 ºC. The samples were preserved in 5 ml 17 % Hydrochloric acid;
- Additional DNA samples A, B and C were filtered through a cleaned peristaltic pump, stored in individual frozen plastic bags, in accordance with the client's DNA Seawater and Sediment Sampling Protocol.

2.3 Seabed Video/Photography

Seabed profile and plan view images were acquired using an AquaFact SPI camera system mounted within a purpose-built camera frame complete with two high resolution stills cameras and flashes, one for taking profile images and one for taking plan view images. Stills were captured to the cameras internal memory card and downloaded upon recovery to verify image quality was sufficient.

Operational procedures for seabed photography were as follows:

- The condition of the SPI camera was checked and confirmed by the Environmental Shift Leader on deck;
- All mechanisms were checked thoroughly prior to deployment;

- Areas of particular interest included:
  - Status of all bolts and ensured that they are tight;
  - All weights were checked that they were secure and split rings present by visually and manually inspecting them;
  - All cables were inspected for damage/fraying;
  - All components were checked to be fitted correctly;
  - All plugs were checked to be in deployment position.
- Once confirmed, the environmental shift leader tested the camera once more;
- Two guide ropes were attached, if required, to the SPI camera frame away from potential snags;
- When all personnel were in place (non-seaward side), the person designated for communications informed the bridge as to the status on deck, and informed them that they wished to deploy. This decision was based on many factors including acceptable distance from target;
- Only when the bridge gave clearance deployment commenced;
- The SPI camera frame was slowly raised and held so that the lifting wire took up the weight of the unit. At this point the safety pins were removed from the system;
- With the safety pins removed, the camera frame was slowly raised to clear the bulwark. The frame was not raised more than necessary for manoeuvring it over the side;
- If attached, the guide ropes each side were pulled taut to control the swing;
- When over the side and clear of the vessel, the camera frame was lowered to the water as quickly as possible to minimise the opportunity for swinging and knocking into the ship and damaging ship and equipment;
- On reaching the sea surface, any steadying ropes were retrieved;
- Following confirmation from the Bridge, the frame was lowered to within 10 m of the seabed and stopped;
- Final confirmation of position was sought from the bridge. Once confirmed, the frame was gently lowered to the seabed at a nominal speed of ~20 m/min. (This is important as it ensures the integrity of the surface of the sample);
- The Environmental Shift Leader then confirmed a fix with the Surveyor;
- Once the system was on the seabed a surface shot was taken;
- When in contact with the seabed the system remained undisturbed (slack cable) for 30 seconds. During this time, the central carriage of the frame slowly lowered itself into the sediment, taking an image of the vertical profile sectioned and begun a resetting count;
- After each picture, the system was lifted clear of the seabed (approximately 15 m) and held for 40 seconds before lowering it to the seabed again where it re-entered the sediment for another photograph. A separate fix was taken with each camera penetration.

Camera recovery procedures were as follows:

- The camera frame was recovered through the water column at the maximum winch speed, slowing the rate of recovery down ~25 m prior to the unit breaking the surface;
- Once at the surface, the unit was brought close in to the side of the ship to minimise any pendulum action. The unit was hauled up the side of the ship to a height where ropes could be put around the frame if necessary. Care was taken not to strike the side of the vessel with any force (care of ship/equipment). All this was coordinated by the Communications Deck Officer who liaised with the rope handlers and winch/crane operator as to when the frame was steady and the winch was stopped. The ropes were then safely put around the frame;
- Once secured, the frame was gently raised inboard, maintaining control with the guide ropes at all times;
- The camera frame was lowered onto a clear area of deck and the safety pins replaced. Care was taken to retain some tension on the lifting wire to enable the insertion of the safety pins and to prevent camera damage;
- The frame was tied off to provide stability.

2.4 Sediment Grab Sampling

Seabed samples were acquired using a USNEL 0.25 m^2 box core.

Operational procedures for grab sampling were as follows:

- The USNEL 0.25 m^2 box core was prepared for operations prior to arrival on station. An ultra-short baseline (USBL) beacon was attached to the box core frame. The Bridge communicated to the deck via an ultra-high frequency (UHF) radio when the vessel was steady and on location, and the box core was deployed from the starboard crane and lowered to the seabed using the starboard winch;
- When the engineer operating the winch observed that the box core had reached the seabed (evidenced through a distinct slackening of the wire rope and snatch block), the on-line surveyor was informed (via UHF radio) and a fix was taken;
- On recovery to the deck, the sample was inspected and judged acceptable or otherwise (see below for rejection criteria);
- The sample was subsampled into two 0.1 m^2 fauna and one physico-chemical samples, which were retained for analysis;
- Deck logs were completed for each sample acquired (including no samples) with: date, time, sample number, fix number, sediment type, depth and colour of strata in the sediment (if any) using Munsell colour codes, odour (i.e. H_2S), bioturbation or debris.

Samples were considered unacceptable in the following instances:

- Evidence of sediment washout caused through improperly closed scoop or inspection hatch;
- Sediment sample taken on an angle; where the box was not parallel to the seabed when it fired;
- Disruption of the sample through striking the side of the vessel;
- Sample represented less than 20 % of the grab's capacity (unless deemed acceptable by the client representative);
- Sample is more than 50 m from the target location, unless deemed acceptable by the client representative, particularly in deeper waters;
- Deemed unacceptable by the client representative for any other reason;
- Presence of Hagfish within the sample, as this species of fish produces mucilaginous slime which renders a sample unusable. Other sessile organisms or fish would not lead to discarding a sample unless exhibiting similar characteristics but the use of box cores is not designed to sample highly mobile fauna such as fish.

2.5 Physico-chemical Sample Processing

Sub-samples were taken from the surface of the sample while retained in the box core as follows:

- Hydrocarbon samples were collected using a metal scoop to a nominal depth of 2 cm. Samples collected were HC-A and HC-B. The samples were preserved in glass jars at -20 ºC;
- Heavy metal samples were collected using a plastic scoop to a nominal depth of 2 cm. Samples collected were HM-A and HM-B. The samples were preserved in polythene bags at – 20 ºC;
- Particle size samples were collected using a plastic scoop to a nominal depth of 5 cm. Samples collected were PSD-A and PSD-B. The samples were preserved in polythene bags at -20 ºC;
- Prior to any subsampling metal scoops was pre-cleaned using acetone;
- DNA samples were collected using a sterile plastic scoop to put approximately 5 g of sediment in three whirlpack bags to collect DNA A, B and C.

2.6 Macrofauna Sample Processing

Macrofauna samples were processed as follows:

- After the sediment had been described and photographed the top 20 cm was transferred into a 0.5 mm mesh sieve along with the remaining supernatant water;
- The sample was then transferred to the Wilson Auto Siever (WAS) for washing;
- Once the sediment had been removed the sample was transferred to containers labelled with the job number, station code, and fauna code (FA or FB depending on replicate) and

fixed in 10 % formal saline (a buffered 4% formaldehyde solution in seawater). The sample containers were then sealed, hazard labelled and stored securely on deck.

2.7 Laboratory and Analytical Methods

2.7.1 Particle Size Analysis

Sediment samples were analysed for particle size using wet, dry sieving and laser diffraction techniques. Data were expressed at 0.5 phi intervals. The phi scale is a logarithmic scale for expressing grain size, with negative phi numbers for grain sizes greater than 1000 µm and positive phi numbers for grain sizes less than 1000 µm.

Particle size data were interpreted from descriptive terms based on the Folk (The distinction between grain size and mineral composition in sedimentary rock nomenclature, 1954) classification. Aggregated data (based on the Wentworth (A scale of grade and class terms for clastic sediments, 1922) scale) of fines (<63 µm), sand (63 µm to 2 mm) and coarse (>2 mm) fractions, and sorting coefficient were also used to characterise and describe the data. The sorting coefficient, which ranges from 0 (very well sorted) to >4 (extremely poorly sorted) indicates the degree to which the particles are of uniform size.

Sediment particle size distribution statistics for each sample were calculated from the raw data using Gradistat V8 (Blott, 2010). Statistics used in the calculation of grain size parameters and associated descriptive terminology included mean, standard deviation, skewness and kurtosis. Calculation of median and mode provided information on the sediment sample distribution statistics together with a set of percentiles to include D_{10}, D_{50} and D_{90}. Monitoring the percentiles allows assessment of changes in the main particle size, as well as changes at the extremes of the distribution, which could be due to, e.g. the presence of fines, or oversized particles/agglomerates.

Correlation analysis between environmental variables was undertaken using the Spearman's correlation coefficient. This correlation analysis, based on ranks, allows characterising of the strength of relationships among a set of variables, without making assumption of linearity between variables (Clarke, Per. Comm., 2014). Correlation analysis provides an effective way of revealing the relationships between multiple variables.

Particle size data were further analysed by multivariate statistical methods. Multivariate analyses were undertaken using the Plymouth Routines in Multivariate Ecological Research (PRIMER) v6.0 statistical package (Clarke and Gorley, 2006). Data for the percentage composition within half phi unit sieve size classes were analysed by hierarchical agglomerative cluster analysis, using the Euclidean distance measure as recommended by Clarke and Gorley (2006). The Principal component analysis (PCA) was undertaken on the major sediment fractions data set (gravel, sand and mud) in order to identify spatial patterns and relationships between variables. The PSD dataset was 4^{th} root transformed to reduce the degree of skewness and bring the dataset as close to normal distribution as possible, which in turn allowed optimum performance of the multivariate analyses, (Clarke, Per. Comm., 2007).

2.7.2 Organic Carbon Content

Organic carbon content of the samples was analysed by measuring total organic carbon (TOC). TOC analysis involves pre-treatment with acid prior to quantitation (by non-dispersive infrared analysis of release CO_2), which liberates inorganic carbonates and thus yields an accurate estimate of organic carbon content. It should also be noted that TOC includes both labile (bio available) and refractory material, and may therefore correlate poorly with perceived biological impact (Loh, 2005).

2.7.3 Hydrocarbon Analysis

Hydrocarbon analysis of sediments was performed by UKAS accredited Fugro EMU laboratories. Samples for hydrocarbon analysis were extracted by ultrasonication with mixed solvents and the resulting extracts cleaned-up using absorption column chromatography. The extracts were analysed for total hydrocarbon content (THC), unresolved complex mixture (UCM), individual and total n-alkanes (nC_{12} to nC_{36}) and the subsequent carbon preference indices (CPIs) using gas chromatography and a flame ionisation detector (GC-FID). Aromatic hydrocarbons were analysed by gas chromatography with mass spectrometry (GC-MS).

The concentration of individual n-alkanes present in the sediments was determined by measuring the response of each component (nC_{12} to nC_{36}) by GC-FID. Standard solutions containing an appropriate range and amount of n-alkanes were run to calibrate the instrument and to acquire response factors for quantification purposes. Individual n-alkanes were quantified using a series of internal standards and summed to give a total n-alkane (nC_{12} to nC_{36}) value for each sediment sample. The total hydrocarbon material present was quantified using response factors calculated from the analysis of mixed oil standard solutions over an appropriate range while the UCM was determined by subtracting the area of all the resolved peaks from the total hydrocarbon area and applying the total hydrocarbon response factor.

The distributions and concentrations of 2 to 6 ring polycyclic aromatic hydrocarbons (PAHs) within the samples were analysed by GC-MS. Standard solutions containing an appropriate range and concentration of aromatic hydrocarbons were run to calibrate the instrument and acquire response factors for quantification purposes. Individual aromatic compounds were quantified using a series of deuterated internal standards to give a total 2 to 6 ring PAH value for the sediment samples. Total hydrocarbon concentration (THC), unresolved complex mixture (UCM) and individual n-alkanes (nC_{12} to nC_{36}) were analysed by gas chromatography with flame ionisation detection (GC-FID).

2.7.4 Heavy and Trace Metals

The majority of heavy and trace metals (arsenic, cadmium, chromium, copper, lead, nickel, vanadium, and zinc) were analysed following total metal digestion using hydrofluoric acid. Samples underwent near total digestions using hydrofluoric and boric acid for aluminium, barium, iron and Strontium. Mercury was determined following nitric acid and hydrogen peroxide digestion. The samples were treated by a hydrofluoric acid digestion followed by multi-element analysis by inductively coupled plasma-mass spectrometry (ICP-MS). This method was used to analyse

arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. The hydrofluoric acid digest was also used to analyse aluminium, barium and iron by inductively coupled plasma-optical emission spectroscopy (ICP-OES). Analysis of total barium was by fusion of solids followed by acid dissolution and analysis by ICP-MS. Mercury was determined by a microwave assisted aqua-regia digestion, followed by reduction using acidic tin chloride with determination by cold vapour atomic fluorescence spectroscopy (CV-AFS).

Since metals from natural and anthropogenic sources accumulate together, it is necessary to determine what proportion of the sedimentary load is associated with one source or the other. This is because of variable anthropogenic inputs and natural sedimentary load can vary by several orders of magnitude depending on the nature, grain size, distribution and provenance of metal-rich/metal-poor minerals/compounds in the sediment (Loring and Rantala, 1992).

Normalization attempts to compensate for the natural variability of trace metals in sediments so that any anthropogenic metal contribution may be detected and quantified (Loring, 1991). In the current study metal concentrations results were normalised to 5% Al in line with the current OSPAR, (2012) guidelines for the monitoring of contaminants in sediments.

2.7.5 Macrofauna

Macrofauna analysis was completed by Fugro EMU laboratories which are members of the National Marine Biological Analytical Quality Control Scheme (NMBAQC scheme) of quality assurance. On return to the laboratory, the samples were further washed on a 0.5 mm mesh. The material retained was placed back in the original container and the preservative changed to phenoxytol (2%). The animals were then separated by hand from the remaining sediment by using a combination of stereo microscopes for the fine sediments and in white trays for any coarser material.

Following checks by a biologist on the efficiency of the sorting procedure, the animals were identified and enumerated by specialist taxonomists. Identification was to species level where possible. A few specimens, due to their immaturity, damage incurred during processing or lack of suitable taxonomic literature, could not be identified to species and were identified at higher taxonomic levels as appropriate. After identification, samples were stored in 70% ethanol/1% propylene glycol/29% water.

Abundances were entered on file in a spreadsheet package which stores and sorts entries into taxonomic order and provides output files for numerical analysis, abundances were added to the lowest taxonomic level identified (usually either species or genus). Nomenclature and taxonomic ordering follows that given on the World Register of Marine Species (http://www.marinespecies.org/). Once all the entries had been checked, the resulting quantitative data were subjected to various statistical techniques to investigate community structure. All quantitative analyses were performed on species abundances pooled from the two replicates at each station, thus the sample size was 0.2 m^2 at all stations.

Prior to statistical analysis, the macrofaunal abundance data was rationalised to avoid spurious enhancement of community statistics this involved the removal of all epibenthic taxa (e.g. Ostracods) and juvenile specimens, as they are not considered to be a permanent part of the community. Some indeterminate species were also rationalised at a higher taxonomic level with another taxa in the same genus in order to maintain these data in the dataset e.g. *Streblosoma intestinalis* with *Streblosoma* sp indet and *Gnathia oxyuraea* with *Gnathia* sp indet (female).

Analysis was therefore undertaken on the data set that excluded juveniles, as well as the data set with juveniles included. Comparison between the results of the two analyses revealed a high level of similarity in the clustering of stations into groups, suggesting that the two datasets were essentially revealing the same ecological pattern. Consequently, the following results in the current study are based on the data set with juveniles excluded.

Various univariate and multivariate analyses have been used to integrate and describe the macrofauna data. Ranked abundance/dominance is a simple, but effective way of determining the most prevalent taxa in the samples taking account of potential differences in abundance between samples. This was achieved by summing the rank scores for all samples to give the overall rank dominance for each taxon. A comparison of the ranked dominance and ranked abundance of each taxon shows whether the abundance is spatially even or confined to single sample/station.

Estimates of the total species richness of the community, and thus an estimation of the sampling efficiency were calculated based on the accumulation of species with increasing sampling. Species accumulation plots calculated by the Chao1, Chao2, Jacknife1 and Jacknife2 formulae were calculated in PRIMER v6 (see (Chao, 2005) for further discussion of these indices).

The primary variables, numbers of taxa (S) and abundance (N), have been calculated together with the univariate measures of diversity; evenness (J′), Simpson's dominance (1-λ) and Shannon-Wiener diversity station data (0.1 m^2) using the PRIMER v6 DIVERSE procedure (Clarke and Gorley, 2006). Pielou's evenness (J′) and the Simpson's index of evenness (1-λ) are measures of equitability (i.e. how evenly the individuals are distributed among different species; low evenness indicates that a sample is dominated by one or a few highly abundant species whereas high evenness means that total abundance is spread more evenly among the constituent species. The Shannon-Wiener index (H′) (Shannon and Weaver, 1949) combines both the components of species richness and evenness to calculate a measure of diversity.

The macrofauna data were further analysed by multivariate analysis using PRIMER V6. Analysis was based on fourth root transformed data, which was considered appropriate due to the reasonably large range in abundance values between the samples. This transformation reduced the influence of highly abundant taxa which would otherwise have a disproportionate influence on the dataset. Bray-Curtis similarity was used to construct a similarity matrix between both sample data and station summed data. Samples were also summed to aggregated data per station to allow analysis of gross spatial trends. Analytical techniques included hierarchical clustering with

SIMPROF, SIMPER and Bio-Env matching. Dendrograms and nMDS ordinations have been used to illustrate the multivariate analyses.

3. RESULTS

3.1 Field Operations

Grab samples were successfully taken at all of the 25 proposed environmental locations with complete suites of samples (2 macrofauna and 2 physico-chemical samples) acquired at all stations.

Water samples and CTD casts were successfully taken at all fifteen proposed locations. Complete suites of samples were acquired at all stations.

SPI camera plan view images were successfully collected at five stations and profile images were successfully collected from eleven stations. Due to technical difficulties, it was decided by the client not to complete SPI sampling.

Table 3.1 details all samples acquired.

Table 3.1: Overview of all Completed Sampling

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W					
Station	**Easting [m]**	**Northing [m]**	**Depth [m BSL]**	**Type**	**Samples**
NC21_16BCE025B	492 845.9	859 475.8	480	Box Core	2 x Fauna 1 x PC
NC21_16BCE024A	489 768.1	873 529.0	1060		
NC21_16BCE004D	514 969.8	863 122.2	1210		
NC21_16BCE003	533 689.7	853 622.4	1280		
NC21_16BCE002	561 350.3	842 307.2	1250		
NC21_16BCE001	555 100.2	872 654.1	1980		
NC21_16BCE005A	521 742.9	878 560.6	1550		
NC21_16BCE006	507 679.2	883 785.8	1570		
Phases II and III NC21_16BCE023	493 418.5	888 796.6	1510		
NC21_16BCE007	501 296.7	892 444.8	1700		
NC21_16BCE008A	518 560.9	897 371.5	1800		
NC21_16BCE009	501 901.8	902 067.1	1900		
NC21_16BCE010	503 236.3	908 940.4	2040		
NC21_16BCE011	498 238.0	908 974.6	2010		
NC21_16BCE012	494 550.4	930 119.5	2210		
NC21_16BCE013	492 558.1	930 097.7	2200		
NC21_16BCE014B	499 626.4	946 103.9	2550		
NC21_16BCE015	463 898.0	949 829.2	2400		
NC21_16BCE016	471 163.5	978 365.0	2760		
NC21_16BCE017	466 834.0	987 157.9	2760		
NC21_16BCE017D	466 846.3	987 168.7	2760		
NC21_16BCE018B	444 740.8	986 775.1	2680		

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W					
Station	**Easting**	**Northing**	**Depth**	**Type**	**Samples**
NC21_16BCE019A	434 891.5	960 929.8	2240		
NC21_16BCE020	405 312.8	944 730.9	1500	Box Core	2 x Fauna 1 x PC
NC21_16BCE021	450 066.7	923 881.1	1660		
NC21_16BCE022	482 091.3	903 844.9	1640		
NC21_16WC025_M2	492 841.3	859 484.2	100		
NC21_16WC025_T1	492 840.5	859 484.9	1		
NC21_16WC024_B2	489 870.6	873 478.0	922		
NC21_16WC024_M2	489 799.1	873 513.9	320		
NC21_16WC024_T1	489 762.4	873 532.2	1		
NC21_16WC002_B2	561 426.9	842 302.5	1171		
NC21_16WC002_M2	561 426.9	842 302.5	371		
NC21_16WC002_T1	561 294.3	842 336.4	1		
NC21_16WC005_B1	521 886.3	878 433.8	1681		
NC21_16WC005_M1	521 700.8	878 577.8	400		
NC21_16WC005_T1	521 655.6	878 595.6	1		
NC21_16WC005_CTD	521 855.4	878 458.6	1681		
NC21_16WC006_B1	507 771.2	883 708.2	1550		
NC21_16WC006_M1	507 771.2	883 708.2	400		
NC21_16WC006_T1	507 572.4	883 856.5	1		
NC21_16WC023_B1	493 466.7	888 755.4	1494		
NC21_16WC023_M1	493 466.7	888 755.4	400		
NC21_16WC023_M2	493 321.4	888 847.1	100	Niskin	Water Sample
NC21_16WC023_M3	493 319.9	888 849.1	40		
NC21_16WC023_T1	493 319.6	888 846.5	1		
NC21_16WC008_B1	518 607.9	897 311.7	1925		
NC21_16WC008_M1	518 471.1	897 428.0	500		
NC21_16WC008_T1	518 444.0	897 442.6	1		
NC21_16WC009_B1	501 947.2	902 090.7	1882		
NC21_16WC009_M1	501 812.6	902 154.1	350		
NC21_16WC009_B2	501 949.8	902 103.1	1880		
NC21_16WC009_B3	501 939.6	902 086.9	1880		
NC21_16WC009_T1	501 794.6	902 170.5	1		
NC21_16WC010_B1	503 288.6	908 925.4	2020		
NC21_16WC010_M1	503 155.2	909 004.0	500		
NC21_16WC010_T1	503 137.8	909 021.1	1		
NC21_16WC010_CTD1	503 289.6	908 950.0	2020		
NC21_16WC010_CTD2	503 351.8	908 856.3	2023		
NC21_16WC012_B1	494 651.6	930 043.8	2350		
NC21_16WC012_M1	494 503.0	930 153.8	600		
NC21_16WC012_T1	494 497.4	930 156.5	1		

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W					
Station	**Easting**	**Northing**	**Depth**	**Type**	**Samples**
NC21_16WC015_B1	463 946.6	949 801.0	2390		
NC21_16WC015_M1	463 800.4	949 883.7	600		
NC21_16WC015_T1	463 802.9	949 881.0	1		
NC21_16WC017_B1	466 817.9	987 201.0	2747		
NC21_16WC017_M1	466 773.3	987 214.3	350		
NC21_16WC017_T1	466 798.2	987 203.5	1		
NC21_16WC017_B3	466 792.0	987 207.6	2743		
NC21_16WC018_B1	444 929.2	986 709.8	2637		
NC21_16WC018_T1	444 729.0	986 761.8	1		
NC21_16WC018_M1	444 722.5	986 765.9	350		
NC21_16WC020_B1	405 447.5	944 832.4	1845		
NC21_16WC020_T1	405 164.1	944 825.4	1		
NC21_16WC020_M1	405 212.3	944 808.9	400		
NC21_16WC021_B1	450 071.3	923 925.7	1740		
NC21_16WC021_T1	449 902.2	924 019.0	1		
NC21_16WC021_M1	449 910.3	924 005.3	265		
NC21_16WC022_B1	482 122.8	903 886.9	1690		
NC21_16WC022_T1	481 918.7	903 996.1	1		
NC21_16WC022_M1	481 934.0	903 973.6	300		
NC21_16WC025_M2	492 841.3	859 484.2	100	Niskin	Water Sample
NC21_16WC025_T1	492 840.5	859 484.9	1		
NC21_16WC024_B2	489 870.6	873 478.0	922		
NC21_16WC024_M2	489 799.1	873 513.9	320		
NC21_16WC024_T1	489 762.4	873 532.2	1		
NC21_16WC002_B2	561 426.9	842 302.5	1171		
NC21_16WC002_M2	561 426.9	842 302.5	371		
NC21_16WC002_T1	561 294.3	842 336.4	1		
NC21_16WC005_B1	521 886.3	878 433.8	1681		
NC21_16WC005_M1	521 700.8	878 577.8	400		
NC21_16WC006_B1	507 771.2	883 708.2	1550		
NC21_16WC006_M1	507 771.2	883 708.2	400		
NC21_16WC006_T1	507 572.4	883 856.5	1		
NC21_16WC023_B1	493 466.7	888 755.4	1494		
NC21_16WC023_M1	493 466.7	888 755.4	400		
NC21_16WC023_M2	493 321.4	888 847.1	100		
NC21_16WC023_M3	493 319.9	888 849.1	40		
NC21_16WC023_T1	493 319.6	888 846.5	1		
NC21_16WC008_B1	518 607.9	897 311.7	1925		
NC21_16WC008_M1	518 471.1	897 428.0	500		
NC21_16WC008_T1	518 444.0	897 442.6	1	Niskin	Water Sample

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W					
Station	**Easting**	**Northing**	**Depth**	**Type**	**Samples**
NC21_16WC009_B1	501 947.2	902 090.7	1882		
NC21_16WC009_M1	501 812.6	902 154.1	350		
NC21_16WC009_B2	501 949.8	902 103.1	1880		
NC21_16WC009_B3	501 939.6	902 086.9	1880		
NC21_16WC009_T1	501 794.6	902 170.5	1		
NC21_16WC010_B1	503 288.6	908 925.4	2020		
NC21_16WC010_M1	503 155.2	909 004.0	500		
NC21_16WC010_T1	503 137.8	909 021.1	1		
NC21_16WC010_CTD1	503 289.6	908 950.0	2020		
NC21_16WC010_CTD2	503 351.8	908 856.3	2023		
NC21_16WC012_B1	494 651.6	930 043.8	2350		
NC21_16WC012_M1	494 503.0	930 153.8	600		
NC21_16WC012_T1	494 497.4	930 156.5	1		
NC21_16WC015_B1	463 946.6	949 801.0	2390		
NC21_16WC015_M1	463 800.4	949 883.7	600		
NC21_16WC015_T1	463 802.9	949 881.0	1		
NC21_16WC017_B1	466 817.9	987 201.0	2747		
NC21_16WC017_M1	466 773.3	987 214.3	350		
NC21_16WC017_T1	466 798.2	987 203.5	1		
NC21_16WC017_B3	466 792.0	987 207.6	2743		
NC21_16WC018_B1	444 929.2	986 709.8	2637		
NC21_16WC018_T1	444 729.0	986 761.8	1		
NC21_16WC018_M1	444 722.5	986 765.9	350		
NC21_16WC020_B1	405 447.5	944 832.4	1845		
NC21_16WC020_T1	405 164.1	944 825.4	1		
NC21_16WC020_M1	405 212.3	944 808.9	400		
NC21_16WC021_B1	450 071.3	923 925.7	1740		
NC21_16WC021_T1	449 902.2	924 019.0	1		
NC21_16WC021_M1	449 910.3	924 005.3	265		
NC21_16WC022_B1	482 122.8	903 886.9	1690		
NC21_16WC022_T1	481 918.7	903 996.1	1		
NC21_16SP025	492 839.9	859 483.1	264		
rep2	492 847.7	859 482.8	264		
rep3	492 844.5	859 480.9	264		
rep4	492 843.1	859 483.4	264	SPI	Still
rep5	492 841.3	859 484.3	264		
NC21_16SP024	489 773.5	873 511.5	938		
rep2	489 770.3	873 513.9	938		
rep3	489 776.8	873 516.3	938	SPI	Still
rep4	489 768.8	873 515.6	938		

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W					
Station	**Easting**	**Northing**	**Depth**	**Type**	**Samples**
rep5	489 770.4	873 518.9	938		
NC21_16SP004D	515 043.4	863 083.3	1132		
rep2	515 043.6	863 086.5	1132		
rep3	515 047.0	863 086.5	1132		
rep4	515 044.0	863 087.4	1132		
rep5	515 045.1	863 089.5	1132		
NC21_16SP002	561 371.8	842 290.4	1188		
rep2	561 374.2	842 288.1	1188		
rep3	561 374.2	842 290.8	1188		
rep4	561 376.0	842 291.3	1188		
rep5	561 375.8	842 290.2	1188		
NC21_16SP001	555 085.7	872 693.4	1994		
rep2	555 095.1	872 692.7	1994		
rep3	555 100.5	872 692.0	1994		
rep4	555 105.8	872 692.6	1994		
rep5	555 109.3	872 693.0	1994		
NC21_16SP005B	521 746.8	878 545.7	1693		
rep2	521 751.9	878 545.6	1693		
rep3	521 757.7	878 544.3	1693		
rep4	521 759.1	878 549.4	1693		
rep5	521 764.5	878 547.1	1693		
NC21_16SP006	507 699.6	883 767.9	1568		
rep2	507 712.2	883 760.9	1568		
rep3	507 717.0	883 756.8	1568		
rep4	507 723.5	883 751.4	1568		
rep5	507 727.2	883 750.9	1568		
NC21_16SP023	493 425.7	888 741.4	1509		
rep2	493 432.6	888 735.5	1509		
rep3	493 437.1	888 731.5	1509		
rep4	493 440.0	888 726.9	1509		
rep5	493 445.4	888 721.7	1509		
NC21_16SP007	501 306.8	892 424.0	1695		
rep2	501 317.8	892 419.4	1695		
rep3	501 323.4	892 416.0	1695		
rep4	501 328.4	892 413.3	1695		
rep5	501 333.6	892 411.6	1695		
NC21_16SP008	518 582.2	897 363.6	1942		
rep2	518 592.6	897 358.6	1942		
rep3	518 597.5	897 356.9	1942	SPI	Still
rep4	518 608.0	897 351.6	1942		

Geodetic Datum: WGS84, UTM Zone 21N, CM 57°W					
Station	**Easting**	**Northing**	**Depth**	**Type**	**Samples**
rep5	518 616.4	897 345.9	1942		
NC21_16SP009	501 873.2	902 086.7	1887		
rep2	501 890.4	902 084.0	1887		
rep3	501 905.9	902 081.4	1887		
rep4	501 919.9	902 077.9	1887		
rep5	501 927.8	902 076.0	1887		

Notes:
† = Coordinates for first successful grab to target are provided
PC = Physico-chemical sample
BSL = Below sea level

3.2 Bathymetry

The following summary has been adapted from geophysical report (Report No. 2415-3066-FieldGeophys).

The bathymetry for the survey area, overlain with the environmental survey stations is shown in Figure 3.1.

Water depth ranged from 105 m (LAT) in the south-west of the survey area to 1,875 m (LAT) in the northwest for the area covered by the geophysical survey, the environmental survey exceeded the extents of this. The seabed ranged from undulating to hummocky in the Liza field development area and hummocky to rugged in the outer shelf area. Seabed gradient within the survey area generally ranged from < 1° to 4°, though some steeper gradients, 4° to 34° were observed along the flanks of the seafloor hummocks. Two large seafloor depressions show localised depressions between 4° and 20°.

The seabed was interpreted to comprise mainly of soft, fine-grained sediments and some coarser grained sediments present on the upper slopes and outer shelf area. Very small, discrete patches of high MBES backscatter and high SSS reflectivity were observed in the southern half of the survey area. These were interpreted to represent possible de-watering processes and/or shallow eroded beds, exposing the coarser underlying substrate. To the northeast, larger patches of high reflectivity and backscatter were observed, particularly on top of the seabed hummocks. These were interpreted as older, underlying sediment beds, exposed by bottom currents and possibly dewatering processes.

3.2.1 Seabed Features

The following summary has been adapted from geophysical report (Report No 2415-3066-FieldGeophys). No prominent seafloor features or hazards were observed during the geophysical survey.

Numerous small depressions were observed across the survey site and were generally up to 30 m in diameter and 0.5 m deep. The two largest depressions observed were 48 m diameter and 1 m deep, and 270 m long, 100 m wide and 6 m to 8 m deep. The smaller of the two had coarser sediments in the bottom but the larger depression did not, suggesting seafloor sinking or collapse in the past. On the upper slope, areas of high MBES backscatter were identified as depressions with hardground possibly associated with expulsion of shallow gas. The hardground could represent authigenic carbonates, surficial hydrates and/or deepwater benthic communities.

The seabed hummocks, as mentioned above, were observed throughout the survey area and ranged in length from < 50 m to 800 m long and 20 m to 300 m wide.

One post-drill well (Liza-1) was identified within the survey area. Disturbed soft and coarse sediment surrounding the well was identified as well cuttings and debris. One subsea cable was identified running northwest to southeast through the survey area. The mainly exposed cable was ~25 mm in diameter and ran through the survey area for 25 km.

Seventy-three sonar contacts were identified as small geological or anthropogenic debris. The origin of the majority of debris was believed to be items thrown from vessels in the area.

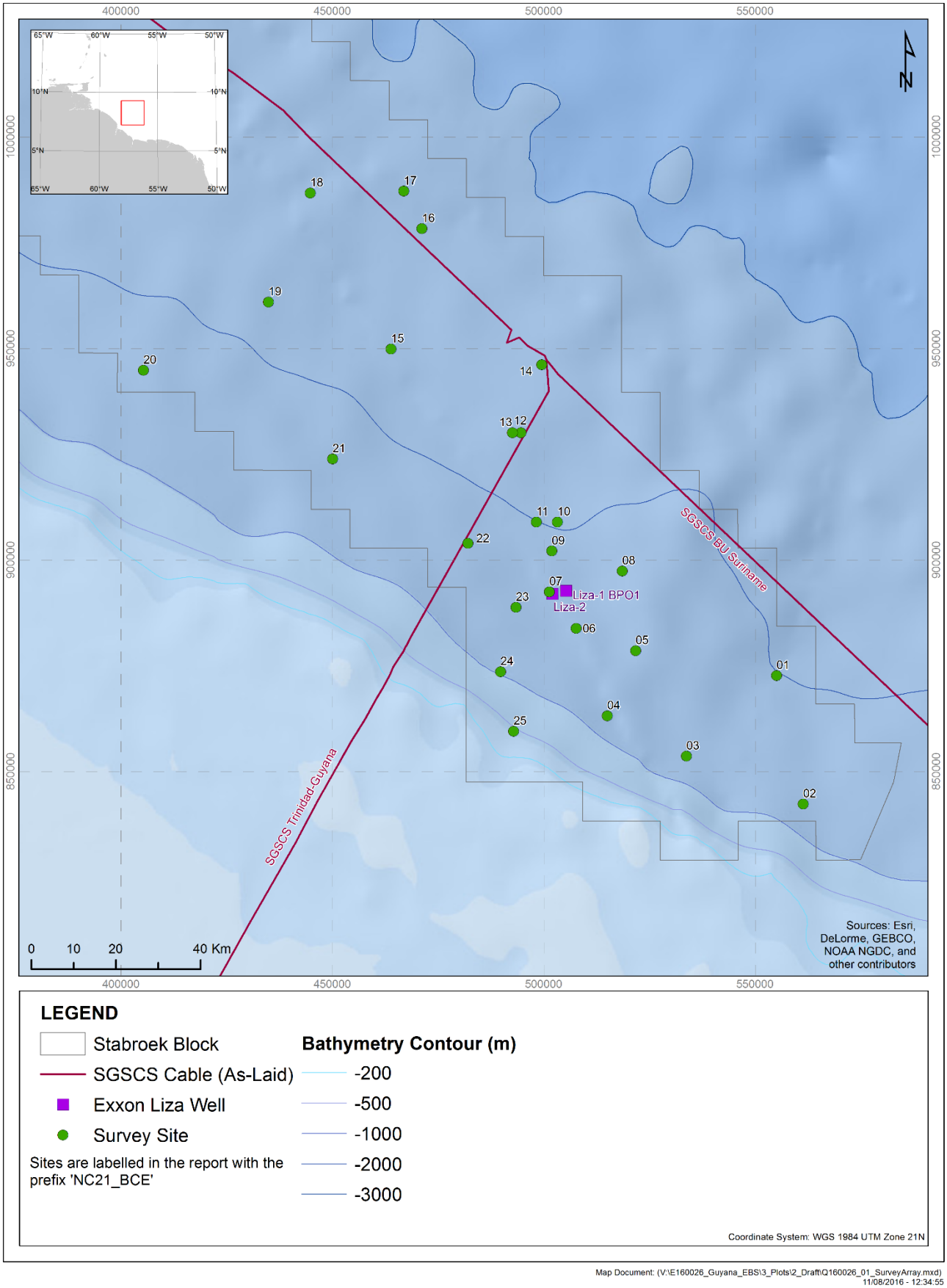


Figure 3.1: Survey area bathymetry and environmental survey stations

3.3 Sediment Particle Size Distribution and Organic Content

3.3.1 Particle Size

Summarised results and sediment descriptions based on Wentworth and Folk Classifications are presented in Table 3.2. The distribution of sediment fractional compositions of samples is illustrated in Figure 3.2.

The majority of sediment samples (56%) were classified as sandy mud, according to the BGS Modified Folk Classification, the remaining samples been represented by muddy sand (32%); mud (8%); and slightly gravelly muddy sand (4%). The sediment sorting ranged from poorly sorted to very poorly sorted, the former associated with muddy sediments, the latter typical of slightly more heterogeneous sediments.

Mud was the predominant sediment type, with values ranging from 18.5% (station NC21_BCE019) to 94.6% (station NC21_BCE003), with an average of 60.8% across the survey area.

Levels of sand were also high across much of the survey area, making up over 30% of the sediment at 16 stations. The highest level of sand was recorded at station NC21_BCE019 (81.4%), the lowest sand content was found at station NC21_BCE003 (5.4%), the average sand content across all stations was 39.1%.

Levels of gravel were low across the survey area, with 96% of samples showing values equal, or very close, to zero. The highest level of gravel was recorded at station NC21_BCE025 (2.3%).

3.3.2 Total Organic Carbon

Organic content, in the form of organic carbon, was generally low across the survey area, with 19 stations showing values below the reporting limit (0.2%) (Table 3.2). The remaining stations showed values of total organic carbon (TOC) of between 0.38% (NC21_BCE025) and 1.10% (NC21_BCE023).

When assessed using Spearmans Rank Coefficient in conjunction with physical variables (depth, gravel, sand and mud content), a significant correlation between TOC and mud content was observed ($rho = 0.56$, $p < 0.01$), with a corresponding negative correlation with sand content ($rho = -0.56$, $p < 0.01$). TOC was also negatively correlated with depth ($rho = -0.70$, $p < 0.01$). The spatial distribution of organic carbon across the survey area is illustrated in Figure 3.3.

3.3.3 In Situ Sediment Parameters

Sediment pH and redox were recorded from samples upon recovery to deck. Sediment pH ranged from 7.17 to 7.92, with an average pH across the survey area of 7.60. Sediment redox in millivolts (mV) ranged from 172 mV to 280 mV with an average of 221 mV. These redox results indicate study sediments across the survey area are anaerobic corresponding to moderately reducing conditions (Delaune and Reddy, 2005).

Table 3.2: Summary of Sediment Particle Size Distribution Data

Station	Sorting	Mean			Mode 1	Mode 2	Mode 3	Fractional Composition				pH	Redox [mV]	TOC [%]
		Phi	µm	Description	Phi	Phi	Phi	Mud [%]	Sand [%]	Gravel [%]	Description [Folk]			
NC21_BCE001	Very poorly sorted	6.03	15.26	Fine silt	7.75	1.25	3.75	74.23	25.77	0.00	Sandy mud	7.58	203	<0.2
NC21_BCE002	Poorly sorted	7.29	6.40	Very fine silt	7.75	0.00	0.00	92.15	7.85	0.00	Mud	7.63	205	0.83
NC21_BCE003	Poorly sorted	7.26	6.54	Very fine silt	7.25	0.00	0.00	94.59	5.41	0.00	Mud	7.66	185	0.61
NC21_BCE004	Very poorly sorted	6.84	8.72	Fine silt	7.25	0.00	0.00	87.31	12.69	0.00	Sandy mud	7.79	198	0.50
NC21_BCE005	Very poorly sorted	6.42	11.71	Fine silt	7.75	3.75	1.75	77.97	22.03	0.00	Sandy mud	7.70	218	<0.2
NC21_BCE006	Very poorly sorted	5.33	24.87	Medium silt	7.75	1.25	0.00	59.14	40.86	0.00	Sandy mud	7.38	218	<0.2
NC21_BCE007	Very poorly sorted	5.01	31.13	Medium silt	1.75	7.75	0.00	55.68	44.28	0.03	Slightly gravelly sandy mud	7.60	233	<0.2
NC21_BCE008	Very poorly sorted	4.19	54.95	Coarse silt	1.75	7.75	0.00	41.50	58.48	0.01	Slightly gravelly muddy sand	7.17	227	<0.2
NC21_BCE009	Very poorly sorted	4.68	38.95	Coarse silt	1.75	7.75	0.00	51.55	48.45	0.00	Sandy mud	7.36	220	<0.2
NC21_BCE010	Very poorly sorted	4.19	54.69	Coarse silt	1.25	8.25	0.00	41.59	58.28	0.13	Slightly gravelly muddy sand	7.68	280	<0.2
NC21_BCE011	Very poorly sorted	4.32	49.97	Coarse silt	1.75	7.75	0.00	44.05	55.93	0.02	Slightly gravelly muddy sand	7.60	219	<0.2
NC21_BCE012	Very poorly sorted	4.45	45.86	Coarse silt	1.25	7.75	3.75	48.39	51.61	0.00	Muddy sand	7.60	236	<0.2
NC21_BCE013	Very poorly sorted	3.92	66.04	Very fine sand	1.25	8.25	0.00	37.58	62.36	0.06	Slightly gravelly muddy sand	7.66	221	<0.2
NC21_BCE014	Very poorly sorted	6.40	11.84	Fine silt	7.75	1.25	0.00	79.55	20.45	0.00	Sandy mud	7.69	190	<0.2
NC21_BCE015	Very poorly sorted	4.00	62.53	Very fine sand	1.25	7.75	0.00	40.34	59.66	0.00	Muddy sand	7.71	221	<0.2
NC21_BCE016	Very poorly sorted	5.84	17.50	Medium silt	7.75	1.25	4.25	69.14	30.86	0.00	Sandy mud	7.87	218	<0.2
NC21_BCE017	Very poorly sorted	6.25	13.18	Fine silt	7.75	1.25	0.00	76.82	23.18	0.00	Sandy mud	7.67	253	<0.2
NC21_BCE018	Very poorly sorted	6.45	11.40	Fine silt	7.75	4.25	1.25	79.26	20.74	0.00	Sandy mud	7.76	225	<0.2
NC21_BCE019	Very poorly sorted	2.50	177.20	Fine sand	1.75	0.00	0.00	18.49	81.45	0.06	Slightly gravelly muddy sand	7.17	267	<0.2
NC21_BCE020	Very poorly sorted	5.15	28.24	Medium silt	7.75	1.25	3.75	59.40	40.47	0.13	Slightly gravelly sandy mud	7.35	235	<0.2

Station	Sorting	Mean			Mode 1	Mode 2	Mode 3	Fractional Composition				pH	Redox	TOC
NC21_BCE021	Very poorly sorted	3.44	92.38	Very fine sand	1.25	8.25	0.00	27.48	72.50	0.03	Slightly gravelly muddy sand	7.52	243	<0.2
NC21_BCE022	Very poorly sorted	4.95	32.44	Coarse silt	1.75	7.75	0.00	54.76	45.24	0.00	Sandy mud	7.40	231	<0.2
NC21_BCE023	Very poorly sorted	6.85	8.68	Fine silt	7.75	0.00	0.00	86.89	13.11	0.00	Sandy mud	7.57	230	1.10
NC21_BCE024	Very poorly sorted	6.70	9.61	Fine silt	7.25	2.25	0.00	87.19	12.81	0.00	Sandy mud	7.88	178	0.82
NC21_BCE025	very poorly sorted	3.91	66.67	Very fine sand	2.75	1.75	7.75	34.37	63.31	2.33	Slightly gravelly muddy sand	7.92	187	0.38
Mean	Very poorly sorted	5.29	37.87	Medium silt	4.75	4.93	3.75	60.78	39.11	0.11	Slightly gravelly sandy mud	7.60	222	0.32
SD		1.32	37.53		3.08	3.16	2.10	21.97	21.84	0.46		0.20	24	0.25
Min	Very poorly sorted	2.50	6.40	Very fine silt	1.25	1.25	1.25	18.49	5.41	0.00	Mud	7.17	178	<0.2
Max	Poorly sorted	7.29	177.20	Fine sand	7.75	8.25	7.75	94.59	81.45	2.33	Slightly gravelly muddy sand	7.92	280	1.10

Notes:
TOC = Total organic carbon

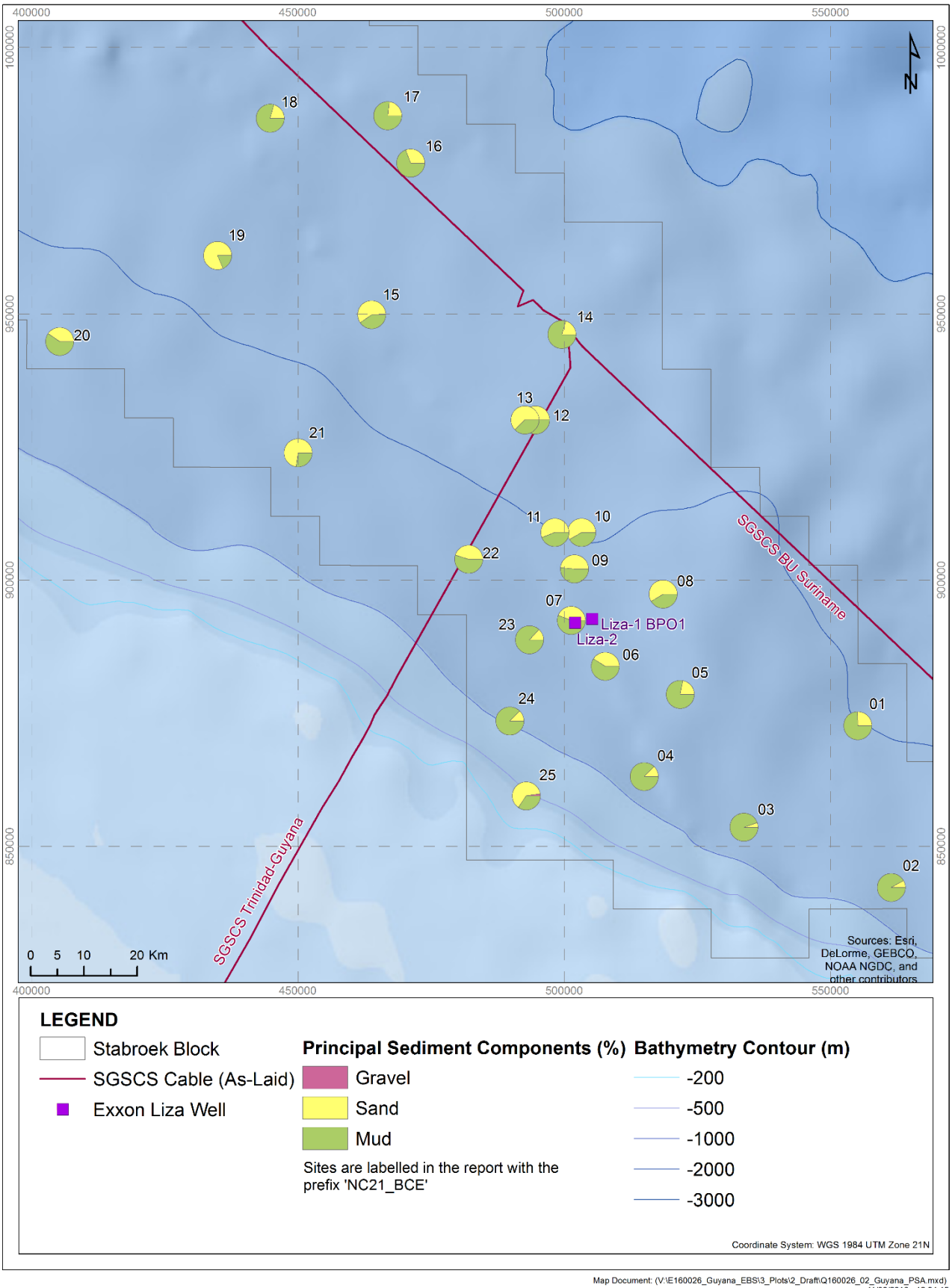


Figure 3.2: Spatial distribution of sediment characteristics

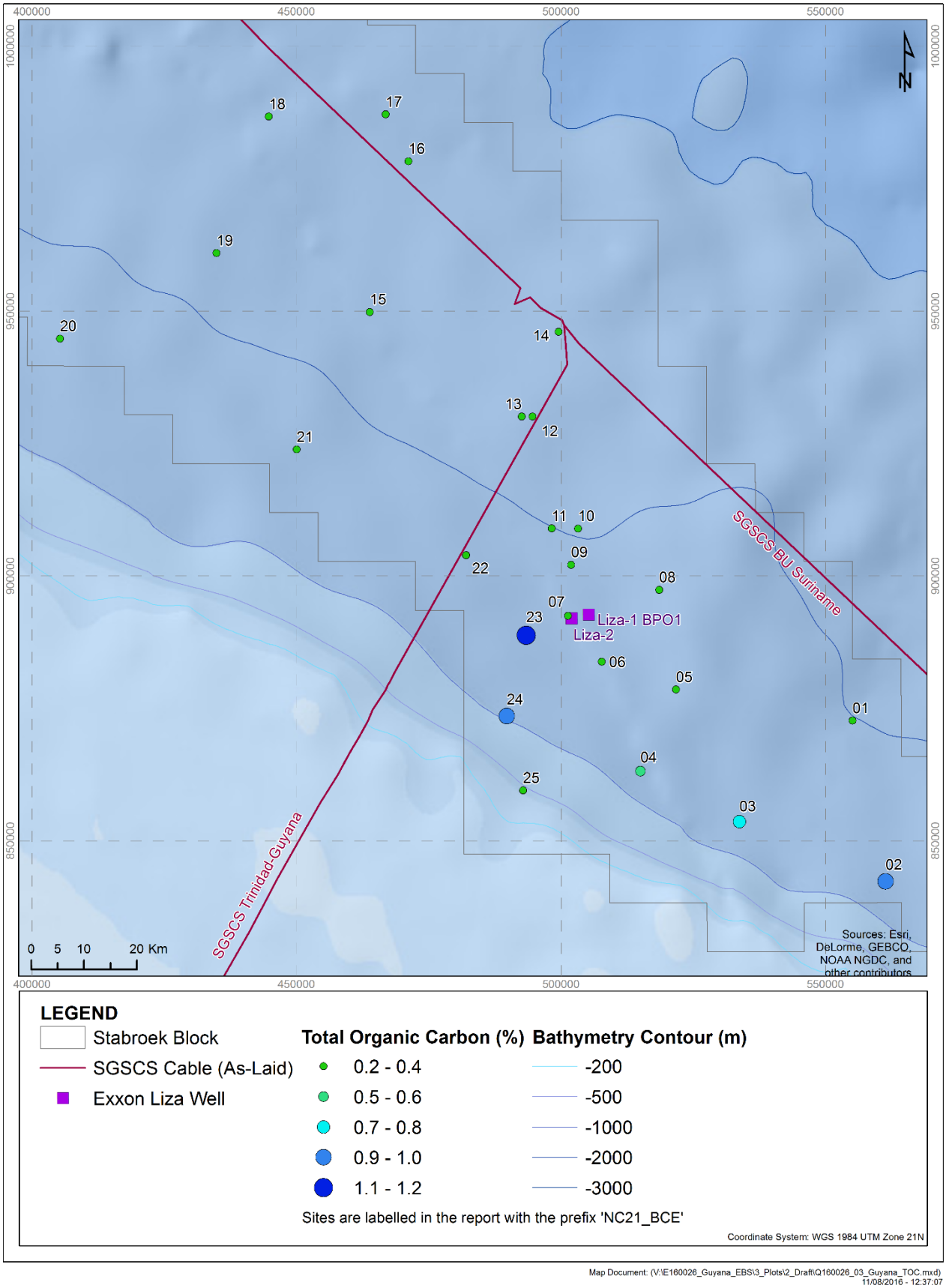


Figure 3.3: Spatial distribution of total organic carbon

3.4 SPI Results

The following results have been extracted from the SPI survey report (Aquafact, 2016). Triplicate SPI photographs were obtained from 11 out of a total of 12 EBS stations attempted for SPI. Plan view images of the seafloor were collected from five stations. Sediment and water samples, as well as in situ CTD profiles were also collated at all 25 EBS stations originally planned.

Seafloor sediment predominantly consisted of soft, oxidised mud and clays, with a smaller sand fraction and shell debris dominated by foraminiferans and to a lesser extent gastropods (Scaphopoda). Most areas were overlaid by a flocculent layer of detrital material, particularly the deeper stations near the edge of the continental slope where mud and clay accumulation was highest. Although the majority of the site was dominated by mud and clay, the shallowest station (SP025), located near the start of the continental slope, was dominated by muddy sand.

Prism penetration was high, usually more than 10 cm, a reflection of the depositional nature of the area dominated by soft mud and clay (< 63 µm; <4 phi) transported from the Essequibo and Demerara Rivers that discharge large quantities of kaolinite and other soft sediments into the sea. Mud clasts were also common on the seafloor surface in most stations. Sediment boundary roughness (SBR) was relatively low, an indication of the relatively flat nature of the seafloor, particularly in the depositional, deeper areas along the continental slope. Changes in SBR were the result of the bioturbating activity of decapods and other invertebrates and the presence of clay casts that accumulated in some stations. Apparent redox potential discontinuity (ARPD) is the depth below the seabed from which processes transition from oxidising to reducing processes, it is measured by looking at the gradient of colour change from the top of the SPI image. ARPD were relatively deep in most areas, with a deep layer of oxygenated, ferric clays in most stations. Considering the overall impoverished community and low faunal richness, it is considered that oxygenation is the result of physicochemical processes and, to a lesser extent, biological activity.

Faunal diversity and richness observed from the SPI was poor overall, the seafloor dominated by tube building polychaetes and, occasionally, by burrowing decapods (e.g. squat lobster), It is worth noting that species diversity and richness determined from stills can differ significantly to that derived from macrofaunal data as it is very hard to identify organisms to species level from SPI stills. Additionally, overall area of benthos sampled by a single SPI still is significantly smaller than that derived from a grab sample, this means that macrofaunal samples could show the community as more diverse and rich than SPI analysis.

The faunal community was transitional, successional stages I to II and III, from the initial colonising stages to intermediate stages dominated by shallow dwelling polychaetes and amphipods. Benthic health quality (BHQ) scores were largely influenced by the presence of deep ARPDs (high scores resulting from deep, i.e. > 5 cm ARPD depths) due to the sedimentology of the site and physicochemical processes. Although in temperate areas high BHQs are correlated with the presence of a well-developed, ‘climax’ infaunal community this was not the case in the study area. Notwithstanding the limitations of SPI to provide a full and detailed description of the composition of infaunal assemblages, the images collected indicate that the ambient conditions at the stations sampled along the continental slope are nonetheless typical of deep sea muds and clays colonised by a naturally species poor infaunal community.

3.5 Sediment Hydrocarbons

Results of hydrocarbon analyses are summarised in Table 3.5 and Table 3.6 and the distribution of total hydrocarbon concentrations (THC) illustrated in Figure 3.8. Total Hydrocarbon (THC) concentrations ranged from 1.5 μgg^{-1} at stations NC21_BCE008, NC21_BCE013 and NC21_BCE019 located through the centre of the survey array, to 4.8 μgg^{-1} at station NC21_BCE003 on the southern edge of Stabroek area. The average concentration of THC across the survey area was 2.8 μgg^{-1} (Table 3.6).

THC concentrations showed relatively strong positive correlation with all tested metals except copper and arsenic. In addition, THC strongly correlated with the percentage of mud in the sediment (rho = 0.843, $p<0.01$). There were also strong positive correlations between THC and TOC (rho = 0.605, $p<0.01$).

The concentrations of n-alkanes (C_{12-36}) were between 0.12 μgg^{-1} (station NC21_BCE019) and 0.50 μgg^{-1} (station NC21_BCE003), with an average of 0.27 μgg^{-1} across the survey area. Levels of the short chain n-alkane (C_{12-20}) were consistently lower than those of the long chain n-alkanes (nC_{21-36}). The highest concentrations of short chain n-alkane (C_{12-20}) and long chain n-alkanes (nC_{21-36}) were recorded at station NC21_BCE002 and station NC21_BCE003 respectively. Concentrations of n-alkane were strongly positively correlated with all metals tested (rho = 0.50598 to 0.6145, $p< 0.01$) except Copper and Mercury, and correlated to a lesser degree with Arsenic and Mercury in addition, the concentration of n-alkanes (C_{12-36}) strongly correlated with percentage of mud (rho = 0.80, $p<0.01$).

The Unresolved Complex Mixture (UCM) concentrations were between 0.9 μgg^{-1} at stations NC21_BCE013 (representing 60% of THC) and 2.8 μgg^{-1} at station NC21_BCE003 (representing 58% of THC). The average across the survey area was 1.8 μgg^{-1}, which represented 64% of the THC concentration. Concentrations of UCM using Spearmans Rank Coefficient was strongly positively correlated with all metals (rho = 0.52519 to 0.67785, $p< 0.01$) except copper, and less positively correlated with Copper, Selenium and Arsenic. In addition, the concentration of n-alkanes (C_{12-36}) strongly correlates with percentage of mud (rho = 0.833, $p<0.01$).

Table 3.3: Summary of Hydrocarbon Results [µgg^{-1} dry weight]

Concentrations Expressed as µgg^{-1} Dry Sediment													
Station Identification	Sample Type	GC											GC-MS
		THC	UCM	n-alkanes			CPI					Pr/Ph Ratio	2 - 6 Ring PAH
				nC_{12-20}	nC_{21-36}	nC_{12-36}	nC_{12-20}	nC_{21-36}	nC_{12-36}	Pristane	Phytane		
NC21_BCE001	SED	3.5	2.5	0.07	0.26	0.33	1.23	2.43	2.07	0.002	0.002	1.43	0.048
NC21_BCE002	SED	4.2	2.2	0.13	0.36	0.49	1.24	2.66	2.14	0.004	0.003	1.47	0.088
NC21_BCE003	SED	4.8	2.8	0.12	0.38	0.50	1.20	2.57	2.10	0.003	0.002	1.98	0.078
NC21_BCE004	SED	3.8	2.0	0.10	0.34	0.44	1.28	2.93	2.37	0.003	0.002	1.79	0.076
NC21_BCE005	SED	2.8	2.0	0.05	0.16	0.21	1.21	2.28	1.96	0.002	0.001	1.35	0.035
NC21_BCE006	SED	2.6	1.5	0.06	0.17	0.22	1.38	2.78	2.27	0.002	0.001	1.49	0.239
NC21_BCE007	SED	2.2	1.3	0.05	0.18	0.23	1.22	2.99	2.39	0.003	0.001	2.27	0.028
NC21_BCE008	SED	1.5	0.9	0.03	0.11	0.14	1.19	2.94	2.36	0.001	0.001	1.37	0.020
NC21_BCE009	SED	2.4	1.5	0.07	0.17	0.24	2.41	2.83	2.70	0.001	0.001	1.08	0.035
NC21_BCE010	SED	2.7	1.8	0.04	0.18	0.22	1.15	2.41	2.11	0.002	0.001	1.31	0.027
NC21_BCE011	SED	2.0	1.3	0.03	0.12	0.15	1.29	2.80	2.32	0.002	0.003	0.66	0.022
NC21_BCE012	SED	1.9	1.2	0.04	0.13	0.17	1.19	2.84	2.30	0.013	0.012	1.05	0.025
NC21_BCE013	SED	1.5	0.9	0.03	0.12	0.15	1.22	2.79	2.27	0.001	0.001	1.65	0.019
NC21_BCE014	SED	3.1	2.0	0.07	0.34	0.41	1.20	2.76	2.37	0.002	0.002	1.12	0.048
NC21_BCE015	SED	2.8	1.9	0.05	0.23	0.28	1.15	2.64	2.23	0.002	0.002	0.81	0.036
NC21_BCE016	SED	2.1	1.4	0.04	0.16	0.20	1.27	2.78	2.34	0.001	0.001	1.27	0.023
NC21_BCE017	SED	3.2	2.2	0.07	0.30	0.37	1.27	2.55	2.21	0.002	0.001	1.53	0.048
NC21_BCE018	SED	3.6	2.6	0.07	0.27	0.34	1.10	2.78	2.23	0.002	0.002	1.49	0.045
NC21_BCE019	SED	1.5	1.0	0.02	0.10	0.12	1.27	2.25	2.02	0.001	0.005	0.18	0.016
NC21_BCE020	SED	2.5	1.8	0.05	0.17	0.22	1.39	2.33	2.04	0.002	0.001	1.75	0.031
NC21_BCE021	SED	1.7	1.1	0.03	0.13	0.17	1.29	2.53	2.18	0.001	0.011	0.13	0.022
NC21_BCE022	SED	2.5	1.7	0.05	0.20	0.25	1.18	2.09	1.86	0.002	0.002	1.06	0.036
NC21_BCE023	SED	3.2	2.2	0.07	0.19	0.26	1.19	2.15	1.83	0.003	0.002	1.35	0.049

Concentrations Expressed as µgg^{-1} Dry Sediment													
Station Identification	**Sample Type**	**GC**											**GC-MS**
		THC	**UCM**	**n-alkanes**			**CPI**					**Pr/Ph Ratio**	**2 - 6 Ring PAH**
NC21_BCE024	SED	4.4	2.7	0.10	0.33	0.43	1.38	2.49	2.16	0.004	0.002	1.68	0.077
NC21_BCE025	SED	2.5	1.4	0.03	0.19	0.22	1.34	2.93	2.60	0.001	0.001	0.70	0.023
Current Survey													
Mean	SED	2.8	1.8	0.06	0.21	0.27	1.29	2.62	2.22	0.002	0.003	1.28	0.05
SD	SED	0.9	0.6	0.03	0.09	0.11	0.24	0.26	0.20	0.002	0.003	0.50	0.04
Min	SED	1.5	0.9	0.02	0.10	0.12	1.10	2.09	1.83	0.001	0.001	0.13	0.02
Max	SED	4.8	2.8	0.13	0.38	0.50	2.41	2.99	2.70	0.013	0.012	2.27	0.24

Notes:
GC = Gas chromatography
GC-MS = Gas chromatography – Mass Spectrometry
THC = Total hydrocarbons
UCM = Unresolved complex mixture
CPI = Carbon preference index (the ratio of odd number carbon chain n-alkanes to even numbered chain n-alkanes)
Pr/Ph = ratio of pristane to phytane
2 to 6 ring PAH = Total 2 to 6 ring polycyclic aromatic hydrocarbons (including alkyl homologues) - see PAH table for full details of compounds quantified).

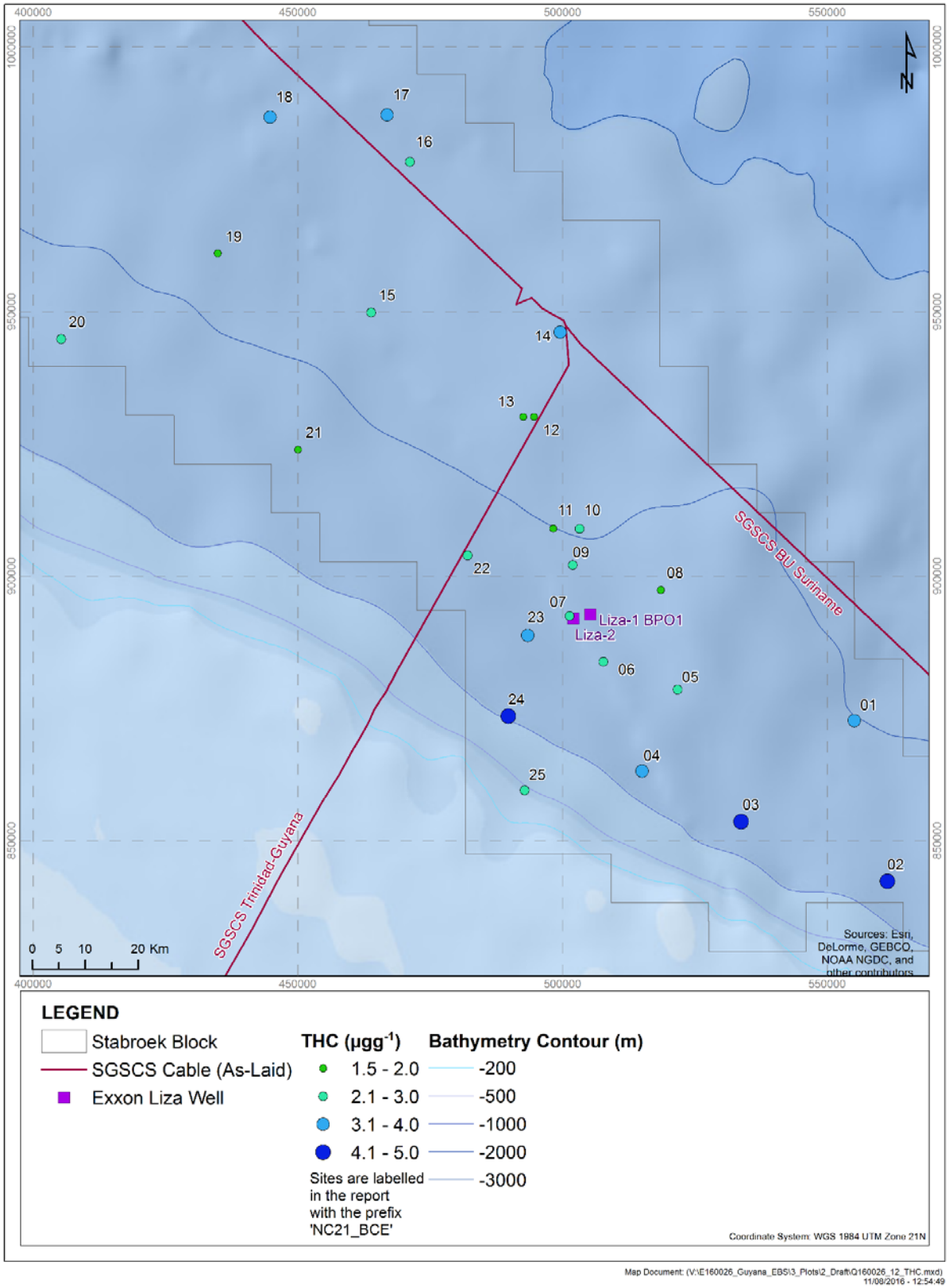


Figure 3.4: Spatial distribution of total hydrocarbon (THC) concentrations [ugg^{-1}]

Table 3.4:Polycyclic Aromatic Hydrocarbons (PAH) Concentrations [ngg^{-1}]

Analyte	Station												
	NC21_ BCE001	NC21_ BCE002	NC21_ BCE003	NC21_ BCE004	NC21_ BCE005	NC21_ BCE006	NC21_ BCE007	NC21_ BCE008	NC21_ BCE009	NC21_ BCE010	NC21_ BCE011	NC21_ BCE012	NC21_ BCE013
Naphthalene	0.3	0.7	0.7	0.6	0.3	1.7	0.3	0.3	0.3	0.3	0.2	0.3	0.4
Acenaphthylene	0.1	0.1	0.1	0.1	0.1	0.9	0.1	0.1	0.1	0.1	0.1	< 0.1	0.1
Acenaphthene	0.1	0.2	0.2	0.1	0.1	4.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Fluorene	0.2	0.3	0.3	0.3	0.1	7.8	0.2	0.1	0.2	0.1	0.1	0.1	0.2
Phenanthrene	1.0	1.4	1.4	1.3	0.8	35.8	0.7	0.5	1.0	0.5	0.5	0.5	0.5
Anthracene	0.1	0.1	0.2	0.1	0.1	9.3	0.1	0.1	0.2	0.1	< 0.1	< 0.1	0.1
Fluoranthene	0.8	1.0	1.0	1.0	0.6	31.9	0.5	0.4	1.0	0.4	0.4	0.4	0.4
Pyrene	0.4	0.7	0.7	0.6	0.3	20.1	0.3	0.2	0.6	0.2	0.2	0.3	0.2
Benz(a)anthracene	0.2	0.3	0.3	0.3	0.1	10.9	0.1	0.1	0.3	0.1	0.1	0.1	0.1
Chrysene	0.8	1.0	0.9	0.9	0.5	8.8	0.4	0.3	0.7	0.4	0.3	0.3	0.3
Benzo(b)fluoranthene	1.1	1.2	1.3	1.0	0.7	6.3	0.5	0.4	0.7	0.4	0.4	0.4	0.4
Benzo(k)fluoranthene	0.2	0.2	0.2	0.1	0.1	3.5	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Benzo(a)pyrene	0.1	0.2	0.2	0.2	0.1	7.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
Indeno(1.2.3.cd)pyrene	0.3	0.3	0.3	0.2	0.2	3.7	0.1	0.1	0.3	0.2	0.1	0.1	0.1
Dibenz(a.h)anthracene	0.1	0.1	0.1	0.1	0.1	1.2	< 0.1	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1
Benzo(g.h.i)perylene	0.5	0.6	0.6	0.5	0.3	3.8	0.2	0.2	0.3	0.2	0.2	0.2	0.2
Total EPA 16	**6.3**	**8.4**	**8.5**	**7.4**	**4.5**	**157**	**3.8**	**3.1**	**6.3**	**3.3**	**2.9**	**3.0**	**3.3**

Table 3.6: Polycyclic Aromatic Hydrocarbons (PAH) Concentrations [ngg^{-1}] Continued

Analyte	EBS Station											
	NC21_ BCE014	NC21_ BCE015	NC21_ BCE016	NC21_ BCE017	NC21_ BCE018	NC21_ BCE019	NC21_ BCE020	NC21_ BCE021	NC21_ BCE022	NC21_ BCE023	NC21_ BCE024	NC21_ BCE025
Naphthalene	0.4	0.3	0.3	0.5	0.4	0.2	0.3	0.2	0.3	0.4	0.4	0.2
Acenaphthylene	0.1	0.1	< 0.1	0.1	0.1	< 0.1	< 0.1	< 0.1	0.1	0.1	0.1	< 0.1
Acenaphthene	0.1	0.1	0.1	0.1	0.1	< 0.1	0.1	< 0.1	0.1	0.1	0.1	< 0.1
Fluorene	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.2	0.1
Phenanthrene	1.0	0.7	0.6	1.0	1.0	0.3	0.7	0.5	0.9	1.1	1.2	0.3
Anthracene	0.1	0.1	< 0.1	0.1	0.1	< 0.1	< 0.1	< 0.1	0.1	0.1	0.1	< 0.1
Fluoranthene	0.7	0.7	0.4	0.9	0.9	0.3	0.5	0.4	0.9	0.8	1.0	0.2
Pyrene	0.4	0.4	0.2	0.5	0.5	0.2	0.3	0.2	0.5	0.4	0.7	0.2
Benz(a)anthracene	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.4	0.1
Chrysene	0.8	0.7	0.4	0.7	0.8	0.3	0.4	0.3	0.6	0.7	0.9	0.2
Benzo(b)fluoranthene	1.1	1.0	0.6	1.2	1.1	0.5	0.7	0.5	0.8	0.9	1.4	0.3
Benzo(k)fluoranthene	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.1
Benzo(a)pyrene	0.1	0.1	0.1	0.1	0.2	0.1	0.1	< 0.1	0.2	0.1	0.2	0.1
Indeno(1.2.3.cd)pyrene	0.3	0.3	0.1	0.3	0.3	0.2	0.2	0.1	0.3	0.2	0.4	0.1
Dibenz(a.h)anthracene	0.1	0.1	< 0.1	0.1	0.1	< 0.1	0.1	< 0.1	0.1	0.1	0.1	< 0.1
Benzo(g.h.i)perylene	0.5	0.4	0.2	0.5	0.4	0.2	0.3	0.1	0.4	0.3	0.7	0.2
Total EPA 16	**6.3**	**5.5**	**3.3**	**6.7**	**6.6**	**2.6**	**4.1**	**2.6**	**5.8**	**5.9**	**8.1**	**2.1**

3.5.1.1 Parent/Alkyl Distribution

Information on the source(s) of PAH in sediment may be obtained from a study of their alkyl homologue distributions (i.e., the degree of methyl, ethyl, substitution of the parent compounds). The distribution of parent 2 to 6 ring PAH compounds also reflects whether the source is petrogenic or pyrolytic. The individual PAHs concentrations are presented in Table 3.9, with examples of parent alkyl distribution shown in Figure 3.11 and Figure 3.12 using a three-dimensional plot which shows the PAH concentrations in terms of parent compound and alkyl homologue distribution of the aromatic material in the sediments analysed. The predominantly pyrogenic nature of the aromatic material present in these sediments is further exemplified by these plots.

Samples showed a predominance of 4 to 6 rings PAHs (Figure 3.11 and Figure 3.12), with a general predominance of 4 to 6 rings PAH parent compound over its alkylated derivatives. The 2 to 3 rings (NPD) PAHs were present in lower concentrations than the 4 to 6 ring PAH's, total concentration of each 2 to 3 ring PAH were made up of a large contribution of alkylated derivatives relative to their parent compounds.

Of the NPD, the naphthalene parent compound was below the detection limit at 21 stations, with the remaining four stations showing values at the detection limit (Table 3.9). Its alkylated derivatives were as high as 5 ngg^{-1} at station NC 21_BCE006 and this station showed the highest total naphthalene concentration across the survey area. A similar distributional pattern was observed with respect to phenanthrene/anthracene with station NC21_BCE006 exhibiting the highest total concentration. The observed naphthalene parent compound was lower than its alkylated derivatives whereas with phenanthrene/anthracene parent compound constituted the highest concentration. Dibenzothiophene concentrations were below the detection limit at all sampling stations but station NC21_BCE006, where all alkyl derivatives were recorded just above at the detection limit (Table 3.9).

PAHs concentrations showed positive correlation with environmental variables, exhibiting a strong positive correlation with percentage mud (rho=0.83, p=0.01, and a lesser correlation with TOC (rho=0.53, p=0.05). A significant positive correlation was found between PAH concentrations and aluminium, barium, iron, lead, selenium and zinc (rho=0.53-0.64, p=0.01), with weaker positive correlations between arsenic, cadmium and chromium (rho=0.36-0.46, p=0.05).

Table 3.5: Individual PAH Concentrations [ngg^{-1} dry weight]

PAH	Station												
	NC21_BCE001	NC21_BCE002	NC21_BCE003	NC21_BCE004	NC21_BCE005	NC21_BCE006	NC21_BCE007	NC21_BCE008	NC21_BCE009	NC21_BCE010	NC21_BCE011	NC21_BCE012	NC21_BCE013
Naphthalene (128)	< 1	1	1	1	< 1	2	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 128	1	2	2	2	1	4	1	1	1	1	1	1	1
C2 128	2	3	3	3	1	5	1	1	2	1	1	1	1
C3 128	2	3	4	3	2	3	2	1	2	1	1	1	1
C4 128	1	2	2	2	1	2	1	1	1	1	1	1	1
TOTAL 128	**6**	**11**	**12**	**11**	**5**	**16**	**5**	**4**	**6**	**4**	**4**	**4**	**4**
Phenanthrene/ Anthracene (178)	1	1	1	1	1	45	1	< 1	1	1	1	1	< 1
C1 178	2	3	3	3	2	10	1	1	2	1	1	1	1
C2 178	4	6	6	5	3	6	2	1	2	2	2	1	1
C3 178	3	5	4	4	2	3	2	1	2	2	1	2	1
TOTAL 178	10	15	14	13	8	64	6	3	7	6	5	5	3
Dibenzothiophene (DBT)	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 184	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C2 184	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C3 184	< 1	1	1	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
TOTAL 184	**< 1**	**1**	**1**	**1**	**< 1**	**2**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**
Fluoranthene/Pyrene (202)	1	2	2	2	1	52	1	< 1	2	< 1	< 1	< 1	< 1
C1 202	1	1	1	1	1	9	< 1	< 1	1	< 1	< 1	< 1	< 1
C2 202	1	1	1	1	1	3	1	< 1	1	1	< 1	< 1	< 1
C3 202	1	2	2	2	1	2	1	1	1	1	< 1	1	< 1
TOTAL 202	**4**	**6**	**6**	**6**	**4**	**66**	**3**	**1**	**5**	**2**	**< 1**	**1**	**< 1**
Benzanthracenes/ Benzphenanthrenes (228)	2	3	2	2	1	24	1	1	2	1	1	1	1
C1 228	2	3	2	2	1	6	1	1	1	1	1	1	1
C2 228	2	4	3	3	2	3	1	1	2	2	2	2	1
TOTAL 228	**6**	**10**	**7**	**7**	**4**	**33**	**3**	**3**	**5**	**4**	**4**	**4**	**3**
m/z 252	15	34	29	29	11	37	8	6	9	7	6	7	6
C1 252	2	3	3	3	1	5	1	1	1	1	1	1	1
C2 252	2	3	2	2	1	2	1	1	1	1	1	1	1
TOTAL 252	**19**	**40**	**34**	**34**	**13**	**44**	**10**	**8**	**11**	**9**	**8**	**9**	**8**
m/z 276	2	3	2	2	1	11	1	1	1	1	1	1	1
C1 276	< 1	1	1	1	< 1	2	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C2 276	1	1	1	1	< 1	1	< 1	< 1	< 1	1	< 1	1	< 1
TOTAL 276	**3**	**5**	**4**	**4**	**1**	**14**	**1**	**1**	**1**	**2**	**1**	**2**	**1**

Table 3.9: Individual PAH Concentrations [ngg-1 dry weight] Continued

n-Alkane	Station (continued)												Mean	SD
	NC21_BCE014	NC21_BCE015	NC21_BCE016	NC21_BCE017	NC21_BCE018	NC21_BCE019	NC21_BCE020	NC21_BCE021	NC21_BCE022	NC21_BCE023	NC21_BCE024	NC21_BCE025		
Naphthalene (128)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	1
C1 128	1	1	1	2	1	1	2	1	1	1	1	1	1	1
C2 128	2	1	1	2	2	1	1	1	1	2	2	1	2	1
C3 128	2	1	1	2	2	1	2	1	2	2	3	1	2	1
C4 128	1	1	1	1	1	< 1	1	1	1	2	2	< 1	1	1
TOTAL 128	**6**	**4**	**4**	**7**	**6**	**3**	**6**	**4**	**5**	**7**	**8**	**3**	**6**	**3**
Phenanthrene/ Anthracene (178)	1	1	1	1	1	< 1	1	1	1	1	1	< 1	3	10
C1 178	2	2	1	2	2	1	2	1	2	3	3	1	2	2
C2 178	3	2	2	3	3	1	3	1	3	4	5	1	3	2
C3 178	3	2	1	2	2	1	2	1	2	3	3	1	2	1
TOTAL 178	**9**	**7**	**5**	**8**	**8**	**3**	**8**	**4**	**8**	**11**	**12**	**3**	**10**	**12**
Dibenzothiophene (DBT)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	-
C1 184	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	-
C2 184	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	-	-
C3 184	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	1	0
TOTAL 184	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**< 1**	**1**	**< 1**	**1**	**0**
Fluoranthene/Pyrene (202)	1	1	< 1	1	2	< 1	1	<1	2	1	2	< 1	5	13
C1 202	1	1	< 1	1	1	< 1	< 1	< 1	1	1	1	< 1	2	2
C2 202	1	< 1	< 1	1	1	< 1	< 1	< 1	< 1	1	1	< 1	1	1
C3 202	1	1	< 1	1	1	< 1	< 1	< 1	1	1	1	< 1	1	0
TOTAL 202	**4**	**3**	**< 1**	**4**	**5**	**< 1**	**1**	**< 1**	**4**	**4**	**5**	**< 1**	**7**	**14**
Benzanthracenes/ Benzphenanthrenes (228)	2	2	1	2	2	1	1	1	2	2	2	1	2	5
C1 228	2	1	1	2	2	< 1	1	1	1	2	3	1	2	1
C2 228	2	1	1	2	2	1	1	1	2	2	3	2	2	1
TOTAL 228	**6**	**4**	**3**	**6**	**6**	**2**	**3**	**3**	**5**	**6**	**8**	**4**	**6**	**6**
m/z 252	15	12	8	16	14	5	10	7	11	15	33	10	14	10
C1 252	2	2	1	2	2	1	1	1	1	2	3	1	2	1
C2 252	2	1	1	2	2	1	1	1	1	2	3	1	1	1
TOTAL 252	**19**	**15**	**10**	**20**	**18**	**7**	**12**	**9**	**13**	**19**	**39**	**12**	**18**	**11**
m/z 276	2	2	1	2	1	1	1	1	1	1	2	1	2	2
C1 276	1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	1	0
C2 276	1	1	< 1	1	1	< 1	< 1	1	< 1	1	1	< 1	1	0
TOTAL 276	**4**	**3**	**1**	**3**	**2**	**1**	**1**	**2**	**1**	**2**	**4**	**1**	**3**	**3**

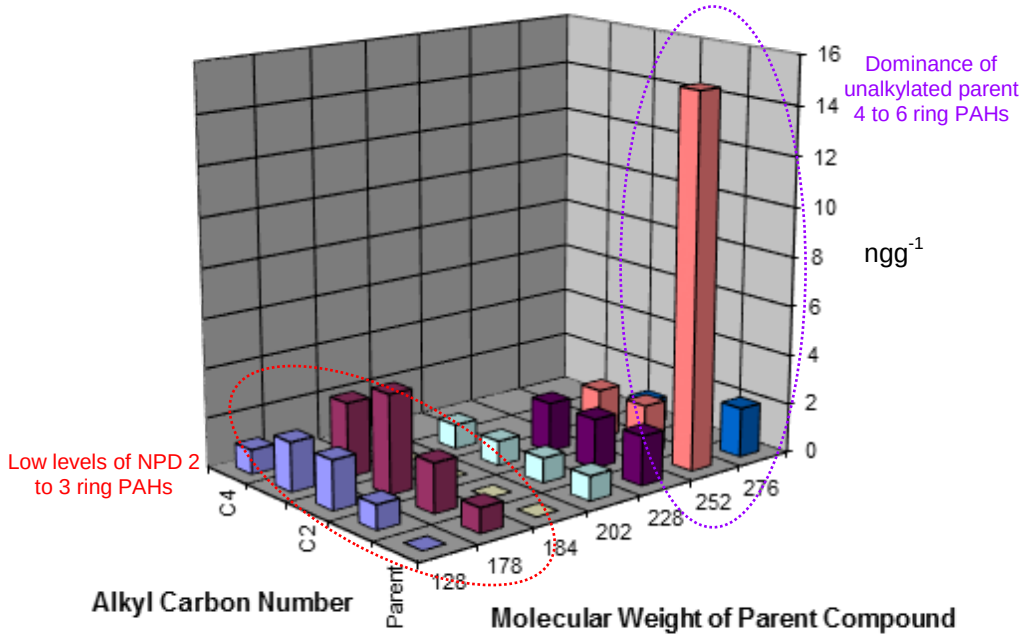
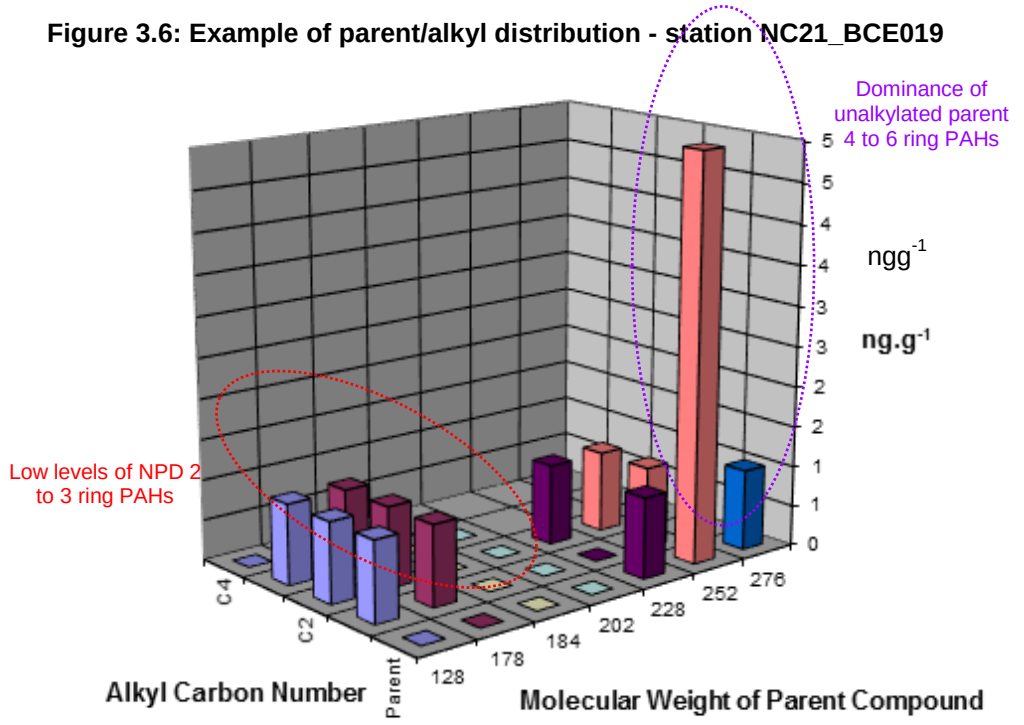


Figure 3.5: Example of parent/alkyl distribution - station NC21_BCE001

Figure 3.6: Example of parent/alkyl distribution - station NC21_BCE019



3.5.1.2 USEPA Specified PAHs

Results of the 16 PAHs recommended as priority pollutants, and referred to as the EPA 16, are summarised in Table 3.10, and assessed against the NOAA Effect Range Low (ERL) values and NOAA Effects Range Median (ERM), also reported in Table 3.10. The ERL represents the threshold below which there is a low probability of PAH presence impacting benthic fauna. The ERM is the threshold above which there is a higher probability of impacts to benthic fauna being observed. Concentrations for each of the 16 PAH were much lower than the equivalent NOAA ERL and NOAA ERM.

Table 3.6: USEPA Specified PAH Concentrations [ngg^{-1} dry weight]

PAH	Station										NOAA ERL	NOAA ERM
	NC21_BCE001	NC21_BCE002	NC21_BCE003	NC21_BCE004	NC21_BCE005	NC21_BCE006	NC21_BCE007	NC21_BCE008	NC21_BCE009	NC21_BCE010		
Naphthalene	0.3	0.7	0.7	0.6	0.3	1.7	0.3	0.3	0.3	0.3	160	2100
Acenaphthylene	0.1	0.1	0.1	0.1	0.1	0.9	0.1	0.1	0.1	0.1	44	640
Acenaphthene	0.1	0.2	0.2	0.1	0.1	4.3	0.1	0.1	0.1	0.1	16	500
Fluorene	0.2	0.3	0.3	0.3	0.1	7.8	0.2	0.1	0.2	0.1	19	540
Phenanthrene	1.0	1.4	1.4	1.3	0.8	35.8	0.7	0.5	1.0	0.5	240	1500
Anthracene	0.1	0.1	0.2	0.1	0.1	9.3	0.1	0.1	0.2	0.1	85	1100
Fluoranthene	0.8	1.0	1.0	1.0	0.6	31.9	0.5	0.4	1.0	0.4	600	5100
Pyrene	0.4	0.7	0.7	0.6	0.3	20.1	0.3	0.2	0.6	0.2	665	2600
Benzo(a)anthracene	0.2	0.3	0.3	0.3	0.1	10.9	0.1	0.1	0.3	0.1	261	1600
Chrysene	0.8	1.0	0.9	0.9	0.5	8.8	0.4	0.3	0.7	0.4	384	2800
Benzo(b)fluoranthene	1.1	1.2	1.3	1.0	0.7	6.3	0.5	0.4	0.7	0.4	-	-
Benzo(k)fluoranthene	0.2	0.2	0.2	0.1	0.1	3.5	0.1	0.1	0.2	0.1	-	-
Benzo(a)pyrene	0.1	0.2	0.2	0.2	0.1	7.1	0.1	0.1	0.2	0.1	430	1600
Indeno(123cd)pyrene	0.3	0.3	0.3	0.2	0.2	3.7	0.1	0.1	0.3	0.2	-	-
Benzo(ghi)perylene	0.5	0.6	0.6	0.5	0.3	3.8	0.2	0.2	0.3	0.2	-	-
Dibenzo(ah)anthracene	0.1	0.1	0.1	0.1	0.1	1.2	<0.1	<0.1	0.1	<0.1	63	260
Total EPA 16	**6.3**	**8.4**	**8.5**	**7.4**	**4.5**	**157**	**3.8**	**3.1**	**6.3**	**3.3**	-	-

Table 3.10: USEPA Specified PAH Concentrations [ngg-1 dry weight] Continued

PAH	Station										NOAA ERL	NOAA ERM
	NC21_BCE011	NC21_BCE012	NC21_BCE013	NC21_BCE014	NC21_BCE015	NC21_BCE016	NC21_BCE017	NC21_BCE018	NC21_BCE019	NC21_BCE020		
Naphthalene	0.2	0.3	0.4	0.4	0.3	0.3	0.5	0.4	0.2	0.3	160	2100
Acenaphthylene	0.1	< 0.1	0.1	0.1	0.1	< 0.1	0.1	0.1	< 0.1	< 0.1	44	640
Acenaphthene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	< 0.1	0.1	16	500
Fluorene	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.2	19	540
Phenanthrene	0.5	0.5	0.5	1.0	0.7	0.6	1.0	1.0	0.3	0.7	240	1500
Anthracene	< 0.1	< 0.1	0.1	0.1	0.1	< 0.1	0.1	0.1	< 0.1	< 0.1	85	1100
Fluoranthene	0.4	0.4	0.4	0.7	0.7	0.4	0.9	0.9	0.3	0.5	600	5100
Pyrene	0.2	0.3	0.2	0.4	0.4	0.2	0.5	0.5	0.2	0.3	665	2600
Benzo(a)anthracene	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	261	1600
Chrysene	0.3	0.3	0.3	0.8	0.7	0.4	0.7	0.8	0.3	0.4	384	2800
Benzo(b)fluoranthene	0.4	0.4	0.4	1.1	1.0	0.6	1.2	1.1	0.5	0.7	-	-
Benzo(k)fluoranthene	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.1	0.1	-	-
Benzo(a)pyrene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	430	1600
Indeno(123cd)pyrene	0.1	0.1	0.1	0.3	0.3	0.1	0.3	0.3	0.2	0.2	-	-
Benzo(ghi)perylene	0.2	0.2	0.2	0.5	0.4	0.2	0.5	0.4	0.2	0.3	-	-
Dibenzo(ah)anthracene	< 0.1	< 0.1	<0.1	0.1	0.1	< 0.1	0.1	0.1	< 0.1	0.1	63	260
Total EPA 16	**2.9**	**3**	**3.3**	**6.3**	**5.5**	**3.3**	**6.7**	**6.6**	**2.6**	**4.1**	**-**	-

Table 3.10: USEPA Specified PAH Concentrations [ngg-1 dry weight] Continued

PAH	Station					Mean	SD	NOAA ERL	NOAA ERM
	NC21_BCE021	NC21_BCE022	NC21_BCE023	NC21_BCE024	NC21_BCE025				
Naphthalene	0.2	0.3	0.4	0.4	0.2	0.4	0.3	160	2100
Acenaphthylene	< 0.1	0.1	0.1	0.1	< 0.1	-	-	44	640
Acenaphthene	< 0.1	0.1	0.1	0.1	< 0.1	-	-	16	500
Fluorene	0.1	0.1	0.2	0.2	0.1	0.5	1.5	19	540
Phenanthrene	0.5	0.9	1.1	1.2	0.3	2.2	7.0	240	1500
Anthracene	< 0.1	0.1	0.1	0.1	< 0.1	-	-	85	1100
Fluoranthene	0.4	0.9	0.8	1.0	0.2	1.9	6.3	600	5100
Pyrene	0.2	0.5	0.4	0.7	0.2	1.2	3.9	665	2600
Benzo(a)anthracene	0.1	0.2	0.2	0.4	0.1	0.6	2.1	261	1600
Chrysene	0.3	0.6	0.7	0.9	0.2	0.9	1.7	384	2800
Benzo(b)fluoranthene	0.5	0.8	0.9	1.4	0.3	1.0	1.2	-	-
Benzo(k)fluoranthene	0.1	0.2	0.2	0.2	0.1	0.3	0.7	-	-
Benzo(a)pyrene	< 0.1	0.2	0.1	0.2	0.1	0.4	1.4	430	1600
Indeno(123cd)pyrene	0.1	0.3	0.2	0.4	0.1	0.4	0.7	-	-
Benzo(ghi)perylene	0.1	0.4	0.3	0.7	0.2	0.5	0.7	-	-
Dibenzo(ah)anthracene	< 0.1	0.1	0.1	0.1	< 0.1	0.2	0.3	63	260
Total EPA 16	**2.6**	**5.8**	**5.9**	**8.1**	**2.1**	**11.1**	**30.5**	**-**	-

3.6 Sediment Heavy and Trace Metals

The current OSPAR Coordinated Environmental Monitoring Programme (CEMP) environmental focus around heavy metals is on cadmium, mercury and lead (OSPAR, 2014). Cadmium and lead both occur naturally the marine environment; however, they are toxic and liable to bio-accumulate so there is a concern for both the overall health of the environment and for human consumption of seafood. Mercury is an extremely rare element in the earth's crust but does occur naturally in young geologically active areas (volcanic regions). It is extremely toxic to humans and biota and can be transformed, once in the environment, into more toxic organometallic compounds (OSPAR, 2009).

3.6.1 Sediment Heavy Metals

The concentrations of hydrofluoric acid extractable metals measured in the surface sediments are listed in Table 3.11, along with background/regional data, where available, including NOAA ERL and ERM values.

Heavy metal concentrations were normalised to 5% aluminium and correlating to iron. Normalisation is a method used to decrease the variability in metal concentrations occurring from changes in the proportions of fine material (<63 µm) and allows comparison of metals levels across different regions. Normalised data for heavy metals to aluminium are displayed in Table 3.12 and correlations to iron are presented in Figure 3.13.

Cadmium (Cd) levels in the sediments ranged from 0.073 $\mu g g^{-1}$ at station NC21_BCE019 to 0.255 $\mu g g^{-1}$ at station NC21_BCE002 (mean 0.120 $\mu g g^{-1}$). Nickel (Ni) levels for the sample stations ranged from 10.8 $\mu g g^{-1}$ at station NC21_BCE019 to 51.5 $\mu g g^{-1}$ at station NC21_BCE003 (mean 27.0 $\mu g g^{-1}$). Mercury (Hg) levels ranged from 0.0161 $\mu g g^{-1}$ at station NC21_BCE025 to 0.0420 $\mu g g^{-1}$ at station NC21_BCE003 (mean 0.0285 $\mu g g^{-1}$).

Chromium (Cr) concentrations in the sediments ranged from 14.5 $\mu g g^{-1}$ at station NC21_BCE019 to 53.4 $\mu g g^{-1}$ at station NC21_BCE025 (mean 36.1 $\mu g g^{-1}$). Copper (Cu) levels ranged from 6.88 $\mu g g^{-1}$ at station NC21_BCE025 to 30.5 $\mu g g^{-1}$ at station NC21_BCE017 (mean 20.2 $\mu g g^{-1}$). Lead (Pb) levels ranged from 9.85 $\mu g g^{-1}$ at station NC21_BCE019 to 27.5 $\mu g g^{-1}$ at station NC21_BCE025 (mean 15.5 $\mu g g^{-1}$). Finally, zinc levels ranged from 32.5 $\mu g g^{-1}$ at station NC21_BCE019 to 101 $\mu g g^{-1}$ at station NC21_BCE024 (mean 69.7 $\mu g g^{-1}$).

Barium (Ba) levels ranged from 43.7$\mu g g^{-1}$ (station NC21_BCE019) to 272 $\mu g g^{-1}$ (station NC21_BCE003), mean 175 $\mu g g^{-1}$. The spatial distribution of barium levels is shown in Figure 3.14. Barium showed a very strong positive correlation with mud content (rho = 0.751, p=0.01) and strong correlations with hydrocarbon variables (THC, n-alkanes, UCM and total 2 to 6 ring PAHs), metals (aluminium, cadmium, chromium, copper, iron, nickel, lead, zinc and mercury) and selenium.

The spatial distribution of arsenic concentrations across the survey area is shown in Figure 3.15. Arsenic concentrations ranged from 6.09 μgg^{-1} at station NC21_BCE012 to 97.10 μgg^{-1} at station NC21_BCE025, the mean concentration was 11.59 μgg^{-1}.

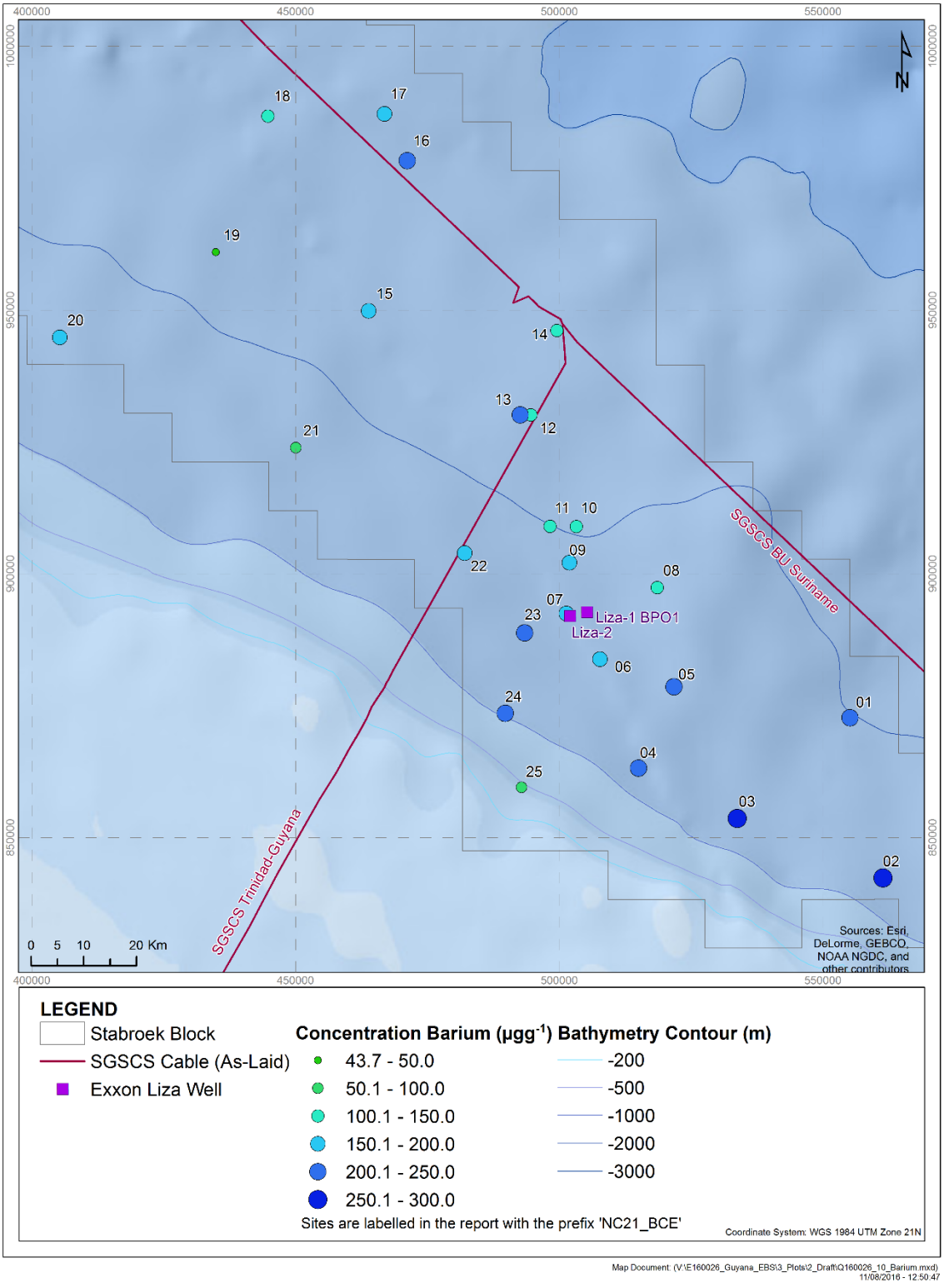


Figure 3.7: Spatial distribution of barium concentrations [ugg^{-1}]

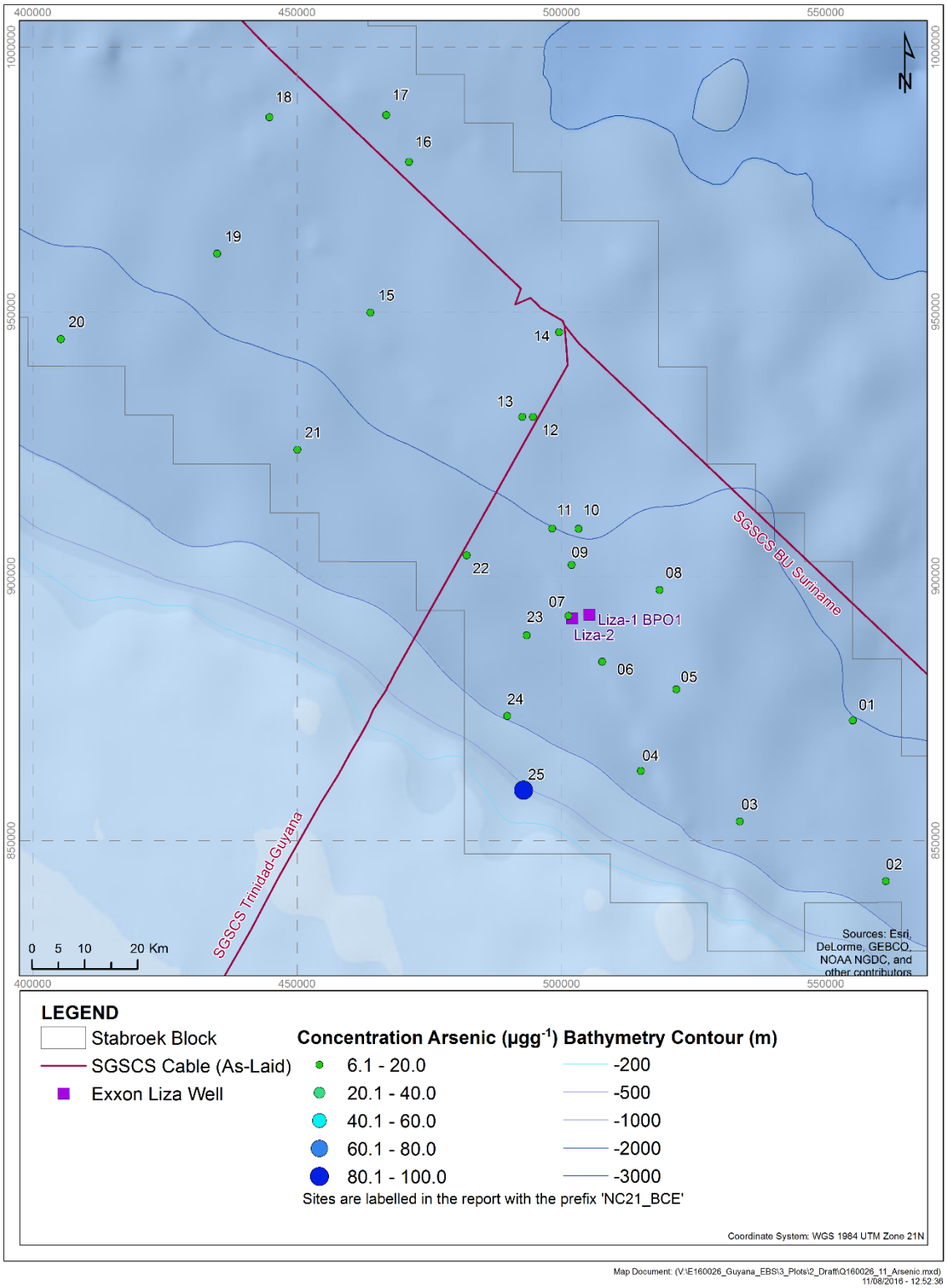


Figure 3.8: Spatial distribution of arsenic concentrations [ugg^{-1}]

Table 3.7: Heavy and Trace Metal Concentrations [µgg^{-1} dry weight]

Station	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Se	Pb	Ni	Zn
NC21_BCE001	54500	8.60	215	0.122	42.1	20.9	30800	0.0324	0.243	16.8	29.1	76.6
NC21_BCE002	66600	6.62	268	0.255	51.0	18.9	39200	0.0357	0.749	20.3	32.1	89.3
NC21_BCE003	62100	11.40	272	0.167	50.6	26.6	41900	0.0420	0.360	21.1	51.5	101.0
NC21_BCE004	59300	9.09	241	0.120	48.1	18.7	36600	0.0339	0.284	19.1	37.3	96.2
NC21_BCE005	55000	9.67	246	0.123	44.4	21.9	34100	0.0331	0.191	17.7	35.7	86.5
NC21_BCE006	44700	8.23	190	0.103	35.9	24	28000	0.0308	0.197	16.2	26.7	75.4
NC21_BCE007	42800	7.01	186	0.108	34.7	17	27400	0.0276	0.219	13.9	24.5	65.1
NC21_BCE008	32000	6.48	126	0.108	25.3	15.2	19200	0.0214	0.175	12.0	19.0	48.0
NC21_BCE009	38600	7.16	165	0.107	30.5	19.5	23400	0.0240	0.184	14.1	23.9	60.3
NC21_BCE010	32400	7.69	125	0.111	26.9	23.4	20900	0.0251	0.173	13.0	21.5	56.7
NC21_BCE011	36900	6.79	144	0.116	29.3	20.6	21800	0.0253	0.144	11.9	21.7	54.9
NC21_BCE012	27900	6.09	106	0.111	22.7	17	16900	0.0217	0.144	10.5	19.3	43.5
NC21_BCE013	51000	7.99	208	0.121	40.1	27.5	29300	0.0359	0.154	14.6	28.7	75.9
NC21_BCE014	33100	7.54	121	0.128	27.3	20.1	20000	0.0248	0.181	11.7	20.4	50.7
NC21_BCE015	46400	7.91	181	0.125	37.4	25.3	27400	0.0274	0.128	13.1	26.6	69.4
NC21_BCE016	51700	8.04	202	0.137	40.3	29.4	30400	0.0352	0.194	16.2	29.8	78.7
NC21_BCE017	50100	8.64	199	0.133	40.9	30.5	30000	0.0339	0.152	15.8	30.9	81.8
NC21_BCE018	35700	6.80	148	0.097	28.4	18	22400	0.0226	0.147	13.3	22.9	56.4
NC21_BCE019	13900	7.25	43.7	0.073	14.5	11.5	12100	0.0167	0.100	9.85	10.8	32.5
NC21_BCE020	47000	8.53	190	0.103	36.0	19	37200	0.0271	0.154	14.3	25.3	67.6
NC21_BCE021	29000	7.10	96.6	0.085	24.5	12.7	19200	0.0199	0.120	11.6	17.2	47.0
NC21_BCE022	37300	7.23	159	0.088	30.5	17	24800	0.0250	0.150	14.4	25.8	66.7
NC21_BCE023	49300	10.10	225	0.131	39.7	22.7	31300	0.0401	0.263	18.5	35.1	84.5
NC21_BCE024	60100	10.70	243	0.124	48.9	19.5	39400	0.0349	0.473	20.5	39.0	101.0
NC21_BCE025	28400	97.10	62.4	0.103	53.4	6.88	98100	0.0161	0.332	27.5	21.3	77.7
Min	**13900**	**6.09**	**44**	**0.073**	**14.5**	**6.9**	**12100**	**0.0161**	**0.120**	**9.9**	**10.8**	**32.5**
Mean	**43432**	**11.59**	**175**	**0.120**	**36.1**	**20.2**	**30472**	**0.0285**	**0.230**	**15.5**	**27.0**	**69.7**
Max	**66600**	**97.1**	**272**	**0.255**	**53.4**	**30.5**	**98100**	**0.0420**	**0.749**	**27.5**	**51.5**	**101**
SD	**12861**	**17.86**	**61**	**0.034**	**10.1**	**5.5**	**16051**	**0.0070**	**0.139**	**4.0**	**8.4**	**18.3**
2014 Survey (Maxon Consulting and TDI Brooks, 2014)												
Min	**7040**	**3.86**	**37.8**	**0.087**	**8.38**	**9.63**	**11300**	**0.022**	**13.8**	**-**	**8.33**	**26.9**
Mean	**10288**	**6.38**	**89.0**	**0.125**	**13.83**	**13.74**	**17217**	**0.039**	**20.0**	**-**	**11.09**	**41.8**
Max	**15000**	**14.10**	**159.0**	**0.165**	**21.10**	**19.60**	**25300**	**0.062**	**32.3**	**-**	**15.60**	**63.7**
SD	**2464**	**2.56**	**28.4**	**0.023**	**3.80**	**2.52**	**4092**	**0.011**	**4.3**	**-**	**1.89**	**10.9**
NOAA Effects Range Low - (Buchman, 2008)												
ERL	**-**	**8.2**	**-**	**1.2**	**81.0**	**34.0**	**-**	**0.15**	**-**	**46.7**	**20.9**	**150.0**
ERM	**-**	**70.0**		**9.6**	**370.0**	**270.0**	**-**	**0.71**	**-**	**218**	**51.6**	**410.0**

Notes:
ERL = effects range low
ERM = Effects range median
SD = Standard deviation

Table 3.8: Heavy and Trace Metal Concentrations Normalised to 5% Al [µgg^{-1} dry weight]

Station	Al	As	Ba	Cd	Cr	Cu	Fe	Hg	Se	Pb	Ni	Zn
NC21_BCE001	50000	7.89	197	0.112	38.6	19.2	32009	0.0297	0.223	15.4	26.7	70.3
NC21_BCE002	50000	4.97	201	0.191	38.3	14.2	29526	0.0268	0.562	15.2	24.1	67.0
NC21_BCE003	50000	9.18	219	0.134	40.7	21.4	30211	0.0338	0.290	17.0	41.5	81.3
NC21_BCE004	50000	7.66	203	0.101	40.6	15.8	30287	0.0286	0.239	16.1	31.5	81.1
NC21_BCE005	50000	8.79	224	0.112	40.4	19.9	28725	0.0301	0.174	16.1	32.5	78.6
NC21_BCE006	50000	9.21	213	0.115	40.2	26.8	32253	0.0345	0.220	18.1	29.9	84.3
NC21_BCE007	50000	8.19	217	0.126	40.5	19.9	29400	0.0322	0.256	16.2	28.6	76.1
NC21_BCE008	50000	10.13	197	0.169	39.5	23.8	29539	0.0334	0.273	18.8	29.7	75.0
NC21_BCE009	50000	9.27	214	0.139	39.5	25.3	29940	0.0311	0.238	18.3	31.0	78.1
NC21_BCE010	50000	11.87	193	0.171	41.5	36.1	30000	0.0387	0.267	20.1	33.2	87.5
NC21_BCE011	50000	9.20	195	0.157	39.7	27.9	28257	0.0343	0.195	16.1	29.4	74.4
NC21_BCE012	50000	10.91	190	0.199	40.7	30.5	29429	0.0389	0.258	18.8	34.6	78.0
NC21_BCE013	50000	7.83	204	0.119	39.3	27.0	32779	0.0352	0.151	14.3	28.1	74.4
NC21_BCE014	50000	11.39	183	0.193	41.2	30.4	30311	0.0375	0.273	17.7	30.8	76.6
NC21_BCE015	50000	8.52	195	0.135	40.3	27.3	33244	0.0295	0.138	14.1	28.7	74.8
NC21_BCE016	50000	7.78	195	0.132	39.0	28.4	33103	0.0340	0.188	15.7	28.8	76.1
NC21_BCE017	50000	8.62	199	0.133	40.8	30.4	172711	0.0338	0.152	15.8	30.8	81.6
NC21_BCE018	50000	9.52	207	0.136	39.8	25.2	30860	0.0317	0.206	18.6	32.1	79.0
NC21_BCE019	50000	26.08	157	0.263	52.2	41.4	39574	0.0601	0.360	35.4	38.8	116.9
NC21_BCE020	50000	9.07	202	0.110	38.3	20.2	33736	0.0288	0.164	15.2	26.9	71.9
NC21_BCE021	50000	12.24	166.6	0.147	42.2	21.9	31744	0.0343	0.207	20.0	29.7	81.0
NC21_BCE022	50000	9.69	213	0.118	40.9	22.8	31000	0.0335	0.201	19.3	34.6	89.4
NC21_BCE023	50000	10.24	228	0.133	40.3	23.0	43525	0.0407	0.267	18.8	35.6	85.7
NC21_BCE024	50000	8.90	202	0.103	40.7	16.2	31373	0.0290	0.394	17.1	32.4	84.0
NC21_BCE025	50000	170.95	109.9	0.181	94.0	12.1	31320	0.0283	0.585	48.4	37.5	136.8
Min	**50000**	**4.97**	**110**	**0.101**	**38.3**	**12.1**	**28257**	**0.027**	**0.138**	**14.1**	**24.1**	**67.0**
Mean	**50000**	**16.32**	**197**	**0.145**	**42.8**	**24.3**	**37394**	**0.034**	**0.255**	**19.1**	**31.5**	**82.4**
Max	**50000**	**170.95**	**228**	**0.263**	**94.0**	**41.4**	**172711**	**0.060**	**0.585**	**48.4**	**41.5**	**136.8**
SD	**0**	**32.43**	**24**	**0.038**	**11.0**	**6.7**	**28387**	**0.007**	**0.113**	**7.3**	**4.0**	**14.7**
2014 Survey (Maxon Consulting and TDI Brooks, 2014)												
Min	**7040**	**3.86**	**37.8**	**0.087**	**8.38**	**9.63**	**11300**	**0.022**	**13.8**	**-**	**8.33**	**26.9**
Mean	**10288**	**6.38**	**89.0**	**0.125**	**13.83**	**13.74**	**17217**	**0.039**	**20.0**	**-**	**11.09**	**41.8**
Max	**15000**	**14.10**	**159.0**	**0.165**	**21.10**	**19.60**	**25300**	**0.062**	**32.3**	**-**	**15.60**	**63.7**
SD	**2464**	**2.56**	**28.4**	**0.023**	**3.80**	**2.52**	**4092**	**0.011**	**4.3**	**-**	**1.89**	**10.9**
OSPAR (2007/2008 CEMP Assessment: Trends and concentrations of selected hazardous substances in sediments and trends in TBT-specific biological effects, 2008) – BC/BAC												
BC		**15**		**0.20**	**60.0**	**20.0**		**0.05**		**30**	**25**	**90.0**
BAC		**25**		**0.31**	**81.0**	**27.0**		**0.07**		**36**	**38**	**122.0**

Notes:
BC = Background concentrations
BAC = Background assessment concentrations

3.7 Seabed Habitats and Epifauna

The following summary describes the identified habitats, and biotopes where possible, within the survey area, focussing on potentially sensitive habitats and species, if present. The 'Biotopes/Ecosystems Nomenclature, Habitats of South America' (Institute of Terrestrial Ecology, 1996) has been used to broadly classify the observed seabed habitats. Due to a lack of more detailed habitat guidelines and background literature for South American marine habitats, the EUNIS habitat classification (European) has also been used. The European classification system remains in agreement for the overarching descriptors of habitats. However, it's species data is significantly different and so in depth classifications (i.e. biotope complexes) cannot be applied.

The results of the seabed photography sediment and faunal data review showed the survey area to be primarily comprised of one broad habitat, namely 'Western Atlantic abyssal benthic communities' (11.2122). This habitat encompasses benthic communities of abyssal plains and abyssal hills of Atlantic waters of South America north of about 42 °S, characteristic of the Western Atlantic province of the Atlantic abyssal region. The equivalent EUNIS habitat was 'Sublittoral sediment' (A5), encompassing sediments from boulders and cobbles, through pebbles and shingles, coarse sands, sands, fine sands, muds and mixed sediments (Davies et al., 2004). Each sediment type hosts characteristic biological communities, which together define biotopes.

The 'Biotopes/Ecosystems Nomenclature, Habitats of South America' habitat classification does not have more detailed biotope descriptions available than 'Western Atlantic abyssal benthic communities' habitat (11.2122). However, within the EUNIS habitat 'Sublittoral sediment', one biotope complex/biotope was identified, which was 'Circalittoral Sandy mud (A5.35) with aspects of 'Deep sea mud' (A6.5), and details of which are presented in following section. Example photographs of the biotope encountered in the survey area are shown in Plate 3.1.

3.7.1 Potentially Sensitive Habitats

No potentially sensitive habitats or species were observed throughout the Stabroek area, however, there are limited sensitive species or habitat guidelines available and as such these have been extrapolated from other guidelines (JNCC and OSPAR. It is important to note that while this has been informed by faunal and sediment data at all stations, supporting still images are only available for eleven stations (profile) and five sites (plan view).

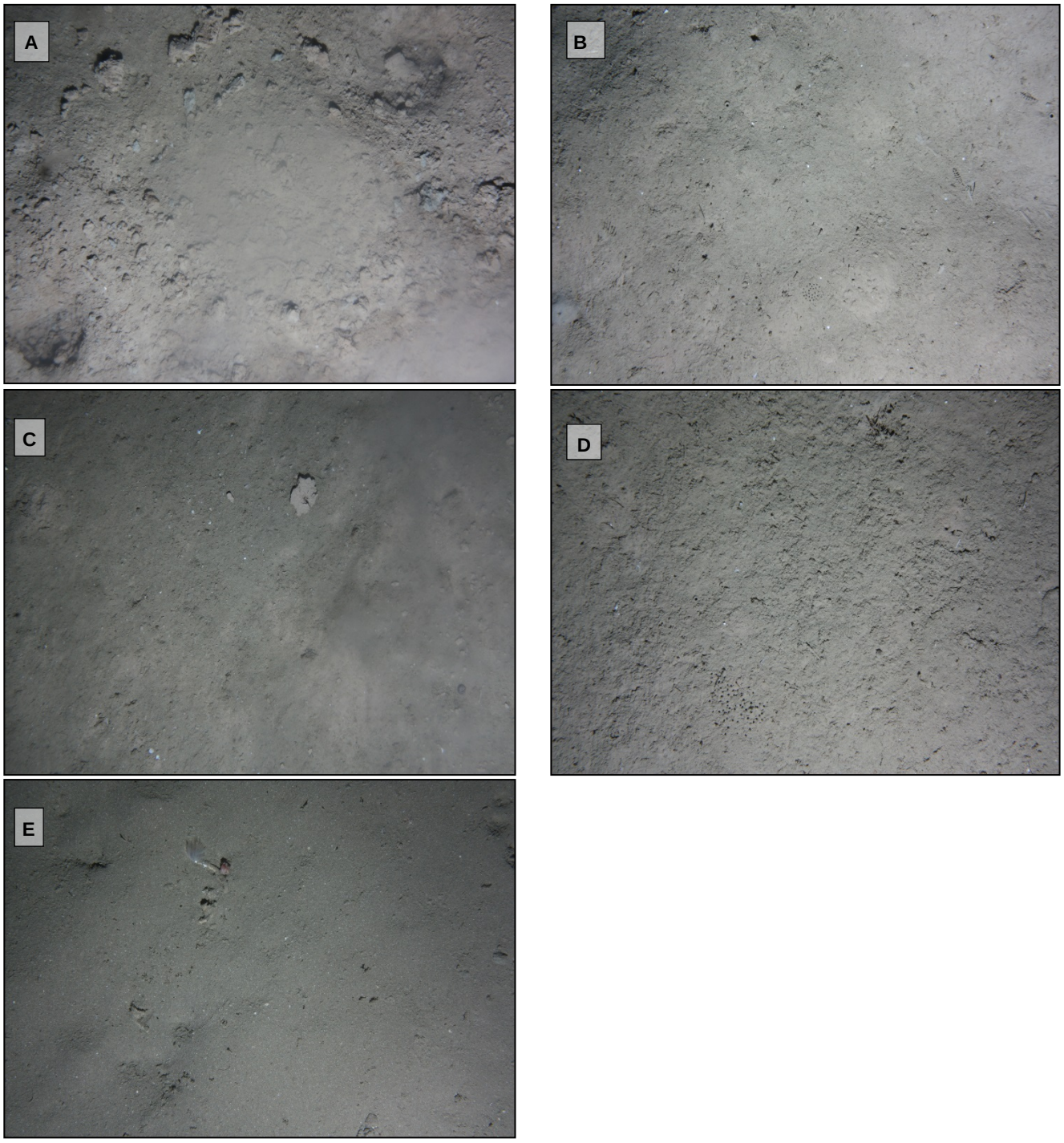


Photo A: Station NC21_BCE002; *Mud*, *tube building polychaetes and amphipods, mud shrimp burrows, Scaphopoda (tusk shells), gastropods, foraminiferans*
Photo B: Station NC21_BCE004; *Sandy Mud*, *tube building polychaetes and amphipods, mud shrimp burrows, foraminiferans. Unidentified hydroid*
Photo C: Station NC21_BCE005 *Sandy Mud*, *tube building polychaetes and amphipods,foraminiferans, Scaphopoda*
Photo D: Station NC21_BCE024 *Sandy Mud*, *tube building polychaetes and amphipods, foraminiferans*
Photo E: Station NC21_BCE025; *Muddy Sand*, *Sabellids and other tube building polychaetes, mud shrimp burrows,*

Plate 3.1: Example seabed photographs

3.8 Macrofauna

Two 0.1 m^2 macrofaunal grab samples (FA and FB) were acquired at each of the 25 stations. All A replicate samples were analysed (25 samples), with individuals of macrofaunal taxa (≥1 mm) identified, enumerated and expressed as abundance per station ($0.1m^2$).

Prior to statistical analysis been undertaken, the data were subjected to rationalisation, specifically a number of taxa of indeterminate identity, and therefore already possibly identified, were either removed from the data set (e.g. were damaged), or merged into higher taxa to avoid spurious enhancement of the species list. Meiofauna and protozoan species were also removed from the data set. Juveniles were assessed for their influence on the faunal species pattern prior to been removed from the species list (details in Section 2.7.5).

Following the rationalisation process, the benthic fauna across the survey area comprised a total of 165 macrofaunal taxa, represented by 506 individuals. These excluded: the juveniles (17 species and 42 individuals); meiofauna (four species and 118 individuals, represented mainly by Nematoda); and damaged organisms (nine taxa and 25 individuals).

Juveniles represented just over 8% of the total faunal abundance, with individual taxon's abundance ranging from 1 to 11 individuals across the survey area. Juvenile abundance was low compared to that of the overall faunal abundance and was therefore not further considered for analyses.

3.8.1 General Description of Phyletic Composition

The phyletic composition of the infaunal communities is summarised in Table 3.13 and graphically represented in Figure 3.16.

Annelida were dominant in terms of species abundance and composition, accounting for 42.7% and 40.0% of the total species abundance and composition, respectively, across the survey area. The crustaceans accounted for the second highest species composition, 38.2%, followed by the molluscs (12.7%) and other taxa (9.1%), with the Echiura hosting the lowest number of species across the survey area, representing 0.6% of the total species composition. Crustacea also hosted the second highest abundance (39.1%), then the molluscs (8.7%), whereas the other taxa had similar abundances, represented 9.5% of the total abundance.

Amongst the annelids, members of the genus *Spiophanes* were the most abundant species, accounting for 32 individuals across the survey area, followed by members of the genus *Myriochele*, the family Ampharetidae and the genus *Monticellina* with abundances of 26, 16, and 11 individuals respectively. *Spiophanes* was the most frequently recorded Annelid taxon across the survey area, occurring in 44% of samples (Table 3.13 and Table 3.14). Of the other dominant polychaetes, *Myriochele* occurred in 36% of the samples, Ampharetidae and *Monticellina* in 24% of samples (Table 3.14).

Amongst the crustaceans, the amphipod family Ampeliscidae was dominant in terms of abundance, accounting for 15.2% (25 individuals) of the crustaceans' abundance and occurring in 48% of samples. Of the other crustaceans recorded, Tanaidacea of the genus *Glabroapseudes*, Isopods from the family Desmosomatidae and the species *Leptanthura affinis* and amphipods from the genus

Harpinia (designated as species A for identification purposes) were the next four most abundant crustacean species, with abundances of 11, 10, 10 and 10 individuals respectively. The isopods *Leptanthura affinis*, Desmosomatidae and *Macrostylis* sp. were the next most frequently occurring, each been recorded in 24% of stations. Of the molluscs, the bivalves of the genus *Ennucula* and the species *Pristigloma alba* were the most abundant molluscan species, accounting for six and five individuals across the survey area, and occurring in 16% and 20% of the stations, respectively.

The holothurian of genus *Synaptidae* was by far the most abundant of the echinoderms, accounting for 3 individuals across 12% of stations. Echinoderms were generally only present in very low numbers at low frequency throughout the survey area. Finally, amongst the other taxa, Nemertea were the most abundant and frequently occurring fauna. However, numbers in all groups were low.

Table 3.9: Abundance of Major Taxonomic Groups

Group	Number of Taxa	Taxa [%]	Abundance	Abundance [%]
Annelida	66	40.0	216	42.7
Crustacea	63	38.2	198	39.1
Molusca	21	12.7	44	8.7
Nemertea	7	4.2	31	6.1
Cnidaria	2	1.2	8	1.6
Echinodermata	5	3.0	8	1.6
Echiura	1	0.6	1	0.2
Total	**165**	**100**	**506**	**100**

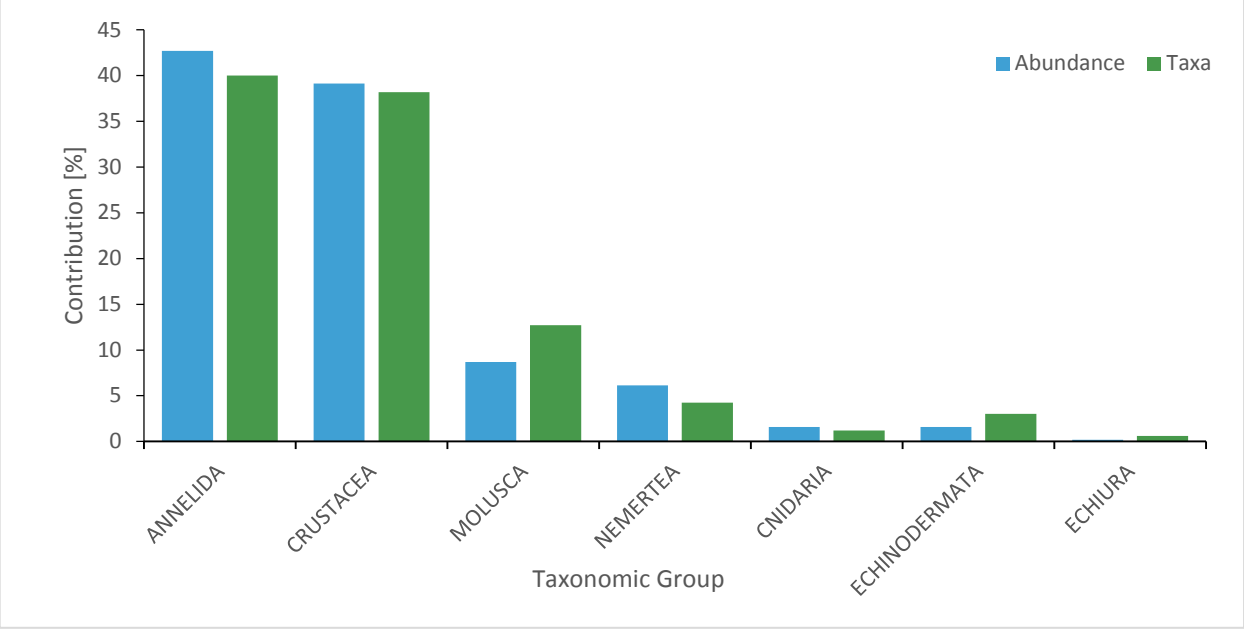


Figure 3.9: Abundance of major taxonomic groups

3.8.2 Ranked Abundance and Dominance

A list of the top ten most abundant taxa recorded within the survey area is presented (Table 3.14), together with their frequency of occurrence. Mean abundances are expressed per station (0.1 m^2).

The rank dominance is a single measure which allows identification of the species which are dominant in terms of abundance and frequency of occurrence. It is derived by ranking the taxa recorded within the survey area in terms of abundance and frequency, which are then combined to give the overall rank dominance for each species.

Frequency of occurrence was relatively low for all taxa with no taxa appearing in more than 48% of samples. As a result, five of the most abundant taxa were also amongst the top ten ranked dominant taxa, with Spiophanes, Myriochele and Ampilescidae, ranked first second and third respectively for abundance and first, third and second respectively for ranked dominance. *Monticellina* sp., *Aspidosiphon zinni* and *Leptanthura affinis* were in the ten most abundant taxa but not amongst the top ten ranked dominant, as their frequency of occurrence were 24% (*Monticellina* spand *Leptanthura affinis*) and 12% (*Aspidosiphon zinni*), equating to a presence at six and three of 25 stations respectively.

Table 3.10: Dominant Taxa and Dominance Rank for Stations [0.1m^2]

Taxon	Rank Abundance	Mean Abundance	Frequency [%]	Rank Dominance
Spiophanes (dam.)	1	1.28	44	1
Myriochele	2	1.04	36	3
Ampeliscidae	3	1.00	48	2
Ampharetidae (dam.)	4	0.64	24	4
Glabroapseudes	5	0.44	12	9
Monticellina	5	0.44	24	11
Desmosomatidae	7	0.40	24	5
Harpinia sp. A	7	0.40	28	10
Leptanthura affinis	7	0.40	24	12
Aspidosiphon zinni	10	0.36	12	32

3.8.3 Species Accumulation and Richness Estimation

The species accumulation plot displayed in Figure 3.17 was generated using untransformed station data (0.1 m^2) in PRIMER. The observed numbers of taxa obtained through repeated sampling (Sobs) were cumulatively plotted, as were richness estimates from repeated sampling as calculated by the Chao1, Chao2, Jacknife1 and Jacknife2 formulae. All of the displayed curves were smoothed by random permutations of the data points.

The observed species accumulation curve appeared to be rising and yet to have reached its asymptote, suggesting that, though most of the taxa in the survey areas were likely sampled, more species/taxa would likely be recorded through further sampling. The richness estimators suggests that the survey area has been moderately described, with estimates for the total macrofaunal diversity of the area ranging from 258 taxa (Chao 2) to 289 taxa (Jacknife 2), compared to the 165 taxa recorded (Sobs). These estimates suggested that between 64.0% and 57.1% of the area's total faunal diversity had been detected by the sampling undertaken. As such, the data is deemed sufficient to characterise the macrofaunal communities within the survey area.

3.8.4 Primary Variables and Diversity

The primary variables, numbers of taxa (S) and abundance (N), were calculated together with the univariate measures, including, equitability (Pielou's Index *J'*) and (Simpson's Index *1-λ*) and diversity (Shannon-Wiener's Index *H'*Log2) per station data (0.1 m^2). This analysis was performed using PRIMER v6. Primary variables and diversity indices station data are presented in Table 3.15. The spatial distributions of the primary variables across the survey area are presented in Figure 3.18 and Figure 3.19.

Visual inspection of the data suggested that the distribution of number of taxa may be influenced by the mud content and/or the depth (Figure 3.18). There seemed to be a general decrease in species, and to a lesser degree abundance (Figure 3.19), from the south to the north of the survey area, such that, as depth and mud content increased, the number of species decreased. A weak negative correlation was observed between depth and number of taxa and abundance (rho = -0.41673 and -0.4176, $p<0.05$, respectively). However, no statistically significant correlation was observed between mud, sand, gravel and number of taxa and abundance.

3.8.4.1 Relationships between Physical and Biological Variables

Relationships between environmental and biological variables were assessed by means of the BEST analysis from the PRIMER suite, in order to identify which of the physical and chemical variables best explained the observed pattern of macrofaunal distribution across the survey area.

Results showed that depth was the single variable that best explained the observed pattern of faunal distribution (rho = 0.561). The combination of variables that returned the highest value of correlation coefficient included: depth, CPInC12-20 and arsenic (rho = 0.611). No other variable, either alone or in combination, returned higher value than these. Results of the global test showed that these relationships were significant (sample statistic rho = 0.611, significance level = 0.1%).

Table 3.11: Primary Variables and Diversity Indices by Sample [0.1 m^2]

Station	Taxa [S]	Abundance [N]*	Margalef's Index [d]	Pielou's Index [j']	Shannon-Wiener Index [H']	Simpson's Index [1-λ]	No. of Juveniles
NC21_BCE001	27	35	7.31	0.97	3.21	0.98	22
NC21_BCE002	19	20	6.01	0.99	2.93	0.99	4
NC21_BCE003	14	20	4.34	0.97	2.55	0.96	0
NC21_BCE004	24	28	6.90	0.98	3.12	0.99	2
NC21_BCE005	12	14	4.17	0.98	2.44	0.98	0
NC21_BCE006	21	35	5.63	0.94	2.85	0.96	19
NC21_BCE007	25	37	6.65	0.91	2.93	0.94	14
NC21_BCE008	18	27	5.16	0.95	2.74	0.96	11
NC21_BCE009	3	7	1.03	0.72	0.80	0.52	2
NC21_BCE010	14	26	3.99	0.94	2.47	0.94	7
NC21_BCE011	15	31	4.08	0.90	2.42	0.92	9
NC21_BCE012	12	21	3.61	0.85	2.12	0.86	18
NC21_BCE013	8	9	3.19	0.98	2.04	0.97	3
NC21_BCE014	11	12	4.02	0.99	2.37	0.98	13
NC21_BCE015	15	16	5.05	0.99	2.69	0.99	6
NC21_BCE016	6	7	2.57	0.98	1.75	0.95	6
NC21_BCE017	8	9	3.19	0.98	2.04	0.97	5
NC21_BCE018	7	7	3.08	1.00	1.95	1.00	0
NC21_BCE019	10	12	3.62	0.98	2.25	0.97	0
NC21_BCE020	6	7	2.57	0.98	1.75	0.95	4
NC21_BCE021	14	20	4.34	0.95	2.51	0.95	10
NC21_BCE022	24	29	6.83	0.98	3.13	0.99	6
NC21_BCE023	12	17	3.88	0.95	2.36	0.95	2
NC21_BCE024	28	44	7.13	0.94	3.14	0.97	13
NC21_BCE025	9	16	2.89	0.90	1.98	0.88	11
Min	**3**	**7**	**1.03**	**0.72**	**0.80**	**0.52**	**0**
Mean	**14**	**20**	**4.74**	**0.95**	**2.42**	**0.94**	**7**
Max	**28**	**44**	**7.31**	**1.00**	**3.21**	**1.00**	**22**
SD	**7**	**11**	**1.65**	**0.06**	**0.56**	**0.09**	**6**

Note:
***** = abundance of juveniles (not included in total abundance N).

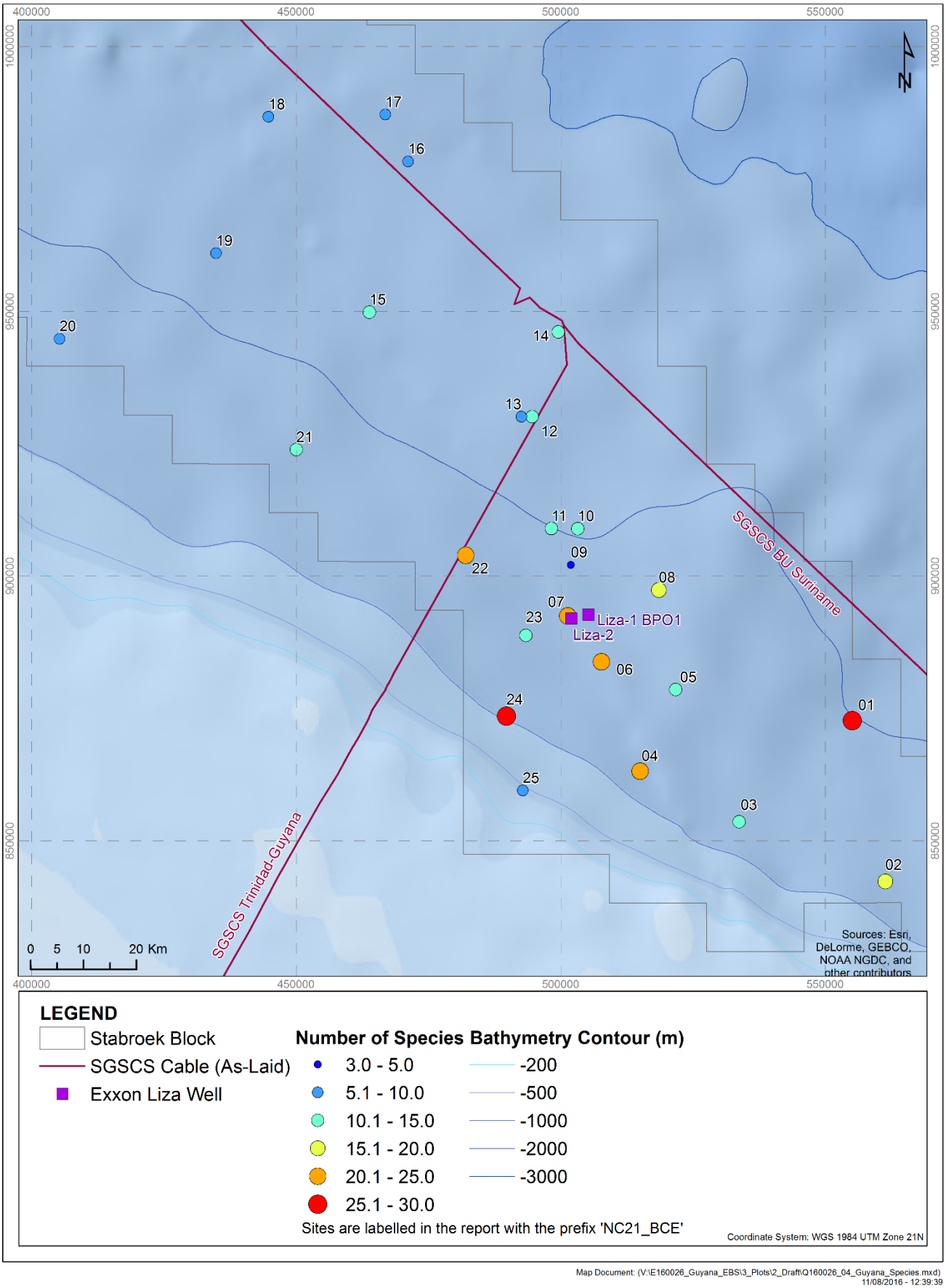


Figure 3.10: Spatial distribution of number of taxa (S) [0.1 m^2]

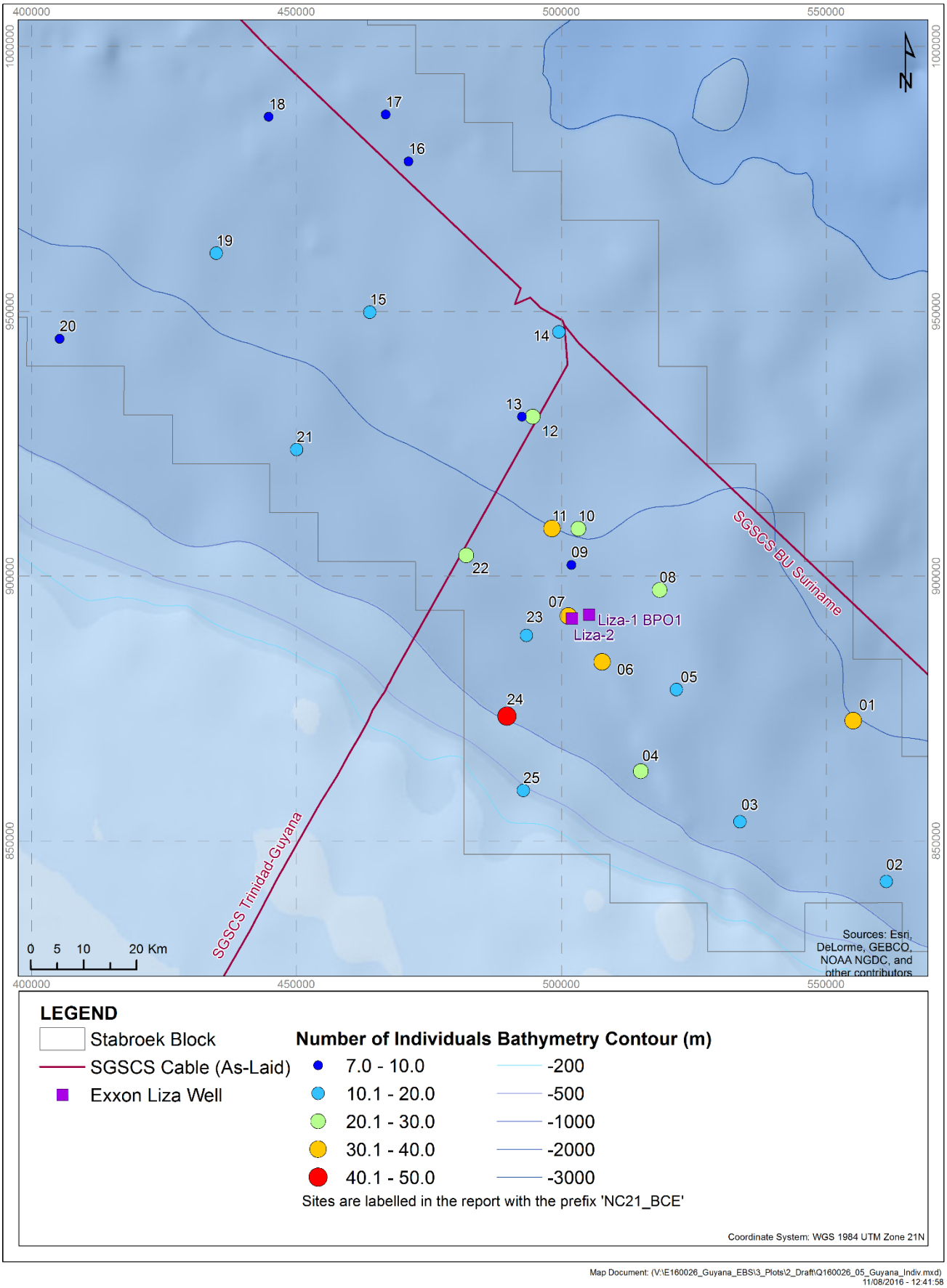


Figure 3.11: Spatial distribution of number of individuals (N) [0.1 m^2]

3.9 Water Samples

3.9.1 Water Profiling

Results of the water column profiles indicated well mixed layers of water across the entire survey area, as indicated by the vertical line on the plots, an example of which is presented in Figure 3.22.

Results showed a stratified water column, with a defined thermocline, halocline and oxygen boundary, below which these parameters notably dropped. All other parameters monitored returned similar values throughout the water column. Spatial variations of the parameters were driven by depth, with boundary layers been deeper in deeper water.

Surface water temperature was fairly uniform across the survey area, with a mean sea surface temperature (SST) of 27.8°C. Temperature at the bottom of the CTD profiles varied between 2.7 °C at station NC21_16WC017 (the deepest site) and 11.2°C at NC21_16WC025 (the shallowest site).

Salinity range was very small, with surface values per station of between 37.05 ppt (NC21_16WC008) and 36.60 ppt (NC21_16WC025). Below the halocline salinity values dropped to between 33.63 ppt (NC21_16WC008) and 35.30 ppt (NC21_16WC025).

Mean values per station of pH were between 8.18 (NC21_16WC025) and 8.47 (NC21_16WC015). Turbidity was very low, with mean values per station equal or less to 2.9 (FTU).

A summary of the water physical parameters, as measured by the water column profiles is presented in Table 3.17.

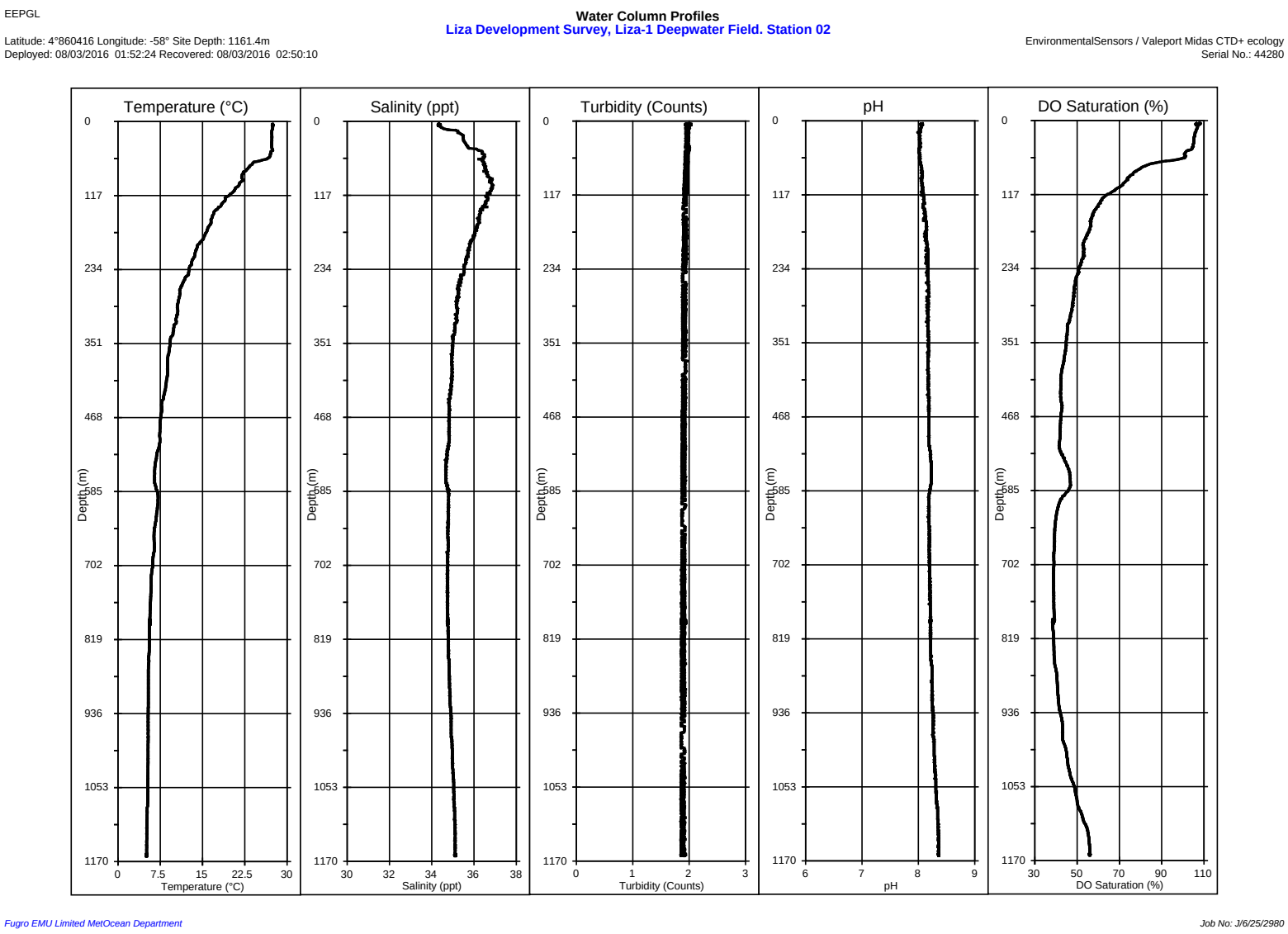


Figure 3.12: Water column profile at sampling station NC21_16WC002

Table 3.12: Summary of Water Physical Parameters Recorded by Water Column Profiles

Station	Statistics	Depth [m]	Temperature [°C]	Salinity [ppt]	DO Saturation [%]	pH	Turbidity [FTU counts]
NC21_16WC002	Min	-	5.07	34.31	38.44	7.99	1.85
	Mean	**-**	10.15	34.93	54.88	8.21	1.91
	Max	1161.87	27.46	36.90	108.34	8.36	2.04
	StDev	-	8.04	0.46	23.28	0.09	0.04
NC21_16WC005	Min	-	3.77	34.50	35.49	7.96	2.31
	Mean	**-**	10.67	34.99	62.66	8.21	2.37
	Max	1666.71	27.58	36.69	101.55	8.44	2.56
	StDev	-	9.25	0.40	21.70	0.12	0.04
NC21_16WC006	Min	-	3.95	33.99	36.14	7.88	1.70
	Mean	**-**	9.27	34.99	58.04	8.12	2.11
	Max	1532.63	27.61	36.61	101.23	8.28	2.97
	StDev	-	7.86	0.49	18.68	0.13	0.25
NC21_16WC008	Min	-	3.44	33.63	35.03	7.85	2.31
	Mean	**-**	8.56	34.96	56.78	8.15	2.35
	Max	1907.46	27.90	37.05	103.12	8.39	2.50
	StDev	-	7.64	0.54	17.64	0.14	0.03
NC21_16WC009	Min	-	3.49	33.34	34.34	-	2.39
	Mean	**-**	7.42	34.98	48.88	**-**	2.44
	Max	1888.06	27.88	36.85	95.54	-	2.58
	StDev	-	5.90	0.49	11.64	-	0.01
NC21_16WC010	Min	-	3.55	33.67	34.07	7.86	2.35
	Mean	**-**	4.87	35.07	57.66	8.26	2.43
	Max	2000.91	27.95	36.96	92.22	8.33	2.49
	StDev	-	3.28	0.24	7.92	0.09	0.02
NC21_16WC012	Min	-	3.19	33.89	34.36	7.89	2.44
	Mean	**-**	7.53	35.00	53.74	8.18	2.52
	Max	2318.35	27.77	36.94	92.68	8.31	2.60
	StDev	-	7.38	0.47	14.62	0.13	0.03
NC21_16WC015	Min	-	3.26	33.91	34.56	8.01	2.56
	Mean	**-**	7.39	35.02	54.08	8.34	2.60
	Max	2363.25	27.99	37.04	93.53	8.47	2.94
	StDev	-	7.37	0.46	14.35	0.15	0.04
NC21_16WC017	Min	-	2.68	34.66	37.89	8.01	2.73
	Mean	**-**	6.61	35.10	55.98	8.30	2.90
	Max	2714.41	28.03	36.91	94.31	8.46	3.00
	StDev	-	7.39	0.37	13.59	0.13	0.08
NC21_16WC018	Min	-	2.77	34.69	36.64	7.99	2.56
	Mean	**-**	7.76	35.13	59.04	8.13	2.66
	Max	2605.08	27.95	37.03	101.51	8.22	2.74
	StDev	-	8.04	0.36	17.31	0.07	0.04
NC21_16WC020	Min	-	3.68	34.64	36.41	7.91	2.81
	Mean	**-**	8.28	35.08	57.83	8.15	2.82
	Max	1832.73	28.05	36.78	99.67	8.29	3.06
	StDev	-	7.49	0.38	16.31	0.12	0.02
NC21_16WC021	Min	-	3.76	34.69	36.69	7.98	2.65
	Mean	**-**	9.62	35.14	59.15	8.12	2.70
	Max	1721.71	28.00	36.88	102.00	8.29	2.76
	StDev	-	8.35	0.40	19.73	0.10	0.02
NC21_16WC022	Min	-	3.62	34.66	39.64	7.91	2.74
	Mean	**-**	4.44	35.01	61.06	8.19	2.83
	Max	1702.74	28.18	37.09	110.41	8.23	3.14
	StDev	-	6.09	0.49	14.68	0.11	0.07

Station	Statistics	Depth [m]	Temperature [°C]	Salinity [ppt]	DO Saturation [%]	pH	Turbidity [FTU counts]
NC21_16WC023	Min	-	4.25	34.19	36.93	7.91	2.20
	Mean	**-**	9.64	35.01	59.66	8.13	2.25
	Max	1474.59	27.51	36.60	102.40	8.34	2.29
	StDev	-	7.78	0.46	18.52	0.13	0.02
NC21_16WC024	Min	-	5.39	34.75	38.60	8.04	1.86
	Mean	**-**	16.11	35.36	69.16	8.15	1.92
	Max	911.79	27.50	36.72	107.16	8.28	1.98
	StDev	-	9.88	0.55	30.55	0.09	0.03
NC21_16WC025	Min	-	11.23	35.30	48.42	8.02	1.90
	Mean	-	22.59	35.93	86.10	8.07	1.94
	Max	248.04	27.45	36.60	105.65	8.18	1.99
	StDev	-	6.42	0.40	24.06	0.06	0.01

3.9.2 Water Total Organic Carbon (TOC)

TOC concentrations are presented in Table 3.18 and showed only slight stratification, with generally marginally lower values for TOC from deeper samples. In surface seawater samples, TOC ranged from 0.9 mgl^{-1} at station NC21_16WC012 to 3.9 mgl^{-1} (station NC21_16WC005). In mid depth samples, TOC ranged from 0.8 mgl^{-1} at station NC21_16WC020 to 4.0 mgl^{-1} (station NC21_16WC002). In the bottom depth samples, TOC concentrations ranged from 0.9 mgl^{-1} at station NC21_16WC025 to 2.4 mgl^{-1} (at stations NC21_16WC005, NC21_16WC006 and NC21_16WC015).

Table 3.13: Summary of Water Total Organic Carbon

Station	Total Organic Carbon [mgl^{-1}]		
	Surface	**Mid**	**Bottom**
NC21_16WC002	1.5	4.0	1.6
NC21_16WC005	3.9	2.9	2.4
NC21_16WC006	2.5	2.1	2.4
NC21_16WC008	2.7	2.2	2.0
NC21_16WC009	2.4	1.5	2.0
NC21_16WC010	2.4	1.8	1.9
NC21_16WC012	0.9	1.3	1.1
NC21_16WC015	3.4	1.7	2.4
NC21_16WC017	3.1	1.8	2.2
NC21_16WC018	1.3	1.0	1.5
NC21_16WC020	2.0	0.8	1.0
NC21_16WC021	3.0	1.9	1.7
NC21_16WC022	2.2	2.3	1.7
NC21_16WC023	2.3	1.8	1.6
NC21_16WC024	1.2	1.8	2.1
NC21_16WC025	2.2	1.0	0.9
Min	**0.9**	**0.8**	**0.9**
Max	**3.9**	**4.0**	**2.4**
Mean	**2.3**	**1.9**	**1.8**

SD	**0.8**	**0.8**	**0.5**

3.9.3 Total Suspended Solids (TSS)

Total suspended solids (TSS) concentrations are presented in Table 3.19 and showed only slight stratification, with generally lower values for TSS from deeper samples. In surface seawater samples, TSS ranged from 2.4 mgl^{-1} at stations NC21_16WC009, NC21_16WC015 and NC21_16WC018 to 18.3 mgl^{-1} (station NC21_16WC021). In mid depth samples, concentrations ranged from below the detection limit at four stations to 6.5 mgl^{-1} (station NC21_16WC021). In the bottom depth sample, TSS concentrations ranged below the detection limit at five stations to 7.7 mgl^{-1} (station NC21_16WC002).

Table 3.14: Summary of Water Total Suspended Solids

Station	Total Suspended Solids [mgl^{-1}]		
	Surface	**Mid**	**Bottom**
NC21_16WC002	6.5	4.1	7.7
NC21_16WC005	7.6	2.3	4.2
NC21_16WC006	4.0	2.9	2.2
NC21_16WC008	7.7	2.1	< 2.0
NC21_16WC009	2.4	< 2.0	2.1
NC21_16WC010	6.7	2.8	2.4
NC21_16WC012	5.4	2.1	< 2.0
NC21_16WC015	2.4	< 2.0	3.2
NC21_16WC017	4.4	3.7	3.3
NC21_16WC018	2.4	2.2	< 2.0
NC21_16WC020	5.5	< 2.0	< 2.0
NC21_16WC021	18.3	6.5	3.2
NC21_16WC022	6.2	2.0	< 2.0
NC21_16WC023	13.3	< 2.0	4.0
NC21_16WC024	9.7	2.8	2.9
NC21_16WC025	4.2	3.7	2.7
Min	**2.4**	**2.0**	**2.1**
Max	**18.3**	**6.5**	**7.7**
Mean	**6.7**	**3.1**	**3.4**
SD	**4.2**	**1.3**	**1.6**

3.9.4 Water Hydrocarbons

3.9.4.1 Total Hydrocarbons and n-Alkanes

Total hydrocarbon analysis results are presented in Table 3.20. Concentrations were generally similar at each depth within a station, with the two exceptions of the bottom samples from NC21_16WC005 and NC21_16WC023. Concentrations ranged from 8.3 μgl^{-1}, in the bottom water sample at station NC21_16WC012, to 35.9 µgl-1, in the bottom water sample at reference station NC21_16WC023.

Table 3.15. Total Hydrocarbon in water samples

Station	Total Hydrocarbon (THC) µg/l Water		
	Top	Middle	Bottom
NC21_16WC002	16.4	17.7	10.8
NC21_16WC005	15.1	9.2	32.9
NC21_16WC006	11.5	13.8	27.7
NC21_16WC008	11.4	10.4	11.2
NC21_16WC009	10.0	9.4	9.1
NC21_16WC010	20.5	9.2	11.1
NC21_16WC012	13.1	14.1	8.3
NC21_16WC015	15.2	13.5	13.7
NC21_16WC017	17.4	19.3	13.6
NC21_16WC018	11.5	13.7	13.5
NC21_16WC020	18.8	12.3	15.0
NC21_16WC021	17.5	13.6	14.5
NC21_16WC022	15.8	12.5	13.3
NC21_16WC023	22.0	16.6	35.9
NC21_16WC024	22.1	18.8	26.1
NC21_16WC025	33.1	26.4	20.5
Min	**10.0**	**9.2**	**8.3**
Max	**33.1**	**26.4**	**35.9**
Mean	**17.0**	**14.4**	**17.3**
SD	**5.7**	**4.5**	**8.7**

Result for the other components of hydrocarbons analysis for the water samples at all stations are presented in Table 3.21.

The ratio of Pristane/Phytane (Table 3.21) was above 1 for the majority of the samples (77%) and < 1 in bottom water samples at stations NC21_WC010, NC21_WC012, NC21_WC015, NC21_WC021 and NC21_WC023. The ratio of Pristane/Phytane was < 1 in mid water samples at stations NC21_WC010, NC21_WC020, NC21_WC021, NC21_WC023 and NC21_WC025, the only surface sample where the ratio of Pristane/Phytane was < 1 was at station NC21_WC025.

Total concentrations for individual n-alkanes analysis at each site were generally low across the survey area. The values ranged between 0.37 $\mu g l^{-1}$, recorded in the bottom water sample at station NC21_WC015, and 16.3 $\mu g l^{-1}$, recorded in the bottom waters sample at station NC21_WC005. The results of individual alkanes are presented in Table 3.22.

Table 3.16: Summary of the Organic Compounds Concentrations in the Water Samples

Concentrations Expressed as µg/l Water											
Station	GC-MS										
	UCM	n-alkanes			CPI			Pristane	Phytane	Pr/Ph Ratio	2 - 6 Ring PAH
		nC_{12-20}	nC_{21-36}	nC_{12-36}	nC_{12-20}	nC_{21-36}	nC_{12-36}				
NC21_WC002 Bottom	2.9	0.28	2.68	2.97	1.20	0.92	0.95	0.012	0.010	1.14	0.064
NC21_WC002 Mid	3.6	0.28	6.49	6.78	1.29	0.92	0.93	0.012	0.010	1.24	0.075
NC21_WC002 Surface	6.3	0.33	3.89	4.22	1.49	0.91	0.95	0.012	0.007	1.77	0.072
NC21_WC005 Bottom	5.5	0.40	15.9	16.3	1.34	0.91	0.92	0.022	0.008	2.67	0.080
NC21_WC005 Mid	4.5	0.26	0.27	0.53	1.29	0.96	1.11	0.015	0.013	1.21	0.067
NC21_WC005 Surface	7.6	0.31	2.40	2.71	1.22	0.92	0.95	0.021	0.009	2.33	0.064
NC21_WC006 Bottom	7.2	0.41	8.90	9.3	1.0	0.98	0.98	0.017	0.016	1.02	0.106
NC21_WC006 Mid	4.0	0.35	4.16	4.52	1.51	0.95	0.98	0.017	0.008	1.98	0.069
NC21_WC006 Surface	5.3	0.38	0.46	0.85	1.49	0.98	1.18	0.019	0.013	1.46	0.080
NC21_WC008 Bottom	5.9	0.30	0.70	1.00	1.40	0.96	1.08	0.014	0.007	2.02	0.067
NC21_WC008 Mid	5.6	0.20	0.20	0.40	1.37	0.96	1.15	0.016	0.005	3.01	0.069
NC21_WC008 Surface	5.8	0.24	1.18	1.42	1.47	0.90	0.97	0.011	0.008	1.39	0.064
NC21_WC009 Bottom	4.7	0.24	0.17	0.41	1.22	0.98	1.12	0.012	0.007	1.78	0.066
NC21_WC009 Mid	4.7	0.22	0.25	0.48	0.93	1.15	1.04	0.019	0.015	1.26	0.065
NC21_WC009 Surface	5.1	0.27	0.43	0.70	1.13	0.95	1.02	0.017	0.015	1.15	0.061
NC21_WC010 Bottom	6.6	0.23	0.19	0.42	0.87	1.11	0.97	0.014	0.022	0.64	0.064
NC21_WC010 Mid	4.1	0.33	0.27	0.60	0.84	0.90	0.87	0.025	0.025	0.99	0.065
NC21_WC010 Surface	12.2	0.32	1.98	2.30	1.04	0.92	0.94	0.028	0.023	1.23	0.089
NC21_WC012 Bottom	3.7	0.27	0.13	0.41	0.86	1.04	0.91	0.013	0.018	0.75	0.059
NC21_WC012 Mid	7.9	0.31	0.71	1.02	0.98	0.94	0.95	0.021	0.016	1.28	0.074
NC21_WC012 Surface	6.7	0.33	0.54	0.86	1.17	0.95	1.03	0.024	0.016	1.51	0.076
NC21_WC015 Bottom	8.6	0.27	0.10	0.37	0.90	0.88	0.89	0.022	0.025	0.86	0.076
NC21_WC015 Mid	8.5	0.35	0.26	0.61	0.87	0.95	0.90	0.021	0.021	1.00	0.084
NC21_WC015 Surface	8.0	0.32	1.98	2.31	1.18	0.88	0.92	0.016	0.022	0.72	0.066
NC21_WC017 Bottom	8.3	0.32	0.27	0.58	0.89	0.93	0.91	0.023	0.015	1.50	0.072
NC21_WC017 Mid	3.7	0.29	7.72	8.01	0.81	0.91	0.91	0.024	0.023	1.08	0.075
NC21_WC017 Surface	10.1	0.24	2.04	2.27	0.79	0.96	0.94	0.016	0.012	1.35	0.084
NC21_WC018 Bottom	9.6	0.16	0.36	0.52	0.85	0.92	0.90	0.009	0.009	1.00	0.076
NC21_WC018 Mid	9.7	0.20	0.22	0.43	0.77	0.84	0.81	0.010	0.007	1.34	0.094
NC21_WC018 Surface	6.2	0.25	0.36	0.61	0.91	0.88	0.89	0.012	0.014	0.89	0.109
NC21_WC020 Bottom	10.1	0.34	0.37	0.72	0.83	0.93	0.88	0.019	0.013	1.48	0.113
NC21_WC020 Mid	8.4	0.25	0.20	0.46	0.91	1.01	0.96	0.012	0.014	0.87	0.091
NC21_WC020 Surface	11.4	0.28	2.44	2.72	1.21	0.91	0.93	0.024	0.016	1.48	0.096
NC21_WC021 Bottom	10.2	0.22	0.48	0.70	0.84	0.95	0.91	0.011	0.014	0.80	0.077
NC21_WC021 Mid	8.8	0.20	0.36	0.56	0.72	0.90	0.83	0.017	0.021	0.84	0.082
NC21_WC021 Surface	12.6	0.24	0.30	0.55	0.78	1.02	0.90	0.011	0.011	1.02	0.087
NC21_WC022 Bottom	9.8	0.18	0.26	0.44	0.78	0.99	0.90	0.017	0.007	2.44	0.067
NC21_WC022 Mid	8.0	0.26	0.21	0.47	0.82	0.63	0.73	0.015	0.010	1.52	0.080
NC21_WC022 Surface	11.6	0.15	0.43	0.58	0.67	1.07	0.95	0.012	0.009	1.34	0.051
NC21_WC023 (100m)	11.9	0.15	9.27	9.41	0.49	0.90	0.89	0.010	0.008	1.22	0.073
NC21_WC023 (40m)	12.0	0.38	0.50	0.88	0.81	0.96	0.89	0.011	0.010	1.08	0.072
NC21_WC023 Bottom	26.8	0.36	0.83	1.19	0.60	0.96	0.84	0.025	0.026	0.96	0.111
NC21_WC023 Mid	11.7	0.13	0.72	0.85	0.50	0.96	0.87	0.007	0.007	0.88	0.058
NC21_WC023 Surface	13.2	0.18	2.29	2.46	0.51	0.95	0.91	0.013	0.010	1.21	0.062

Concentrations Expressed as µg/l Water											
Station	GC-MS										
	UCM	n-alkanes			CPI			Pristane	Phytane	Pr/Ph Ratio	2 - 6 Ring PAH
NC21_WC024 Bottom	28.3	0.26	0.52	0.77	0.73	0.94	0.87	0.019	0.017	1.15	0.065
NC21_WC024 Mid	14.0	0.16	0.57	0.73	0.49	0.98	0.85	0.017	0.010	1.78	0.054
NC21_WC024 Surface	14.1	0.21	1.37	1.58	0.48	0.93	0.86	0.012	0.010	1.19	0.062
NC21_WC025 Bottom	13.8	0.19	0.98	1.17	0.46	0.94	0.85	0.012	0.010	1.16	0.063

Notes:
UCM = Unresolved complex mixture
CPI = Carbon preference index (the ratio of odd number carbon chain n-alkanes to even numbered chain n-alkanes)
Pr/Ph = ratio of pristane to phytane
2 - 6 ring PAH = Total 2 - 6 ring polycyclic aromatic hydrocarbons (including alkyl homologues - see PAH table for full details of compounds quantified)

Table 3.17: Individual n-Alkanes Average Concentrations at Each Site [ngl^{-1} of Water]

Alkanes	NC21_WC002 Bottom	NC21_WC002 Mid	NC21_WC002 Surface	NC21_WC005 Bottom	NC21_WC005 Mid	NC21_WC005 Surface	NC21_WC006 Bottom	NC21_WC006 Mid	NC21_WC006 Surface	NC21_WC008 Bottom	NC21_WC008 Mid	NC21_WC008 Surface
nC_{12}	31.7	23.6	27.4	27.5	21.0	24.5	32.1	29.0	23.9	22.9	16.8	20.3
nC_{13}	95.4	84.0	91.1	123	86.6	94.2	135	96.8	96.3	81.4	60.6	61.3
nC_{14}	46.7	45.8	49.9	71.0	48.2	56.2	67.1	54.6	55.9	46.9	34.2	37.0
nC_{15}	29.3	33.5	61.8	64.9	22.0	38.1	15.7	80.1	76.9	56.1	28.4	53.3
nC_{16}	13.0	15.5	15.3	22.7	15.4	20.7	26.2	17.3	19.8	15.3	14.9	13.3
nC_{17}	13.0	22.3	23.8	26.9	22.8	20.3	29.5	19.3	26.4	19.9	13.8	11.6
nC_{18}	19.6	23.6	20.0	29.1	15.6	22.0	41.2	18.4	29.5	21.3	12.6	13.1
nC_{19}	17.2	18.6	18.5	15.4	16.6	18.2	24.2	16.7	30.6	16.2	15.6	14.2
nC_{20}	18.5	14.5	18.1	21.7	14.8	16.9	36.1	22.1	24.9	17.9	7.8	11.8
nC_{21}	11.0	12.5	6.2	10.5	3.2	7.5	11.9	10.2	9.0	3.0	6.6	7.7
nC_{22}	4.7	6.3	9.4	9.1	5.5	8.7	8.4	4.2	8.4	4.6	8.0	4.1
nC_{23}	8.6	6.1	7.4	12.9	5.9	10.5	10.8	5.5	5.1	5.7	2.8	5.0
nC_{24}	11.5	9.9	9.4	16.9	5.0	18.6	21.9	9.4	8.4	6.5	6.7	6.6
nC_{25}	8.9	11.6	11.6	22.7	8.4	22.2	48.6	16.4	7.5	6.0	8.1	7.5
nC_{26}	12.3	26.8	19.5	57.8	10.8	29.0	118	33.0	10.7	6.4	6.7	8.4
nC_{27}	25.5	54.6	35.8	109	18.6	51.8	252	84.6	11.2	14.3	12.4	13.8
nC_{28}	55.0	126	81.6	242	21.4	74.1	456	160	12.3	18.9	11.6	21.2
nC_{29}	109	264	156	545	23.5	119	708	265	20.9	24.3	11.8	42.7
nC_{30}	190	455	276	1050	25.4	169	972	369	25.4	47.4	15.7	70.4
nC_{31}	308	746	446	1800	29.3	236	1310	506	39.0	83.9	15.1	111
nC_{32}	395	954	569	2340	34.7	302	1390	577	55.0	96.5	19.9	154
nC_{33}	437	1050	630	2660	26.7	355	1290	610	67.9	114	18.3	187
nC_{34}	423	1020	600	2570	22.9	373	1020	565	66.5	104	17.0	203
nC_{35}	379	959	563	2430	14.3	346	775	526	69.4	94.3	20.8	183
nC_{36}	304	793	473	2030	9.8	275	522	420	48.1	74.3	14.2	154
Total (µg/l)	**2.97**	**6.78**	**4.22**	**16.3**	**0.528**	**2.71**	**9.31**	**4.52**	**0.849**	**1.00**	**0.400**	**1.42**

Table 3.22: Individual n-Alkanes Average Concentrations at Each Site [ngl-1 of Water] Continued

Alkanes	NC21_WC009 Bottom	NC21_WC009 Mid	NC21_WC009 Surface	NC21_WC010 Bottom	NC21_WC010 Mid	NC21_WC010 Surface	NC21_WC012 Bottom	NC21_WC012 Mid	NC21_WC012 Surface	NC21_WC015 Bottom	NC21_WC015 Mid	NC21_WC015 Surface
nC_{12}	15.5	20.7	23.2	21.7	33.1	29.6	30.6	27.0	27.6	24.9	32.3	24.8
nC_{13}	61.9	49.5	53.3	52.2	73.7	64.4	61.8	65.9	69.6	57.4	70.7	57.4
nC_{14}	39.5	39.1	41.4	39.0	53.3	50.2	49.4	45.5	47.8	43.7	53.8	40.1
nC_{15}	38.6	19.7	48.6	18.3	25.0	47.1	26.1	28.8	57.8	22.5	34.3	64.8
nC_{16}	13.5	13.7	20.4	17.3	28.2	23.3	20.6	28.6	20.9	25.0	29.1	20.4
nC_{17}	14.0	19.4	22.9	19.5	26.8	28.3	20.6	25.0	25.7	25.0	31.4	25.1
nC_{18}	17.9	22.3	27.7	26.9	38.3	37.7	30.8	36.8	32.7	33.0	39.4	35.3
nC_{19}	17.6	18.6	18.7	17.6	24.9	26.2	17.1	32.2	22.9	24.9	28.1	28.6
nC_{20}	22.1	19.1	14.2	18.9	26.4	18.3	15.1	16.9	21.4	17.8	34.3	28.1
nC_{21}	9.2	10.2	5.3	11.2	12.3	23.4	9.9	10.2	9.8	11.3	12.3	14.1
nC_{22}	7.9	7.8	4.6	6.9	8.6	18.2	8.0	8.4	11.3	7.5	8.6	16.6
nC_{23}	6.5	9.0	7.6	5.0	8.0	16.6	7.3	9.5	11.2	6.0	8.2	30.4
nC_{24}	11.7	9.9	12.1	12.1	26.9	18.9	7.8	23.2	23.3	22.9	14.5	56.5
nC_{25}	10.3	14.7	12.8	11.2	11.0	13.5	9.1	32.4	13.8	4.8	10.8	65.5
nC_{26}	13.8	18.2	18.2	10.2	13.8	15.6	6.9	43.8	14.0	4.0	15.8	68.3
nC_{27}	17.6	19.6	22.6	15.0	18.8	17.2	9.6	47.6	20.9	5.6	20.4	74.2
nC_{28}	14.1	20.5	26.2	11.6	17.5	28.3	11.6	52.9	21.4	6.6	19.8	74.7
nC_{29}	11.4	23.0	35.9	13.4	23.7	60.7	9.9	57.3	25.4	3.9	19.3	100
nC_{30}	9.5	15.8	42.2	15.6	22.1	126	9.7	61.8	35.1	3.6	19.2	151
nC_{31}	11.8	18.5	49.4	17.0	25.3	220	8.0	73.8	51.1	6.3	19.5	204
nC_{32}	8.3	21.9	54.1	15.4	24.6	274	9.3	76.8	62.7	3.7	20.6	272
nC_{33}	7.4	22.0	51.9	14.2	21.1	313	7.6	69.4	68.3	4.2	25.1	245
nC_{34}	7.7	14.7	41.8	9.8	20.6	304	7.0	65.0	61.6	1.9	18.8	222
nC_{35}	10.0	19.2	25.7	14.0	10.2	284	6.2	46.2	61.7	3.4	10.5	196
nC_{36}	12.4	9.9	22.7	9.3	10.1	245	5.0	36.2	46.3	1.2	15.8	195
Total (µg/l)	**0.410**	**0.477**	**0.703**	**0.423**	**0.604**	**2.30**	**0.405**	**1.02**	**0.864**	**0.371**	**0.613**	**2.31**

Table 3.22: Individual n-Alkanes Average Concentrations at Each Site [ngl-1 of Water] Continued

Alkanes	NC21_WC017 Bottom	NC21_WC017 Mid	NC21_WC017 Surface	NC21_WC018 Bottom	NC21_WC018 Mid	NC21_WC018 Surface	NC21_WC020 Bottom	NC21_WC020 Mid	NC21_WC020 Surface	NC21_WC021 Bottom	NC21_WC021 Mid	NC21_WC021 Surface
nC_{12}	29.6	28.8	27.0	17.2	23.0	26.1	44.8	27.4	27.7	21.3	18.0	22.6
nC_{13}	62.9	56.7	53.6	38.6	42.1	49.4	83.5	60.9	49.7	46.8	37.5	51.7
nC_{14}	50.7	46.5	41.6	29.7	30.4	41.8	61.8	47.1	32.4	43.6	34.7	43.3
nC_{15}	23.3	25.5	10.1	10.5	13.9	11.7	27.3	25.4	62.6	22.8	11.6	17.5
nC_{16}	21.2	28.6	17.3	13.0	17.1	20.6	23.2	15.8	17.5	15.0	15.4	16.5
nC_{17}	26.2	24.8	24.3	11.5	14.0	41.0	25.0	17.0	21.0	14.5	14.6	17.7
nC_{18}	37.6	34.8	26.4	16.6	24.9	24.8	36.1	24.7	27.1	24.1	25.6	29.4
nC_{19}	37.3	24.5	15.6	15.0	18.6	18.1	19.7	17.7	20.2	18.1	19.5	20.6
nC_{20}	28.7	23.2	19.2	12.0	20.0	18.9	21.7	17.4	22.1	17.2	21.2	25.6
nC_{21}	8.8	11.1	13.4	7.1	10.1	9.2	10.8	13.3	9.6	8.5	15.3	10.1
nC_{22}	9.1	7.4	8.7	6.4	9.3	6.3	9.3	11.6	9.6	10.0	15.0	8.9
nC_{23}	6.5	8.8	10.1	6.2	7.4	5.7	9.2	6.4	10.9	13.5	14.4	13.7
nC_{24}	8.2	9.5	31.9	19.1	14.0	12.2	25.9	16.5	24.4	21.4	24.5	15.9
nC_{25}	7.4	10.4	27.2	13.1	7.4	10.8	9.2	10.1	11.9	19.7	18.8	16.1
nC_{26}	7.3	14.2	45.5	17.7	10.4	8.7	11.3	14.2	16.9	21.9	20.5	14.1
nC_{27}	11.3	31.2	69.0	20.4	12.9	12.4	17.9	15.5	23.0	28.1	21.0	17.3
nC_{28}	13.5	71.0	105	27.0	13.8	10.2	24.8	11.2	41.5	35.7	27.6	18.8
nC_{29}	14.7	212	150	30.5	18.4	13.3	24.8	12.7	84.8	38.9	22.4	17.9
nC_{30}	14.3	485	205	32.9	18.2	18.7	36.2	16.2	178	43.1	19.9	18.5
nC_{31}	23.3	884	267	39.4	18.9	27.8	39.8	15.7	283	44.4	27.5	26.2
nC_{32}	25.4	1140	293	37.5	20.4	35.7	41.8	11.5	351	54.6	26.0	27.1
nC_{33}	24.2	1290	280	31.8	14.3	49.3	43.2	17.5	391	51.8	26.7	31.1
nC_{34}	33.4	1250	228	26.3	18.3	52.2	29.2	16.0	366	36.3	25.0	24.3
nC_{35}	32.1	1230	183	22.5	12.6	39.6	25.3	11.3	345	26.9	24.7	21.0
nC_{36}	26.9	1060	121	19.4	16.4	46.1	15.6	3.7	292	21.2	30.9	23.6
Total (µg/l)	**0.584**	**8.01**	**2.27**	**0.521**	**0.427**	**0.610**	**0.72**	**0.457**	**2.72**	**0.70**	**0.558**	**0.550**

Table 3.22: Individual n-Alkanes Average Concentrations at Each Site [ngl-1 of Water] Continued

Alkanes	NC21_WC022 Bottom	NC21_WC022 Mid	NC21_WC022 Surface	NC21_WC023 Bottom	NC21_WC023 Mid	NC21_WC023 Surface	NC21_WC024 Bottom	NC21_WC024 Mid	NC21_WC024 Surface	NC21_WC025 Bottom	NC21_WC025 Mid	NC21_WC025 Surface
nC_{12}	18.6	27.1	3.7	15.3	1.7	7.4	4.5	14.9	14.6	9.2	4.5	8.9
nC_{13}	40.8	55.3	7.1	14.1	1.1	5.4	8.4	4.0	19.9	7.3	4.0	10.9
nC_{14}	31.6	46.2	20.4	55.3	35.6	38.0	57.7	33.5	54.6	50.5	28.9	44.3
nC_{15}	11.7	21.0	14.7	24.1	8.7	9.4	25.6	9.9	10.2	10.7	17.2	17.2
nC_{16}	14.8	22.8	16.5	35.7	11.4	15.5	22.4	15.0	14.1	23.9	17.4	12.9
nC_{17}	12.5	19.3	20.0	43.0	16.0	21.3	46.5	21.6	20.6	25.6	15.9	15.3
nC_{18}	16.4	31.4	18.3	73.0	18.6	33.6	33.8	18.0	31.9	21.4	24.5	26.1
nC_{19}	13.2	21.4	18.9	54.7	17.7	23.2	28.4	16.6	17.2	14.9	22.3	13.9
nC_{20}	19.1	16.0	30.9	45.8	19.2	22.3	29.7	24.2	26.6	22.1	12.5	20.5
nC_{21}	10.3	10.8	14.9	14.5	9.4	12.2	16.0	13.1	11.0	5.4	10.6	11.0
nC_{22}	6.6	9.1	8.2	7.6	7.2	11.1	12.4	7.2	13.2	8.0	6.6	12.2
nC_{23}	8.9	7.4	20.8	18.9	7.7	13.1	5.5	8.1	7.1	18.6	6.9	17.6
nC_{24}	11.1	55.7	32.3	10.2	9.3	19.3	8.6	11.6	7.1	16.1	15.1	32.4
nC_{25}	8.0	5.6	52.0	10.7	10.7	24.5	5.1	16.8	9.9	14.1	28.2	46.7
nC_{26}	13.4	7.8	49.8	10.0	16.9	35.6	6.9	20.6	14.4	14.1	43.3	92.1
nC_{27}	12.1	10.5	46.8	11.7	26.3	67.2	8.0	27.1	24.4	19.3	76.8	188
nC_{28}	19.8	10.5	41.4	21.9	45.1	103	22.6	41.5	46.2	27.8	166	390
nC_{29}	20.9	13.0	32.8	38.8	61.8	154	34.0	46.9	79.6	46.3	288	706
nC_{30}	25.2	13.2	25.3	60.4	73.5	211	46.3	58.3	122	64.2	421	1040
nC_{31}	26.4	12.6	22.1	92.9	94.1	295	64.0	65.7	174	91.7	577	1430
nC_{32}	25.9	13.9	17.8	113	98.3	354	69.3	74.7	190	118	629	1580
nC_{33}	21.2	10.9	14.2	126	94.6	334	70.1	69.1	198	147	619	1560
nC_{34}	20.5	11.1	15.9	113	73.7	271	61.0	49.2	188	143	553	1370
nC_{35}	23.2	11.1	16.5	95.5	49.2	214	48.1	35.1	157	135	470	1190
nC_{36}	10.0	8.0	14.3	88.4	45.2	170	39.4	25.7	127	115	376	931
Total (µg/l)	**0.442**	**0.472**	**0.576**	**1.20**	**0.853**	**2.46**	**0.774**	**0.729**	**1.58**	**1.17**	**4.43**	**10.8**

3.9.4.2 Polycyclic Aromatic Hydrocarbons

The concentrations of all 16 PAHs in the water samples at the sixteen water sampling stations are presented in Table 3.23. The total concentrations ranged from 6.0 ngl^{-1}, in the mid water sample at station NC21_WC023, to 20.6 ngl^{-1}, in the middle water sample at station NC21_WC018.

Table 3.18: Concentrations of all 16 PAHs (ng/l Water)

PAH	NC21_WC002 Bottom	NC21_WC002 Mid	NC21_WC002 Surface	NC21_WC005 Bottom	NC21_WC005 Mid	NC21_WC005 Surface	NC21_WC006 Bottom	NC21_WC006 Mid	NC21_WC006 Surface	NC21_WC008 Bottom	NC21_WC008 Mid	NC21_WC008 Surface	Benchmark (ng/L)
Naphthalene	2.5	2.7	3.1	3.7	2.3	2.9	6.3	4.1	3.9	3.0	2.8	2.8	193 500
Acenaphthylene	0.3	0.2	0.3	0.3	0.3	0.2	0.5	0.3	0.3	0.3	0.3	0.3	306 900
Acenaphthene	0.7	0.8	1.0	1.2	0.8	0.9	1.3	0.9	1.1	1.1	0.7	0.6	55 850
Fluorene	0.8	1.0	1.0	1.3	0.8	1.0	1.6	1.0	1.2	1.1	0.7	0.8	39 300
Phenanthrene	1.0	1.0	1.1	1.3	0.9	1.0	1.2	1.0	1.1	1.2	0.8	0.8	19 130
Anthracene	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	20 730
Fluoranthene	0.4	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.3	0.3	0.2	0.2	7 109
Pyrene	0.4	0.4	0.4	0.3	0.4	0.3	0.5	0.2	0.3	0.3	0.3	0.2	10 110
Benzo(a)anthracene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	2 227
Chrysene	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.4	0.1	0.2	0.1	2 042
Benzo(b)fluoranthene	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.2	0.1	979
Benzo(k)fluoranthene	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.1	0.1	0.1	981
Benzo(a)pyrene	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.1	957
Indeno(123cd)pyrene	0.4	0.3	0.2	0.2	0.2	0.1	0.2	0.1	0.3	0.2	0.2	0.2	275
Benzo(ghi)perylene	0.3	0.2	0.1	0.2	0.2	0.1	0.2	0.1	0.3	0.1	0.1	0.1	439
Dibenzo(ah)anthracene	0.5	0.3	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	282
Tot EPA 16	**8.4**	**7.9**	**8.5**	**9.7**	**7.2**	**7.4**	**13.0**	**8.6**	**10.8**	**8.3**	**7.1**	**6.8**	**-**

Table 3.23: Concentrations of all 16 PAHs (ng/l Water) Continued

PAH	NC21_WC009 Bottom	NC21_WC009 Mid	NC21_WC009 Surface	NC21_WC010 Bottom	NC21_WC010 Mid	NC21_WC010 Surface	NC21_WC012 Bottom	NC21_WC012 Mid	NC21_WC012 Surface	NC21_WC015 Bottom	NC21_WC015 Mid	NC21_WC015 Surface	Benchmark (ng/L)
Naphthalene	3.0	3.3	2.7	3.5	3.8	6.0	4.3	3.1	4.5	5.5	4.2	3.9	193 500
Acenaphthylene	0.2	0.3	0.3	0.6	0.3	0.3	0.4	0.2	0.2	0.5	0.2	0.2	306 900
Acenaphthene	0.6	1.2	1.3	1.4	1.5	2.4	1.5	1.2	1.4	1.6	1.6	1.5	55 850
Fluorene	0.7	1.4	1.5	1.5	1.9	2.7	1.6	1.4	1.5	1.9	1.9	1.9	39 300
Phenanthrene	0.8	1.2	1.2	1.1	1.3	2.4	1.2	1.2	1.3	1.1	1.4	1.5	19 130
Anthracene	0.1	0.2	0.1	0.2	0.2	0.3	0.1	0.2	0.2	0.2	0.1	0.1	20 730
Fluoranthene	0.2	0.3	0.3	0.3	0.2	0.4	0.2	0.3	0.2	0.3	0.2	0.3	7 109
Pyrene	0.4	0.4	0.4	0.2	0.3	0.4	0.2	0.3	0.3	0.2	0.3	0.5	10 110
Benzo(a)anthracene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2 227
Chrysene	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	2 042
Benzo(b)fluoranthene	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	979
Benzo(k)fluoranthene	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	981
Benzo(a)pyrene	<0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.1	<0.1	0.1	0.1	957
Indeno(123cd)pyrene	0.2	0.4	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.1	275
Benzo(ghi)perylene	0.1	0.3	0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	439
Dibenzo(ah)anthracene	0.1	0.4	0.2	0.2	0.1	0.2	0.1	0.3	0.2	0.1	0.2	0.1	282
Tot EPA 16	**6.9**	**10.4**	**8.8**	**9.9**	**10.3**	**15.9**	**10.3**	**9.4**	**10.8**	**12.0**	**11.0**	**10.7**	**-**

Table 3.23: Concentrations of all 16 PAHs (ng/l Water) Continued

PAH	NC21_WC017 Bottom	NC21_WC017 Mid	NC21_WC017 Surface	NC21_WC018 Bottom	NC21_WC018 Mid	NC21_WC018 Surface	NC21_WC020 Bottom	NC21_WC020 Mid	NC21_WC020 Surface	NC21_WC021 Bottom	NC21_WC021 Mid	NC21_WC021 Surface	Benchmark (ng/L)
Naphthalene	4.3	3.8	3.8	2.9	3.8	5.7	3.8	2.9	3.6	3.3	4.9	3.9	193 500
Acenaphthylene	0.4	0.2	0.8	0.5	0.3	0.4	0.4	0.3	0.2	0.3	0.3	0.2	306 900
Acenaphthene	1.7	1.5	1.0	0.6	0.6	4.4	1.2	1.0	0.9	0.7	0.8	0.7	55 850
Fluorene	2.1	2.0	1.3	0.9	0.8	3.7	1.3	0.9	1.1	0.9	1.1	0.9	39 300
Phenanthrene	1.3	1.4	1.6	0.9	1.0	3.4	1.3	1.0	1.3	0.8	1.0	1.0	19 130
Anthracene	0.1	0.1	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.1	20 730
Fluoranthene	0.2	0.2	0.4	0.3	0.3	0.6	0.5	0.3	0.2	0.3	0.3	0.3	7 109
Pyrene	0.2	0.3	0.8	0.3	0.3	0.5	0.5	0.3	0.3	0.3	0.3	0.3	10 110
Benzo(a)anthracene	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2	2 227
Chrysene	0.1	0.1	0.3	0.1	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.2	2 042
Benzo(b)fluoranthene	0.1	0.1	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.1	0.2	979
Benzo(k)fluoranthene	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.3	981
Benzo(a)pyrene	0.1	0.1	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.1	0.1	0.2	957
Indeno(123cd)pyrene	0.1	0.2	0.6	0.3	0.4	0.3	0.5	0.3	0.4	0.2	0.1	0.4	275
Benzo(ghi)perylene	0.1	0.1	0.4	0.3	0.3	0.2	0.3	0.3	0.3	0.1	0.1	0.3	439
Dibenzo(ah)anthracene	0.2	0.1	0.7	0.3	0.4	0.2	0.5	0.4	0.4	0.2	0.2	0.4	282
Tot EPA 16	**11.2**	**10.4**	**13.0**	**8.2**	**9.5**	**20.6**	**11.8**	**8.7**	**9.9**	**7.9**	**9.8**	**9.6**	**-**

Table 3.23: Concentrations of all 16 PAHs (ng/l Water) Continued

PAH	NC21_WC022 Bottom	NC21_WC022 Mid	NC21_WC022 Surface	NC21_WC023 Bottom	NC21_WC023 Mid	NC21_WC023 Surface	NC21_WC024 Bottom	NC21_WC024 Mid	NC21_WC024 Surface	NC21_WC025 Bottom	NC21_WC025 Mid	NC21_WC025 Surface	Benchmark (ng/L)
Naphthalene	2.8	3.5	2.8	7.0	2.6	3.2	4.7	2.5	3.3	3.7	3.5	6.6	193 500
Acenaphthylene	0.2	0.3	0.2	0.4	0.2	0.3	0.1	0.2	0.1	0.2	0.2	0.2	306 900
Acenaphthene	0.5	0.7	0.3	1.2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	55 850
Fluorene	0.6	0.9	0.6	2.3	0.7	0.8	0.9	0.7	0.9	0.9	0.8	1.1	39 300
Phenanthrene	0.7	0.9	0.5	1.1	0.6	0.9	0.7	0.8	0.8	0.8	0.8	1.0	19 130
Anthracene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	0.1	20 730
Fluoranthene	0.2	0.2	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	7 109
Pyrene	0.2	0.2	0.3	0.4	0.3	0.5	0.2	0.3	0.2	0.3	0.3	0.3	10 110
Benzo(a)anthracene	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1	<0.1	2 227
Chrysene	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1	0.1	2 042
Benzo(b)fluoranthene	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	979
Benzo(k)fluoranthene	0.1	0.1	0.2	0.1	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	<0.1	981
Benzo(a)pyrene	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	957
Indeno(123cd)pyrene	0.2	0.2	0.4	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	275
Benzo(ghi)perylene	0.2	0.1	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	439
Dibenzo(ah)anthracene	0.2	0.2	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	282
Tot EPA 16	**6.6**	**7.8**	**7.2**	**14.0**	**6.0**	**7.4**	**8.2**	**6.2**	**7.0**	**7.5**	**7.0**	**10.7**	**-**

Among the 16 PAHs, PAHs with short-chain compounds (NPD) had high proportional concentrations, ranging between 39 % to 69 % of the total PAHs. This was due to the high concentrations of naphtalene at all sites. 4 to 6 ring PAH's showed higher concentrations across the survey stations (Table 3.24).

Table 3.19: Individual PAH Concentrations [per Station ngl^{-1}]

Analyte	NC21_WC002 Bottom	NC21_WC002 Mid	NC21_WC002 Surface	NC21_WC005 Bottom	NC21_WC005 Mid	NC21_WC005 Surface	NC21_WC006 Bottom	NC21_WC006 Mid	NC21_WC006 Surface	NC21_WC008 Bottom	NC21_WC008 Mid	NC21_WC008 Surface
Naphthalene (128)	2	3	3	4	2	3	6	4	4	3	3	3
C1 128	4	5	5	7	5	5	11	5	5	4	4	5
C2 128	5	7	8	7	7	5	23	6	7	5	7	5
C3 128	4	5	5	7	4	6	9	5	11	5	5	5
C4 128	2	3	2	3	2	3	6	2	3	3	2	2
TOTAL 128	**17**	**23**	**23**	**28**	**20**	**22**	**55**	**22**	**30**	**20**	**21**	**20**
Phenanthrene/ anthracene (178)	1	1	1	1	1	1	1	1	1	1	1	1
C1 178	1	1	1	1	1	1	1	1	1	1	1	1
C2 178	2	2	2	2	2	2	2	2	2	2	1	2
C3 178	3	3	3	3	2	2	3	2	3	2	2	2
TOTAL 178	**7**	**7**	**7**	**7**	**6**	**6**	**7**	**6**	**7**	**6**	**5**	**6**
Dibenzothiophene (DBT)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 184	1	< 1	1	1	1	1	1	< 1	1	1	1	1
C2 184	1	1	1	1	1	1	1	1	1	1	1	1
C3 184	4	4	4	4	4	4	5	4	4	4	3	3
TOTAL 184	**6**	**5**	**6**	**6**	**6**	**6**	**7**	**5**	**6**	**6**	**5**	**5**
Fluoranthene/ pyrene (202)	< 1	< 1	< 1	< 1	< 1	< 1	1	< 1	< 1	< 1	< 1	< 1
C1 202	1	1	1	1	1	1	1	< 1	1	1	1	1
C2 202	1	1	1	1	1	1	1	1	1	1	1	1
C3 202	2	2	2	2	1	2	2	2	2	2	2	2
TOTAL 202	**4**	**4**	**4**	**4**	**3**	**4**	**5**	**3**	**4**	**4**	**4**	**4**
Benzanthracenes/ benzphenanthrenes (228)	1	1	1	1	1	1	1	1	1	1	1	1
C1 228	1	1	1	1	2	1	1	1	1	1	1	1
C2 228	7	10	8	8	9	6	7	9	7	7	9	6
TOTAL 228	**9**	**12**	**10**	**10**	**12**	**8**	**9**	**11**	**9**	**9**	**11**	**8**
m/z 252	3	5	3	6	3	3	3	3	4	3	3	3
C1 252	5	6	6	6	5	5	6	6	5	6	5	5
C2 252	7	6	6	6	6	5	7	6	6	5	6	5
TOTAL 252	**15**	**17**	**15**	**18**	**14**	**13**	**16**	**15**	**15**	**14**	**14**	**13**
m/z 276	2	2	2	2	2	2	2	2	3	2	3	2
C1 276	1	2	1	2	1	1	2	1	2	2	1	2
C2 276	3	3	4	3	3	2	3	4	4	4	5	4
TOTAL 276	**6**	**7**	**7**	**7**	**6**	**5**	**7**	**7**	**9**	**8**	**9**	**8**
NPD	30	35	36	41	32	34	69	33	43	32	31	31
% NPD	47	47	50	51	48	53	65	48	54	48	45	48
Total 2-6 ring PAH	**64**	**75**	**72**	**80**	**67**	**64**	**106**	**69**	**80**	**67**	**69**	**64**

Table 3.24: Individual PAH Concentrations [per Station ngl-1] Continued

Analyte	NC21_WC009 Bottom	NC21_WC009 Mid	NC21_WC009 Surface	NC21_WC010 Bottom	NC21_WC010 Mid	NC21_WC010 Surface	NC21_WC012 Bottom	NC21_WC012 Mid	NC21_WC012 Surface	NC21_WC015 Bottom	NC21_WC015 Mid	NC21_WC015 Surface
Naphthalene (128)	3	3	3	4	4	6	4	3	4	6	4	4
C1 128	5	4	4	6	5	7	6	4	5	7	5	6
C2 128	7	4	4	4	4	7	5	5	5	6	5	5
C3 128	4	4	4	5	6	8	5	6	7	6	6	5
C4 128	2	2	3	3	3	4	3	4	4	4	4	3
TOTAL 128	**21**	**17**	**18**	**22**	**22**	**32**	**23**	**22**	**25**	**29**	**24**	**23**
Phenanthrene/ anthracene (178)	1	1	1	1	1	2	1	1	1	1	1	1
C1 178	1	1	1	1	1	2	1	1	1	2	1	1
C2 178	2	2	1	2	2	2	1	2	2	2	2	2
C3 178	2	2	2	2	2	3	2	3	2	2	2	2
TOTAL 178	**6**	**6**	**5**	**6**	**6**	**9**	**5**	**7**	**6**	**7**	**6**	**6**
Dibenzothiophene (DBT)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 184	1	1	1	1	1	1	1	1	1	1	1	1
C2 184	1	1	1	1	1	1	1	1	1	1	1	1
C3 184	4	3	3	3	3	3	3	3	4	3	3	4
TOTAL 184	**6**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**6**	**5**	**5**	**6**
Fluoranthene/ pyrene (202)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 202	1	1	1	1	1	1	1	1	1	1	1	< 1
C2 202	1	1	1	1	1	1	1	1	1	1	1	1
C3 202	1	2	2	2	2	2	1	2	2	1	2	2
TOTAL 202	**3**	**4**	**4**	**4**	**4**	**4**	**3**	**4**	**4**	**3**	**4**	**3**
Benzanthracenes/ benzphenanthrenes (228)	1	1	1	1	1	1	1	1	1	1	1	1
C1 228	1	1	1	1	1	1	1	1	1	1	1	1
C2 228	8	8	8	7	7	7	6	7	9	9	8	9
TOTAL 228	**10**	**10**	**10**	**9**	**9**	**9**	**8**	**9**	**11**	**11**	**10**	**11**
m/z 252	2	3	2	2	2	4	2	4	3	3	5	2
C1 252	4	4	5	5	5	8	4	6	6	5	8	4
C2 252	6	7	4	4	4	7	3	6	5	5	8	4
TOTAL 252	**12**	**14**	**11**	**11**	**11**	**19**	**9**	**16**	**14**	**13**	**21**	**10**
m/z 276	2	3	2	2	2	3	2	3	3	2	4	2
C1 276	2	2	2	2	2	3	1	2	2	2	3	1
C2 276	4	4	4	3	4	5	3	6	5	4	7	4
TOTAL 276	**8**	**9**	**8**	**7**	**8**	**11**	**6**	**11**	**10**	**8**	**14**	**7**
NPD	33	28	28	33	33	46	33	34	37	41	35	35
% NPD	50	43	46	52	51	52	56	46	49	54	42	53
Total 2-6 ring PAH	**66**	**65**	**61**	**64**	**65**	**89**	**59**	**74**	**76**	**76**	**84**	**66**

Table 3.24: Individual PAH Concentrations [per Station ngl-1] Continued

Analyte	NC21_WC017 Bottom	NC21_WC017 Mid	NC21_WC017 Surface	NC21_WC018 Bottom	NC21_WC018 Mid	NC21_WC018 Surface	NC21_WC020 Bottom	NC21_WC020 Mid	NC21_WC020 Surface	NC21_WC021 Bottom	NC21_WC021 Mid	NC21_WC021 Surface
Naphthalene (128)	4	4	4	3	4	6	4	3	4	3	5	4
C1 128	6	5	7	7	6	11	8	6	7	6	8	6
C2 128	5	5	7	5	5	9	6	5	5	4	5	5
C3 128	5	5	7	5	7	11	8	5	7	6	8	8
C4 128	4	3	3	3	3	4	4	3	3	2	4	3
TOTAL 128	**24**	**22**	**28**	**23**	**25**	**41**	**30**	**22**	**26**	**21**	**30**	**26**
Phenanthrene/ anthracene (178)	1	1	2	1	1	3	1	1	1	1	1	1
C1 178	2	1	2	1	1	2	2	1	1	1	1	1
C2 178	2	2	2	2	2	3	3	2	3	2	2	2
C3 178	2	2	3	3	2	3	3	2	3	3	3	4
TOTAL 178	**7**	**6**	**9**	**7**	**6**	**11**	**9**	**6**	**8**	**7**	**7**	**8**
Dibenzothiophene (DBT)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 184	1	1	1	1	1	1	1	1	1	1	1	1
C2 184	1	1	1	1	2	1	2	3	2	2	2	1
C3 184	3	4	3	3	3	3	4	4	4	3	3	3
TOTAL 184	**5**	**6**	**5**	**5**	**6**	**5**	**7**	**8**	**7**	**6**	**6**	**5**
Fluoranthene/ pyrene (202)	< 1	< 1	1	< 1	< 1	2	1	< 1	< 1	< 1	< 1	< 1
C1 202	1	1	1	1	1	1	1	1	1	1	1	1
C2 202	1	1	1	1	1	1	1	1	1	1	1	1
C3 202	2	2	1	2	1	2	2	1	2	2	2	1
TOTAL 202	**4**	**4**	**4**	**4**	**3**	**6**	**5**	**3**	**4**	**4**	**4**	**3**
Benzanthracenes/ benzphenanthrenes (228)	1	1	1	1	1	1	1	1	1	1	1	1
C1 228	1	1	2	2	3	3	4	3	4	2	2	3
C2 228	7	9	8	7	8	11	9	8	9	9	9	9
TOTAL 228	**9**	**11**	**11**	**10**	**12**	**15**	**14**	**12**	**14**	**12**	**12**	**13**
m/z 252	3	5	4	3	5	4	6	5	5	3	3	4
C1 252	6	6	5	5	9	6	8	8	8	7	5	6
C2 252	5	6	8	8	11	9	12	11	9	6	6	9
TOTAL 252	**14**	**17**	**17**	**16**	**25**	**19**	**26**	**24**	**22**	**16**	**14**	**19**
m/z 276	2	2	3	3	4	3	6	4	4	3	2	3
C1 276	2	2	2	2	4	3	5	4	4	3	2	3
C2 276	5	5	5	6	9	6	11	8	7	5	5	7
TOTAL 276	**9**	**9**	**10**	**11**	**17**	**12**	**22**	**16**	**15**	**11**	**9**	**13**
NPD	36	34	42	35	37	57	46	36	41	34	43	39
% NPD	50	45	50	46	39	52	41	40	43	44	52	45
Total 2-6 ring PAH	**72**	**75**	**84**	**76**	**94**	**109**	**113**	**91**	**96**	**77**	**82**	**87**

Table 3.24: Individual PAH Concentrations [per Station ngl-1] Continued

Analyte	NC21_WC017 Bottom	NC21_WC017 Mid	NC21_WC017 Surface	NC21_WC018 Bottom	NC21_WC018 Mid	NC21_WC018 Surface	NC21_WC020 Bottom	NC21_WC020 Mid	NC21_WC020 Surface	NC21_WC021 Bottom	NC21_WC021 Mid	NC21_WC021 Surface
Naphthalene (128)	3	3	3	7	3	3	5	2	3	4	3	7
C1 128	5	7	6	13	5	6	6	5	6	6	5	11
C2 128	4	5	2	22	4	5	6	5	4	5	5	9
C3 128	5	6	4	10	4	4	5	4	4	5	4	6
C4 128	2	2	2	7	2	2	3	2	2	3	2	4
TOTAL 128	**19**	**23**	**17**	**59**	**18**	**20**	**25**	**18**	**19**	**23**	**19**	**37**
Phenanthrene/ anthracene (178)	1	1	< 1	1	1	1	1	1	1	1	1	1
C1 178	1	1	1	2	1	1	1	1	1	1	1	1
C2 178	2	2	1	3	2	2	2	2	2	2	2	3
C3 178	3	2	1	3	2	2	2	2	2	2	2	2
TOTAL 178	**7**	**6**	**3**	**9**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**7**
Dibenzothiophene (DBT)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 184	1	1	< 1	1	1	1	1	1	1	1	1	1
C2 184	1	2	1	3	2	2	1	1	2	1	2	1
C3 184	3	3	2	5	3	3	4	4	3	4	4	4
TOTAL 184	**5**	**6**	**3**	**9**	**6**	**6**	**6**	**6**	**6**	**6**	**7**	**6**
Fluoranthene/ pyrene (202)	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
C1 202	1	1	< 1	1	1	1	1	< 1	1	1	1	1
C2 202	1	1	< 1	1	1	1	1	1	1	1	1	1
C3 202	1	1	1	2	1	1	1	1	1	1	1	1
TOTAL 202	**3**	**3**	**1**	**4**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**3**
Benzanthracenes/ benzphenanthrenes (228)	1	1	1	1	1	1	1	1	1	1	1	1
C1 228	2	3	1	1	1	1	1	1	1	1	1	1
C2 228	7	8	5	5	5	5	5	4	5	5	5	5
TOTAL 228	**10**	**12**	**7**	**7**	**7**	**7**	**7**	**6**	**7**	**7**	**7**	**7**
m/z 252	3	3	3	3	2	3	2	2	3	3	3	3
C1 252	4	7	4	5	4	5	5	4	5	4	5	5
C2 252	7	8	5	6	5	5	4	4	5	5	5	4
TOTAL 252	**14**	**18**	**12**	**14**	**11**	**13**	**11**	**10**	**13**	**12**	**13**	**12**
m/z 276	3	3	3	3	2	2	2	2	2	2	2	1
C1 276	2	3	1	2	1	1	1	1	1	1	1	1
C2 276	4	6	4	4	4	4	4	3	5	3	4	2
TOTAL 276	**9**	**12**	**8**	**9**	**7**	**7**	**7**	**6**	**8**	**6**	**7**	**4**
NPD	31	35	23	77	30	32	37	30	31	35	32	50
% NPD	46	44	45	69	52	52	57	56	50	56	52	66
Total 2-6 ring PAH	**67**	**80**	**51**	**111**	**58**	**62**	**65**	**54**	**62**	**63**	**62**	**76**

Notes:
NPD = Total of all naphthalenes, phenanthrenes and dibenzothiophenes

3.9.5 Water Heavy and Trace Metals

Heavy metals are natural constituents of the aquatic environment and are generally found in very low concentrations. Current environmental interest in metals in seawater is mainly focussed on arsenic, cadmium, copper, mercury and zinc with environmental quality standards derived for these parameters (EPA, 2015). The concentrations of heavy metals in the seawater water are presented in water samples are presented in Table 3.25. Concentrations of barium, iron, mercury and vanadium were below detection limits at all stations and depths (Table 3.25).

Concentrations of cadmium were below detection limits in 56% of the water samples collected, primarily in samples collected from the surface or the bottom of the water column. Where cadmium samples were above detection limits all values were still near the detection limit, ranging from 0.03 μgl^{-1} at the bottom sample of station NC21_16WC012 to 0.064 μgl^{-1} at the midwater sample for station NC21_WC002.

Concentrations of chromium were below detection limits at the surface, while they were only seen at mid water at two stations (NC21_16WC017 and NC21_16WC017 and in the bottom sample at one station (NC21_16WC017), at each of these locations the concentrations were still only just above the detection limit of <0.5 μgl^{-1}.

Copper concentrations in the surface seawater samples ranged from below the limit of detection (0.2 μgl^{-1}) at eight stations to 0.801 μgl^{-1} at station NC21_16WC002 (mean 0.361 μgl^{-1}). Mid depth seawater copper concentrations ranged from below the limit of detection at fourteen stations to 0.286 μgl^{-1} at station NC21_16WC002 (mean 0.237 μgl^{-1}). Copper concentrations in the bottom depth seawater samples ranged from below the limit of detection at nine stations to 0.985 μgl^{-1} (NC21_16WC023), with an average concentration of 0.405 μgl^{-1}.

Lead concentrations in the surface seawater samples ranged from below the limit of detection (0.04 μgl^{-1}) at eight stations to 0.345 μgl^{-1} at station NC21 16WC010 (mean 0.135 μgl^{-1}). Mid depth seawater lead concentrations ranged from below the limit of detection at nine stations to 0.186 μgl^{-1} at station NC21 16WC006 (mean 0.0.085 μgl^{-1}). In the bottom depth samples, lead concentrations ranged from below the limit of detection at six stations to 0.625 μgl^{-1} at station NC21_16WC023 (mean 0.0.163 μgl^{-1}).

Zinc concentrations in the surface seawater samples ranged from 1.15 μgl^{-1} at station NC21 16WC008 to 18.40 μgl^{-1} at station NC21 16WC006 (mean 5.68 μgl^{-1}). Mid depth seawater zinc concentrations ranged from 0.448 μgl^{-1} at station NC21_16WC008 to 23.1 μgl^{-1} at station NC21_16WC002 (mean 5.393 μgl^{-1}). In the bottom depth samples, zinc concentrations ranged from 0.867 μgl^{-1} at station NC21_16WC012 to 26.40 μgl^{-1} at station NC21_16WC023 (mean 8.75 μgl^{-1}).

Surface seawater arsenic concentrations ranged from below the limit of detection at one station (1 μgl^{-1}) to 1.41 μgl^{-1} at station NC21_16WC002 (mean 1.253 μgl^{-1}). Mid depth seawater arsenic concentrations ranged from 1.12 μgl^{-1} at station NC21 16WCO22 to 1.75 μgl^{-1} at station NC21_16WC002 (mean 1.49 μgl^{-1}). In the bottom depth samples, arsenic concentrations ranged from 1.38 μgl^{-1} at station NC21_16WC024 to 1.77 μgl^{-1} at station NC21_16WC002 (mean 1.51 μgl^{-1}).

Table 3.20: Summary of Water Sample Heavy Metal Analysis

Concentrations Expressed as $\mu g l^{-1}$										
Station	**Depth**	**Cadmium**	**Copper**	**Lead**	**Zinc**	**Barium**	**Iron**	**Mercury**	**Chromium**	**Arsenic**
NC21_16WC002	Bottom	0.043	< 0.2	< 0.04	5.11	< 100	< 100	< 0.01	< 0.5	1.77
	Mid	0.064	0.286	0.084	23.10	< 100	< 100	< 0.01	< 0.5	1.75
	Surface	< 0.03	0.807	< 0.04	3.40	< 100	< 100	< 0.01	< 0.5	1.41
NC21_16WC005	Bottom	0.034	0.41	0.406	20.10	< 100	< 100	< 0.01	< 0.5	1.59
	Mid	0.04	< 0.2	< 0.04	1.61	< 100	< 100	< 0.01	< 0.5	1.59
	Surface	< 0.03	0.211	0.207	18.00	< 100	< 100	< 0.01	< 0.5	1.24
NC21_16WC006	Bottom	< 0.03	0.502	0.191	11.80	< 100	< 100	< 0.01	< 0.5	1.43
	Mid	0.044	< 0.2	0.186	5.82	< 100	< 100	< 0.01	< 0.5	1.7
	Surface	< 0.03	0.338	0.254	18.40	< 100	< 100	< 0.01	< 0.5	1.3
NC21_16WC008	Bottom	< 0.03	0.245	0.218	5.84	< 100	< 100	< 0.01	< 0.5	1.57
	Mid	0.043	< 0.2	< 0.04	0.45	< 100	< 100	< 0.01	< 0.5	1.61
	Surface	< 0.03	0.53	0.065	7.18	< 100	< 100	< 0.01	< 0.5	1.28
NC21_16WC009	Bottom	0.034	< 0.2	< 0.04	< 0.4	< 100	< 100	< 0.01	< 0.5	1.58
	Mid	0.038	< 0.2	< 0.04	2.47	< 100	< 100	< 0.01	< 0.5	1.47
	Surface	< 0.03	< 0.2	< 0.04	1.15	< 100	< 100	< 0.01	< 0.5	1.26
NC21_16WC010	Bottom	< 0.03	< 0.2	0.046	4.02	< 100	< 100	< 0.01	< 0.5	1.52
	Mid	0.059	< 0.2	< 0.04	1.11	< 100	< 100	< 0.01	< 0.5	1.69
	Surface	< 0.03	< 0.2	0.343	9.52	< 100	< 100	< 0.01	< 0.5	<1
NC21_16WC012	Bottom	0.03	< 0.2	< 0.04	0.87	< 100	< 100	< 0.01	< 0.5	1.45
	Mid	0.054	< 0.2	< 0.04	0.45	< 100	< 100	< 0.01	< 0.5	1.47
	Surface	< 0.03	< 0.2	< 0.04	2.57	< 100	< 100	< 0.01	< 0.5	1.02
NC21_16WC015	Bottom	0.03	< 0.2	< 0.04	1.63	< 100	< 100	< 0.01	< 0.5	1.6
	Mid	< 0.03	< 0.2	0.122	6.04	< 100	< 100	< 0.01	< 0.5	1.62
	Surface	0.06	< 0.2	< 0.04	2.39	< 100	< 100	< 0.01	< 0.5	1.28
NC21_16WC017	Bottom	0.038	0.215	0.102	8.74	< 100	< 100	< 0.01	0.673	1.51
	Mid	0.033	< 0.2	0.06	2.84	< 100	< 100	< 0.01	0.778	1.59
	Surface	< 0.03	< 0.2	< 0.04	2.87	< 100	< 100	< 0.01	< 0.5	1.37
NC21_16WC018	Bottom	< 0.03	< 0.2	< 0.04	14.20	< 100	< 100	< 0.01	< 0.5	1.44
	Mid	0.039	< 0.2	< 0.04	2.13	< 100	< 100	< 0.01	0.523	1.44
	Surface	< 0.03	< 0.2	0.069	3.11	< 100	< 100	< 0.01	< 0.5	1.27
NC21_16WC020	Bottom	< 0.03	< 0.2	0.041	2.49	< 100	< 100	< 0.01	< 0.5	1.56
	Mid	0.046	< 0.2	0.08	5.28	< 100	< 100	< 0.01	< 0.5	1.64
	Surface	< 0.03	0.38	0.112	5.12	< 100	< 100	< 0.01	< 0.5	1.2
NC21_16WC021	Bottom	< 0.03	< 0.2	< 0.04	2.87	< 100	< 100	< 0.01	< 0.5	1.39
	Mid	< 0.03	< 0.2	0.041	3.55	< 100	< 100	< 0.01	< 0.5	1.3
	Surface	< 0.03	< 0.2	0.041	1.97	< 100	< 100	< 0.01	< 0.5	1.36
NC21_16WC022	Bottom	< 0.03	0.264	0.043	2.26	< 100	< 100	< 0.01	< 0.5	1.49
	Mid	0.034	< 0.2	< 0.04	0.63	< 100	< 100	< 0.01	< 0.5	1.12
	Surface	< 0.03	< 0.2	< 0.04	1.34	< 100	< 100	< 0.01	< 0.5	1.28

Concentrations Expressed as $\mu g l^{-1}$										
Station	**Depth**	**Cadmium**	**Copper**	**Lead**	**Zinc**	**Barium**	**Iron**	**Mercury**	**Chromium**	**Arsenic**
NC21_16WC023	Bottom	0.052	0.985	0.625	26.40	< 100	< 100	< 0.01	< 0.5	1.49
	Mid	0.041	< 0.2	< 0.04	3.98	< 100	< 100	< 0.01	< 0.5	1.73
	Surface	< 0.03	0.223	< 0.04	1.88	< 100	< 100	< 0.01	< 0.5	1.21
NC21_16WC023 40m	40m	< 0.03	< 0.2	0.156	4.47	< 100	< 100	< 0.01	< 0.5	<1
NC21_16WC023 100m	100m	< 0.03	< 0.2	0.104	11.90	< 100	< 100	< 0.01	< 0.5	1.32
NC21_16WC024	Bottom	0.058	< 0.2	0.059	3.22	< 100	< 100	< 0.01	< 0.5	1.38
	Mid	0.036	0.212	< 0.04	4.43	< 100	< 100	< 0.01	< 0.5	1.26
	Surface	< 0.03	0.286	< 0.04	4.48	< 100	< 100	< 0.01	< 0.5	1.36
NC21_WC025	Bottom	< 0.03	< 0.2	0.089	22.80	< 100	< 100	< 0.01	0.649	1.46
	Mid	< 0.03	< 0.2	0.068	6.59	< 100	< 100	< 0.01	< 0.5	1.26
	Surface	< 0.03	0.261	0.085	12.00	< 100	< 100	< 0.01	< 0.5	1.19
MIN		**0.030**	**0.211**	**0.041**	**0.45**	**-**	**-**	**-**	**0.523**	**1.02**
MEAN		**0.043**	**0.385**	**0.144**	**6.42**	**-**	**-**	**-**	**0.656**	**1.43**
MAX		**0.064**	**0.985**	**0.625**	**26.40**	**-**	**-**	**-**	**0.778**	**1.77**
ST DEV		**0.010**	**0.225**	**0.134**	**6.59**	**-**	**-**	**-**	**0.105**	**0.18**
US EPA Saltwater Quality Standards (EPA, 2015)										
CMC		40	4.8	210	90	-	-	1.8	-	69
CCC		8.8	3.1	8.1	81	-	-	0.94	-	36

Notes:
Blank cells indicate that the value could not be calculated
Concentrations exceeding the US EPA CMC
CMC = criterion maximum concentration
CCC = criterion continuous concentration

4. DISCUSSION

Sediment descriptions consisted of a range of sediment types, from slightly gravelly muddy sand at the shallowest site to poorly sorted sandy mud or mud, with sandy mud being the predominant sediment type across the survey area. A pattern of sediment distribution was identified, with the shallowest station (< 500 m) consisting of slightly gravelly muddy sand. Stations in waters deeper than 500 m but shallower than 2500 m varied between mud, muddy sand and sandy mud, characterised by varying proportions of sand and mud. Stations at sites > 2500 m consisted entirely of sandy mud and were characterised by a high proportion of mud and a smaller fraction of sand. Samples from shallower stations showed a degree of heterogeneity encompassing notable percentages of coarser sediment, specifically sand, particularly the stations located in the south of the survey array. Multivariate analysis of the particle size data broadly supported this pattern. The shallowest station, NC21_16BCE025 remained ungrouped, whilst the other stations were split between two clusters. The two clusters did not appear to support the pattern, as Cluster 1 contained the shallowest stations bar NC21_16BCE025 but also the deepest station, possibly due to insufficient sampling from each depth, or a degree of heterogeneity across the Stabroek area.

Samples from most stations showed a degree of disturbance, as indicated by the bimodal and trimodal distribution (Hein, 2007) of all samples from all but three stations. Such disturbance is likely to be associated with the local hydrodynamic conditions of the area (e.g. seabed bottom current velocity), as well as local sediment mineral composition and/or biological activity (Holmes et al., 2004).

TOC concentrations were found to be higher at stations with a greater proportion of fine sediments. A significant positive correlation was calculated between TOC and the proportion of mud, with a corresponding significant negative correlation with the proportion of sand. These indicated that sediment composition was directly related to the concentration of organic material found at each station. This would be expected since fine particles provide a greater surface area for the adsorption of organic matter (Keil et al, 1994).

Total hydrocarbon concentrations (THC) were considered to be at low levels across the survey area with a pattern of higher levels of THC associated with finer sediments and a higher mean phi. It has been suggested that typical THC levels (i.e. ‘background’) in sediments remote from anthropogenic activities range from 0.2 μgg^{-1} to 5 μgg^{-1}, with values in some areas being as high as 15 μgg^{-1} (NSTF, 1993). Concentrations of THC were below 5 μgg^{-1} at all stations and, as such, not sufficiently high to be considered contaminated to any notable degree.

The ratio of odd to even carbon numbered normal alkanes is termed the CPI, and was calculated over various chain length ranges. Elevated ratios (i.e. those >1.00) over the nC_{21-36} carbon range are due to the domination of odd-chain length n-alkanes and typically observed/associated with inputs from terrestrial run-off (leaf waxes, etc). High CPI ratios (>1.0) were found for the entire range of n-alkanes (nC_{12-36}) at all stations and indicated a dominance of biogenic alkanes rather than those derived from petrogenic sources. This could be expected given the volume of land runoff from the Essequibo and Demerara rivers and therefore the potential influence of the nearby landmass on the immediate marine environment (Miller et al., 2003).

An examination of the concentrations of individual n-alkanes and GC traces indicated the presence of very low levels of UCM (possibly as a result of low long term background levels of hydrocarbons, however there is currently no existing evidence to support this), and odd carbon number dominated sequences represented by small peaks at longer chain lengths (nC_{21-36}) suggesting terrestrially derived organic plant matter. More specifically a presence of elevated peaks of nC_{31}, then nC_{29}, followed by nC_{33} is indicative of the n-alkane pattern of terrestrial grasses and the soil under grassland (Zech et al., 2009).

Concentrations of total 2 to 6 ring PAH varied across the survey area. The 2 to 3 ring PAHs and alkylated PAHs dominate in crude oils (National Research Council, 1985), and, as such, their presence may be indicative of contamination associated with offshore oil and gas production and/or diesel contamination from shipping activities (DTI, 2001). PAHs from combustion sources are characterised by a lesser degree of alkylation than PAHs from petroleum, as high temperature processes (incomplete combustion or pyrolysis) favour less alkylation (National Research Council, 1985). In addition, combustion sources contain relatively low quantities of 2 to 3 ring aromatic families (e.g. naphthalenes), while being dominated by 4 to 6 ring PAHs, (e.g. pyrene and benzofluoranthenes) (Boitsov et al., 2009). NPD levels at station NC21_BCE006 are higher than those at other stations, which could be resulting from drilling operations at the Liza 1 well, however these elevated levels are not evident at stations NC21_BCE007 and NC21_BCE0023, both of which are closer to the well.

Throughout the Liza development EBS survey all stations were dominated by 4 to 6 ring PAHs with very low degrees of alkylation, indicating predominantly pyrolytic rather than petrogenic sources of input into the marine environment. However, high concentrations of the parent compounds in the mass to charge ratio (m/z) 252 were recorded across all stations. This pattern was attributed to the PAH perylene, which is linked to plant pigments from terrestrial runoff and is not indicative of either petrogenic or pyrolytic sources (Irwin, 1997).

Metals concentrations in sediments were generally low and variations in observed levels appear to reflect a common background source with the exception of one station (NC21_BCE025) where elevated concentrations appear to be due to an additional anthropogenic source. These metals could be, in part, introduced from contaminated terrestrial runoff from Guyana's' mining industry and the two main riverine inputs to the Guyana basin (TDI Brooks, 2014). Arsenic is a known by-product of gold mining, which is a key industry in Guyana. Concentrations of arsenic, lead and

chromium exceeded the conservative NOAA ERL threshold values at 10, 2 and 1 stations, respectively but did not exceed the NOAA ERM screening values with the exception of arsenic at BCE025. If NOAA ERM values are exceeded, there is a higher probability that sediment quality will be impaired and impact the benthic community. However, such impacts are not obvious based on the analysis of macrobenthos collected at this site. All metals were present at low or undetectable concentrations in the water column and below USEPA marine water quality criteria.

Analysis of the photographic data collected by the SPI camera identified one biotope complex as defined by the European Union nature information service habitat classification system (EUNIS, 2015), 'circalittoral sandy mud' (A5.35) with aspects of 'Deep sea mud' (A6.5). Due to the limited snapshot nature of photographs taken by the system, benthic epifauna was scarcely observed. Where visible, the seabed observed on the SPI plan view images was inhabited by tube building polychaetes (possibly Sabellidae and Terebellidae) and burrowing shrimp. Seafloor features of biogenic origin, e.g. tubes, burrows, feeding pits, faecal casts and mounds were recorded in some stations using a combination of plan view and profile images. No potentially sensitive habitats were identified in the current survey.

The infaunal community recorded for the current survey was dominated by polychaetes (40% of taxa). The most abundant taxa overall were polychaetes from the genus *Spiophanes* and *Myriochele,* and amphipods of the family Ampilescidae.

Spiophanes only occurred in 44% of samples, while *Myriochele* occurred in 36% of samples and Ampilescidae occurred in 48% of samples. No taxa occurred in more than 48% of the samples taken, suggesting that there was notable variability in the benthic communities within the region.

Univariate analysis supported the suggestion that there was notable variability in the benthic community within the region. Primary variables (number of taxa and abundance of individuals) appeared to vary greatly between stations indicating variation in benthic community structure. Univariate measures of evenness (J' and 1-λ) varied between stations but the distribution of individuals amongst the different taxa tended towards evenness at all stations with station NC21_BCE018 being perfectly even (same number of species and individual taxa were present).

The diversity measure (H'), varied greatly between stations. Higher diversity was found at stations with greater evenness, whilst lower diversity was found at stations with greater dominance. Overall, diversity was relatively high across the survey area, with over ten species identified at 17 of the 25 grab sample stations. A weak negative correlation was observed between depth and number of taxa and abundance.

Multivariate analysis of the macrofauna data divided the stations into four groups of similar community composition, and two unclassified stations. It produced results suggesting that community structure was influenced by sediment type to some degree and depth. Within cluster similarity was low (<20%) for all clusters indicating that there was variation within the cluster groupings.

All cluster communities were significantly different from each other, with the top five characterising taxa from each cluster having no species in common except Ampilescidae, which was the third and first most characterising taxon of cluster groups D and E respectively. These differences in community structure may be linked to changes in sediment composition and water depth, as each group appears to comprise of similar sediment descriptions and depth ranges. However, the analyses showed no significant correlation between these abiotic factors and number of taxa or number of individuals. Multivariate analysis of the macrofauna community with PSD data showed no correlation between grain size and macrofauna assemblages. As such, it is difficult to deduce whether there is a dominant influencing factor on the faunal communities.

Water profiling at the sixteen water sampling stations identified a generally stratified water column, with similarly shaped profiles at each station, with depth of thermocline, halocline and oxygen boundary increasing with water depth.

At all sixteen water profiling stations temperature, salinity and dissolved oxygen displayed a strong thermocline, halocline and oxygen boundary. Surface temperature at all stations were reasonably similar, however, lowest profile temperature decreased proportionally to water depth. Turbidity within the water column remained reasonably constant throughout the entire length of all water profiles, this is because the survey area is located offshore in deep water with little influence of direct fluvial (riverine) input. At all water sampling stations, the pH increased slowly with increasing depth and all profiles were very similar between stations.

TOC and TSS were generally low at all stations, with TOC increasing slightly overall with depth and TSS generally decreasing with depth.

Total hydrocarbon concentrations and polycyclic aromatic hydrocarbon (PAH) concentrations in seawater samples were generally considered to be at low levels across the survey area, with little variation between samples. All levels were found to be below the USEPA water quality guidelines published in Burgess *et al.* 2013. Gas chromatography traces exhibited only small spikes in individual long-chain n-alkanes at the water sampling stations at all stations. These long-chain n-alkanes are widely distributed in the plant kingdom (Douglas and Eglinton, 1966; Eglinton et al., 1962) and their presence may be indicative of an input to the water column through runoff from adjacent landmasses.

Heavy and trace metal concentrations were low in all water samples, being close to or below their respective detection limits in all cases and did not vary substantially between stations or with depth. Concentrations of all metals were below their respective US EPA Saltwater Quality Standards thresholds, where these were available.

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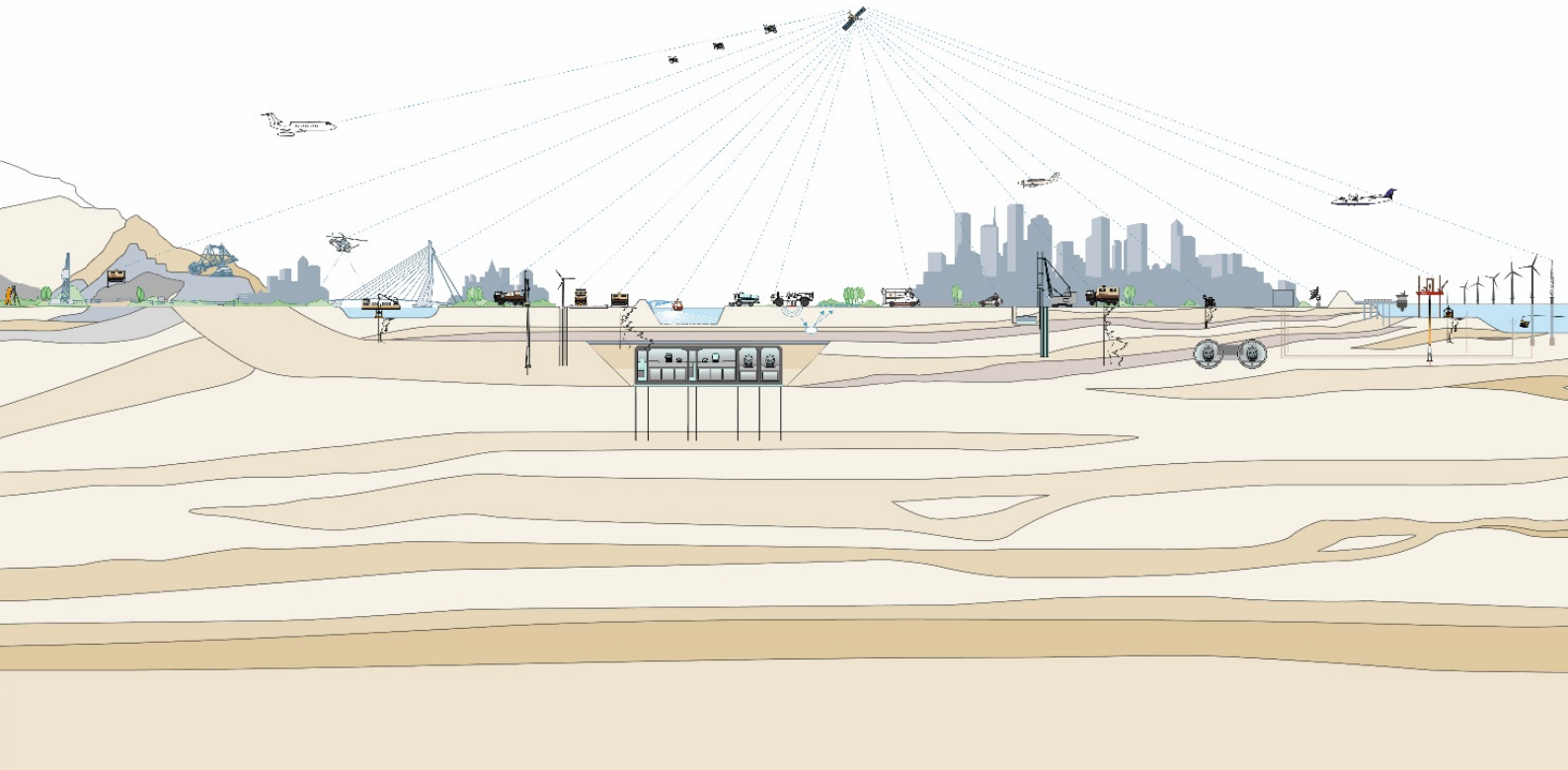
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APPENDIX G – Flora and Fauna of Shell Beach

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APPENDIX IV. BIODIVERSITY

List of Biodiversity found within the Shell Beach Area

Appendix IVa: Avifauna of Shell Beach

Source: *Mendonca, Sean; Michelle Kalamandeen and Robin S. McCall (2006) A Bird's Eye View: Coastal Birds of Shell Beach. Proceedings of International Conference on the Status of Biological Sciences in Caribbean and Latin American Societies.*

Common Name	Scientific Name
Amazilia Hummingbird	*Amazilia spp.*
Amazon Kingfisher	*Chloroceryle amazona*
American Flamingo	*Phoenicopterus ruber*
American Kestrel	*Falco sparverius*
American Pgymy Kingfisher	*Chloroceryle aenea*
Anhinga	*Anhinga anhinga*
Bananaquit	*Coereba flaveola*
Barn Swallow	*Hirundo rustica*
Barred Antshrike	*Thamnophilus doliatus*
Barred Forest-Falcon	*Micrastur ruficollis*
Bat Falcon	*Falco rufigularis*
Bicolored Conebill	*Conirostrum bicolor*
Black Caracara	*Daptrius ater*
Black Skimmer	*Rynchops niger*
Black Vulture	*Coragyps atratus*
Blackbellied Cuckoo	*Piaya melanogaster*
Blackbellied Whistling-duck	*Dendrocyna autumnalis*
Black-collared Hawk	*Busarellus nigricollis*
Black-crested Antshrike	*Sakesphorus canadensis*
Blackcrowned Night-heron	*Nycticorax nycticorax*
Blackface Ant-thrush	*Formicarius analis*
Blacknecked Aracari	*Pteroglossus aracari*
Blackthroated Antbird	*Myrmceciza atrothorax*
Blackthroated Antshrike	*Frederickena viridis*
Blue & Gold Macaw	*Ara ararauna*
Blue Ground-Dove	*Claravis prestiosa*
Blue-black Grassquit	*Volatinia jacarina*
Blue-chinned Sapphire	*Chlorestes notatus*
Blue-crowned Motmot	*Momotus momota*
Blue-gray Tanager	*Thraupis episcopus*
Blue-headed Parrot	*Pionus menstruus*
Boat-billed Flycatcher	*Megarynchus pitangua*

Boat-billed Heron	*Cochlearius cochlearius*
Bridled Tern	*Sterna anaethetus*
Bright-rumped Attila	*Attila spadiceus*
Brown Pelican	*Pelecanus occidentalis*
Buff throated Woodcreeper	*Xiphorhynchus guttatus*
Buff-breasted Wren	*Thryothorus leucotis*
Buff-throated Woodcreeper	*Xiphorhynchus guttatus*
Carib Grackle	*Quiscalus lugubris*
Cattle Egret	*Bubulcus ibis*
Cayanne Jay	*Cyanocorax cayanus*
Channel-billed Toucan	*Ramphastos vitellinus*
Chestnut-bellied Seedeater	*Oryzoborus angolensis*
Cocoi Heron	*Ardea cocoi*
Collared Plover	*Charadrius collaris*
Common Black Hawk	*Buteogallus anthracinus*
Common Paraque	*Nyctidromus albicollis*
Common Piping-guan	*Pipile pipile*
Common Tody-flycatcher	*Todirostrum cinereum*
Coraya Wren	*Thryothorus coraya*
Crane Hawk	*Geranospiza caerulescens*
Creamcolored Woodpecker	*Celeus flavus*
Crested Eagle	*Morphnus guianensis*
Crested Oropendula	*Psarocolius decumanus*
Crimson-hooded Manakin	*Pipra aureola*
Dark-billed Cuckoo	*Coccyzus melacoryphus*
Dull-colored Grassquit	*Tiaris obscura*
Dusky Antshrike	*Cercomacra tyrannina*
Fasciated Antshrike	*Cymbilaimus lineatus*
Forest Elaenia	*Myiopagis gaimardi*
Forktailed Flycatcher	*Tyrannus savana*
Forktailed Palm-Swift	*Tachornis squamata*
Giant Cowbird	*Scaphidura oryzivora*
Glittering-throat Emerald	*Amazilia fimbriata*
Gray fronted Dove	*Leptotila rufaxilla*
Gray Hawk	*Asturina nitida*
Gray Kingbird	*Tyrannus dominicensis*
Graybreasted Martin	*Progne chalybea*
Graybrested Sabrewing	*Campylopterus largipennis*
Grayish Saltator	*Saltator coerulescens*
Gray-necked Woodrail	*Aramides cajanea*
Great Egret	*Ardea alba*
Great Horned-owl	*Bubo virginianus*

Great Pootoo	*Nyctibius grandis*
Great Tinamou	*Tinamus major*
Greater Ani	*Crotophaga major*
Greater Kisskadee	*Pitangus sulphuratus*
Greater Yellowlegs	*Tringa melanoleuca*
Green & Rufous Kingfisher	*Chloroceryle inda*
Green Honeycreeper	*Chlorophanes spiza*
Green Ibis	*Mesembrinibis cayennensis*
Green Kingfisher	*Chloroceryle americana*
Green Oropendula	*Psarocolius viridis*
Grosbeak	*Pitylus spp*
Gull-billed Tern	*Sterna nilotica*
Harpy Eagle	*Harpia harpyja*
Helmeted pygmy Tyrant	*Lophotriccus galeatus*
King Vulture	*Sarcoramphus papa*
Large-billed Tern	*Phaetusa simplex*
Laughing Falcon	*Herpetotheres cachinnans*
Laughing Gull	*Larus atricilla*
Least Sandpiper	*Calidris minutilla*
Least Tern	*Sterna antillarum*
Lesser Kiskadee	*Philohydor lictor*
Lesser Yellowlegs	*Tringa flavipes*
Lineated Woodpecker	*Dryocopus lineatus*
Little Blue Heron	*Egretta caerulea*
Little Chacalaca	*Ortalis motmot*
Little Cuckoo	*Piaya minuta*
Longtailed Hermit	*Phaethornis superciliosus*
Longtailed Woodcreeper	*Dendrocyna longicauda*
Long-winged Harrier	*Circus buffoni*
Magnificent Frigatebird	*Fregata magnificens*
Magpie Tanager	*Cissopis leveriana*
Maguari Stork	*Ciconia maguari*
Marbled Woodquail	*Odontophorus gujanensis*
Moriche Oriole	*Icterus chrysocephalus*
Mouse-coloured Antshrike	*Thamnophilus murinus*
Muscovy Duck	*Cairina moshata*
Neotropical Cormorant	*Phalacrocorax brasilianus*
Northern Waterthrush	*Seiurus noveboracensis*
Nothern Scrub-Flycatcher	*Sublegatus arenarum*
Orange-winged Parrot	*Amazona amazonica*
Osprey	*Pandion haliaetus*
Pale breasted Thrush	*Turdus leucomelas*

Palm Tanager	*Thraupis palmarum*
Peregrine Falcon	*Falco peregrinus*
Piculet	*Picumus spp*
Pied Plover	*Hoploxypterus cayanus*
Pied Water-Tyrant	*Fluvicola pica*
Plumbeous Pigeon	*Columba plumbea*
Purplethroated Fruitcrow	*Querula purpurata*
Pygmy Antwren	*Myrmotherula brachyura*
Pygmy Kingfisher	*Chloroceryle aenea*
Red & Green Macaw	*Ara chloropterus*
Red-bellied Macaw	*Ara manilata*
Red-billed Toucan	*Ramphastos tucanus*
Redbreasted Blackbird	*Sturnella militaris*
Red-eyed Vireo	*Vireo olivaceus*
Red-rumped Cacique	*Cacicus haemorrhous*
Red-shouldered Macaw	*Ara nobilis*
Red-throated Caracara	*Ibycter americanus*
Ring kingfisher	*Ceryle torquata*
River Warbler	*Phaeothlypis flaveola*
Roadside Hawk	*Buteo magnirostris*
Royal Tern	*Sterna maxima*
Ruddy Ground-dove	*Columbina talpacoti*
Ruddy Pigeon	*Columba subvinacea*
Ruddy Turnstone	*Arenaria interpres*
Rufescent Tiger Heron	*Tigrisoma lineatum*
Rufous Crab-hawk	*Buteogallus aequinoctialis*
Rufous-breasted Hermit	*Glaucis hirsuta*
Rusty-margined Flycatcher	*Myiozetetes cayanensis*
Scarlet Ibis	*Eudocimus ruber*
Screaming Piha	*Lipaugus vociferans*
Semipalmated Sandpiper	*Calidris pusilla*
Short-crested Flycatcher	*Myiarchus ferox*
Silverbeak Tanager	*Ramphocelus carbo*
Slaty Antwren	*Cercomacra spp*
Smooth-billed Ani	*Crotophaga ani*
Snail Kite	*Rostrhamus sociabilis*
Snowy Egret	*Egretta thula*
Solitary Sandpiper	*Tringa solitaria*
Sora Crake	*Porzana carolina*
Southern beardless Tyrantlet	*Camptostoma obsoletum*
Southern Housewren	*Troglodytes aedon*
Southern Lapwing	*Vanellus chilensis*

Spectacled Owl	*Pulsatrix perspicillata*
Spix's Guan	*Penelope jacquacu*
Spotted Sandpiper	*Actitis macularia*
Spotted Tody-flycatcher	*Todirostrum maculatum*
Squirrel Cuckoo	*Piaya cayana*
Straight-billed Woodcreeper	
Streaked Flycatcher	*Myiodynastes maculatus*
Striated Heron	*Butorides striatus*
Striped Cuckoo	*Tapera naevia*
Sun Grebe	*Heliornis fulica*
Sunbittern	*Eurypga helias*
Swainson's Flycatcher	*Myiarchus swainsoni*
Swallow-tailed Kite	*Elanoides forficatus*
Swallow-wing Puffbird	*Chelidoptera tenebrosa*
Tricolored Heron	*Egretta tricolor*
Tropical Kingbird	*Tyrannus melancholicus*
Tropical Screech-Owl	*Otus choliba*
Turkey Vulture	*Cathartes aura*
Turquoise Tanager	*Tangara mexicana*
Violaceous Euphonia	*Euphonia violacea*
Wattled Jacana	*Jacana jacana*
Wedge billed wood creeper	*Glyphorynchus spirurus*
Whibrel	*Numenius phaeopus*
White bearded Manakin	*Manacus manacus*
White- headed Marsh Tyrant	*Arundinicola leucocephala*
White-Chested Emerald	*Amazilia chionopectus*
White-earred Conebill	*Conirostrum leucogenys*
White-lined tananger	*Tachyphonus rufus*
White-necked Heron	*Ardei cocoi*
White-tail Hawk	*Elanus leucurus*
Whitetailed Trogon	*Trogon viridis*
White-tipped Dove	*Leptotila verreauxi*
White-winged Swallow	*Tachycineta albiventer*
Wilson's Plover	*Charadrius wilsonia*
Wing-banded Antbird	*Myrmornis torquata*
Yellow bellied Elania	*Elaenia flavogaster*
Yellow billed Jacamar	*Galbula albirostris*
Yellow chinned Spinetail	*Certhiaxis cinnamomea*
Yellow Oriole	*Icterus nigrogularis*
Yellow Warbler	*Dendroica aestiva*
Yellow-billed Tern	*Sterna superciliaris*
Yellow-crowned Night-Heron	*Nyctanassa violacea*

Yellow-crowned Parrot	*Amazona ochrocephala*
Yellow-headed Caracara	*Milvago chimachima*
Yellow-headed Vulture	*Cathartes burrovianus*
Yellow-hooded Blackbird	*Agelaius icterocephalus*
Yellow-rump Cacique	*Cacicus cela*
Yellow-throated Spinetail	*Certhiaxis cinnamomea*
Yellow-tufted woodpecker	*Melanerpes cruentatus*

Appendix IVb: Herpetofauna of Shell Beach

Sources: *(1) Kalamandeen, Michelle and Phillip DaSilva (2005) A Preliminary Survey of the Herpetofauna of Shell Beach. Biodiversity and Conservation Studies in Guyana: Volume 2.*
(2) Prince, Waldyke et al (2004) Report on the Rapid Biodiversity Assessment of the proposed Shell Beach Protected Area. GMTCS Publication.

Common Name	Scientific Name
Reptiles	
Ameiva lizard	*Ameiva ameiva*
Anaconda	*Eunectus marinus*
Anolis lizard	*Anolis spp*
Blind snake	*Leptotyphlops spp*
Boa constrictor	*Constrictor constrictor*
-	*Cnemidophorus gramivagus*
Cooks Tree-boa	*Corallus hortulanus*
Gecko	*Gonatodes humeralis*
Gecko	*Gonatodes spp*
Green turtle	*Chelonia mydas*
Hawksbill turtle	*Eretmochelys imbricata*
-	*Hydropis spp*
Green Iguana	*Iguana iguana*
-	*Kentropyx calcarata*
Labaria	*Bothrops atrox*
Labaria turtle	*Rhinoclemmys punctularia*
Leatherback turtle	*Dermochelys coriacea*
Mabuya	*Mabuya mabuya*
Mud turtle	Kinosternon scropiodes
Spectacle Caiman	*Caiman crocodilus*
Tegu	*Tupinambis negropunctatus*
Tiger snake	*Drymarchon corais*
Tree lizard	*Plica plica*
Turnip tail Gecko	*Thecadactylus rapicauda*
Water labaria	*Helicops angulatus*
Water snake	*Liophis cobella*

Whiptail lizard	*Cnemidorphous lemniscatus*
Yakman snake	*Chironius spp*
Amphibians	
	Hyla crepitans
	Hyla marmorata
	Hyla minuta
	Hyla spp1
	Hyla spp2
	Hyla spp3
	Hyla spp4
	Leptodactylus mystaceus
	Leptodactylus spp
Paradox frog	*Psuedes paradox*
	Scinax rubra
Surinamese Toad	*Pipa pipa*
Toad	*Rhaebo marinus*

Appendix IVc: Mammals of Shell Beach

Sources: *(1) Kalamandeen, Michelle and Phillip DaSilva (2005) A Preliminary Survey of the Herpetofauna of Shell Beach. Biodiversity and Conservation Studies in Guyana: Volume 2.*
(2) Prince, Waldyke et al (2004) Report on the Rapid Biodiversity Assessment of the proposed Shell Beach Protected Area. GMTCS Publication.

Common Name	Scientific Name
Wedge capped capuchin	*Cebus olivaceus*
Agouti	*Dasyprocta agouti*
-	*Artibeus obscurus*
-	*Artibeus spp*
-	*Artibeus spp 2*
Brown Capuchins	*Cebus apella*
Bulldog bat	*Noctilio leporinus*
Coati	*Nasua nasua*
Common long-tongue bat	*Glossophaga soricina*
Common Tent-making Bat	*Uroderma bilobatum*
Deer	*unidentified genera*
Giant River Otter	*Pteronura brasiliensis*
Jaguar	*Panthera onca*
Long nose bat	*unidentified genera*
Manatee	*Trichechus manatus*
Porpoises	*Inia geoffrensis*
Raccoon	*Procyon cancrivorus*
Rat	*unidentified genera*
Red Howler monkey	*Alouatta seniculus*
Southern River otter	*Lontra longicaudis*
Southern Tamandua	*Tamandua tetradactyla*
Spider Monkey	*Ateles paniscus*
Squirrel monkey	*Saimiri sciureus*

Tayra	*Eira barbara*
Three-toe sloth	*Bradypus tridactylus*
Two-lined riverside bat	*Saccopteryx bilineata*
White face Saki	*Pithecia pithecia*

Appendix IVd: Fishes of Shell Beach

Sources: *(1) Kalamandeen, Michelle and Phillip DaSilva (2005) A Preliminary Survey of the Herpetofauna of Shell Beach. Biodiversity and Conservation Studies in Guyana: Volume 2.*
(2) Prince, Waldyke et al (2004) Report on the Rapid Biodiversity Assessment of the proposed Shell Beach Protected Area. GMTCS Publication.

Common Name	Scientific Name
Anafouk	*unidentified genera*
Banga mary	*Macrodon ancylodon*
Basha	*Plagioscion sp*
Black pirai	*Pygocentrus niger*
Blinker	*unidentified genera*
Butterhead	*unidentified genera*
Cassi	*Pimelodus blochii*
Catfish	*Bagre marinus*
Catfish	*Cathorops spixii*
Cock-a-net	*unidentified genera*
Couvalli	*Caranx hippos*
Cow stingray	*Dasyatis sp*
Crocrer basha	*Plagioscion squamosissimus*
Cuffum	*Megaolops ottonticus*
Cuma Cuma/Black Cuirass	*unidentified genera*
Curimai	*Brycon falcatus*
Flounder	*Bothus ocellatus*
Foureye	*Anableps anableps*
Gillbacker	*Ariuz herzbergii*
Gillbacker	*Hexanematichthys parkeri*
Grey Anglefish	*Pomacanthus arcuatus*
Grey Snapper	*Cynoscion ocoupa*
Guppy	*Poecilia reticulata*
Guppy	*unidentified genera*
Hardhead Courass	*unidentified genera*
Hasser	*Hoplosternum sp.*
Highwater	*unidentified genera*
Houri	*Hoplias malabaricus*

Imeri	*Parauchenipterus galeatus*
Jewfish	*Epinephelus itajara*
Katabac	*Myleus rubripinnis*
Kavalli	*Caranx hippos*
Kokwari	*Hexanematichthys proops*
Lukanani	*Cichla ocellaris*
Mackerel	*Scomberomorus brasiliensis*
Manta Ray	*Manta birostris*
Mullet	*Mugil cephalus*
Pacu	*unidentified genera*
Pargee	*Lobotes surinamensis*
Patwa	*Cichlasoma sp*
Quamina	*unidentified genera*
Red Snapper	*Lutjanus campechanus*
Rock head	*unidentified genera*
Sabakoua stingray	*Dasyatis sp*
Sea patwa	*Diapterus rhombeus/Caitipa mojarra*
Seahassa	*unidentified genera*
Shark	*Heptranchias perlo*
Snapper	*Lutjanus griseus*
Snook	*Centropomus undecimalis*
Spadefish	*unidentified genera*
Spring Courass	*Cathorops spixii*
Sunfish	*Crenicichla sp.*
Swordfish	*Boulengerella cuvieri*
Tampocker	*unidentified genera*
Trout	*Cynoscion virescens*
Trout	*Oncorhynchus mykiss*
Wabaru	*unidentified genera*
Yadaro	*Pseudodoras (Oxydoras) niger*
Yarrow	*Hoplerythrinus unitaeniatus*

Appendix IVe: Plants of Shell Beach

Sources: *(1) Kalamandeen, Michelle and Phillip DaSilva (2005) A Preliminary Survey of the Herpetofauna of Shell Beach. Biodiversity and Conservation Studies in Guyana: Volume 2.*
(2) Prince, Waldyke et al (2004) Report on the Rapid Biodiversity Assessment of the proposed Shell Beach Protected Area. GMTCS Publication.

Common Name	Scientific Name
Almond trees	*Terminalia catappa*

Back Mangrove	*Avicennia germinans*
Bloodwood	*Vismia spp*
-	*Caesalpinia bonduc*
-	*Canvalia rosea*
-	*Carica papaya*
-	*Cecropia spp.*
-	*Ceiba pentandra*
-	*Cissus verticillatus*
Coconut trees	*Cocos nucifera*
Corkwood	*Pterocarpus spp*
Crab-wood	*Carapa guianensis*
-	*Cucurbita moschata*
-	*Cuscuta umbellata*
-	*Cyperus spp*
Dukalli	*Parahancornia spp*
-	*Hibiscus pernambucensis*
-	*Ipomea pes-caprae*
Ite Palms	*Mauritia flexuosa*
-	*Jatropha gossypiifolia*
Kabukalli	*Goupia glabra*
Kakaralli	*Eschiwella spp*
Kaunta	*Chrysobalanus spp*
Manicole	*Euterpe spp*
-	*Manihot esculenta*
Mora	*Mora excelsa*
Noni trees	*Morindra citrifolia*
Papaya trees	*Carica papaya*
Red Mangroves	*Rhizophora mangle*
-	*Sesuvium portulacastum*
Soft Wallaba	*Eperu falcata*
-	*Thespesia populnea*
White Mangrove	*Languncularia racemosa*

Appendix IVf: Marco-invertebrates of Shell Beach

Source: *Kalamandeen, Michelle and Phillip DaSilva (2005) A Preliminary Survey of the Herpetofauna of Shell Beach. Biodiversity and Conservation Studies in Guyana: Volume 2.*

Common Name	Scientific Name
Bee	*unidentified genera*
Blue Morpho	*Morpho menelaus*

Bug	*unidentified genera*
Bundari crab	*Cardisoma guanhumi*
Butterfly	*Euedes spp*
Butterfly	*Eurema spp*
Butterfly	*Parides spp*
Butterly	*Euptichia spp*
Centipede	*unidentified genera*
Coconut worm	*unidentified genera*
Dragonfly	*unidentified genera*
Fiddler crab	*Uca rapax*
Field cricket	*unidentified genera*
Flies	*unidentified genera*
Ghost crab	*Ocypode quadrata*
Grasshopper	*Thelpusa spp*
Lady bug	*unidentified genera*
Machusi Ant	*Atta spp*
Millipede	*unidentified genera*
Monarch	*Danaus plexipus*
Mosquito	*unidentified genera*
Roach	*unidentified genera*
Sand wasp	*unidentified genera*
Scorpion	*unidentified genera*
Spider	*unidentified genera*
Tarantula	*Avicularia spp*
Tree crab	*Aratus pisonii*

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APPENDIX H – IUCN Listed Species

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Common Name	Scientific Name	Species Status
Spotted Eagle Ray	*Aetobatus narinari*	NT
Agami heron	*Agamia agami*	VU
Common Thresher Shark	*Alopias vulpinus*	VU
Foureyed Flounder	*Ancylopsetta kumperae*	DD
Bryde's Whale	*Balaenoptera edeni*	DD
Gray Tiggerfish	*Balistes capriscus*	VU
Blackbelly Skate	*Breviraja nigriventralis*	DD
Semipalmated Sandpiper	*Calidris pusilla*	NT
Blacknose Shark	*Carcharhinus acronotus*	NT
Spinner Shark	*Carcharhinus brevipinna*	NT
Silky Shark	*Carcharhinus falciformis*	NT
Bull Shark	*Carcharhinus leucas*	NT
Blacktip Shark	*Carcharhinus limbatus*	NT
Oceanic Whitetip Shark	*Carcharhinus longimanus*	VU
Dusky Shark	*Carcharhinus obscurus*	VU
Caribbean Reef Shark	*Carcharhinus perezi*	NT
Smalltail Shark	*Carcharhinus porosus*	DD
Night Shark	*Carcharhinus signatus*	VU
Green Turtle	*Chelonia mydas*	EN
Frilled Shark	*Chlamydoselachus anguineus*	NT
Hollowsnout Grenadier	*Coelorinchus caelorhincus*	DD
Hookskate	*Dactylobatus clarkii*	DD
Southern Stingray	*Dasyatis americana*	DD
Sharpsnout Stingray	*Dasyatis geijskesi*	NT
Red hogfish	*Decodon puellaris*	DD
Long-beaked Common Dolphin	*Delphinus capensis*	DD
Sickelfish Grouper	*Dermatolepis inermis*	NT
Leatherback	*Dermochelys coriacea*	VU
Variegated Electric Ray	*Diplobatis pictus*	VU
Malacho	*Elops smithi*	DD
Atlantic Goliath Grouper	*Epinephelus itajara*	CE
Red Grouper	*Epinephelus morio*	NT
Nassau Grouper	*Epinephelus striatus*	EN
Pluto Skate	*Fenestraja plutonia*	DD
Pygmy Killer Whale	*Feresa attenuata*	DD
Tiger Shark	*Galeocerdo cuvier*	NT
Nurse Shark	*Ginglymostoma cirratum*	DD
Short-finned Pilot Whale	*Globicephala macrorhynchus*	DD
Spiny Butterfly Ray	*Gymnura altavela*	VU

Common Name	Scientific Name	Species Status
Smooth Butterfly Ray	*Gymnura micrura*	DD
Striped Grunt	*Haemulon striatum*	DD
Bigeyed Sixgill Shark	*Hexanchus nakamurai*	DD
Chupare Stingray	*Himantura schmardae*	DD
	Holothuria arenicola	DD
Poey's Grouper	*Hyporthodus flavolimbatus*	VU
Spotted Grouper	*Hyporthodus niveatus*	VU
Daggernose Shark	*Isogomphodon oxyrhynchus*	CE
Shortfin Mako	*Isurus oxyrinchus*	VU
White Marlin	*Kajikia albida*	VU
Pygmy Sperm Whale	*Kogia breviceps*	DD
Dwarf Sperm Whale	*Kogia sima*	DD
Hogfish	*Lachnolaimus maximus*	VU
Olive Ridley	*Lepidochelys olivacea*	VU
Neotropical Otter	*Lontra longicaudis*	DD
Golden Tilefish	*Lopholatilus chamaeleonticeps*	EN
Mutton snapper	*Lutjanus analis*	VU
Cubera Snapper	*Lutjanus cyanopterus*	VU
Giant Manta Ray	*Manta birostris*	VU
Tarpon	*Megalops atlanticus*	VU
Blainville's Beaked Whale	*Mesoplodon densirostris*	DD
Ocean Sunfish	*Mola mola*	VU
Yellowfin Grouper	*Mycteroperca venenosa*	NT
Bullnose Ray	*Myliobatis freminvillii*	DD
Southern Eagle Ray	*Myliobatis goodei*	DD
Caribbean Electric Ray	*Narcine bancroftii*	CE
Lemon Shark	*Negaprion brevirostris*	NT
Killer Whale	*Orcinus orca*	DD
Caribbean Spiny Lobster)	*Panulirus argus*	DD
Smoothtail Spiny Lobster	*Panulirus laevicauda*	DD
Sperm Whale	*Physeter macrocephalus*	VU
Blue Shark	*Prionace glauca*	NT
Largetooth Sawfish	*Pristis pristis*	CE
False Killer Whale	*Pseudorca crassidens*	DD
Giant Otter	*Pteronura brasiliensis*	EN
Venezuela Skate	*Raja cervigoni*	NT
Whale Shark	*Rhincodon typus*	VU
Southern Guitarfish	*Rhinobatos percellens*	NT
Cownose Ray	*Rhinoptera bonasus*	NT
Brazilian Sharpnose Shark	*Rhizoprionodon lalandii*	DD

Common Name	Scientific Name	Species Status
Gillbacker Sea Catfish	*Sciades parkeri*	NT
Three-spot Slipper Lobster	*Scyllarides delfosi*	DD
Guiana Dolphin	*Sotalia guianensis*	DD
Scalloped Hammerhead	*Sphyrna lewini*	EN
Scoophead Shark	*Sphyrna media*	DD
Squat-headed Hammerhead Shark	*Sphyrna mokarran*	EN
Smalleye Hammerhead Shark	*Sphyrna tudes*	VU
Roundscale Spearfish	*Tetrapturus georgii*	DD
Albacore Tuna	*Thunnus alalunga*	NT
Yellowfin Tuna	*Thunnus albacares*	NT
Bigeye Tuna	*Thunnus obesus*	VU
Atlantic Bluefin Tuna	*Thunnus thynnus*	EN
Great Torpedo Ray	*Torpedo nobiliana*	DD
West Indian Manatee	*Trichechus manatus*	VU

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APPENDIX I – Birds of Guyana

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A Field Checklist of the Birds of Guyana

2nd Edition



Michael J. Braun
Davis W. Finch
Mark B. Robbins
and
Brian K. Schmidt

Smithsonian Institution





A Field Checklist of the Birds of Guyana

2nd Edition

by

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and
Brian K. Schmidt

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COVER ILLUSTRATION:
Guyana's national bird, the Hoatzin or Canje Pheasant, O*pisthocomus hoazin,* by Dan Lane.

INTRODUCTION

This publication presents a comprehensive list of the birds of Guyana with summary information on their habitats, biogeographical affinities, migratory behavior and abundance, in a format suitable for use in the field. It should facilitate field identification, especially when used in conjunction with an illustrated work such as *Birds of Venezuela* (Hilty 2003). It is part of a series of comprehensive lists of the flora and fauna of Guyana being developed by the Smithsonian Institution's Biological Diversity of the Guiana Shield Program and the Centre for the Study of Biological Diversity, University of Guyana (Boggan *et al.* 1997, Hollowell & Reynolds 2005, www.nmnh.si.edu/biodiversity/bdg.htm).

The first edition of this list (Braun *et al*. 2000) included 786 species. The list presently stands at 814 species that have been documented as occurring in Guyana. It builds upon the long out-of-print work of Snyder (1966), who listed 720 species. Her list is largely treated as authoritative, but 10 species are removed for lack of concrete documentation. These are *Tinamus tao, Butorides virescens, Patagioenas fasciata, Crotophaga sulcirostris, Pharomachrus fulgidus, Iodopleura pipra, Tangara peruviana, Loxigilla noctis, Sporophila hypochroma* and *Gymnomystax mexicanus.* Species included are those whose occurrence in the country is supported by physical evidence (specimen, photograph, sound recording, or band recovery) or written documentation of a sight record by a reliable, experienced observer (see below). The nomenclature follows *A Classification of the Bird Species of South America* (Remsen *et al*. 2007).

DEFINITIONS

Abbreviations and symbols are used for various categories of habitat, endemism, migration and abundance. The endemism and habitat codes follow Stotz *et al*. (1996); some habitat codes are modified to reflect the authors' experience in Guyana. Figure 1 (inside back cover) shows the distribution of principal habitats in Guyana.

Habitat Codes

LF	Lowland forest, including both *terra firme* and seasonally flooded forest.
MF	Montane forest.
RI	Riverine habitats, including the river and their islands, banks, waterfalls, and riparian forests.
MA	Marine or salt water habitats, including coastal and pelagic waters.
MU	Mudflats and coastal beaches.

FW Fresh water habitats, including lakes, impoundments, ponds, oxbows, marshes, and canals.
MN Mangrove forest.
HU Habitats altered by humans, such as gardens, towns, roadsides, agricultural lands, disturbed forests and forest edge.
SV Savanna grasslands.
SC Scrub or brush habitats, including white sand scrub, bush islands, and dense, low second growth.
PA Palm trees and forests.

Endemism and Migration Codes (EN/MI)

GUI Restricted to the Guianas and adjacent Venezuela and Brazil.
TEP Restricted to the tepui highlands of Venezuela, Brazil and Guyana. In Guyana, these include the Pacaraima and Merume Mountains.
AMN Restricted to Amazonian (and Guianan) lowlands north of the Amazon.
NEA Nearctic migrant; except for shorebirds, these occur September-May and are absent in the northern summer months of June-August.
AUS Austral migrant; typically present May- September.

Abundance Codes (ABU)

C Common; more than 20 individuals encountered daily in prime habitat and season.
F Fairly common; 5-20 individuals encountered daily in prime habitat and season.
U Uncommon; present in small numbers (fewer than 5 individuals per day); not encountered daily even in prime habitat and season.
S Scarce; only occasionally encountered in small numbers even in prime habitat and season.
? Occurs in Guyana but status unclear due to scarcity of data.
E Extirpated; no longer occurs, probably as a result of hunting (Horned Screamer).
† Extinct (Eskimo Curlew).
L Local; used with other abundance codes to indicate that a species' distribution in the country is patchy and that it is absent from large areas of apparently suitable habitat.
[ ] Sight records only (24 species).
* Reported for Guyana, but needs verification (14 species).

DOCUMENTING NEW RECORDS

While this list contains new information, much remains to be learned. Every effort should be made to document species not on this list, as well as those marked by brackets or asterisks, or with an abundance code of "?". Copies of photographs, tape recordings and/or written details of sight records may be sent to the first author. These should include date, time, specific locality, observers' names and addresses, description of size, shape and color pattern with specific field marks used to eliminate similar species, habitat, behavior, light conditions, optical equipment and previous experience of the observers with the species in question and its relatives.

Documenting new or unusual distributional records of birds is only the beginning. Little is known of the habitat, behavior, migration, breeding and ecology of many Neotropical birds. New and significant discoveries await any keen observer with a pair of binoculars and a field guide! We hope this publication will generate new information on the status and distribution of Guyana's birdlife and result in an increased commitment to its preservation.

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	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	Tinamous **Tinamidae**			
	1 **Great Tinamou** *Tinamus major*	LF		F
	2 **Cinereous Tinamou** *Crypturellus cinereus*	LF, SC		F
	3 **Little Tinamou** *Crypturellus soui*	SC, LF		F
	4 **Undulated Tinamou** *Crypturellus undulatus*	LF		F
	5 **Red-legged Tinamou** *Crypturellus erythropus*	LF, SC		U
	6 **Variegated Tinamou** *Crypturellus variegatus*	LF		F
	7 **Rusty Tinamou** *Crypturellus brevirostris*	LF, MF		S
	Screamers **Anhimidae**			
	8 **Horned Screamer** *Anhima cornuta*	FW		E
	Ducks, Geese **Anatidae**			
	9 **Fulvous Whistling-Duck** *Dendrocygna bicolor*	FW		S
	10 **White-faced Whistling-Duck** *Dendrocygna viduata*	FW		C
	11 **Black-bellied Whistling-Duck** *Dendrocygna autumnalis*	FW		C
	12 **Orinoco Goose** *Neochen jubata*	RI, FW		S
	13 **Muscovy Duck** *Cairina moschata*	FW, RI		C
	14 **Comb Duck** *Sarkidiornis melanotos*	FW		S
	15 **Brazilian Teal** *Amazonetta brasiliensis*	FW		C
	16 **Northern Pintail** *Anas acuta*	FW	NEA	S
	17 **White-cheeked Pintail** *Anas bahamensis*	FW, MN		S
	18 **Blue-winged Teal** *Anas discors*	FW	NEA	S
	19 **Masked Duck** *Nomonyx dominicus*	FW		U
	Curassows, Guans **Cracidae**			
	20 **Variable Chachalaca** *Ortalis motmot*	LF, SC		C
	21 **Marail Guan** *Penelope marail*	LF	GUI	U
	22 **Spix's Guan** *Penelope jacquacu*	LF		F
	23 **Blue-throated Piping-Guan** *Pipile cumanensis*	LF, MF		FL
	24 **Crestless Curassow** *Mitu tomentosum*	RI, LF	AMN	UL
	25 **Black Curassow** *Crax alector*	LF, MF	AMN	F
	Quails **Odontophoridae**			
	26 **Crested Bobwhite** *Colinus cristatus*	SV, SC, HU		F
	27 **Marbled Wood-Quail** *Odontophorus gujanensis*	LF		F
	Grebes **Podicipedidae**			
	28 **Least Grebe** *Tachybaptus dominicus*	FW		F
	29 **Pied-billed Grebe** *Podilymbus podiceps*	FW		S
	Shearwaters **Procellariidae**			
	30 **Cory's Shearwater** *Calonectris diomedea*	MA		?
	31 **Greater Shearwater** *Puffinus gravis* *	MA		?
	32 **Audubon's Shearwater** *Puffinus lherminieri*	MA		?
	Storm-Petrels **Hydrobatidae**			
	33 **Wilson's Storm-Petrel** *Oceanites oceanicus*	MA		?
	34 **Leach's Storm-Petrel** *Oceanodroma leucorhoa*	MA		?
	Pelicans **Pelecanidae**			
	35 **Brown Pelican** *Pelecanus occidentalis*	MA		F
	Boobies **Sulidae**			
	36 **Brown Booby** *Sula leucogaster*	MA		?

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	Cormorants **Phalacrocoracidae**			
	37 **Neotropic Cormorant** *Phalacrocorax brasilianus*	FW, RI		C
	Anhingas **Anhingidae**			
	38 **Anhinga** *Anhinga anhinga*	FW, RI		C
	Frigatebirds **Fregatidae**			
	39 **Magnificent Frigatebird** *Fregata magnificens*	MA, MN		C
	Herons **Ardeidae**			
	40 **Rufescent Tiger-Heron** *Tigrisoma lineatum*	FW		F
	41 **Fasciated Tiger-Heron** *Tigrisoma fasciatum*	RI		S
	42 **Agami Heron** *Agamia agami*	LF, RI		U
	43 **Boat-billed Heron** *Cochlearius cochlearius*	FW, MN		F
	44 **Zigzag Heron** *Zebrilus undulatus*	LF, RI		S
	45 **Pinnated Bittern** *Botaurus pinnatus*	FW		F
	46 **Least Bittern** *Ixobrychus exilis*	FW		F
	47 **Stripe-backed Bittern** *Ixobrychus involucris*	FW		?
	48 **Black-crowned Night-Heron** *Nycticorax nycticorax*	FW, MU		C
	49 **Yellow-crowned Night-Heron** *Nyctanassa violacea*	MN, FW, MU		U
	50 **Striated Heron** *Butorides striata*	FW, MN, RI		C
	51 **Cattle Egret** *Bubulcus ibis*	HU		C
	52 **Cocoi Heron** *Ardea cocoi*	FW, RI		C
	53 **Great Egret** *Ardea alba*	MU, FW		C
	54 **Capped Heron** *Pilherodius pileatus*	FW, RI		F
	55 **Tricolored Heron** *Egretta tricolor*	MN, MU		C
	56 **Snowy Egret** *Egretta thula*	MU, MN, FW		C
	57 **Little Blue Heron** *Egretta caerulea*	MN, MU, FW		C
	Ibises **Threskiornithidae**			
	58 **Scarlet Ibis** *Eudocimus ruber*	FW, MN, HU		C
	59 [**Glossy Ibis** *Plegadis falcinellus*] *	FW		?
	60 **Sharp-tailed Ibis** *Cercibis oxycerca*	FW, SV		F
	61 **Green Ibis** *Mesembrinibis cayennensis*	LF, RI		C
	62 **Bare-faced Ibis** *Phimosus infuscatus* *	FW		?
	63 **Buff-necked Ibis** *Theristicus caudatus*	FW, HU, SV		F
	64 **Roseate Spoonbill** *Platalea ajaja*	MU, FW		F
	Storks **Ciconiidae**			
	65 **Maguari Stork** *Ciconia maguari*	SV, HU, FW		F
	66 **Jabiru** *Jabiru mycteria*	FW, SV		F
	67 **Wood Stork** *Mycteria americana*	FW		C
	Vultures **Cathartidae**			
	68 **Turkey Vulture** *Cathartes aura*	HU, SC, SV		C
	69 **Lesser Yellow-headed Vulture** *Cathartes burrovianus*	SV,SC, FW		C

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	70 **Greater Yellow-headed Vulture** *Cathartes melambrotus*	LF		C
	71 **Black Vulture** *Coragyps atratus*	SC, HU		C
	72 **King Vulture** *Sarcoramphus papa*	LF, SV		F
	Flamingos **Phoenicopteridae**			
	73 **Greater Flamingo** *Phoenicopterus ruber*	MU, MA		?
	Osprey **Pandionidae**			
	74 **Osprey** *Pandion haliaetus*	MA, FW, RI	NEA	F
	Hawks, Eagles **Accipitridae**			
	75 **Gray-headed Kite** *Leptodon cayanensis*	LF		U
	76 **Hook-billed Kite** *Chondrohierax uncinatus*	LF, RI, MF		U
	77 **Swallow-tailed Kite** *Elanoides forficatus*	LF, MF		F
	78 **Pearl Kite** *Gampsonyx swainsonii*	SV, SC, HU		U
	79 **White-tailed Kite** *Elanus leucurus*	HU, SV, SC		F
	80 **Snail Kite** *Rostrhamus sociabilis*	FW, HU		C
	81 **Slender-billed Kite** *Helicolestes hamatus*	RI, FW		S
	82 **Double-toothed Kite** *Harpagus bidentatus*	LF, MF		U
	83 **Rufous-thighed Kite** *Harpagus diodon*	LF, MF	AUS?	S
	84 **Plumbeous Kite** *Ictinia plumbea*	LF		F
	85 **Long-winged Harrier** *Circus buffoni*	SV, SC, FW		U
	86 **Gray-bellied Hawk** *Accipiter poliogaster*	LF	AUS?	S
	87 **Tiny Hawk** *Accipiter superciliosus*	LF, MF		S
	88 **Sharp-shinned Hawk** *Accipiter striatus*	LF, MF		S
	89 **Bicolored Hawk** *Accipiter bicolor*	LF, SC, SV		U
	90 **Crane Hawk** *Geranospiza caerulescens*	LF		F
	91 **Black-faced Hawk** *Leucopternis melanops*	LF		U
	92 **White Hawk** *Leucopternis albicollis*	LF, MF		F
	93 **Common Black-Hawk** *Buteogallus anthracinus*	MN, PA		UL
	94 **Rufous Crab-Hawk** *Buteogallus aequinoctialis*	MN, HU		F
	95 **Great Black-Hawk** *Buteogallus urubitinga*	LF, RI		F
	96 **Savanna Hawk** *Buteogallus meridionalis*	SV, SC		C
	97 [**Solitary Eagle** *Harpyhaliaetus solitarius*] *	?		?
	98 **Black-collared Hawk** *Busarellus nigricollis*	FW, RI		F
	99 **Roadside Hawk** *Buteo magnirostris*	HU, SC		F
	100 [**Broad-winged Hawk** *Buteo platypterus*]	LF, MF		S
	101 **Gray Hawk** *Buteo nitidus*	SC, HU		F
	102 **Short-tailed Hawk** *Buteo brachyurus*	LF		U
	103 **White-tailed Hawk** *Buteo albicaudatus*	SV, SC		F
	104 **Zone-tailed Hawk** *Buteo albonotatus*	LF, SC		U
	105 **Crested Eagle** *Morphnus guianensis*	LF		S
	106 **Harpy Eagle** *Harpia harpyja*	LF		S
	107 **Black-and-white Hawk-Eagle** *Spizaetus melanoleucus*	LF, MF		U
	108 **Black Hawk-Eagle** *Spizaetus tyrannus*	LF, MF, PA		U
	109 **Ornate Hawk-Eagle** *Spizaetus ornatus*	LF, MF		U

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	Falcons, Caracaras **Falconidae**			
	110 **Black Caracara** *Daptrius ater*	RI, LF, SC		F
	111 **Red-throated Caracara** *Ibycter americanus*	LF		F
	112 **Southern Caracara** *Caracara plancus*	SV, HU, SC		C
	113 **Yellow-headed Caracara** *Milvago chimachima*	SV, SC, HU		F
	114 **Laughing Falcon** *Herpetotheres cachinnans*	LF, SC		U
	115 **Barred Forest-Falcon** *Micrastur ruficollis*	LF		U
	116 **Lined Forest-Falcon** *Micrastur gilvicollis*	LF		U
	117 **Slaty-backed Forest-Falcon** *Micrastur mirandollei*	LF		S
	118 **Collared Forest-Falcon** *Micrastur semitorquatus*	LF, SC		U
	119 **American Kestrel** *Falco sparverius*	SV, SC, HU		F
	120 [**Merlin** *Falco columbarius*]	HU, MU, SV	NEA	S
	121 **Bat Falcon** *Falco rufigularis*	LF, SC, RI		F
	122 **Orange-breasted Falcon** *Falco deiroleucus*	LF, MF		S
	123 **Aplomado Falcon** *Falco femoralis*	SV, SC		U
	124 **Peregrine Falcon** *Falco peregrinus*	MU, SC, HU	NEA	U
	Limpkin **Aramidae**			
	125 **Limpkin** *Aramus guarauna*	FW		F
	Trumpeters **Psophiidae**			
	126 **Gray-winged Trumpeter** *Psophia crepitans*	LF		F
	Rails **Rallidae**			
	127 **Speckled Crake** *Coturnicops notatus*	SV		S
	128 **Ocellated Crake** *Micropygia schomburgkii*	SV		U
	129 **Clapper Rail** *Rallus longirostris*	MN		F
	130 **Gray-necked Wood-Rail** *Aramides cajanea*	FW, MN, LF		F
	131 **Rufous-necked Wood-Rail** *Aramides axillaris*	MN, LF		U
	132 **Uniform Crake** *Amaurolimnas concolor*	LF		S
	133 **Russet-crowned Crake** *Anurolimnas viridis*	SV, SC		U
	134 **Rufous-sided Crake** *Laterallus melanophaius*	FW		F
	135 **Gray-breasted Crake** *Laterallus exilis*	FW, SV		S
	136 **Yellow-breasted Crake** *Porzana flaviventer*	FW		U
	137 **Ash-throated Crake** *Porzana albicollis*	FW		F
	138 **Sora** *Porzana carolina*	FW	NEA	S
	139 **Paint-billed Crake** *Neocrex erythrops*	HU, FW		U
	140 **Common Moorhen** *Gallinula chloropus*	FW		S
	141 **Purple Gallinule** *Porphyrio martinica*	FW		F
	142 **Azure Gallinule** *Porphyrio flavirostris*	FW		F
	Finfoots **Heliornithidae**			
	143 **Sungrebe** *Heliornis fulica*	FW, RI		F
	Sunbittern **Eurypygidae**			
	144 **Sunbittern** *Eurypyga helias*	RI, LF		F

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	Plovers **Charadriidae**			
	145 **Pied Lapwing** *Vanellus cayanus*	RI		F
	146 **Southern Lapwing** *Vanellus chilensis*	FW, HU, SV		C
	147 **American Golden-Plover** *Pluvialis dominica*	SV, HU	NEA	F
	148 **Black-bellied Plover** *Pluvialis squatarola*	MU	NEA	C
	149 **Semipalmated Plover** *Charadrius semipalmatus*	MU	NEA	C
	150 **Wilson's Plover** *Charadrius wilsonia*	MU		U
	151 **Collared Plover** *Charadrius collaris*	MU, RI		F
	Stilts **Recurvirostridae**			
	152 **Black-necked Stilt** *Himantopus mexicanus*	FW	NEA?	S
	Thick-knees **Burhinidae**			
	153 **Double-striped Thick-knee** *Burhinus bistriatus*	SV, HU		F
	Sandpipers **Scolopacidae**			
	154 **Wilson's Snipe** *Gallinago delicata*	FW, SV	NEA	?
	155 **South American Snipe** *Gallinago paraguaiae*	FW, SV		F
	156 **Giant Snipe** *Gallinago undulata*	SV, FW		S
	157 **Short-billed Dowitcher** *Limnodromus griseus*	MU	NEA	C
	158 [**Hudsonian Godwit** *Limosa haemastica*]	MU, FW	NEA	S
	159 **Eskimo Curlew** *Numenius borealis* †	SV	NEA	†
	160 **Whimbrel** *Numenius phaeopus*	MU, MN, HU	NEA	F
	161 **Upland Sandpiper** *Bartramia longicauda*	SV, HU	NEA	S
	162 **Willet** *Tringa semipalmata*	MU, MN	NEA	F
	163 **Greater Yellowlegs** *Tringa melanoleuca*	FW, MU, HU	NEA	C
	164 **Lesser Yellowlegs** *Tringa flavipes*	FW, MU, HU	NEA	C
	165 **Solitary Sandpiper** *Tringa solitaria*	FW, RI	NEA	F
	166 **Spotted Sandpiper** *Actitis macularius*	RI, MN, FW	NEA	C
	167 **Ruddy Turnstone** *Arenaria interpres*	MU	NEA	C
	168 **Red Knot** *Calidris canutus*	MU	NEA	C
	169 **Sanderling** *Calidris alba*	MU	NEA	C
	170 **Semipalmated Sandpiper** *Calidris pusilla*	MU	NEA	C
	171 **Western Sandpiper** *Calidris mauri*	MU	NEA	C
	172 **Least Sandpiper** *Calidris minutilla*	MU, FW	NEA	F
	173 **White-rumped Sandpiper** *Calidris fuscicollis*	MU, FW	NEA	C
	174 **Pectoral Sandpiper** *Calidris melanotos*	MU, FW, HU	NEA	F
	175 [**Stilt Sandpiper** *Calidris himantopus*]	MU, FW	NEA	U
	176 [**Buff-breasted Sandpiper** *Tryngites subruficollis*]	SV, HU	NEA	S
	Jacanas **Jacanidae**			
	177 **Wattled Jacana** *Jacana jacana*	FW		C
	Skuas **Stercorariidae**			
	178 **Great Skua** *Stercorarius skua*	MA	NEA	?
	179 **Pomarine Jaeger** *Stercorarius pomarinus*	MA	NEA	S
	180 [**Parasitic Jaeger** *Stercorarius parasiticus*]	MA	NEA	?
	Gulls, Terns **Laridae**			
	181 [**Lesser Black-backed Gull** *Larus fuscus*]	MA, MU	NEA	U

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	182 **Laughing Gull** *Larus atricilla*	MA, MU		C
	183 **Brown Noddy** *Anous stolidus*	MA		S
	184 **Sooty Tern** *Onychoprion fuscatus*	MA		S
	185 [**Bridled Tern** *Onychoprion anaethetus*]	MA		?
	186 **Least Tern** *Sternula antillarum*	MA, MU	NEA	F
	187 **Yellow-billed Tern** *Sternula superciliaris*	RI, FW		C
	188 **Large-billed Tern** *Phaetusa simplex*	RI, FW		F
	189 **Gull-billed Tern** *Gelochelidon nilotica*	MA, MU, FW		U
	190 [**Black Tern** *Chlidonias niger*]	MA	NEA	F
	191 **Common Tern** *Sterna hirundo*	MA, MU	NEA	C
	192 **Roseate Tern** *Sterna dougallii*	MA, MU	NEA	C
	193 [**Arctic Tern** *Sterna paradisaea*]	MA	NEA	?
	194 **Sandwich Tern** *Thalasseus sandvicensis*	MA, MU		C
	195 [**Royal Tern** *Thalasseus maximus*]	MA, MU		C
	Skimmers **Rynchopidae**			
	196 **Black Skimmer** *Rynchops niger*	MA, MU, RI		C
	Pigeons, Doves **Columbidae**			
	197 **Common Ground-Dove** *Columbina passerina*	SC, HU, SV		C
	198 **Plain-breasted Ground-Dove** *Columbina minuta*	SV, SC		U
	199 **Ruddy Ground-Dove** *Columbina talpacoti*	SC, HU		C
	200 **Blue Ground-Dove** *Claravis pretiosa*	LF, SC		F
	201 **Rock Pigeon** *Columba livia*	HU		CL
	202 **Scaled Pigeon** *Patagioenas speciosa*	LF, SC, SV		F
	203 **Pale-vented Pigeon** *Patagioenas cayennensis*	SC, SV, RI		C
	204 **Plumbeous Pigeon** *Patagioenas plumbea*	LF, MF		F
	205 **Ruddy Pigeon** *Patagioenas subvinacea*	LF, MF		F
	206 **Eared Dove** *Zenaida auriculata*	SC, HU, SV		C
	207 **White-tipped Dove** *Leptotila verreauxi*	SC		C
	208 **Gray-fronted Dove** *Leptotila rufaxilla*	LF		F
	209 **Violaceous Quail-Dove** *Geotrygon violacea*	LF		?
	210 **Ruddy Quail-Dove** *Geotrygon montana*	LF		U
	Parrots **Psittacidae**			
	211 **Blue-and-yellow Macaw** *Ara ararauna*	PA, LF, RI		F
	212 **Scarlet Macaw** *Ara macao*	LF		F
	213 **Red-and-green Macaw** *Ara chloropterus*	LF		F
	214 **Chestnut-fronted Macaw** *Ara severus*	LF, SC		SL
	215 **Red-bellied Macaw** *Orthopsittaca manilata*	PA, SV		C
	216 **Red-shouldered Macaw** *Diopsittaca nobilis*	PA, SV, SC		C
	217 **White-eyed Parakeet** *Aratinga leucophthalma*	LF		C
	218 **Sun Parakeet** *Aratinga solstitialis*	SV, SC	AMN	SL
	219 **Brown-throated Parakeet** *Aratinga pertinax*	SV, SC		C
	220 **Painted Parakeet** *Pyrrhura picta*	LF, MF		C
	221 **Fiery-shouldered Parakeet** *Pyrrhura egregia*	MF	TEP	F
	222 **Green-rumped Parrotlet** *Forpus passerinus*	LF, HU		C
	223 **Dusky-billed Parrotlet** *Forpus sclateri*	LF		U

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	224 **Golden-winged Parakeet** *Brotogeris chrysoptera*	LF		C
	225 **Tepui Parrotlet** *Nannopsittaca panychlora*	MF, LF	TEP	C
	226 **Lilac-tailed Parrotlet** *Touit batavicus*	LF		C
	227 **Scarlet-shouldered Parrotlet** *Touit huetii*	LF		U
	228 **Sapphire-rumped Parrotlet** *Touit purpuratus*	LF, MF		U
	229 **Black-headed Parrot** *Pionites melanocephalus*	LF	AMN	F
	230 **Caica Parrot** *Gypopsitta caica*	LF	GUI	F
	231 **Blue-headed Parrot** *Pionus menstruus*	LF		C
	232 **Dusky Parrot** *Pionus fuscus*	LF		C
	233 **Blue-cheeked Parrot** *Amazona dufresniana*	LF, RI		U
	234 **Festive Parrot** *Amazona festiva*	LF		?
	235 **Yellow-crowned Parrot** *Amazona ochrocephala*	SV, SC		C
	236 **Orange-winged Parrot** *Amazona amazonica*	LF, SC		C
	237 **Mealy Parrot** *Amazona farinosa*	LF		C
	238 **Red-fan Parrot** *Deroptyus accipitrinus*	LF		C
	Hoatzin **Opisthocomidae**			
	239 **Hoatzin** *Opisthocomus hoazin*	RI, FW		CL
	Cuckoos **Cuculidae**			
	240 **Yellow-billed Cuckoo** *Coccyzus americanus*	LF	NEA	U
	241 **Pearly-breasted Cuckoo** *Coccyzus euleri*	LF	AUS?	S
	242 **Mangrove Cuckoo** *Coccyzus minor*	MN		U
	243 **Dark-billed Cuckoo** *Coccyzus melacoryphus*	LF	AUS?	U
	244 **Squirrel Cuckoo** *Piaya cayana*	LF		F
	245 **Black-bellied Cuckoo** *Piaya melanogaster*	LF		U
	246 **Little Cuckoo** *Piaya minuta*	SC, FW		F
	247 **Greater Ani** *Crotophaga major*	RI, MN, FW		C
	248 **Smooth-billed Ani** *Crotophaga ani*	SC, HU		C
	249 **Striped Cuckoo** *Tapera naevia*	SC, SV, HU		F
	250 **Pavonine Cuckoo** *Dromococcyx pavoninus*	LF, MF		U
	251 **Rufous-winged Ground-Cuckoo** *Neomorphus rufipennis*	LF	GUI	U
	Barn Owls **Tytonidae**			
	252 **Barn Owl** *Tyto alba*	SC, HU		U
	Typical Owls **Strigidae**			
	253 **Tropical Screech-Owl** *Megascops choliba*	SC, LF		F
	254 **Tawny-bellied Screech-Owl** *Megascops watsonii*	LF		U
	255 **Vermiculated Screech-Owl** *Megascops guatemalae*	MF		U
	256 **Crested Owl** *Lophostrix cristata*	LF, MF		U
	257 **Spectacled Owl** *Pulsatrix perspicillata*	LF		U
	258 **Great Horned Owl** *Bubo virginianus*	SC, SV		U
	259 **Mottled Owl** *Ciccaba virgata*	LF, MF		?
	260 **Black-banded Owl** *Ciccaba huhula*	LF, MF		?
	261 **Amazonian Pygmy-Owl** *Glaucidium hardyi*	LF, MF		U
	262 **Ferruginous Pygmy-Owl** *Glaucidium brasilianum*	SC, LF		F
	263 **Burrowing Owl** *Athene cunicularia*	SV, SC		F
	264 **Striped Owl** *Pseudoscops clamator*	SV, SC		S
	265 **Stygian Owl** *Asio stygius*	SC, LF		S
	266 **Short-eared Owl** *Asio flammeus*	SV, HU		S

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	Oilbird **Steatornithidae**			
	267 **Oilbird** *Steatornis caripensis*	LF, MF		CL
	Potoos **Nyctibiidae**			
	268 **Great Potoo** *Nyctibius grandis*	LF		U
	269 **Long-tailed Potoo** *Nyctibius aethereus*	LF		S
	270 **Common Potoo** *Nyctibius griseus*	LF, SC, MN		F
	271 **White-winged Potoo** *Nyctibius leucopterus*	LF		U
	272 **Rufous Potoo** *Nyctibius bracteatus*	LF		S
	Nighthawks, Nightjars **Caprimulgidae**			
	273 **Short-tailed Nighthawk** *Lurocalis semitorquatus*	LF, RI		F
	274 **Least Nighthawk** *Chordeiles pusillus*	SV		C
	275 **Lesser Nighthawk** *Chordeiles acutipennis*	SC, SV		C
	276 **Band-tailed Nighthawk** *Nyctiprogne leucopyga*	RI		C
	277 **Nacunda Nighthawk** *Podager nacunda*	SV, SC		C
	278 **Common Pauraque** *Nyctidromus albicollis*	SC, HU		C
	279 **Rufous Nightjar** *Caprimulgus rufus*	SC, LF		F
	280 **Band-winged Nightjar** *Caprimulgus longirostris*	SC, SV		?
	281 **White-tailed Nightjar** *Caprimulgus cayennensis*	SV, SC		F
	282 **Spot-tailed Nightjar** *Caprimulgus maculicaudus*	SV, FW		F
	283 **Blackish Nightjar** *Caprimulgus nigrescens*	LF, SC, RI		F
	284 **Roraiman Nightjar** *Caprimulgus whitelyi*	SC, SV	TEP	UL
	285 **Ladder-tailed Nightjar** *Hydropsalis climacocerca*	RI		F
	Swifts **Apodidae**			
	286 **White-chinned Swift** *Cypseloides cryptus*	MF, RI		CL
	287 **Black Swift** *Cypseloides niger*	?	NEA?	?
	288 **Tepui Swift** *Streptoprocne phelpsi*	MF, RI	TEP	CL
	289 **White-collared Swift** *Streptoprocne zonaris*	MF, LF, SC		C
	290 **Band-rumped Swift** *Chaetura spinicaudus*	LF, RI		C
	291 **Gray-rumped Swift** *Chaetura cinereiventris*	LF, MF, RI		C
	292 **Chapman's Swift** *Chaetura chapmani*	LF, SC, RI		U
	293 **Short-tailed Swift** *Chaetura brachyura*	LF, SC, HU		C
	294 **[White-tipped Swift** *Aeronautes montivagus*]	MF		FL
	295 **Fork-tailed Palm-Swift** *Tachornis squamata*	PA, SV, SC		C
	296 **Lesser Swallow-tailed Swift** *Panyptila cayennensis*	LF		U
	Hummingbirds **Trochilidae**			
	297 **Rufous-breasted Hermit** *Glaucis hirsutus*	LF		U
	298 **Pale-tailed Barbthroat** *Threnetes leucurus*	LF, RI		U
	299 **Streak-throated Hermit** *Phaethornis rupurumii*	LF, RI		U
	300 **Little Hermit** *Phaethornis longuemareus*	LF		U
	301 **Reddish Hermit** *Phaethornis ruber*	LF		F
	302 **Sooty-capped Hermit** *Phaethornis augusti*	SC, LF, MF		U

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	303 **Straight-billed Hermit** *Phaethornis bourcieri*	LF, MF		F
	304 **Long-tailed Hermit** *Phaethornis superciliosus*	LF, MF		F
	305 **Blue-fronted Lancebill** *Doryfera johannae*	MF		U
	306 **Gray-breasted Sabrewing** *Campylopterus largipennis*	LF		F
	307 **Rufous-breasted Sabrewing** *Campylopterus hyperythrus*	MF	TEP	C
	308 **White-necked Jacobin** *Florisuga mellivora*	LF, RI		F
	309 **Brown Violetear** *Colibri delphinae*	MF		U
	310 **[Sparkling Violetear** *Colibri coruscans*]	MF, SC		FL
	311 **Green-throated Mango** *Anthracothorax viridigula*	MN, SC		U
	312 **Black-throated Mango** *Anthracothorax nigricollis*	SC, LF, RI		F
	313 **Fiery-tailed Awlbill** *Avocettula recurvirostris*	LF		S
	314 **Crimson Topaz** *Topaza pella*	RI, LF		U
	315 **Ruby-topaz Hummingbird** *Chrysolampis mosquitus*	SC, SV		F
	316 **Tufted Coquette** *Lophornis ornatus*	LF		U
	317 **Peacock Coquette** *Lophornis pavoninus*	MF	TEP	U
	318 **Racket-tailed Coquette** *Discosura longicaudus*	LF		U
	319 **Blue-chinned Sapphire** *Chlorestes notata*	LF, SC		F
	320 **Blue-tailed Emerald** *Chlorostilbon mellisugus*	SC, SV, LF		F
	321 **Fork-tailed Woodnymph** *Thalurania furcata*	LF, MF		F
	322 **Rufous-throated Sapphire** *Hylocharis sapphirina*	LF, SC		U
	323 **White-chinned Sapphire** *Hylocharis cyanus*	LF		F
	324 **White-tailed Goldenthroat** *Polytmus guainumbi*	SV		F
	325 **[Tepui Goldenthroat** *Polytmus milleri*] *****	?	TEP	?
	326 **Green-tailed Goldenthroat** *Polytmus theresiae*	FW, SV		F
	327 **Plain-bellied Emerald** *Amazilia leucogaster*	LF, MN, HU		F
	328 **Versicolored Emerald** *Amazilia versicolor*	LF, SC		UL
	329 **White-chested Emerald** *Amazilia brevirostris*	LF, SC		F
	330 **Glittering-throated Emerald** *Amazilia fimbriata*	SV, SC, LF		C
	331 **Green-bellied Hummingbird** *Amazilia viridigaster*	MF, SC, RI		U
	332 **Velvet-browed Brilliant** *Heliodoxa xanthogonys*	MF, SC	TEP	C
	333 **Black-eared Fairy** *Heliothryx auritus*	LF		U
	334 **Long-billed Starthroat** *Heliomaster longirostris*	LF, RI		F
	335 **Amethyst Woodstar** *Calliphlox amethystina*	SC, LF		U
	Trogons **Trogonidae**			
	336 **White-tailed Trogon** *Trogon viridis*	LF		F
	337 **Violaceous Trogon** *Trogon violaceus*	LF		F
	338 **Collared Trogon** *Trogon collaris*	MF		F
	339 **Masked Trogon** *Trogon personatus*	MF		U
	340 **Black-throated Trogon** *Trogon rufus*	LF		F
	341 **Black-tailed Trogon** *Trogon melanurus*	LF		F
	Kingfishers **Alcedinidae**			
	342 **Ringed Kingfisher** *Megaceryle torquata*	RI, FW, MN		F
	343 [**Belted Kingfisher** *Megaceryle alcyon*]	FW	NEA	S

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	344 **Amazon Kingfisher** *Chloroceryle amazona*	RI, FW, MN		F
	345 **Green Kingfisher** *Chloroceryle americana*	RI, FW, MN		F
	346 **Green-and-rufous Kingfisher** *Chloroceryle inda*	RI, FW, LF		U
	347 **American Pygmy Kingfisher** *Chloroceryle aenea*	RI, LF, FW		U
	Motmots **Momotidae**			
	348 **Blue-crowned Motmot** *Momotus momota*	LF		F
	Jacamars **Galbulidae**			
	349 **Brown Jacamar** *Brachygalba lugubris*	RI, SC		CL
	350 **Yellow-billed Jacamar** *Galbula albirostris*	LF	AMN	F
	351 **Rufous-tailed Jacamar** *Galbula ruficauda*	LF, SC		UL
	352 **Green-tailed Jacamar** *Galbula galbula*	LF, SC		F
	353 **Bronzy Jacamar** *Galbula leucogastra*	SC, LF		F
	354 **Paradise Jacamar** *Galbula dea*	LF, RI		F
	355 **Great Jacamar** *Jacamerops aureus*	LF		U
	Puffbirds **Bucconidae**			
	356 **Guianan Puffbird** *Notharchus macrorhynchos*	LF	GUI	U
	357 **Pied Puffbird** *Notharchus tectus*	LF		U
	358 **Spotted Puffbird** *Bucco tamatia*	SC, LF		F
	359 **Collared Puffbird** *Bucco capensis*	LF		F
	360 **White-chested Puffbird** *Malacoptila fusca*	LF		U
	361 **Rusty-breasted Nunlet** *Nonnula rubecula*	LF		U
	362 **Black Nunbird** *Monasa atra*	LF	AMN	C
	363 **Swallow-winged Puffbird** *Chelidoptera tenebrosa*	RI, SC, LF		C
	New World Barbets **Capitonidae**			
	364 **Black-spotted Barbet** *Capito niger*	LF, MF		U
	Toucans **Ramphastidae**			
	365 **Toco Toucan** *Ramphastos toco*	SV, RI		UL
	366 **White-throated Toucan** *Ramphastos tucanus*	LF		C
	367 **Channel-billed Toucan** *Ramphastos vitellinus*	LF		C
	368 **Chestnut-tipped Toucanet** *Aulacorhynchus derbianus*	MF		U
	369 **Guianan Toucanet** *Selenidera culik*	LF	GUI	F
	370 **Tawny-tufted Toucanet** *Selenidera nattereri* *	LF		S
	371 **Green Aracari** *Pteroglossus viridis*	LF	GUI	F
	372 **Black-necked Aracari** *Pteroglossus aracari*	LF		F
	Woodpeckers **Picidae**			
	373 **Golden-spangled Piculet** *Picumnus exilis*	LF		F
	374 **White-bellied Piculet** *Picumnus spilogaster*	MN, RI, HU		F
	375 **White-barred Piculet** *Picumnus cirratus*	SC		F
	376 [**White Woodpecker** *Melanerpes candidus*]	HU		S
	377 **Yellow-tufted Woodpecker** *Melanerpes cruentatus*	LF, HU		F
	378 **Red-crowned Woodpecker** *Melanerpes rubricapillus*	LF, MN		?

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	379 **Little Woodpecker** *Veniliornis passerinus*	RI, SC		F
	380 **Blood-colored Woodpecker** *Veniliornis sanguineus*	LF, MN, HU	GUI	F
	381 **Red-rumped Woodpecker** *Veniliornis kirkii*	MF		U
	382 **Golden-collared Woodpecker** *Veniliornis cassini*	LF	GUI	F
	383 **Yellow-throated Woodpecker** *Piculus flavigula*	LF		F
	384 **Golden-green Woodpecker** *Piculus chrysochloros*	LF		U
	385 **Golden-olive Woodpecker** *Piculus rubiginosus*	MF, LF		F
	386 **Spot-breasted Woodpecker** *Colaptes punctigula*	RI, MN, SC		F
	387 **Waved Woodpecker** *Celeus undatus*	LF		F
	388 **Chestnut Woodpecker** *Celeus elegans*	LF		F
	389 **Cream-colored Woodpecker** *Celeus flavus*	LF		F
	390 **Ringed Woodpecker** *Celeus torquatus*	LF		U
	391 **Lineated Woodpecker** *Dryocopus lineatus*	LF, SC, HU		F
	392 **Red-necked Woodpecker** *Campephilus rubricollis*	LF, MF		F
	393 **Crimson-crested Woodpecker** *Campephilus melanoleucos*	LF, HU		F
	Ovenbirds **Furnariidae**			
	394 **Pale-legged Hornero** *Furnarius leucopus*	RI, SC		F
	395 **Pale-breasted Spinetail** *Synallaxis albescens*	SV, HU, SC		F
	396 **Ruddy Spinetail** *Synallaxis rutilans*	LF		U
	397 **McConnell's Spinetail** *Synallaxis macconnelli*	LF, MF	GUI	SL
	398 **Plain-crowned Spinetail** *Synallaxis gujanensis*	SC, HU		F
	399 **Hoary-throated Spinetail** *Synallaxis kollari*	RI, SC	GUI	FL
	400 **Rusty-backed Spinetail** *Cranioleuca vulpina* *	RI, SC		?
	401 **Tepui Spinetail** *Cranioleuca demissa*	MF	TEP	F
	402 **Yellow-chinned Spinetail** *Certhiaxis cinnamomeus*	FW, SC		C
	403 **Roraiman Barbtail** *Roraimia adusta*	MF	TEP	F
	404 **Point-tailed Palmcreeper** *Berlepschia rikeri*	PA		F
	405 **Rufous-tailed Foliage-gleaner** *Philydor ruficaudatum*	LF, MF		U
	406 **Rufous-rumped Foliage-gleaner** *Philydor erythrocercum*	LF, MF		F
	407 **Cinnamon-rumped Foliage-gleaner** *Philydor pyrrhodes*	LF		U
	408 **Buff-throated Foliage-gleaner** *Automolus ochrolaemus*	LF		F
	409 **Olive-backed Foliage-gleaner** *Automolus infuscatus*	LF		F
	410 **White-throated Foliage-gleaner** *Automolus roraimae*	MF	TEP	U
	411 **Ruddy Foliage-gleaner** *Automolus rubiginosus*	MF, LF		U
	412 **Chestnut-crowned Foliage-gleaner** *Automolus rufipileatus*	RI, LF		F
	413 **Tawny-throated Leaftosser** *Sclerurus mexicanus*	LF, MF		U
	414 **Short-billed Leaftosser** *Sclerurus rufigularis*	LF		U
	415 **Black-tailed Leaftosser** *Sclerurus caudacutus*	LF, MF		U
	416 **Sharp-tailed Streamcreeper** *Lochmias nematura*	MF, RI		UL
	417 **Rufous-tailed Xenops** *Xenops milleri*	LF		S

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	418 **Slender-billed Xenops** *Xenops tenuirostris*	LF		S
	419 **Plain Xenops** *Xenops minutus*	LF		F
	420 **Plain-brown Woodcreeper** *Dendrocincla fuliginosa*	LF		F
	421 **White-chinned Woodcreeper** *Dendrocincla merula*	LF		U
	422 **Long-tailed Woodcreeper** *Deconychura longicauda*	LF		U
	423 **Spot-throated Woodcreeper** *Deconychura stictolaema*	LF		U
	424 **Olivaceous Woodcreeper** *Sittasomus griseicapillus*	LF, SC		UL
	425 **Wedge-billed Woodcreeper** *Glyphorynchus spirurus*	LF, MF		F
	426 **Cinnamon-throated Woodcreeper** *Dendrexetastes rufigula*	RI, LF		UL
	427 **Red-billed Woodcreeper** *Hylexetastes perrotii*	LF		U
	428 **Strong-billed Woodcreeper** *Xiphocolaptes promeropirhynchus*	LF, MF		U
	429 **Amazonian Barred-Woodcreeper** *Dendrocolaptes certhia*	LF		F
	430 **Black-banded Woodcreeper** *Dendrocolaptes picumnus*	LF, MF		U
	431 **Straight-billed Woodcreeper** *Xiphorhynchus picus*	MN, RI, SC		F
	432 **Striped Woodcreeper** *Xiphorhynchus obsoletus*	LF, RI		F
	433 **Chestnut-rumped Woodcreeper** *Xiphorhynchus pardalotus*	LF, MF		F
	434 **Buff-throated Woodcreeper** *Xiphorhynchus guttatus*	LF		F
	435 **Streak-headed Woodcreeper** *Lepidocolaptes souleyetii*	RI, SC		UL
	436 **Lineated Woodcreeper** *Lepidocolaptes albolineatus*	LF		F
	437 **Curve-billed Scythebill** *Campylorhamphus procurvoides*	LF		U
	Typical Antbirds **Thamnophilidae**			
	438 **Fasciated Antshrike** *Cymbilaimus lineatus*	LF		F
	439 **Black-throated Antshrike** *Frederickena viridis*	LF	GUI	U
	440 **Great Antshrike** *Taraba major*	HU, SC		F
	441 **Black-crested Antshrike** *Sakesphorus canadensis*	SC, MN		F
	442 **Band-tailed Antshrike** *Sakesphorus melanothorax*	LF, RI	GUI	SL
	443 **Barred Antshrike** *Thamnophilus doliatus*	HU, SC		F
	444 **Mouse-colored Antshrike** *Thamnophilus murinus*	LF		F
	445 **Northern Slaty-Antshrike** *Thamnophilus punctatus*	LF, SC		F
	446 **Amazonian Antshrike** *Thamnophilus amazonicus*	LF, RI		F
	447 **Streaked-backed Antshrike** *Thamnophilus insignis*	MF, SC	TEP	U
	448 **Plain Antvireo** *Dysithamnus mentalis*	MF		U
	449 **Dusky-throated Antshrike** *Thamnomanes ardesiacus*	LF		F
	450 **Cinereous Antshrike** *Thamnomanes caesius*	LF		F
	451 **Spot-winged Antshrike** *Pygiptila stellaris*	LF		U
	452 **Brown-bellied Antwren** *Myrmotherula gutturalis*	LF	GUI	F
	453 **Pygmy Antwren** *Myrmotherula brachyura*	LF, RI		F
	454 **Guianan Streaked-Antwren** *Myrmotherula surinamensis*	RI, LF		F
	455 **Rufous-bellied Antwren** *Myrmotherula guttata*	LF	GUI	F
	456 **White-flanked Antwren** *Myrmotherula axillaris*	LF, SC		F
	457 **Long-winged Antwren** *Myrmotherula longipennis*	LF		F

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	458 **Plain-winged Antwren** *Myrmotherula behni*	MF		F
	459 **Gray Antwren** *Myrmotherula menetriesii*	LF		F
	460 **Spot-tailed Antwren** *Herpsilochmus sticturus*	LF	AMN	F
	461 **Todd's Antwren** *Herpsilochmus stictocephalus*	LF	GUI	F
	462 **Roraiman Antwren** *Herpsilochmus roraimae*	MF	TEP	F
	463 **Rufous-winged Antwren** *Herpsilochmus rufimarginatus*	LF, MF		FL
	464 **Dot-winged Antwren** *Microrhopias quixensis*	LF		U
	465 **White-fringed Antwren** *Formicivora grisea*	SC, RI		F
	466 **Rufous-rumped Antwren** *Terenura callinota*	MF		SL
	467 **Ash-winged Antwren** *Terenura spodioptila*	LF		F
	468 **Gray Antbird** *Cercomacra cinerascens*	LF		F
	469 **Dusky Antbird** *Cercomacra tyrannina*	LF, SC, HU		F
	470 **Willis's Antbird** *Cercomacra laeta*	SC		FL
	471 **Blackish Antbird** *Cercomacra nigrescens*	RI, LF		UL
	472 **Rio Branco Antbird** *Cercomacra carbonaria*	RI	GUI	UL
	473 **White-browed Antbird** *Myrmoborus leucophrys*	LF, RI, HU		F
	474 **Warbling Antbird** *Hypocnemis cantator*	LF		F
	475 **Black-chinned Antbird** *Hypocnemoides melanopogon*	LF, RI		F
	476 **Silvered Antbird** *Sclateria naevia*	RI, FW, LF		F
	477 **Black-headed Antbird** *Percnostola rufifrons*	LF	AMN	F
	478 **Spot-winged Antbird** *Schistocichla leucostigma*	LF, MF		F
	479 **Roraiman Antbird** *Schistocichla saturata*	MF, RI	TEP	F
	480 **White-bellied Antbird** *Myrmeciza longipes*	LF, SC		F
	481 **Ferruginous-backed Antbird** *Myrmeciza ferruginea*	LF		F
	482 **Black-throated Antbird** *Myrmeciza atrothorax*	LF, SC, HU		F
	483 **Wing-banded Antbird** *Myrmornis torquata*	LF		U
	484 **White-plumed Antbird** *Pithys albifrons*	LF		F
	485 **Rufous-throated Antbird** *Gymnopithys rufigula*	LF	GUI	F
	486 **Spot-backed Antbird** *Hylophylax naevius*	LF		F
	487 **Scale-backed Antbird** *Hylophylax poecilinotus*	LF		F
	Ground Antbirds **Formicariidae**			
	488 **Rufous-capped Antthrush** *Formicarius colma*	LF		F
	489 **Black-faced Antthrush** *Formicarius analis*	LF		F
	490 **Short-tailed Antthrush** *Chamaeza campanisona*	MF		S
	491 **Variegated Antpitta** *Grallaria varia*	LF, MF		U
	492 **Scaled Antpitta** *Grallaria guatimalensis*	MF		F
	493 **Spotted Antpitta** *Hylopezus macularius*	LF		U
	494 **Thrush-like Antpitta** *Myrmothera campanisona*	LF		F
	495 **Tepui Antpitta** *Myrmothera simplex*	MF	TEP	F
	496 **Slate-crowned Antpitta** *Grallaricula nana*	MF		U
	Gnateaters **Conopophagidae**			
	497 **Chestnut-belted Gnateater** *Conopophaga aurita*	LF		S
	Tyrant Flycatchers **Tyrannidae**			
	498 **Sooty-headed Tyrannulet** *Phyllomyias griseiceps*	LF		UL
	499 **Yellow-crowned Tyrannulet** *Tyrannulus elatus*	LF, SC		F
	500 **Forest Elaenia** *Myiopagis gaimardii*	LF		F
	501 **Gray Elaenia** *Myiopagis caniceps*	LF		SL

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	502 **Yellow-crowned Elaenia** *Myiopagis flavivertex*	RI, LF		F
	503 **Greenish Elaenia** *Myiopagis viridicata*	SC		F
	504 **Yellow-bellied Elaenia** *Elaenia flavogaster*	SC, HU		C
	505 **Small-billed Elaenia** *Elaenia parvirostris*	SC, LF	AUS	U
	506 **Plain-crested Elaenia** *Elaenia cristata*	SV, SC		F
	507 **Lesser Elaenia** *Elaenia chiriquensis*	SV, SC		F
	508 **Rufous-crowned Elaenia** *Elaenia ruficeps*	SC		U
	509 **Sierran Elaenia** *Elaenia pallatangae*	MF		F
	510 **White-lored Tyrannulet** *Ornithion inerme*	LF, RI, SC		F
	511 **Southern Beardless-Tyrannulet** *Camptostoma obsoletum*	SC, LF		F
	512 **Mouse-colored Tyrannulet** *Phaeomyias murina*	SC		F
	513 **Yellow Tyrannulet** *Capsiempis flaveola*	LF, SC		SL
	514 **Bearded Tachuri** *Polystictus pectoralis*	SV		U
	515 **Crested Doradito** *Pseudocolopteryx sclateri*	FW	AUS?	?
	516 **Ringed Antpipit** *Corythopis torquatus*	LF		U
	517 **Slender-footed Tyrannulet** *Zimmerius gracilipes*	LF		F
	518 **Chapman's Bristle-Tyrant** *Phylloscartes chapmani*	MF	TEP	F
	519 **Olive-green Tyrannulet** *Phylloscartes virescens*	LF	GUI	S
	520 **Black-fronted Tyrannulet** *Phylloscartes nigrifrons*	MF	TEP	U
	521 **Ochre-bellied Flycatcher** *Mionectes oleagineus*	LF		F
	522 **McConnell's Flycatcher** *Mionectes macconnelli*	LF, MF		F
	523 **Sepia-capped Flycatcher** *Leptopogon amaurocephalus*	LF, MF		U
	524 **Northern Scrub-Flycatcher** *Sublegatus arenarum*	MN, SC		F
	525 **Amazonian Scrub-Flycatcher** *Sublegatus obscurior*	LF, SC		U
	526 **Southern Scrub-Flycatcher** *Sublegatus modestus*	SV		F
	527 **Pale-tipped Tyrannulet** *Inezia caudata*	SC, MN, RI		F
	528 **Short-tailed Pygmy-Tyrant** *Myiornis ecaudatus*	LF		F
	529 **Double-banded Pygmy-Tyrant** *Lophotriccus vitiosus*	LF		F
	530 **Helmeted Pygmy-Tyrant** *Lophotriccus galeatus*	LF, MF		F
	531 **Pale-eyed Pygmy-Tyrant** *Atalotriccus pilaris*	SC		F
	532 **Boat-billed Tody-Tyrant** *Hemitriccus josephinae*	LF	GUI	SL
	533 **White-eyed Tody-Tyrant** *Hemitriccus zosterops*	LF		F
	534 **Pearly-vented Tody-Tyrant** *Hemitriccus margaritaceiventer*	SC		F
	535 **Ruddy Tody-Flycatcher** *Poecilotriccus russatus*	MF, SC	TEP	U
	536 **Slate-headed Tody-Flycatcher** *Poecilotriccus sylvia*	SC		F
	537 **Spotted Tody-Flycatcher** *Todirostrum maculatum*	MN, SC, RI		C
	538 **Common Tody-Flycatcher** *Todirostrum cinereum*	SC, HU		F
	539 **Painted Tody-Flycatcher** *Todirostrum pictum*	LF	GUI	F
	540 **Olivaceous Flatbill** *Rhynchocyclus olivaceus*	LF		U
	541 **Yellow-olive Flycatcher** *Tolmomyias sulphurescens*	LF		F
	542 **Yellow-margined Flycatcher** *Tolmomyias assimilis*	LF		F
	543 **Gray-crowned Flycatcher** *Tolmomyias poliocephalus*	LF		F
	544 **Yellow-breasted Flycatcher** *Tolmomyias flaviventris*	SC, MN		F
	545 **Cinnamon-crested Spadebill** *Platyrinchus saturatus*	LF		U

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	546 **White-throated Spadebill** *Platyrinchus mystaceus*	MF		U
	547 **Golden-crowned Spadebill** *Platyrinchus coronatus*	LF		U
	548 **White-crested Spadebill** *Platyrinchus platyrhynchos*	LF		U
	549 **Royal Flycatcher** *Onychorhynchus coronatus*	LF		U
	550 **Roraiman Flycatcher** *Myiophobus roraimae*	MF, SC		F
	551 **Bran-colored Flycatcher** *Myiophobus fasciatus*	SC		S
	552 **Sulphur-rumped Flycatcher** *Myiobius barbatus*	LF		F
	553 **Ruddy-tailed Flycatcher** *Terenotriccus erythrurus*	LF		F
	554 **Cinnamon Manakin-Tyrant** *Neopipo cinnamomea*	LF		U
	555 **Cliff Flycatcher** *Hirundinea ferruginea*	MF		UL
	556 **Euler's Flycatcher** *Lathrotriccus euleri*	LF		UL
	557 **Fuscous Flycatcher** *Cnemotriccus fuscatus*	LF, SC		U
	558 **Olive-sided Flycatcher** *Contopus cooperi*	MF, LF	NEA	S
	559 **Smoke-colored Pewee** *Contopus fumigatus*	MF		U
	560 **Tropical Pewee** *Contopus cinereus*	LF		S
	561 **Blackish Pewee** *Contopus nigrescens*	MF		FL
	562 **Vermilion Flycatcher** *Pyrocephalus rubinus*	SV, SC	AUS?	F
	563 **Amazonian Black-Tyrant** *Knipolegus poecilocercus*	RI		UL
	564 **Rufous-tailed Tyrant** *Knipolegus poecilurus*	MF, SC		UL
	565 **Drab Water-Tyrant** *Ochthornis littoralis*	RI		CL
	566 **Pied Water-Tyrant** *Fluvicola pica*	FW		F
	567 **White-headed Marsh-Tyrant** *Arundinicola leucocephala*	FW		F
	568 **Long-tailed Tyrant** *Colonia colonus*	LF, MF		F
	569 **Piratic Flycatcher** *Legatus leucophaius*	LF, HU	AUS	F
	570 **Rusty-margined Flycatcher** *Myiozetetes cayanensis*	HU, SC, RI		C
	571 **Dusky-chested Flycatcher** *Myiozetetes luteiventris*	LF, RI		S
	572 **Great Kiskadee** *Pitangus sulphuratus*	HU, SC, MN		C
	573 **Lesser Kiskadee** *Philohydor lictor*	FW, RI		F
	574 **Yellow-throated Flycatcher** *Conopias parvus*	LF	AMN	F
	575 **Streaked Flycatcher** *Myiodynastes maculatus*	LF	AUS	U
	576 **Boat-billed Flycatcher** *Megarynchus pitangua*	LF, RI		F
	577 **Sulphury Flycatcher** *Tyrannopsis sulphurea*	PA		F
	578 **Variegated Flycatcher** *Empidonomus varius*	LF, SC	AUS	F
	579 **Crowned Slaty Flycatcher** *Empidonomus aurantioatrocristatus*	SC, SV	AUS	S
	580 **White-throated Kingbird** *Tyrannus albogularis*	SV, RI	AUS?	U
	581 **Tropical Kingbird** *Tyrannus melancholicus*	SC, HU, SV	AUS	C
	582 **Fork-tailed Flycatcher** *Tyrannus savana*	SV, HU, SC	AUS	C
	583 **Eastern Kingbird** *Tyrannus tyrannus*	SC, HU, LF	NEA	S
	584 **Gray Kingbird** *Tyrannus dominicensis*	HU, SC, MN	NEA	F
	585 **Grayish Mourner** *Rhytipterna simplex*	LF		F
	586 **Pale-bellied Mourner** *Rhytipterna immunda*	SC		SL
	587 **Sirystes** *Sirystes sibilator*	LF		S
	588 **Dusky-capped Flycatcher** *Myiarchus tuberculifer*	MF, LF		U
	589 **Swainson's Flycatcher** *Myiarchus swainsoni*	LF, RI	AUS	U
	590 **Short-crested Flycatcher** *Myiarchus ferox*	LF, SC		F

	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	591 **Brown-crested Flycatcher** *Myiarchus tyrannulus*	SC, RI, MN		F
	592 **Large-headed Flatbill** *Ramphotrigon megacephalum*	LF		S
	593 **Rufous-tailed Flatbill** *Ramphotrigon ruficauda*	LF		U
	594 **Cinnamon Attila** *Attila cinnamomeus*	LF, SC, RI		F
	595 **Bright-rumped Attila** *Attila spadiceus*	LF, MF		U
	Sharpbill **Oxyruncidae**			
	596 **Sharpbill** *Oxyruncus cristatus*	MF		U
	Cotingas **Cotingidae**			
	597 **Red-banded Fruiteater** *Pipreola whitelyi*	MF	TEP	C
	598 **Guianan Cock-of-the-Rock** *Rupicola rupicola*	MF, LF	AMN	F
	599 **Guianan Red-Cotinga** *Phoenicircus carnifex*	LF		F
	600 **Purple-breasted Cotinga** *Cotinga cotinga*	LF		U
	601 **Spangled Cotinga** *Cotinga cayana*	LF		U
	602 **White Bellbird** *Procnias albus*	MF, LF		U
	603 **Bearded Bellbird** *Procnias averano*	MF		FL
	604 **Screaming Piha** *Lipaugus vociferans*	LF		C
	605 **Rose-collared Piha** *Lipaugus streptophorus*	MF	TEP	S
	606 **Pompadour Cotinga** *Xipholena punicea*	LF		U
	607 **Bare-necked Fruitcrow** *Gymnoderus foetidus*	RI, LF		U
	608 **Purple-throated Fruitcrow** *Querula purpurata*	LF		F
	609 **Crimson Fruitcrow** *Haematoderus militaris*	LF		S
	610 **Red-ruffed Fruitcrow** *Pyroderus scutatus*	?		?
	611 **Capuchinbird** *Perissocephalus tricolor*	LF	AMN	F
	612 **Amazonian Umbrellabird** *Cephalopterus ornatus*	LF		S
	Manakins **Pipridae**			
	613 **Pale-bellied Tyrant-Manakin** *Neopelma pallescens*	SC		U
	614 **Saffron-crested Tyrant-Manakin** *Neopelma chrysocephalum*	SC, LF	AMN	F
	615 **Tiny Tyrant-Manakin** *Tyranneutes virescens*	LF	GUI	F
	616 **White-throated Manakin** *Corapipo gutturalis*	MF, LF	GUI	F
	617 **Striped Manakin** *Machaeropterus regulus*	LF, MF		?
	618 **White-fronted Manakin** *Lepidothrix serena*	LF, MF	GUI	F
	619 **Orange-bellied Manakin** *Lepidothrix suavissima*	LF, MF	TEP	F
	620 **White-bearded Manakin** *Manacus manacus*	RI, LF, SC		F
	621 **Blue-backed Manakin** *Chiroxiphia pareola*	SC, LF		C
	622 **Olive Manakin** *Xenopipo uniformis*	MF	TEP	S
	623 **Black Manakin** *Xenopipo atronitens*	SC		F
	624 **White-crowned Manakin** *Pipra pipra*	LF, MF		F
	625 **Crimson-hooded Manakin** *Pipra aureola*	LF		U
	626 **Scarlet-horned Manakin** *Pipra cornuta*	MF	TEP	F
	627 **Golden-headed Manakin** *Pipra erythrocephala*	LF		F
	INCERTAE SEDIS			
	628 **Black-crowned Tityra** *Tityra inquisitor*	LF		UL
	629 **Black-tailed Tityra** *Tityra cayana*	LF		U
	630 **Thrush-like Schiffornis** *Schiffornis turdina*	LF, MF		F
	631 **Cinereous Mourner** *Laniocera hypopyrra*	LF		U
	632 **Dusky Purpletuft** *Iodopleura fusca*	LF	GUI	U

	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	633 **White-naped Xenopsaris** *Xenopsaris albinucha*	SV, SC		S
	634 **Green-backed Becard** *Pachyramphus viridis* *	MF		?
	635 **Cinereous Becard** *Pachyramphus rufus*	SC, LF		F
	636 **White-winged Becard** *Pachyramphus polychopterus*	LF, SC		F
	637 **Black-capped Becard** *Pachyramphus marginatus*	LF		F
	638 **Glossy-backed Becard** *Pachyramphus surinamus*	LF		SL
	639 **Pink-throated Becard** *Pachyramphus minor*	LF		F
	640 **Wing-barred Piprites** *Piprites chloris*	LF		F
	Vireos **Vireonidae**			
	641 **Rufous-browed Peppershrike** *Cyclarhis gujanensis*	SC, RI, MF		F
	642 **Slaty-capped Shrike-Vireo** *Vireolanius leucotis*	LF, MF		F
	643 **Red-eyed Vireo** *Vireo olivaceus*	LF	NEA	F
	644 **Black-whiskered Vireo** *Vireo altiloquus*	LF, MN	NEA	U
	645 **Lemon-chested Greenlet** *Hylophilus thoracicus*	LF		F
	646 **Ashy-headed Greenlet** *Hylophilus pectoralis*	SC, MN		C
	647 **Tepui Greenlet** *Hylophilus sclateri*	MF	TEP	F
	648 **Buff-cheeked Greenlet** *Hylophilus muscicapinus*	LF, MF		F
	649 **Tawny-crowned Greenlet** *Hylophilus ochraceiceps*	LF		F
	Jays **Corvidae**			
	650 **Violaceous Jay** *Cyanocorax violaceus* *	LF		?L
	651 **Cayenne Jay** *Cyanocorax cayanus*	LF	GUI	F
	Swallows **Hirundinidae**			
	652 **Tree Swallow** *Tachycineta bicolor* *	FW	NEA	?
	653 **White-winged Swallow** *Tachycineta albiventer*	RI, FW		C
	654 **Brown-chested Martin** *Progne tapera*	SV, SC, RI	AUS	F
	655 **Purple Martin** *Progne subis*	SC, HU, RI	NEA	S
	656 [**Caribbean Martin** *Progne dominicensis*] *	SC, HU	NEA	?
	657 **Gray-breasted Martin** *Progne chalybea*	HU, SC		C
	658 **Blue-and-white Swallow** *Pygochelidon cyanoleuca*	SC, HU	AUS	U
	659 **White-banded Swallow** *Atticora fasciata*	RI		C
	660 **Black-collared Swallow** *Atticora melanoleuca*	RI		FL
	661 **White-thighed Swallow** *Neochelidon tibialis*	MF, LF		UL
	662 **Tawny-headed Swallow** *Alopochelidon fucata*	SV		F
	663 **Southern Rough-winged Swallow** *Stelgidopteryx ruficollis*	FW, RI, SC		C
	664 **Bank Swallow** *Riparia riparia*	SV, HU, FW	NEA	F
	665 **Barn Swallow** *Hirundo rustica*	SV, HU, SC	NEA	C
	666 [**Cliff Swallow** *Petrochelidon pyrrhonota*]	HU, FW	NEA	?
	Wrens **Troglodytidae**			
	667 **Flutist Wren** *Microcerculus ustulatus*	MF	TEP	F
	668 **Wing-banded Wren** *Microcerculus bambla*	LF		U
	669 **House Wren** *Troglodytes aedon*	SC, HU		C
	670 **Tepui Wren** *Troglodytes rufulus*	MF	TEP	U
	671 **Sedge Wren** *Cistothorus platensis*	SV		S
	672 **Bicolored Wren** *Campylorhynchus griseus*	SC, PA		F

	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	673 **Coraya Wren** *Thryothorus coraya*	LF		F
	674 **Buff-breasted Wren** *Thryothorus leucotis*	LF, RI, SC		F
	675 **White-breasted Wood-Wren** *Henicorhina leucosticta*	LF, MF		F
	676 **Musician Wren** *Cyphorhinus arada*	LF		F
	Gnatwrens, Gnatcatchers Polioptilidae			
	677 **Collared Gnatwren** *Microbates collaris*	LF, MF	AMN	U
	678 **Long-billed Gnatwren** *Ramphocaenus melanurus*	LF		F
	679 **Tropical Gnatcatcher** *Polioptila plumbea*	SC, LF		F
	680 **Guianan Gnatcatcher** *Polioptila guianensis*	LF		U
	INCERTAE SEDIS			
	681 **Black-capped Donacobius** *Donacobius atricapillus*	FW		F
	Thrushes Turdidae			
	682 **Veery** *Catharus fuscescens*	LF	NEA	S
	683 **Gray-cheeked Thrush** *Catharus minimus*	LF	NEA	S
	684 **Rufous-brown Solitaire** *Cichlopsis leucogenys*	MF		U
	685 **Yellow-legged Thrush** *Turdus flavipes*	MF		S
	686 **Pale-eyed Thrush** *Turdus leucops*	MF		?
	687 **Black-hooded Thrush** *Turdus olivater*	MF		F
	688 **Pale-breasted Thrush** *Turdus leucomelas*	HU, SC		C
	689 **Black-billed Thrush** *Turdus ignobilis*	LF, MF, SC		CL
	690 **Cocoa Thrush** *Turdus fumigatus*	LF		F
	691 **Bare-eyed Robin** *Turdus nudigenis*	SC, HU		F
	692 **White-necked Robin** *Turdus albicollis*	LF, MF		F
	Mockingbirds Mimidae			
	693 **Tropical Mockingbird** *Mimus gilvus*	SC, HU		C
	Pipits Motacillidae			
	694 **Yellowish Pipit** *Anthus lutescens*	SV, HU		F
	Tanagers Thraupidae			
	695 **Black-faced Tanager** *Schistochlamys melanopis*	SV, SC, FW		U
	696 **Magpie Tanager** *Cissopis leveriana*	LF, HU		UL
	697 **Red-billed Pied Tanager** *Lamprospiza melanoleuca*	LF		U
	698 **Hooded Tanager** *Nemosia pileata*	SC		F
	699 **Gray-headed Tanager** *Eucometis penicillata*	LF		S
	700 **Flame-crested Tanager** *Tachyphonus cristatus*	LF		F
	701 **Fulvous-crested Tanager** *Tachyphonus surinamus*	LF		F
	702 **White-shouldered Tanager** *Tachyphonus luctuosus*	LF		U
	703 **White-lined Tanager** *Tachyphonus rufus*	SC, HU		F
	704 **Red-shouldered Tanager** *Tachyphonus phoenicius*	SC, SV		F
	705 **Fulvous Shrike-Tanager** *Lanio fulvus*	LF	AMN	U
	706 **Silver-beaked Tanager** *Ramphocelus carbo*	SC, HU		C
	707 **Blue-gray Tanager** *Thraupis episcopus*	SC, HU		C
	708 **Palm Tanager** *Thraupis palmarum*	SC, HU, PA		C

	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	709 **Blue-backed Tanager** *Cyanicterus cyanicterus*	LF	GUI	U
	710 **Turquoise Tanager** *Tangara mexicana*	LF, HU		F
	711 **Paradise Tanager** *Tangara chilensis*	LF, MF		F
	712 **Yellow-bellied Tanager** *Tangara xanthogastra*	MF		F
	713 **Spotted Tanager** *Tangara punctata*	LF, MF		F
	714 **Speckled Tanager** *Tangara guttata*	MF		UL
	715 **Dotted Tanager** *Tangara varia*	MF		S
	716 **Bay-headed Tanager** *Tangara gyrola*	MF, LF		F
	717 **Burnished-buff Tanager** *Tangara cayana*	SC, SV, HU		C
	718 **Masked Tanager** *Tangara nigrocincta* *	LF		?
	719 **Black-headed Tanager** *Tangara cyanoptera*	MF, SC		F
	720 **Opal-rumped Tanager** *Tangara velia*	LF		F
	721 **Swallow-Tanager** *Tersina viridis*	LF, RI		F
	722 **Black-faced Dacnis** *Dacnis lineata*	LF, MF		U
	723 **Blue Dacnis** *Dacnis cayana*	LF, SC		C
	724 **Short-billed Honeycreeper** *Cyanerpes nitidus*	LF		S
	725 **Purple Honeycreeper** *Cyanerpes caeruleus*	LF, MF		F
	726 **Red-legged Honeycreeper** *Cyanerpes cyaneus*	LF		F
	727 **Green Honeycreeper** *Chlorophanes spiza*	LF		C
	728 **Guira Tanager** *Hemithraupis guira*	LF		F
	729 **Yellow-backed Tanager** *Hemithraupis flavicollis*	LF		F
	730 **Chestnut-vented Conebill** *Conirostrum speciosum*	SC, LF		F
	731 **Bicolored Conebill** *Conirostrum bicolor*	MN		F
	732 **Greater Flowerpiercer** *Diglossa major*	MF	TEP	F
	INCERTAE SEDIS			
	733 **Hepatic Tanager** *Piranga flava*	SV, SC, MF		U
	734 **Summer Tanager** *Piranga rubra*	LF, MF	NEA	S
	735 [**Scarlet Tanager** *Piranga olivacea*] *	LF	NEA	S
	736 **White-winged Tanager** *Piranga leucoptera*	MF, SC		S
	737 **Olive-backed Tanager** *Mitrospingus oleagineus*	MF	TEP	F
	738 **Bananaquit** *Coereba flaveola*	LF, SC, HU		C
	739 **Sooty Grassquit** *Tiaris fuliginosus*	MF, SC		?
	Emberizine Finches **Emberizidae**			
	740 **Rufous-collared Sparrow** *Zonotrichia capensis*	SC, HU		FL
	741 **Grassland Sparrow** *Ammodramus humeralis*	SV, HU		C
	742 **Stripe-tailed Yellow-Finch** *Sicalis citrina*	SV, HU		UL
	743 **Saffron Finch** *Sicalis flaveola*	SC, HU		?
	744 **Grassland Yellow-Finch** *Sicalis luteola*	SV, HU		F
	745 **Wedge-tailed Grass-Finch** *Emberizoides herbicola*	SV, SC, FW		F
	746 **Blue-black Grassquit** *Volatinia jacarina*	HU, FW, SC		C
	747 **Slate-colored Seedeater** *Sporophila schistacea*	LF, RI		CL
	748 **Gray Seedeater** *Sporophila intermedia*	SV, SC		F
	749 **Plumbeous Seedeater** *Sporophila plumbea*	SV		F
	750 **Wing-barred Seedeater** *Sporophila americana*	SC, HU		F
	751 **Lesson's Seedeater** *Sporophila bouvronides*	SC		U
	752 **Lined Seedeater** *Sporophila lineola*	SC	AUS	U
	753 **Yellow-bellied Seedeater** *Sporophila nigricollis*	SC, HU		CL
	754 **Ruddy-breasted Seedeater** *Sporophila minuta*	SC, FW, HU		C

	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	755 **Chestnut-bellied Seedeater** *Sporophila castaneiventris*	SC, HU		F
	756 **Chestnut-bellied Seed-Finch** *Oryzoborus angolensis*	SC, HU, LF		F
	757 **Large-billed Seed-Finch** *Oryzoborus crassirostris*	FW, SC		U
	758 **Great-billed Seed-Finch** *Oryzoborus maximiliani*	FW, SC		?
	759 **White-naped Seedeater** *Dolospingus fringilloides*	SC, SV	AMN	FL
	760 [**Paramo Seedeater** *Catamenia homochroa*]	SV, SC		CL
	761 **Pectoral Sparrow** *Arremon taciturnus*	LF		F
	762 **Tepui Brush-Finch** *Atlapetes personatus*	MF, SC	TEP	U
	763 **Red-crested Finch** *Coryphospingus cucullatus* *	SC		?
	764 **Red-capped Cardinal** *Paroaria gularis*	RI, SC		C
	Grosbeaks, Saltators **Cardinalidae**			
	765 **Yellow-green Grosbeak** *Caryothraustes canadensis*	LF		F
	766 **Red-and-black Grosbeak** *Periporphyrus erythromelas*	LF		U
	767 **Slate-colored Grosbeak** *Saltator grossus*	LF		F
	768 **Buff-throated Saltator** *Saltator maximus*	SC, LF		F
	769 **Grayish Saltator** *Saltator coerulescens*	SC, HU		F
	770 **Blue-black Grosbeak** *Cyanocompsa cyanoides*	LF		F
	771 **Dickcissel** *Spiza americana*	HU, SV	NEA	?
	Wood Warblers **Parulidae**			
	772 **Tropical Parula** *Parula pitiayumi*	MF, LF		U
	773 **Yellow Warbler** *Dendroica petechia*	MN, SC, HU	NEA	F
	774 **Blackpoll Warbler** *Dendroica striata*	LF	NEA	U
	775 [**Bay-breasted Warbler** *Dendroica castanea*]	LF	NEA	S
	776 [**Blackburnian Warbler** *Dendroica fusca*]	MF	NEA	S
	777 **American Redstart** *Setophaga ruticilla*	LF, MF, MN	NEA	U
	778 **Prothonotary Warbler** *Protonotaria citrea*	MN	NEA	S
	779 **Northern Waterthrush** *Seiurus noveboracensis*	MN	NEA	C
	780 **Masked Yellowthroat** *Geothlypis aequinoctialis*	FW, SC		F
	781 **Slate-throated Redstart** *Myioborus miniatus*	MF		F
	782 **Tepui Redstart** *Myioborus castaneocapillus*	MF, SC	TEP	F
	783 **Two-banded Warbler** *Basileuterus bivittatus*	MF, SC		F
	784 **Golden-crowned Warbler** *Basileuterus culicivorus*	MF, LF		UL
	785 **Flavescent Warbler** *Basileuterus flaveolus*	SC		FL
	786 **Riverbank Warbler** *Phaeothlypis rivularis*	LF, RI		F
	INCERTAE SEDIS			
	787 **Rose-breasted Chat** *Granatellus pelzelni*	LF		U
	New World Blackbirds **Icteridae**			
	788 **Green Oropendola** *Psarocolius viridis*	LF, MF		C
	789 **Crested Oropendola** *Psarocolius decumanus*	LF		C
	790 **Yellow-rumped Cacique** *Cacicus cela*	RI, LF, HU		C
	791 **Red-rumped Cacique** *Cacicus haemorrhous*	LF		C
	792 **Troupial** *Icterus icterus*	SC, SV		F
	793 **Epaulet Oriole** *Icterus cayanensis*	SC, PA, HU		F
	794 **Yellow Oriole** *Icterus nigrogularis*	SC, HU, MN		F

	ENGLISH NAME - SCIENTIFIC NAME	HABITAT	EN/MI	ABU
	795 **Golden-tufted Grackle** *Macroagelaius imthurni*	MF	TEP	F
	796 **Velvet-fronted Grackle** *Lampropsar tanagrinus*	LF, MN		U
	797 **Yellow-hooded Blackbird** *Chrysomus icterocephalus*	FW		C
	798 **Giant Cowbird** *Molothrus oryzivorus*	LF, SC, HU		C
	799 **Shiny Cowbird** *Molothrus bonariensis*	SC, HU		C
	800 **Carib Grackle** *Quiscalus lugubris*	SC, HU, MN		C
	801 **Red-breasted Blackbird** *Sturnella militaris*	HU, FW, SV		C
	802 **Eastern Meadowlark** *Sturnella magna*	SV, HU		C
	803 **Bobolink** *Dolichonyx oryzivorus*	HU, FW, SV	NEA	S
	Cardueline Finches **Fringillidae**			
	804 **Red Siskin** *Carduelis cucullata*	SC, SV		CL
	805 **Hooded Siskin** *Carduelis magellanica*	SC, SV	GUI	SL
	806 **Plumbeous Euphonia** *Euphonia plumbea*	LF, SC, MF		U
	807 **Purple-throated Euphonia** *Euphonia chlorotica*	LF, MF		U
	808 **Finsch's Euphonia** *Euphonia finschi*	LF, SC	GUI	F
	809 **Violaceous Euphonia** *Euphonia violacea*	LF, HU		F
	810 **Golden-bellied Euphonia** *Euphonia chrysopasta*	LF, RI		F
	811 **White-vented Euphonia** *Euphonia minuta*	LF		F
	812 **Orange-bellied Euphonia** *Euphonia xanthogaster*	MF, LF		F
	813 **Golden-sided Euphonia** *Euphonia cayennensis*	LF		F
	814 **Blue-naped Chlorophonia** *Chlorophonia cyanea*	MF		U

NOTES

NOTES

NOTES

VENEZUELA
ATLANTIC OCEAN
SURINAME
BRAZIL
Barima R.
Cuyuni R.
Mazaruni R.
Pacaraima Mts.
Essequibo R.
Demerara R.
Berbice R.
Courantyne R.
Rupununi Savanna
Kanuku Mts
Acary Mts
Lowland Forest (LF)
Montane Forest (MF)
Savanna (SV)
Mangrove (MN)
Human impacted (HU)

If found, return to:

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APPENDIX J – Protected Species Observer Summary

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Protected Species Observer Summary

Prepared for: ExxonMobil

ExxonMobil

Guyana

2015-2016







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Table of Contents

Table of Contents ii
List of Figures iii
List of Tables iii
1 Executive Summary 5
2 Introduction 6
2.1 General Program Information 6
2.1.1 Stabroek 3D Survey 6
2.1.2 LIZA AUV Survey 6
2.1.3 Canje 3D Survey 6
2.2 Vessel and Seismic Equipment Specifications 7
2.2.1 Stabroek 3D Survey 7
2.2.2 LIZA AUV Survey 8
2.2.3 Canje 3D Survey 8
2.3 Passive Acoustic Monitoring (PAM) Parameters 10
3 Methodology 12
3.1 Visual Survey Methodology 12
3.2 Acoustic Monitoring Methodology 12
4 Survey Data 16
4.1 Source Operations Summary 16
4.2 Visual Monitoring Summary 17
4.3 Acoustic Monitoring Summary 17
4.4 Mitigation Actions 18
4.5 Wildlife Summary 19
4.5.1 Overview 19
4.5.2 Visual Detections 21
4.5.3 Acoustic Detections 22
4.5.4 Wildlife Summary Tables 29
5 Protected Species Summary Table 33

List of Figures

Figure 1: Map indicating the general location of the surveys. 7
Figure 2. Data pathway through PAM system 11
Figure 3: High frequency delphinid click trains on the bearing/time display 13
Figure 4: Clean click waveform display and click spectrum of delphinid pulse emissions 14
Figure 5: The amplitude/time module during a high frequency delphinid detection 14
Figure 6: Breakdown of acoustic source operations 16
Figure 7: Breakdown of source operations by source activity and survey 17
Figure 8: Breakdown of visual and acoustic monitoring while source active and silent by survey 18
Figure 9: Protected species detections by species group on each of the ExxonMobil Guyana survey programs 19
Figure 10: Protected species detections (visual and acoustic) shown as a breakdown by species over all ExxonMobil Guyana programs during 2015 and 2016 20
Figure 11: Seismic source activity at the initial detection of a marine mammal or sea turtle 21
Figure 12: Visual protected species detections shown as a breakdown by species over all ExxonMobil Guyana programs during 2015 and 2016 22
Figure 13: Acoustic protected species detections shown as a breakdown by species over all ExxonMobil Guyana programs during 2015 and 2016 23
Figure 14: Distribution of visual protected species detections during ExxonMobil Guyana Stabroek 3D, LIZA AUV, and Canje 3D programs 25
Figure 15: Distribution of acoustic protected species detections during ExxonMobil Guyana Stabroek 3D and Canje 3D programs 26
Figure 16: Bird species observed during Stabroek 3D Survey, LIZA AUV Survey, and Canje 3D Survey 27
Figure 17: Fish species observed during Stabroek 3D Survey, LIZA AUV Survey, and Canje 3D Survey 28

List of Tables

Table 1. Seismic Acquisition Parameters Summary Table 9
Table 2. AUV Acquisition Parameters Summary Table 10
Table 3: Summary of mitigation actions by visual and acoustic observers. 19
Table 4: Protected species visual and acoustic detection summary during the Stabroek survey program 24
Table 5: Birds observed during visual monitoring 29
Table 6: Fish species observed during visual monitoring 31
Table 7: Marine invertebrates observed during visual monitoring 32
Table 8: Other wildlife observed during visual monitoring 32

Table 9: Protected species detected visually and acoustically during the Stabroek 3D Survey, LIZA AUV Survey, and Canje 3D Survey.....33

1 Executive Summary

This report summarizes the protected species observer data collected by ExxonMobil on various programs from 2014 through 2016 in Guyana. Data from the Stabroek 3D, LIZA AUV, and Canje 3D surveys conducted over the periods of 12 July 2015 to 17 February 2016, 17 December 2015 to 23 March 2016, and 18 March 2016 to 20 August 2016 respectively are included in this report.

During all surveys, two protected species observers (PSOs) provided by RPS were on board the vessels to undertake visual observations in accordance with Joint Nature Conservation Committee (JNCC) *guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys*. During the Stabroek 3D and Canje 3D Surveys, there was also one passive acoustic monitoring (PAM) operator provided by RPS on board each vessel to undertake acoustic observations in accordance with JNCC guidelines.

In addition to permit requirements, ExxonMobil voluntarily mandated that soft starts would be delayed for sea turtles in addition to marine mammals if detected within in the 500 meter exclusion zone during the search period prior to initiation of the source and if the source activity ceased or reduced power, a silent period of only five minutes would be permitted after which a soft-start was required to resume source operations.

Throughout all surveys, PSOs conducted visual observations for a total of 8187 hours and 37 minutes. PAM Operators performed acoustic monitoring for a total of 5135 hours and 55 minutes.

During the seismic surveys, the seismic source was active for a total of 8558 hours and 30 minutes. This included 7879 hours and 28 minute while in production, 218 hours and 40 minutes while at full volume or partial volume while not in production, 344 hours and 23 minutes of soft-start, and 115 hours and 59 minutes conducting source testing. There was no use of the mitigation source throughout any survey. During the AUV survey, there was a total of 786 hours of AUV Payload Ops, 201 hours and 30 minutes of MBES (EM302) activity, 104 hours and 03 minutes of SBP activity, and 469 hours and 51 minutes of Single Beam (EA600) activity.

There were 417 total protected species detections recorded during all surveys, including 153 visual detections, 264 acoustic detections and three correlated visual-acoustic detections. Visual detections consisted of 53 detections of whales, 91 detections of dolphins, and 09 detections of turtles. Acoustic detections consisted of 09 sperm whale detections and 255 dolphin detections, three of which were correlated with visual detections.

There were a total of nine mitigation actions conducted throughout these surveys due to marine mammals detected within the exclusion zone prior to source operations. All mitigation actions occurred aboard the *CGG Alize* during the Stabroek survey and were delays to initiation of the source, including eight of which were undertaken for dolphin detections and one for a sperm whale detection.

2 Introduction

2.1 General Program Information

2.1.1 Stabroek 3D Survey

The Stabroek I 3D survey was conducted by CGG on behalf of ExxonMobil. The survey area was located off the coast of Guyana in the Stabroek block (Figure 1). The survey was conducted under regulatory permit number GUY 05 5099 0 00 B and consisted of 472 sail lines, shot in the Northeast to Southwest direction. The average length of each sail line was 72 kilometers. The survey was broken into three priority sections which were independently surveyed by the *CGG Alize* and the *CGG Geo Celtic* where the *CGG Alize* surveyed priority area three and the CGG *Geo Celtic* surveyed priority areas one and two.

2.1.2 LIZA AUV Survey

The LIZA Deep Water Field AUV survey was conducted off the coast of Guyana in the Stabroek Block. The survey was separated into two segments: geophysical and geotechnical. The geophysical survey took place in the approximate area of 8°14 to 7°09 North and 56°4 to 57°05 West, where water depths ranged from approximately 200 to 2200m covering an area approximately 350 square km, potentially increasing up to 1000 square km (Figure 1).

The geotechnical survey began on 26 February and concluded on 23 March 2016 and consisted of three coring phases. The first phase of this survey lasted for approximately 1 week where a piston core was used to collect 8 - 9 meter sediment samples. The second phase lasted for approximately 2 weeks and a box core was used to collect environmental samples as well as CTD and water samples. The final phase continued for 2 days and also used the box core to collect samples.

2.1.3 Canje 3D Survey

The Canje survey was a 3D survey conducted by Polarcus on behalf of ExxonMobil. The survey area was approximately 7742 square kilometres off the coast of Guyana (Figure 1). The survey was conducted under a Letter of Authorization issued by the Environmental Protection Agency of Guyana. The Canje survey consisted of 201 sail lines, shot in the North to South direction. The average length of each sail line was 64 kilometers. The survey was broken into an eastern and western section with the eastern section given priority. The *Polarcus Adira* began the survey in the eastern priority area.

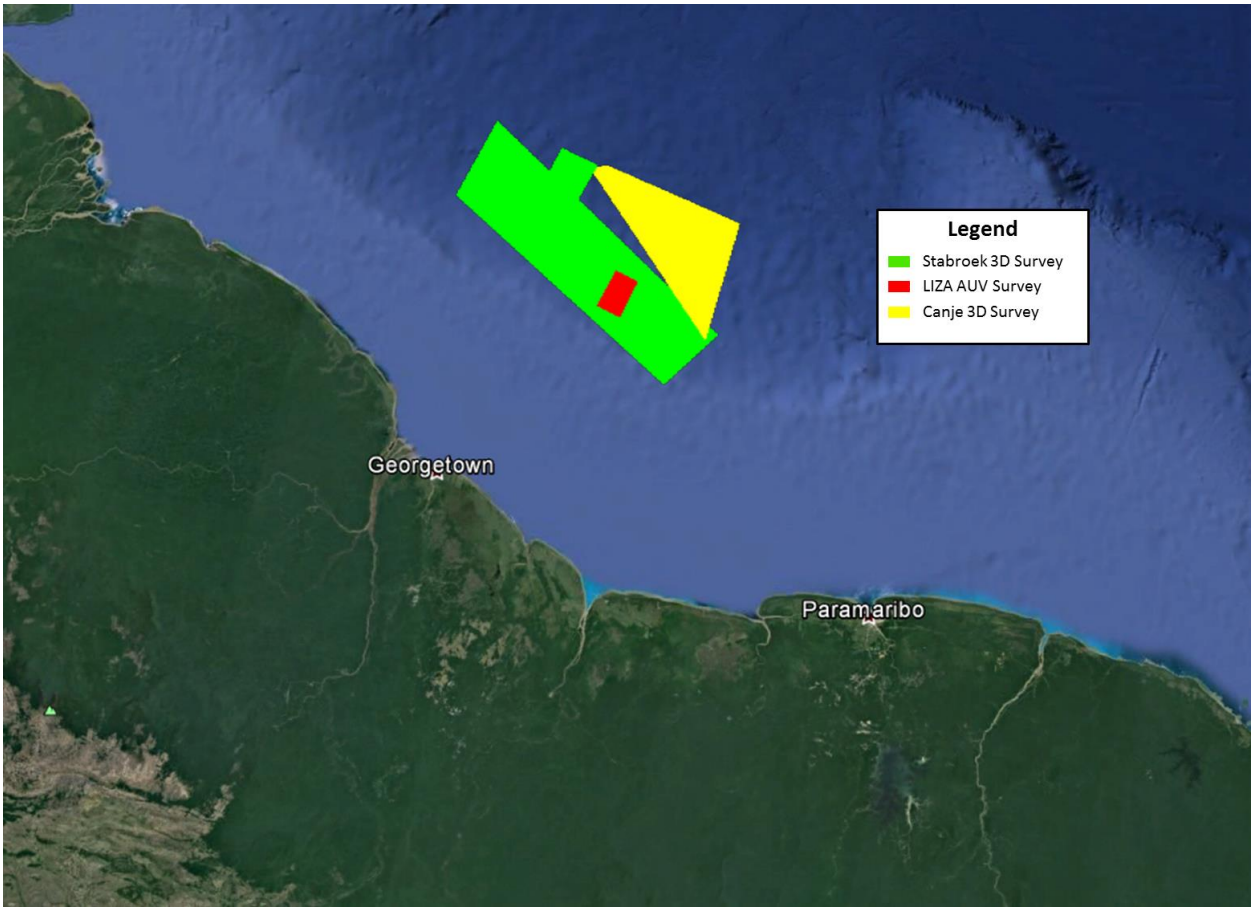


Figure 1: Map indicating the general location of the surveys.

2.2 Vessel and Seismic Equipment Specifications

2.2.1 Stabroek 3D Survey

The *CGG Alize* and *CGG Geo Celtic* were the two vessels utilized to complete this survey, however the two vessels worked independently of one another in different sections of the prospect area. The chase vessels utilized during this survey consisted of the *Thor Omega, The Fenny, the Bourbon Cormorant, the Linda C, the Bourbon Grebe, and the Bourbon Petrel.*

Each vessel was towing ten streamers at the start of the survey, each 10 kilometers in length with a 100 meter separation and a tow depth of seven meters. The *CGG Alize* reduced to an eight-streamer configuration for a period of 17 days in December 2015, then returned to the original ten-streamer configuration. The seismic source on each vessel consisted of six source strings, each made up of 12 elements. While in production, the source used a flip-flop firing pattern, where the starboard three source strings fire one shot, then the port side three source strings fire on the next shot and continue to flip-flop throughout the survey line. The source arrays were towed at a depth of six meters. The full volume of each source was 4070 cubic inches with a frequency response of 200-370 kHz and an intensity

of 45-70 dB re 1 µPa (Table 1). Soft-starts were conducted by gradually increasing the numbers of active airguns over a period of 20 to 40 minutes.

2.2.2 LIZA AUV Survey

The *Fugro Americas* was utilized to complete this survey. The geophysical Deep Water Field Development survey employed an Autonomous Underwater Vehicle (AUV) equipped with standard equipment including a Multi-Beam Echo Sounder (MBES), Side Scan Sonar (SSS), and Sub-Bottom Profiler (SBP).

The AUV payload source consisted of three acquisition acoustic systems. These systems included a Multi-Beam Echo Sounder (MBES), Side Scan Sonar (SSS), and Sub-Bottom Profiler (SBP). The Multibeam system was a Kongsberg EM2040 with a frequency of 200 kHz and range of 250 meters. The Side Scan Sonar was an Edgetech 2200M, with a low frequency of 105 kHz and a high frequency of 410 KHz and a range of 200 meters. The Sub-bottom Profiler was an Edgetech DW-106 with a pulse rate of 20m/sec, and record length of 200m/sec (Table 2).

In addition to the operations of the AUV, a Kongsberg EM302 multibeam echo sounder (MBES), a Kongsberg EA600 Single Beam Echo Sounder, and an Edgetech Sub-bottom profiler were operated from the *Americas* throughout the survey. These sound sources are operated from the *Americas* during transits into and out of port as well as throughout the Stabroek Block.

2.2.3 Canje 3D Survey

The *Polarcus Adira* was the sole vessel utilized to complete this survey. The chase vessels utilized during this survey consisted of the *Vos Athos* and the *7 Oceans*.

The *Polarcus Adira* is a streamer vessel 92 meters in length and 21 meters in breadth. The seismic source consisted of six source strings each made up of 12 elements. While in production, the source used a flip-flop firing pattern where the starboard three source strings fire one shot, then the port side three source strings fire on the next shot and continue to flip-flop throughout the survey line. The individual source modules varied in volume from 45 to 380 cubic inches. The full volume of the source was 4240 cubic inches with a frequency response of 128 Hz and an intensity of 52.4 dB. During acquisition, the shot point interval was approximately 11.5 seconds, at a distance of 25 meters. The source arrays were towed 488 meters astern at a depth of six meters. The vessel towed 12 streamers, each 8.1 kilometers in length, with a 100-meter separation and a tow depth of 12 meters (Table 1). Soft-starts were conducted by gradually increasing the numbers of active airguns over a period of 20 to 40 minutes.

Table 1. Seismic Acquisition Parameters Summary Table

General Specifications			
Client / Contractor:	CGG		Polarcus
Program/Project Name:	Stabroek 3D Guyana 2015 Survey		Stabroek II 3D Guyana 2016 Survey
Program Period:	12 July 2015 to 17 February 2016		19 March 2016 to 20 August 2016
Type of Survey:	3D Seismic		3D Seismic
General Location:	Guyana		Guyana
Prospect Size (km²):	8209		7742
Vessel / Vessel Length (m):	*CGG Alize* / 101.4 *CGG Geo Celtic* / 108.3		*Polarcus Adira* / 92
Support/Chase Vessels:	*Thor Omega, The Fenny, the Bourbon Cormorant, the Linda C, the Bourbon Grebe, and the Bourbon Petrel.*		*Vos Athos, 7 Oceans*
Vessel Configuration description:	Two streamer vessels working independently of one another on different areas of the prospect area.		Single source and recording vessel
Energy Source (Airgun) Specifications			
	CGG Alize	***CGG Geo Celtic***	
Total source volume (in^3)	4070	4070	4240
Number of source arrays:	6	6	6
Total number of source elements per array / In full volume source	12 elements per array/ 72 elements total	12 elements per array/ 72 elements total	12 elements per array/ 72 elements total, 66 active with 6 spares
Source depth:	6 meters	6 meters	6 meters
Source distance astern (meters):	200-341	369-424	488
Source frequency (Hz):	200	370	128
Source intensity (dB re 1µPa or bar meters)	45	69.8	52.4
Shot point interval (meters and seconds)	25 meters	25 meters	25 meters, 11.5 seconds
Recording System Specifications:			
Number of streamers or nodes/cables:	8-10	10	12
Streamer depth (meters):	7	7	12
Streamer length /separation (meters)	10000 / 100	10000 / 100	8100 / 100
Streamer description:	Sentinel solid streamers	Sentinel solid streamers	Sentinel solid streamers

Table 2. AUV Acquisition Parameters Summary Table

General Specifications			
Client / Contractor:	Fugro		
Program/Project Name:	LIZA AUV Survey		
Program Period:	17 December 2015 to 23 March 2016		
General Location:	Stabroek Block of Guyana		
Prospect Size (km²):	350		
Vessel / Vessel Length (m):	Fugro Americas/58.8 meters		
Energy Source AUV Specifications			
Vehicle Altitude:	42 meters		
Ping rate:	2.8Hz (Payload – Mulitbeam, Sub-bottom Profiler, Sidescan Sonar)		
Sub-bottom Profiler (SBP):	Edgetech DW-106	Frequency : 1-6 kHz	Pulse rate of 20m/sec, Record length of 200m/sec
Side Scan Sonar (SSS):	Edgetech 2200M	Frequency: 105 kHz (Low), 410 kHz (High)	Range of 200m
Mulitbeam Echo Sounder (MBES)	Kongsberg EM2040	Frequency: 200 kHz	Range of 250m
Energy Source Hull mount Specifications			
Mulitbeam Echo Sounder (MBES)	Kongsberg EM302	Frequency : 30 kHz	
Sub-bottom Profiler (SBP):	Edgetech 7X	Frequency : 1-6 kHz	
Single Beam Echo Sounder	Kongsberg EA600	Frequency : 200kHz, 38kHz	

2.3 Passive Acoustic Monitoring (PAM) Parameters

A Passive Acoustic Monitoring (PAM) system, designed to detect most species of marine mammals found in the waters off of Guyana, was installed on board each seismic source vessel. The system was provided by Seiche Measurements and consisted of a conventionally towed hydrophone array cable, deck cable, data processing unit, headphones for aural monitoring, and a rack mounted computer with an acoustic analysis software package. In addition to the main array setup, a full spare system was available on each source vessel to serve as a back-up in case of equipment failure.

Each hydrophone array consisted of two broadband hydrophone elements (200Hz to 200kHz) and two standard hydrophone elements (2kHz to 200kHz) and a depth gauge (100m capacity) potted directly into the 14 millimeter cable.

At the data processing unit, a buffer box circuitry splits each hydrophone input into low frequency and high frequency band outputs. Four hydrophone channels are input to an *ASIO* sound card to be digitized at 48 kilohertz (two channels). This was the primary audio input for lower frequency detections in *Pamguard*. The *RME Fireface800* software allowed the PAM Operator to control which hydrophone signals were monitored over headphones. The headphone mix could consist of the raw hydrophone signals or the processed playback signal from the data processing unit. The high frequency output of the

buffer box was digitized at the buffer box by the National Instruments data acquisition card at 333 kilohertz (two channels). The custom rack mount data processing unit contained Intel core i5 processors with clock speeds of 3.40 gigahertz and eight gigabytes of RAM. Two wide screen computer monitors were provided to divide the monitoring into low frequency and high frequency displays. Figure 2 outlines the system data flow for the PAM system. An entire second electronic processing system and rack mounted data processing unit were configured for use as spares.

Pamguard was the primary software utilized. *Pamguard* is an open-source software program that is widely considered the world standard for acoustic detection, localization, and classification for mitigation regarding marine mammals and for research into their abundance, distribution, and behaviour (www.*Pamguard*.org).

One monitor was configured for monitoring high frequency clicks, and the second monitor was configured for monitoring low frequency moans, creaks, whistles, clicks, and burst pulses. The high frequency monitor received the raw audio from the *National Instruments DAQ* sound card and contained *Pamguard* modules for monitoring and recording high frequency cetacean clicks, spectrogram, and a sound recorder. The low frequency monitor received raw audio from the *ASIO Fireface* sound card and contained a more elaborate configuration of *Pamguard* modules than the high frequency monitor. This included a click detector, whistle and moan detector, spectrogram, depth gauge display and tracker, map with a GPS feed from the vessel, and a sound recorder.

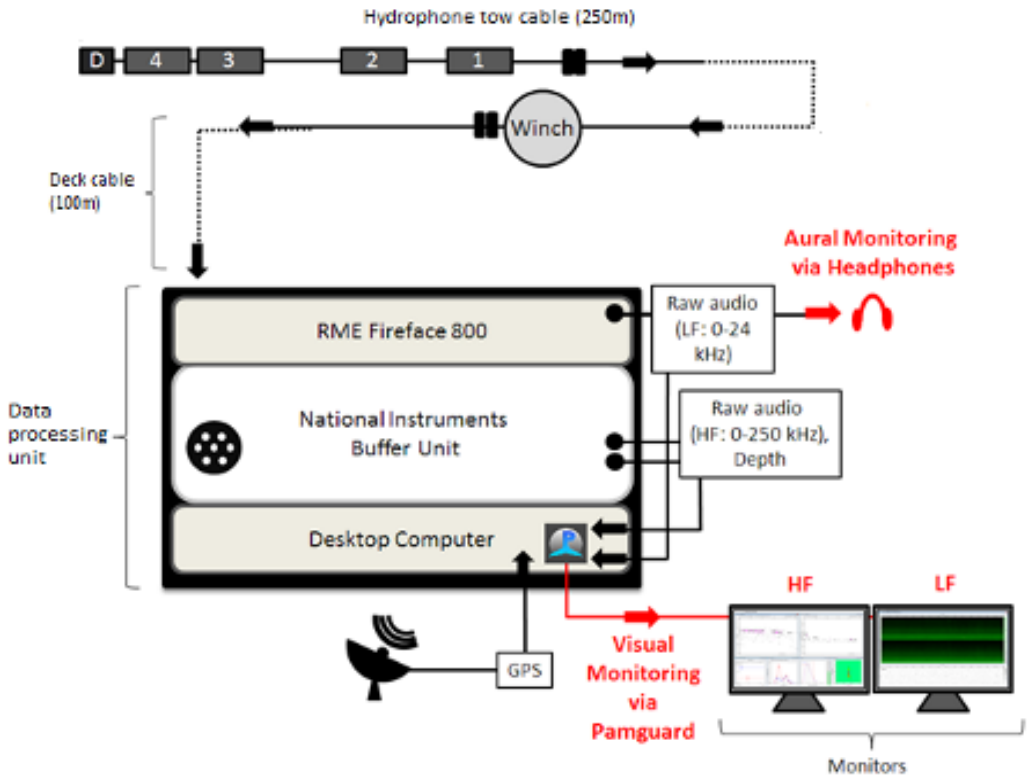


Figure 2. Data pathway through PAM system

3 Methodology

3.1 Visual Survey Methodology

Visual monitoring for protected species was conducted by two PSOs provided by RPS, each of whom have completed a PSO training program. One observer was on watch at a time and monitored the exclusion zone and surrounding areas during all daytime operations when the acoustic source was in the water, regardless of source activity.

Observers scanned the sea surface with the naked eye and the aid of various binoculars, and big-eyes per ExxonMobil's request during the Stabroek 3D Survey. Shifts lasted no more than four hours followed by a break of no less than two hours. Monitoring occurred daily beginning at dawn (defined as approximately 15 minutes before sunrise) and continued throughout the day until the exclusion zone could no longer be effectively observed due to darkness (approximately 15 minutes after sunset).

PSOs collected data at approximately 20-minute intervals while on watch and recorded in observation logs. Daily observation logs included information about environmental conditions, vessel and survey operations, marine debris observed, any vessel/gear and wildlife interactions, and any wildlife sightings.

Identification of marine mammals and sea turtles and wildlife was made or confirmed using identification guides:

- *Guide to Marine Mammals and Turtles of the U.S. Atlantic & Gulow frequency of Mexico* (Wynne, K. and Schwartz, M. 1999)
- *Guide to Marine Mammals of the World* (Reeves et al. 2002).
- *Sea Birds of the World (Harrison, Peter, Princeton University press, Princeton, New Jersey, 2003)*

Distances to protected species were determined visually by comparing an animal or an object's position relative to other vessels and/or installations at known distances, and/or by use of reticle binoculars. Prior to the initiation of the source for ramp-ups or tests during daylight hours, dedicated watches of no less than 30 minutes in waters less than 200 meters and 60 minutes in waters greater than 200 meters were conducted to monitor for protected species within the exclusion zone. Communication between visual observers, PAM Operators and seismic operators was carried out using handheld very high-frequency (VHF) radios.

3.2 Acoustic Monitoring Methodology

One PAM Operator was present on board each seismic source vessel to conduct acoustic monitoring prior to all ramp ups conducted during periods of reduced visibility and/or darkness. In addition, acoustic monitoring was conducted opportunistically during source operations as much as possible, allowing breaks for the PAM Operator to maintain concentration.

Acoustic monitoring was conducted nightly, beginning approximately 15 to 20 minutes prior to dusk, and continuing until daylight, so long as the PAM hydrophone cable was deployed. Acoustic monitoring overlapped visual monitoring efforts by 15 to 20 minutes at dawn and dusk.

During an acoustic monitoring period, the PAM Operator aurally monitored audio feed using Sennheiser headphones from up to all four hydrophone elements which was first mixed using a RME *Fireface800* unit. Visualizations of the audio feed were also monitored via the *Pamguard* software on two computer monitors: one configured to display low frequency modules and the other configured to display the high frequency modules.

Audible clicks, burst pulses, moans, and creaks at frequencies less than 24 kilohertz, including sperm whale clicks and delphinid whistles and clicks, can be detected on the low frequency spectrogram display, the low frequency click detector display, and the low frequency whistle/moan detector display within *Pamguard*.

Vocalizations at frequencies greater than 24 kilohertz including pulse emissions from beaked whales, Kogia whales, and various delphinid species are detected on high frequency click detector displays. The click detector is configured to sample audio at 333 kilohertz for vocalizations with frequency spectra up to approximately 166.5 kilohertz.

During an acoustic monitoring period, the Operators were specifically looking for a combination of factors that may indicate biological pulse emissions. The Operators monitored for click trains on the high frequency bearing/time display; specifically, click trains that showed a progressive change in bearing (Figure 3). When click trains were present, individual clicks were highlighted by the Operator, and the click spectrum module referenced to determine if the clicks had broadband frequencies and consistent peak intensities near a frequency of 30 kilohertz or higher. The click waveform display module provided additional indication of an acoustic detection; biological pulse emissions are generally associated with clean, extremely brief waveforms (Figure 4). Operators also referenced the high frequency amplitude/time display module during monitoring periods; the intensity of pulse emissions generally register at higher intensities than a majority of the ambient noise with click amplitudes for delphinid clicks registering between 155 and 190 decibels relative to 1 micro Pascal (Figure 5). Additionally, consistent click intervals are indicators of pulse emissions; intervals are designated by the unit clicks per second. High frequency dolphin click trains vary widely in click intervals with most click trains displaying an interval of 5 to 40 clicks per second. Click trains within this range are labelled as *echolocation* click trains. Additionally, pulse emissions with much higher click intervals of more than 200 clicks per second are labelled as *burst pulses*. Recorded sound files of vocalizing marine mammals were analysed using *Spectrogram 16*, visualization software that allows the operators to slow down and aurally/visually audit for ultrasonic pulse emissions recorded during a high frequency acoustic detection.

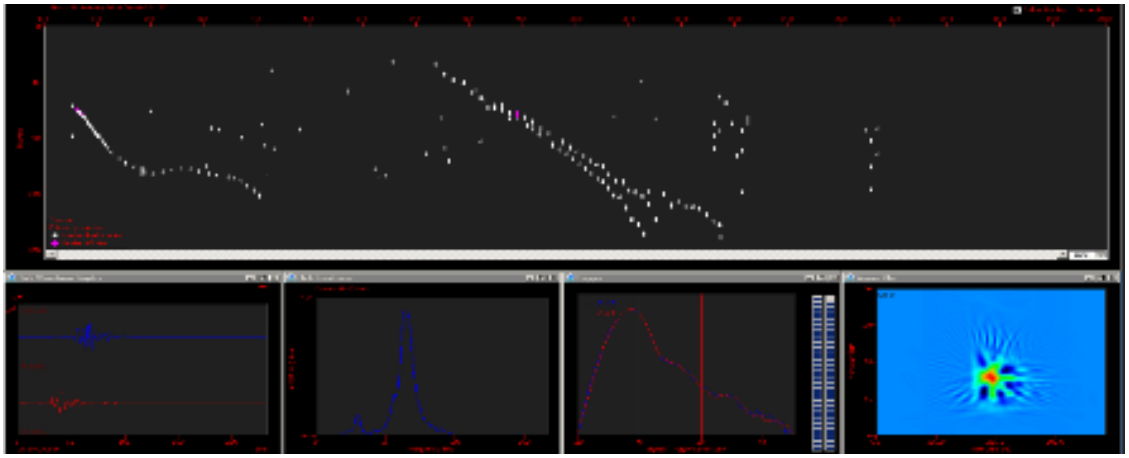


Figure 3: High frequency delphinid click trains on the bearing/time display

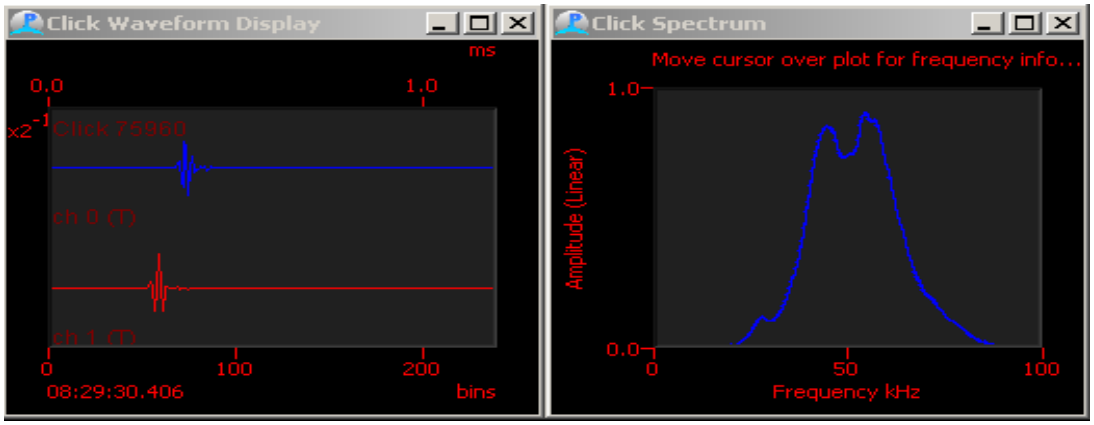


Figure 4: Clean click waveform display and click spectrum of delphinid pulse emissions

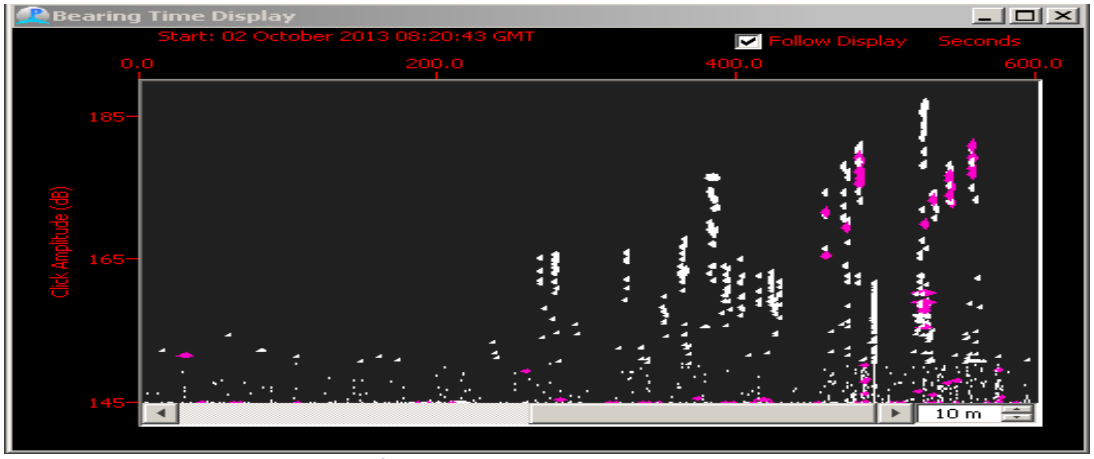


Figure 5: The amplitude/time module during a high frequency delphinid detection

Pamguard contains a function for calculating the range to vocalizing marine mammals based upon the least squares fit test. This method is most effective with animals that are relatively stationary in comparison to the moving vessel, such as sperm whales. The mathematical function estimates the range to vocalizing marine mammals by calculating the most likely crossing of a series of bearing lines generated from tracked clicks or whistles and plotted on a map display. Since the hydrophones are linear, and in close proximity to each other, there is a left-right ambiguity to these localizations, meaning that there is a 1:2 probability that recorded vocalizations are originating from the equal but opposite bearing to that indicated in *Pamguard's* bearing/time display. Thus, a bearing of zero degrees refers to a location directly ahead of the hydrophone array while a bearing of 180 degrees is directly astern of the hydrophone array. A 90 degree bearing could be located at either 90 or 270 degrees in relation to the array. All bearings for acoustic detections indicated in this report are relative to the hydrophone, and this left/right ambiguity should be understood.

Since ultrasonic sounds have a high attenuation rate in water, the distance of a mammal detected vocalizing at frequencies greater than 24 kilohertz is generally estimated to be well within the 500 meter exclusion zone. When the distance to a vocalizing animal could not be determined by *Pamguard*, the experienced PAM Operator made a distance estimation assisted by the noise or detection score system developed by Gannier et al. (2002). Gannier et al. monitored sperm whales in the Mediterranean both visually and acoustically. A scale was developed based upon the strength or intensity of the sperm whale

clicks at various distances that were then measured when the sperm whales surfaced and were visually observed. Although the scale is subjective and sounds produced in marine environments will vary according to local conditions, the scale provides a measure for approximating distances when using a single, linear hydrophone array.

Sound recordings were made using a recorder whenever potential marine mammal vocalizations were detected by the PAM operator.

PAM Operators communicated with seismic personnel via handheld VHF radios or by word of mouth while in the instrument room.

4 Survey Data

4.1 Source Operations Summary

Over the course of all of the survey programs, the seismic source was active for a total of 8558 hours and 30 minutes including: 344 hours and 23 minutes spent in ramp up, 115 hours and 59 minutes spent conducting source testing, 7879 hours and 28 minutes in production and 218 hours and 40 minutes spent at full volume or partial volume not in production, including time prior to the start of lines and during line changes. During the AUV survey, there was a total of 786 hours of AUV Payload Operations, 201 hours and 30 minutes of MBES (EM302) activity, 104 hours and 03 minutes of SBP activity, and 469 hours and 51 minutes of Single Beam (EA600) activity (Figures 6 and 7).

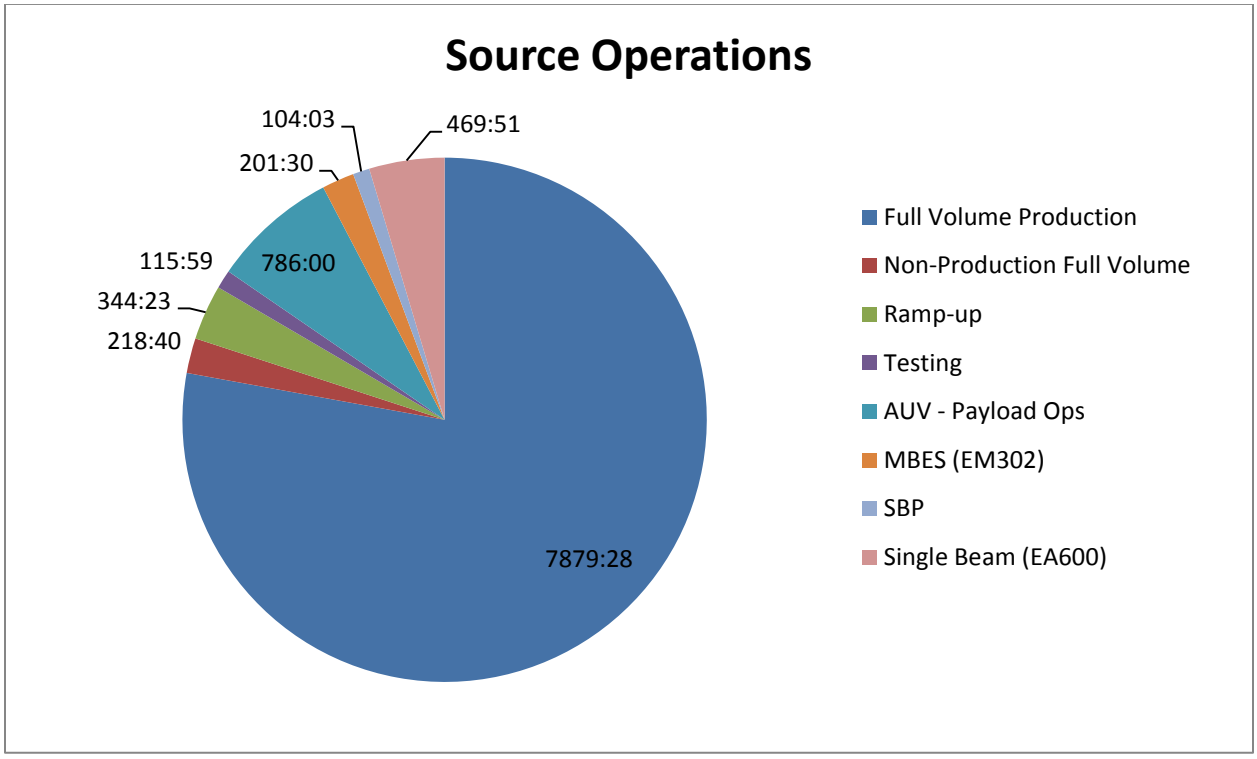


Figure 6: Breakdown of acoustic source operations

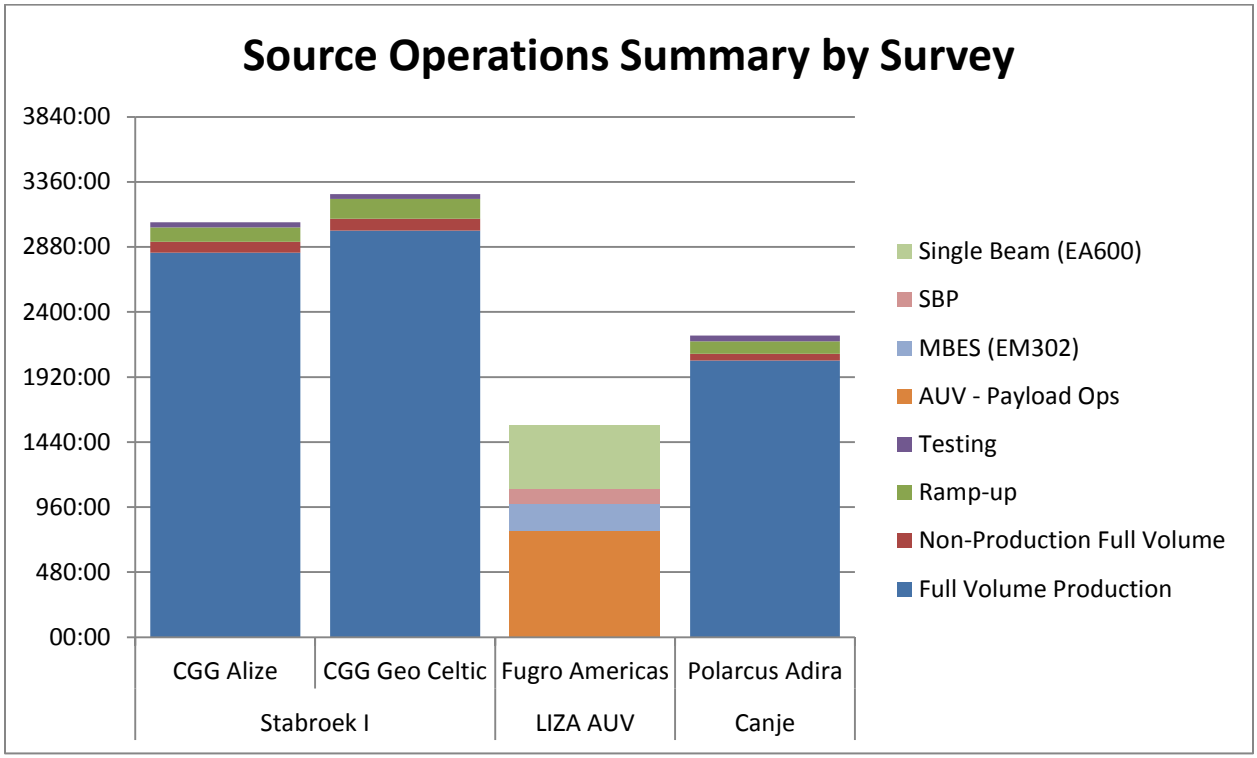


Figure 7: Breakdown of source operations by source activity and survey

4.2 Visual Monitoring Summary

PSOs conducted visual observations throughout these surveys for a total of 8187 hours and 37 minutes. Visual observations while the source was active accounted for 4504 hours and 24 minutes, observations during periods of source inactivity accounted for 2663 hours and 48 minutes, and observations during the AUV survey accounted for 1019 hours and 25 minutes (Figure 8).

4.3 Acoustic Monitoring Summary

Passive acoustic monitoring (PAM) was conducted for a total of 5135 hours and 55 minutes throughout the Stabroek 3D and Canje 3D Surveys, which included 3282 hours and 24 minutes of acoustic observations while the source was active and 1853 hours and 31 minutes while the source was inactive (Figure 8).

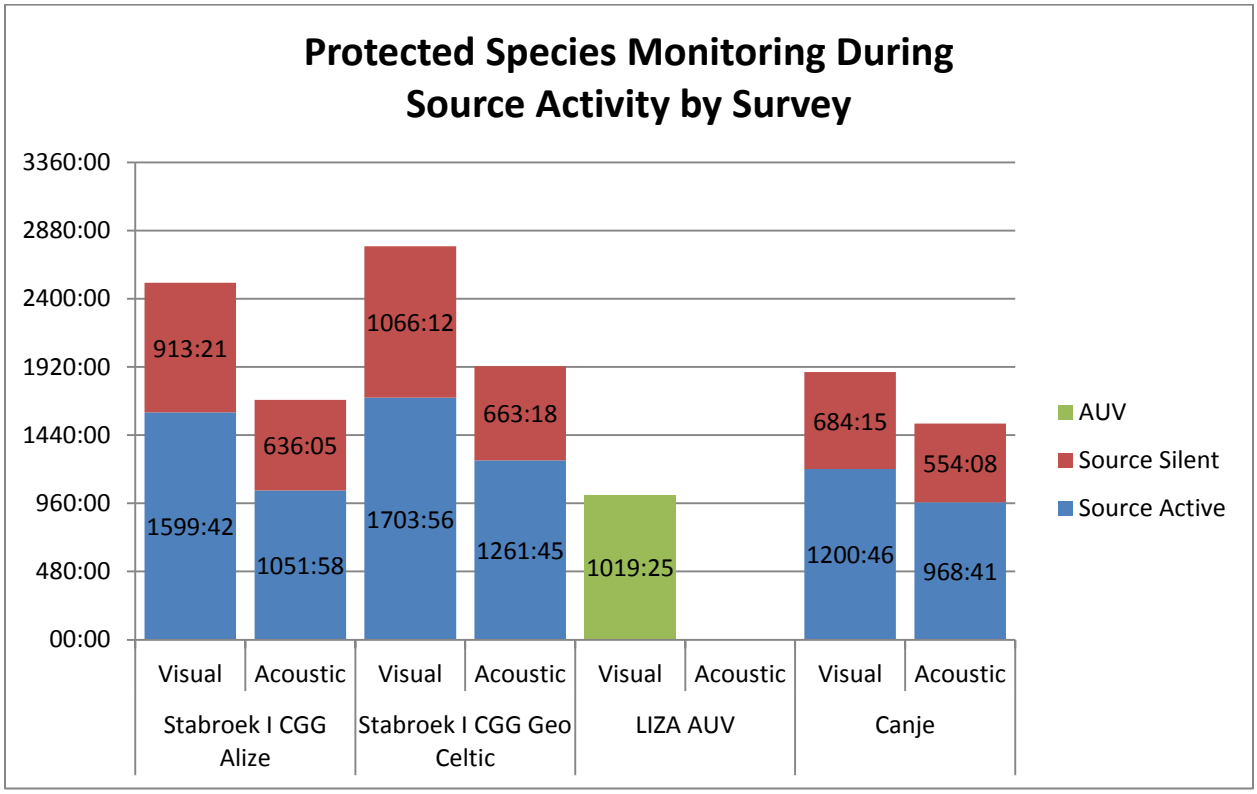


Figure 8: Breakdown of visual and acoustic monitoring while source active and silent by survey

4.4 Mitigation Actions

The *Joint Nature Conservation Committee (JNCC) guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys* were implemented during each of the survey programs summarized in this report. As such, delays to initiation of the sound source, airguns or otherwise, were implemented if marine mammals or sea turtles were detected inside the 500 meter exclusion zone around the center of the sound source in the search period conducted prior to initiating the source from silence.

There were a total of nine mitigation actions implemented throughout this survey due to marine mammals detected within the exclusion zone prior to source operations, all occurred aboard the *CGG Alize* during the Stabroek 3D Survey and were delays to soft-start implemented for protected species detected inside the mitigation zone prior to commencement of soft-start. Eight of the nine delays were implemented for delphinids and one delay was implemented for sperm whales (Table 3). All mitigation actions were implemented as a result of acoustic detections where one acoustic detection was also accompanied by a visual sighting of the animals.

Table 3: Summary of mitigation actions by visual and acoustic observers.

	Total Number	Duration
Total number of delays to ramp-up for acoustic detections of dolphins	08*	19:54
Total number of delays to ramp-up for acoustic detections of whales	01	00:16
Total delays to ramp-up for acoustic detections	09	20:10
Total number of delays to ramp-up for visual detections of dolphins	01	
Total number of delays to ramp-up for visual detections of whales	00	00:00
Total delays to ramp-up for visual detections	**01***	**00:09***
Total delays to ramp-up for dolphins	**08**	**19:54**
Total delays to ramp-up for whales	**01**	**00:16**
Total delays to ramp-up up	**09**	**20:10**

*One delay was implemented as a result of a correlated visual and acoustic detection

4.5 Wildlife Summary

4.5.1 Overview

There were a total of 417 protected species detections made both visually and acoustically throughout all of the survey programs: 153 visual detections, 264 acoustic detections, and three detections that were made both visually and acoustically. The visual detections included whales, dolphins and sea turtles while acoustic detections consisted of whales and dolphins (Table 4, Figure 9).

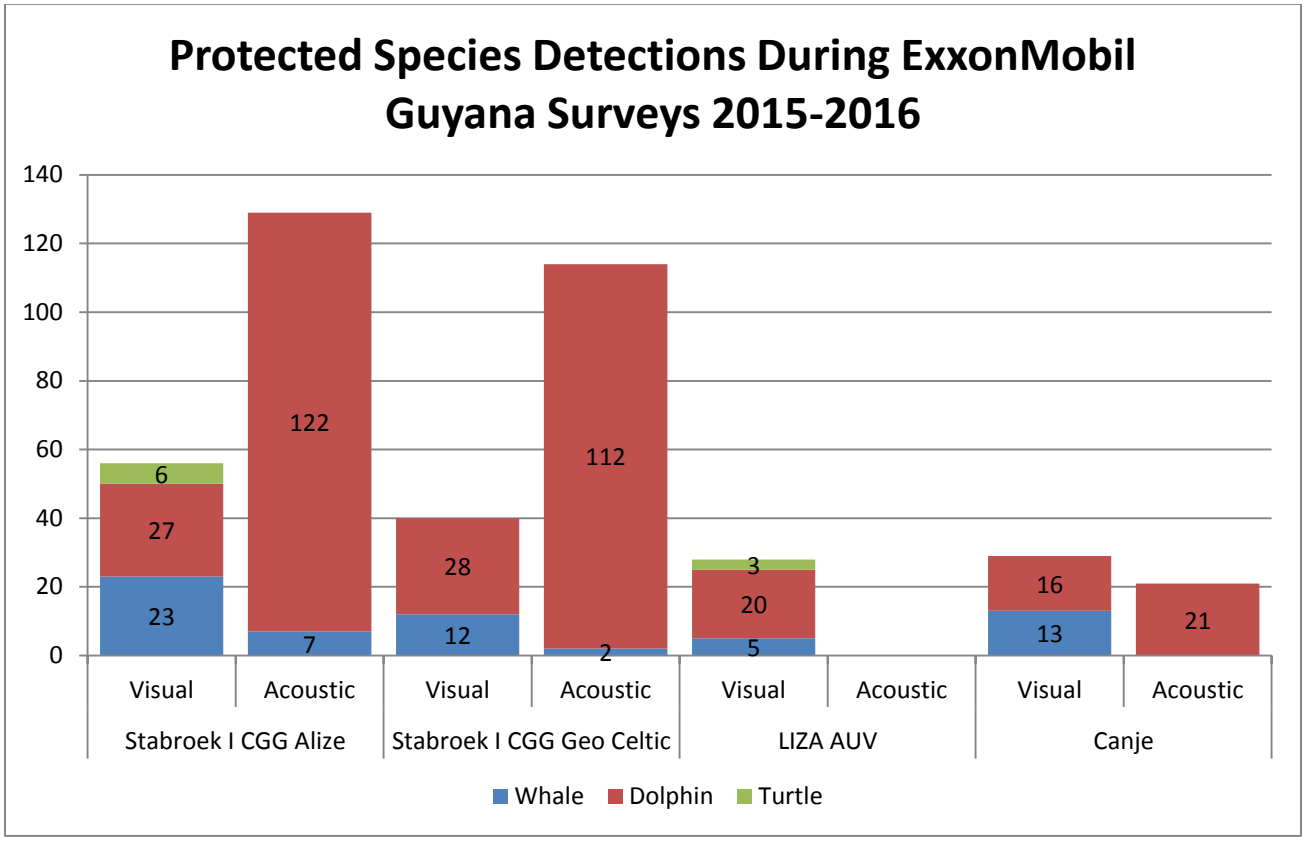


Figure 9: Protected species detections by species group on each of the ExxonMobil Guyana survey programs

A total of 12 different identified species were observed over the course of all of the programs, two species of whales, seven species of delphinid and three species of sea turtles (Figure 10).

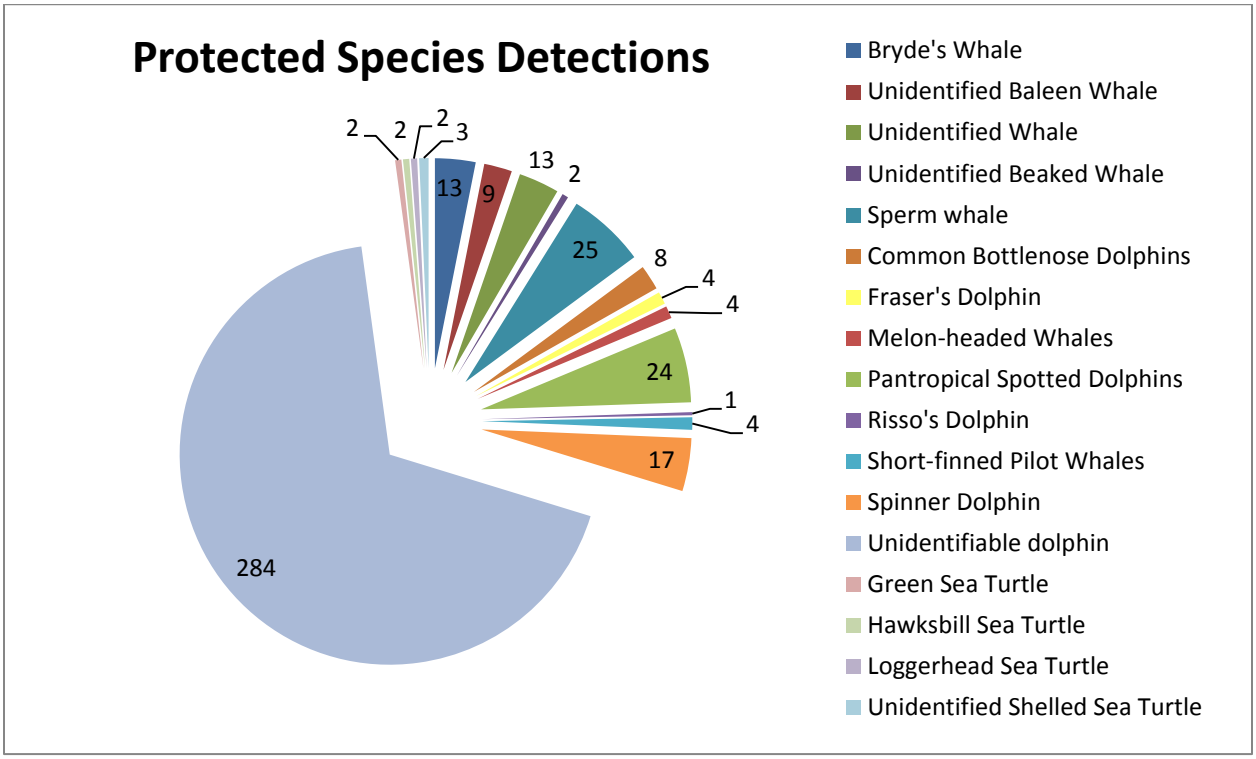


Figure 10: Protected species detections (visual and acoustic) shown as a breakdown by species over all ExxonMobil Guyana programs during 2015 and 2016

Of the 417 total protected species detections made during all programs, 260 occurred while the acoustic source was active. Of the 260 detections during source activity, eight occurred during soft starts, nine occurred during reduced power source testing, three occurred during full volume non-production firing and 240 occurred during full volume production. The remaining 157 protected species detections occurred while the acoustic source was silent (Figure 11).

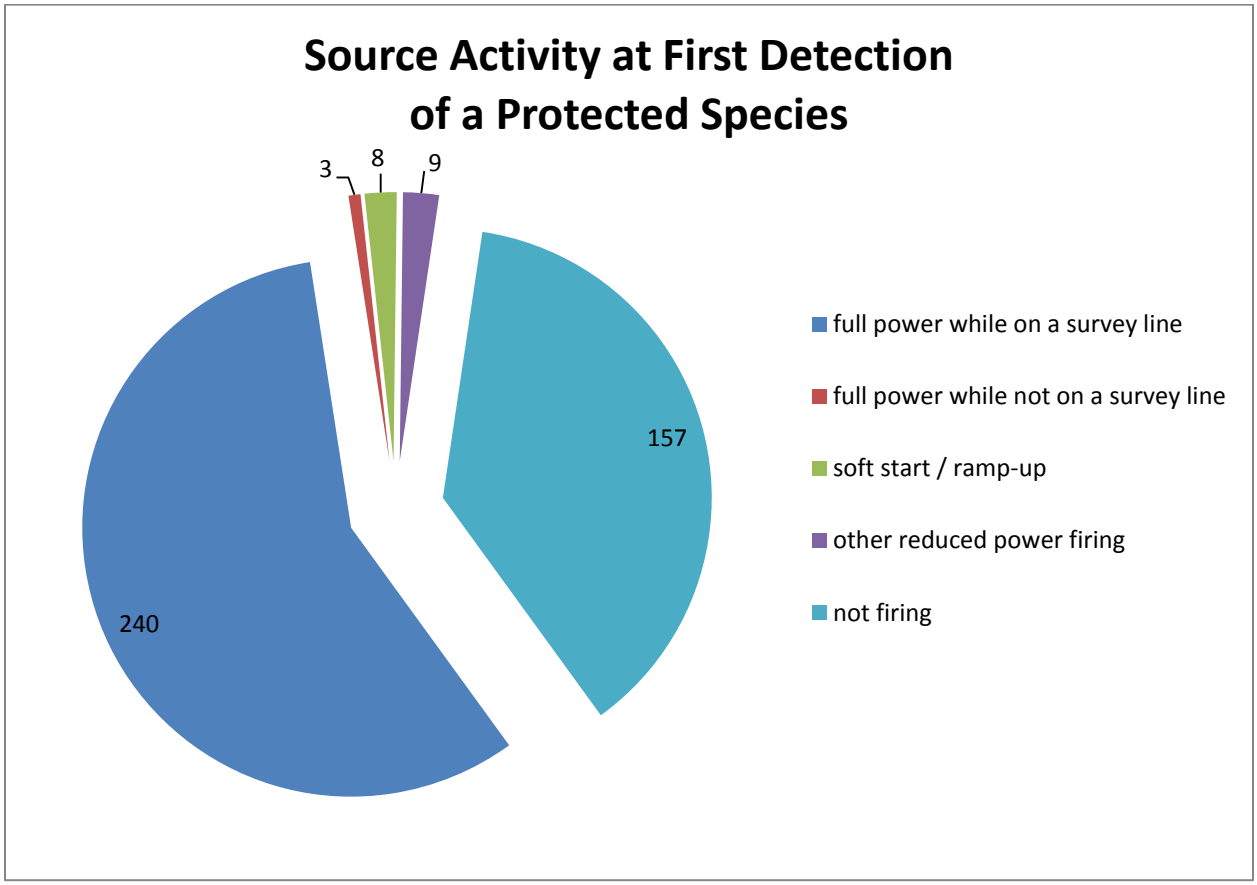


Figure 11: Seismic source activity at the initial detection of a marine mammal or sea turtle

4.5.2 Visual Detections

Protected species were visually detected on 153 occasions during the surveys included in this summary. Delphinids were detected more frequently than any other species group, with seven species identified in 346 separate detection events. Two whale species were identified, Bryde's whales and sperm whales and additional sightings were made of unidentified beaked whales, unidentified baleen whales and unidentified whales. A total of 53 whale detections were made during all of the programs. Three sea turtle species were observed in additional to sightings of unidentified shelled turtles and a total of nine sea turtles were detected (Figure 12, Table 4).

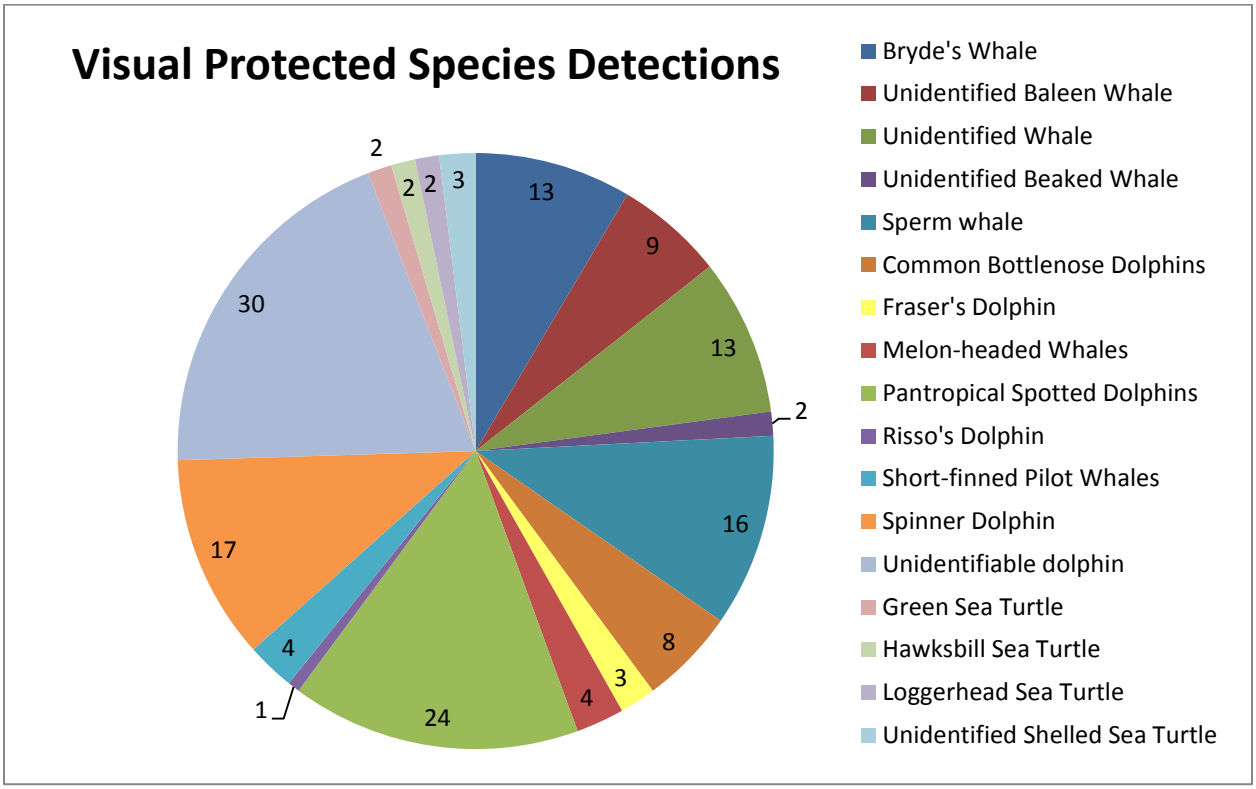


Figure 12: Visual protected species detections shown as a breakdown by species over all ExxonMobil Guyana programs during 2015 and 2016

4.5.3 Acoustic Detections

Marine mammals were acoustically detected on 264 occasions throughout this survey where unidentified delphinids were by far the most frequently detected species with 254 detections. Sperm whales were detected on nine occasions and Fraser's dolphins were detected as part of a correlated visual sighting of the pod (Figure 13, Table 4).

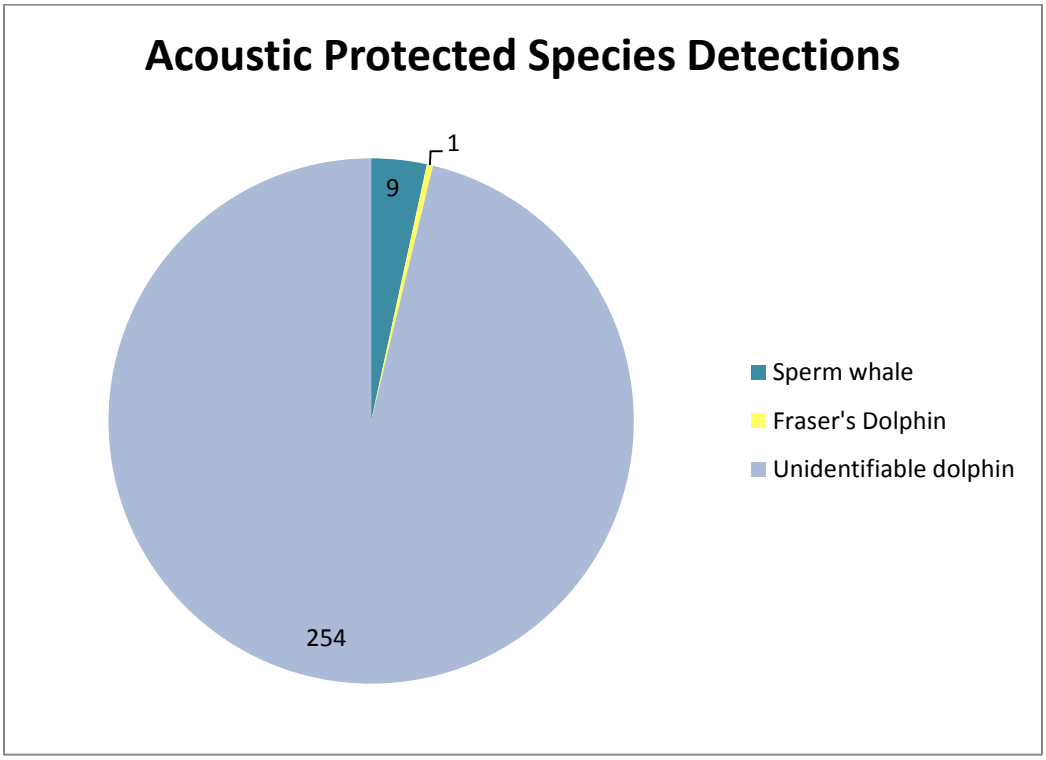


Figure 13: Acoustic protected species detections shown as a breakdown by species over all ExxonMobil Guyana programs during 2015 and 2016

Figure 14 shows the distribution of visual protected species detections, while Figure 15 depicts acoustic protected species detections—both maps include the three correlated visual and acoustic detections.

Table 4: Protected species visual and acoustic detection summary during the Stabroek survey program

	Stabroek I *CGG Alize*		Stabroek I *CGG Geo Celtic*		LIZA AUV		Canje		Total Number of Detection Events
	Visual	Acoustic	Visual	Acoustic	Visual	Acoustic	Visual	Acoustic	
Bryde's Whale	3		5		2		3		13
Unidentified Baleen Whale	5		1		1		2		9
Unidentified Whale	11						2		13
Unidentified Beaked Whale							2		2
Sperm whale	4	7	6	2	2		4		25
Total number of whale detections	**23**	**7**	**12**	**2**	**5**	**0**	**13**	**0**	**62**
Common Bottlenose Dolphins					8				8
Fraser's Dolphin	1*	1*					2		4
Melon-headed Whales			2		1		1		4
Pantropical Spotted Dolphins	6		6		7		5		24
Risso's Dolphin			1						1
Short-finned Pilot Whales	2				2				4
Spinner Dolphin	5		9				3		17
Unidentifiable dolphin	13	121**	10	112	2		5	21	284
Total number of dolphin detections	**27**	**122**	**28**	**112**	**20**	**0**	**16**	**21**	**346**
Total number of marine mammal detections	**50**	**129**	**40**	**114**	**25**	**0**	**29**	**21**	**408**
Green Sea Turtle	1				1				2
Hawksbill Sea Turtle					2				2
Loggerhead Sea Turtle	2								2
Unidentified Shelled Sea Turtle	3								3
Total number of sea turtle detections	**6**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**9**

*Correlated with a visual detection

**Two detections correlated with visual detections

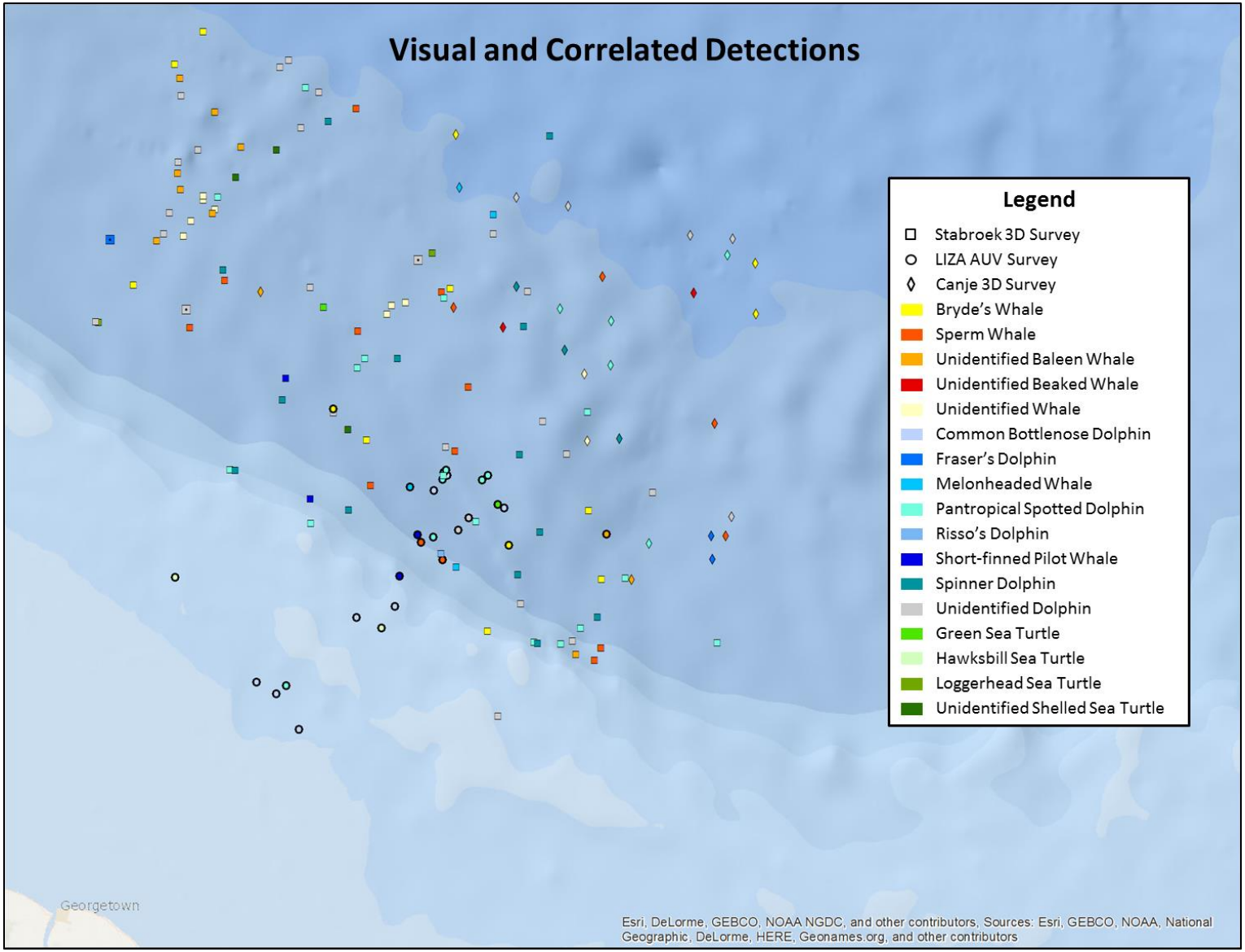


Figure 14: Distribution of visual protected species detections during ExxonMobil Guyana Stabroek 3D, LIZA AUV, and Canje 3D programs

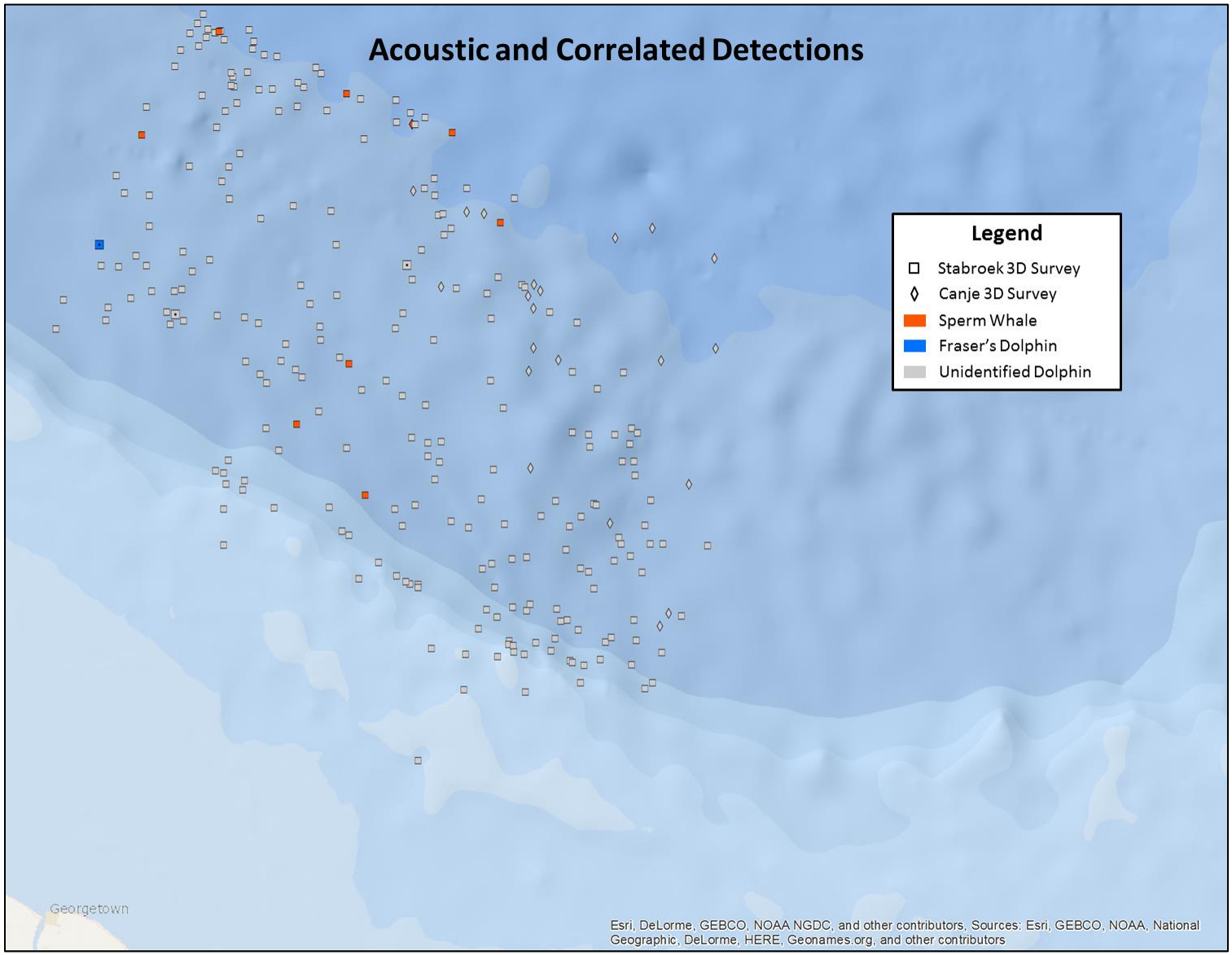


Figure 15: Distribution of acoustic protected species detections during ExxonMobil Guyana Stabroek 3D and Canje 3D programs

In addition to data collected during marine mammal and sea turtle detections, PSOs also recorded observations for other wildlife observed during monitoring watches. Additional wildlife observed throughout this survey included 59 avian species, 10 of which were unidentifiable, 31 fish species, seven of which were unidentifiable, three marine invertebrate species, and five other wildlife species.

The most frequently observed avian species was the masked booby (*Sula dactylatra*, 36.6%) which had 1016 individuals recorded over a period of 385 days. Other frequently observed avian species, each with at least 100 individuals recorded throughout the surveys, included unidentified birds (18.6%), Cory's shearwater (*Calonectris diomedea*, 8%), magnificent frigatebird (*Fregata magnificens*, 4.9%), white-tailed tropic bird (*Phaethon lepturus*, 4.9%), great shearwater (*Puffinus gravis*, 4.6%), bank swallow (*Riparia riparia*, 4.6%), and brown booby (*Sula leucogaster*, 4.3%) (Figure 16, Table 5).

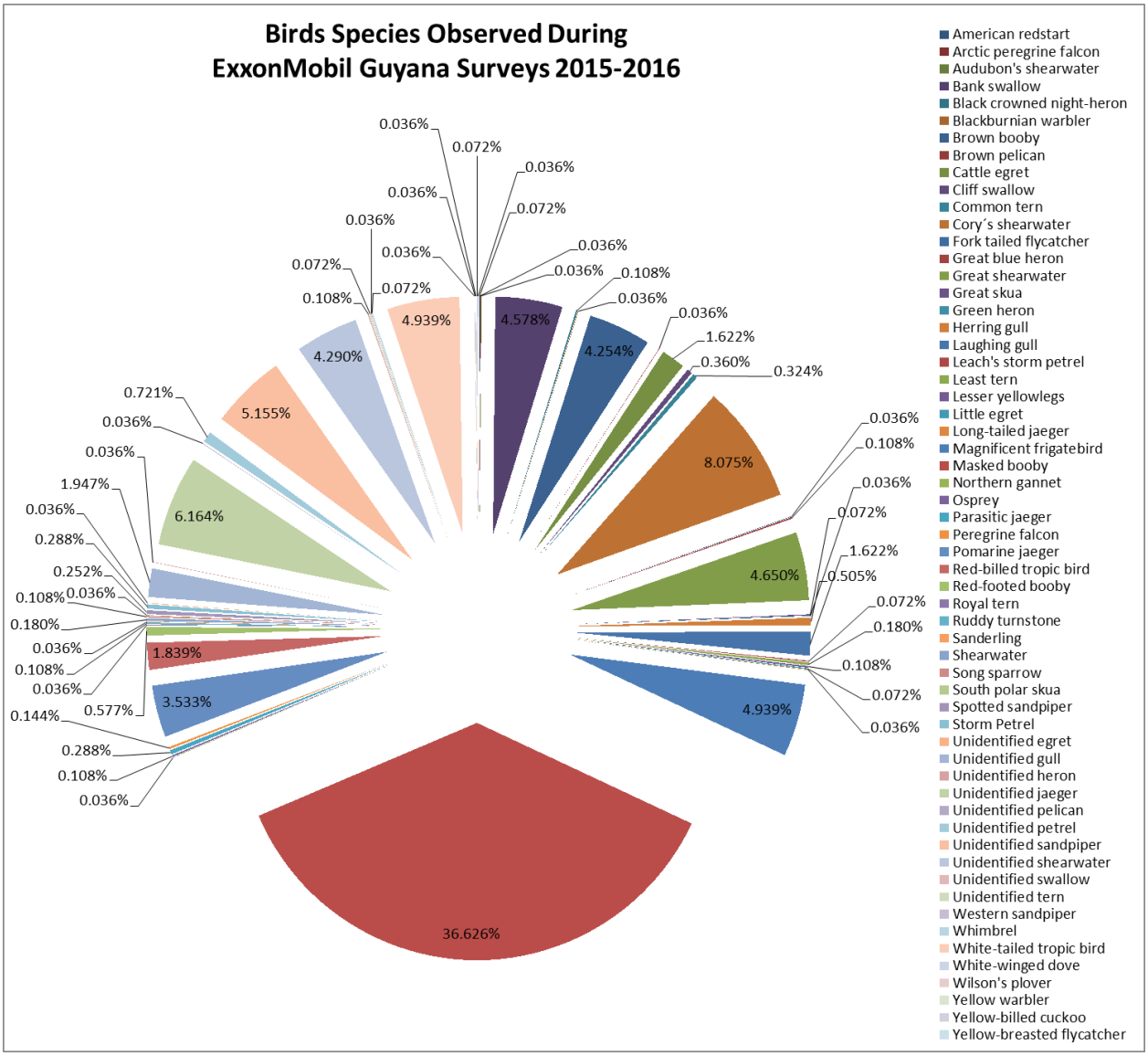


Figure 16: Bird species observed during Stabroek 3D Survey, LIZA AUV Survey, and Canje 3D Survey

The most commonly observed fish species was the unidentified flying fish (Family Exocoetidae, 97%) which had 88281 individuals recorded over a period of 589 days throughout the surveys. Other notable fish species observed, each with more than 100 individuals recorded throughout the surveys, included unidentified fish (1.02%), including a large number of unidentified tuna species (0.47%), skip jack tuna (*Katsuwonus pelamis*, 0.78%), Atlantic tripletail (*Lobotes surinamensis*, 0.26%), mahi mahi (*Coryphaena hipparus*, 0.26%), clearwing flying fish (*Cypselurus comatus*, 0.14%), Atlantic bonito tuna (*Sarda sarda*, 0.13%), yellow fin tuna (*Thunnus albacares*, 0.13%), and Atlantic flying fish (*Cheliopogon melanurus*, 0.13%) (Figure 17, Table 6).

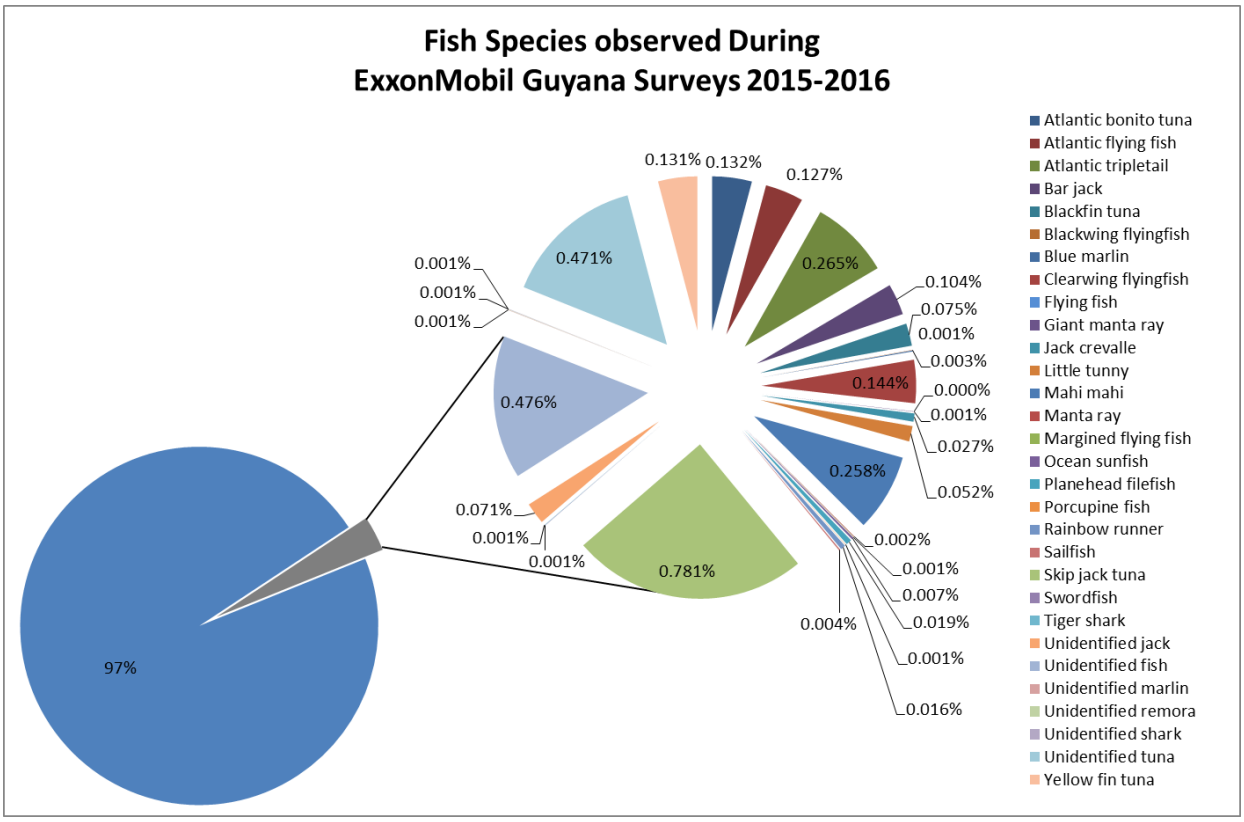


Figure 17: Fish species observed during Stabroek 3D Survey, LIZA AUV Survey, and Canje 3D Survey

Marine invertebrate species observed throughout the surveys, in order of frequency of observation, were the Portuguese man o' war (*Physalia physalis*), unidentified salps (Family Salpidae), and an unidentified jellyfish (Table 7).

Other wildlife species observed throughout the surveys included, in order of observation frequency, houseflies (*Musca domestica*), dragon flies (Order Odonata), butterflies (Order Lepidoptera), green-banded Urania (*Urania leilus*), and moths (Order Lepidoptera) (Table 8).

4.5.4 Wildlife Summary Tables

Table 5: Birds observed during visual monitoring

Common Name	Class	Order	Family	Genus	Species	Number of Individuals Observed	Number of Days Observed
American redstart	Aves	Passeriformes	Parulidae	*Steophaga*	*ruticilla*	2	2
Arctic peregrine falcon	Aves	Falconiformes	Falconidae	*Falco*	*peregrinus tundrius*	1	1
Audubon's shearwater	Aves	Procellariformes	Procellariidae	*Puffinus*	*lherminieri*	1	1
Bank swallow	Aves	Passeriformes	Hirundinidae	*Riparia*	*riparia*	127	59
Black crowned night-heron	Aves	Ciconiiformes	Ardeidae	*Nycticorax*	*nycticorax*	3	2
Blackburnian warbler	Aves	Passeriformes	Parulidae	*Setophaga*	*fusca*	1	1
Brown booby	Aves	Pelecaniformes	Sulidae	*Sula*	*leucogaster*	118	92
Brown pelican	Aves	Pelecaniformes	Pelecanidae	*Pelecanus*	*occidentalis*	1	1
Cattle egret	Aves	Ciconiiformes	Ardeidae	*Bubulcus*	*ibis*	45	25
Cliff swallow	Aves	Passeriformes	Hirundinidae	*Petrochelidon*	*pyrrhonota*	10	6
Common tern	Aves	Charadriformes	Sternidae	*Sterna*	*hirundo*	9	8
Cory´s shearwater	Aves	Procellariiformes	Procellariidae	*Calonectris*	*diomedea*	224	45
Fork tailed flycatcher	Aves	Passeriformes	Tyrannidae	*Tyrannus*	*savana*	1	1
Great blue heron	Aves	Ciconiiformes	Ardeidae	*Ardea*	*herodias*	3	2
Great shearwater	Aves	Procellariiformes	Procellariidae	*Puffinus*	*gravis*	129	30
Great skua	Aves	Charadriiformes	Stercorariidae	*Stercorarius*	*skua*	2	2
Green heron	Aves	Ciconiiformes	Rallidae	*Butorides*	*virescens*	1	1
Herring gull	Aves	Charadriiformes	Laridae	*Larus*	*argentatus*	14	6
Laughing gull	Aves	Charadriiformes	Laridae	*Larus*	*atricilla*	45	18
Leach's storm petrel	Aves	Procellariiformes	Hydrobatidae	*Oceanodroma*	*leucorhoa*	2	2
Least tern	Aves	Charadriiformes	Sternidae	*Sternula*	*antillarum*	5	3
Lesser yellowlegs	Aves	Charadriiformes	Scolopacidae	*Tringa*	*flavipes*	3	3
Little egret	Aves	Ciconiiformes	Ardeidae	*Egretta*	*garzetta*	2	2
Long-tailed jaeger	Aves	Charadriiformes	Stercorariidae	*Stercoarius*	*longicaudus*	1	1
Magnificent frigatebird	Aves	Suliformes	Fregatidae	*Fregata*	*magnificens*	137	69
Masked booby	Aves	Suliformes	Sulidae	*Sula*	*dactylatra*	1016	385
Northern gannet	Aves	Pelecaniformes	Sulidae	*Morus*	*bassanus*	1	1
Osprey	Aves	Falconiformes	Pandionidae	*Pandion*	*haliaetus*	3	3
Parasitic jaeger	Aves	Charadriiformes	Stercorariidae	*Stercorarius*	*parasiticus*	8	2
Peregrine falcon	Aves	Falconiformes	Falconidae	*Falco*	*peregrinus*	4	4
Pomarine jaeger	Aves	Charadriiformes	Stercorariidae	*Stercorarius*	*pomarinus*	98	34
Red-billed tropic bird	Aves	Pelecaniformes	Phaethontidae	*Phaethon*	*aethereus*	51	26
Red-footed booby	Aves	Suliformes	Sulidae	*Sula*	*sula*	16	12

Common Name	Class	Order	Family	Genus	Species	Number of Individuals Observed	Number of Days Observed
Royal tern	Aves	Charadriiformes	Laridae	*Sterna*	*maxima*	1	1
Ruddy turnstone	Aves	Charadriiformes	Scolopacidae	*Arenaria*	*interpres*	3	2
Sanderling	Aves	Charadriiformes	Scolopacidae	*Calidris*	*alba*	1	1
Shearwater	Aves	Procellariiformes	Procellariidae	*NA*	*NA*	5	4
Song sparrow	Aves	Passeriformes	Emberizidea	*Melospiza*	*melodia*	3	2
South polar skua	Aves	Charadriiformes	Stercorariidae	*Stercorarius*	*maccormicki*	1	1
Spotted sandpiper	Aves	Charadriiformes	Scolopacidae	*Actitis*	*macularius*	7	7
Storm Petrel	Aves	Procellariiformes	Hydrobatidae	*NA*	*NA*	8	7
Unidentified egret	Aves	Ciconiiformes	Ardeidae	*n/a*	*n/a*	1	1
Unidentified gull	Aves	Charadriformes	Laridae	*n/a*	*n/a*	54	27
Unidentified heron	Aves	Ciconiiformes	Ardeidae	*n/a*	*n/a*	1	1
Unidentified jaeger	Aves	Charadriformes	Stercorariidae	*n/a*	*n/a*	171	23
Unidentified pelican	Aves	Pelecaniformes	Pelecanidae	*n/a*	*n/a*	1	1
Unidentified petrel	Aves	Procellariformes	n/a	*n/a*	*n/a*	20	11
Unidentified sandpiper	Aves	Charadriformes	Scolopacidae	*n/a*	*n/a*	143	29
Unidentified shearwater	Aves	Procellariformes	Procellariidae	*n/a*	*n/a*	119	21
Unidentified swallow	Aves	Passeriformes	Hirundinidae	*n/a*	*n/a*	3	3
Unidentified tern	Aves	Charadriformes	Sternidae	*n/a*	*n/a*	2	2
Western sandpiper	Aves	Charadriiformes	Scolopacidae	*Calidris*	*mauri*	1	1
Whimbrel	Aves	Charadriiformes	Scolopacidae	*Numenius*	*phaeopus*	2	1
White-tailed tropic bird	Aves	Phaethontiformes	Phaethontidae	*Phaethon*	*lepturus*	137	58
White-winged dove	Aves	Columbiformes	Columbidae	*Zenaida*	*asiatica*	1	1
Wilson's plover	Aves	Charadriiformes	Charadriidae	*Charadriaus*	*wilsonia*	1	1
Yellow warbler	Aves	Passeriformes	Parulidae	*Dendroica*	*petechia*	1	1
Yellow-billed cuckoo	Aves	Cuculiformes	Cuculidae	*Cuccyzus*	*americanus*	2	2
Yellow-breasted flycatcher	Aves	Passeriformes	Tyrannidae	*Tolmomyias*	*flaviventris*	1	1

Table 6: Fish species observed during visual monitoring

Common Name	Class	Order	Family	Genus	Species	Number of Individuals Observed	Number of Days Observed
Atlantic bonito tuna	Actinopterygii	Perciformes	Scrombidae	*Sarda*	*sarda*	120	1
Atlantic flying fish	Actinopterygii	Beloniformes	Exocoetidae	*Cheilopogon*	*melanurus*	116	1
Atlantic tripletail	Actinopterygii	Perciformes	Lobotidae	*Lobotes*	*surinamensis*	242	46
Bar jack	Actinopterygii	Perciformes	Carangidae	*Caranx*	*ruber*	95	4
Blackfin tuna	Actinopterygii	Perciformes	Scombridae	*Thunnus*	*atlanticus*	68	3
Blackwing flyingfish	Actinopterygii	Beloniformes	Exocoetidae	*Hirundichthys*	*rondeletii*	1	1
Blue marlin	Actinopterygii	Perciformes	Istiophoridae	*Makaira*	*nigricans*	3	3
Clearwing flyingfish	Actinopterygii	Beloniformes	Exocoetidae	*Cypselurus*	*comatus*	131	2
Flying fish	Actinopterygii	Beloniformes	Exocoetidae	*n/a*	*n/a*	88281	589
Giant manta ray	Chondrichthyes	Myliobatiformes	Myliobatidae	*Manta*	*birostris*	1	1
Jack crevalle	Actinopterygii	Perciformes	Carangidae	*Caranx*	*hippos*	25	1
Little tunny	Actinopterygii	Perciformes	Scombridae	*Euthynnus*	*alleteratus*	47	2
Mahi mahi	Actinopterygii	Perciformes	Coryphaenidae	*Coryphaena*	*hippurus*	235	52
Manta ray	Chondrichthyes	Myliobatiformes	Myliobatidae	*Manta*	*n/a*	2	2
Margined flying fish	Actinopterygii	Beloniformes	Exocoetidae	*Cheilopogon*	*cyanopterus*	1	1
Ocean sunfish	Actinopterygii	Tetraodontiformes	Molidae	*Mola*	*mola*	6	2
Planehead filefish	Actinopterygii	Tetraodontiformes	Monacanthidae	*Stephanolepis*	*hispidus*	17	5
Porcupine fish	Actinopterygii	Tetraodontiformes	Diodontidae	*Diodon*	*hystrix*	1	1
Rainbow runner	Actinopterygii	Perciformes	Carangidae	*Elagatis*	*bipinnulata*	15	1
Sailfish	Actinopterygii	Perciformes	Istiophoridae	*Istiophorus*	*platypterus*	4	3
Skip jack tuna	Actinopterygii	Perciformes	Scrombidae	*Katsuwonus*	*pelamis*	712	33
Swordfish	Actinopterygii	Perciformes	Xiphiidae	*Xiphias*	*gladius*	1	1
Tiger shark	Chondrichthyes	Carcharhiniformes	Carcharhinidae	*Galeocerdo*	*cuvier*	1	1
Unidentified jack	Actinopterygii	Perciformes	Carangidae	*NA*	*NA*	65	4
Unidentified fish	Actinopterygii	n/a	n/a	*n/a*	*n/a*	434	57
Unidentified marlin	Actinopterygii	Perciformes	Istiophoridae	*n/a*	*n/a*	1	1
Unidentified remora	Actinopterygii	Actinopterygii	Perciformes	*n/a*	*n/a*	1	1
Unidentified shark	Chondrichthyes	n/a	n/a	*n/a*	*n/a*	1	1
Unidentified tuna	Actinopterygii	Perciformes	Scombridae	*n/a*	*n/a*	429	23
Yellow fin tuna	Actinopterygii	Perciformes	Scombridae	*Thunnus*	*albacares*	119	8

Table 7: Marine invertebrates observed during visual monitoring

Common Name	Class	Order	Family	Genus	Species	Number of Individuals Observed	Number of Days Observed
Portuguese Man O'War	Hydrozoa	Siphonophora	Physaliidae	*Physalia*	*physalis*	53	30
Salp	Thaliacea	Salpida	Salpidae	*n/a*	*n/a*	2	2
Unidentified jellyfish	n/a	n/a	n/a	*n/a*	*n/a*	1	1

Table 8: Other wildlife observed during visual monitoring

Common Name	Class	Order	Family	Genus	Species	Number of Individuals Observed	Number of Days Observed
Butterly	Insecta	Lepidoptera	n/a	*n/a*	*n/a*	3	2
Dragon fly	Insecta	Odonata	NA	*NA*	*NA*	30	9
Green-banded Urania	Insecta	Lepidoptera	Uraniidae	*Urania*	*leilus*	1	1
Housefly	Insecta	Diptera	Muscidae	*Musca*	*domestica*	35	1
Moth	Insecta	Lepidoptera	n/a	*n/a*	*n/a*	1	1

5 Protected Species Summary Table

Table 9: Protected species detected visually and acoustically during the Stabroek 3D Survey, LIZA AUV Survey, and Canje 3D Survey

Date	Visual Det. #	Acoustic Det. #	Time at Initial Det.	Time at Last Det.	Common Name	Detection Method	Latitude	Longitude	Water Depth (m)	No. of Animals	Range when First Detected	Source Activity at First Det.	Source Activity at Last Det.	Closest distance to source (m)	Mitigation Actions	Total Duration Animals Observed inside EZ	Total Duration of Production Loss
Stabroek 3D CGG Alize																	
18-Jul-2015		1001	1:30	1:48	Unidentifiable dolphin	acoustically	07.90733	-057.64238	65	1	1000	not firing	not firing		none	0:00	0:00
18-Jul-2015		1002	3:05	5:30	Unidentifiable dolphin	acoustically	08.01395	-057.64163	93	1	700	not firing	not firing		none	0:00	
26-Jul-2015		1003	4:13	4:34	Unidentifiable dolphin	acoustically	09.22342	-057.23768	2974	5	1000	not firing	not firing	500	none	0:15	0:00
26-Jul-2015		1004	4:50	5:50	Sperm whale	acoustically	09.23773	-057.27802	2965	3	800	not firing	not firing	600	none	0:00	0:00
01-Aug-2015		1005	22:11	22:39	Unidentifiable dolphin	acoustically	09.10558	-057.22688	2931	3	1000	full power while on survey line	not firing	1000	none	0:00	
02-Aug-2015		1006	5:22	7:03	Unidentifiable dolphin	acoustically	08.90803	-057.43658	2593	3	1000	full power while on survey line	full power while on survey line	500	none	1:26	0:00
06-Aug-2015	1		10:42	10:43	Unidentifiable whale	visually	09.17818	-057.28305	2904	1	1000	not firing	not firing	1450	none	0:00	
06-Aug-2015	2		10:46	10:48	Sperm whale	visually	09.17818	-057.28305	2904	3	700	not firing	not firing	850	none	0:00	
07-Aug-2015		1007	23:17	0:17	Unidentifiable dolphin	acoustically	08.57878	-057.58092	2136	5	1000	full power while on survey line	not firing	500	none	0:47	0:00
09-Aug-2015		1008	8:52	9:20	Unidentifiable dolphin	acoustically	08.86990	-057.53170	2527	1	1000	full power while on survey line	full power while on survey line	1000	none	0:00	0:00
12-Aug-2015	3		13:33	13:48	Spinner dolphin	visually	09.14000	-057.36667	2869	17	150	full power while on survey line	full power while on survey line	460	none	0:13	0:00
13-Aug-2015		1009	6:04	6:08	Unidentifiable dolphin	acoustically	08.58455	-057.66033	2002	3	500	not firing	not firing	400	delayed start of firing	0:04	0:11
16-Aug-2015		1010	22:05	22:15	Unidentifiable dolphin	acoustically	09.18830	-057.33705	2992	3	500	not firing	not firing	500	none	0:10	0:00
19-Aug-2015		1011	9:30	9:33	Unidentifiable dolphin	acoustically	08.56165	-057.53953	2132	1	500	full power while on survey line	full power while on survey line	500	none	0:03	0:00
20-Aug-2015		1012	0:28	1:21	Unidentifiable dolphin	acoustically	09.29868	-057.35438	2753	4	500	not firing	not firing	500	none	0:21	0:00
21-Aug-2015		1013	1:17	1:50	Unidentifiable dolphin	acoustically	09.31478	-057.36933	2951	2	500	not firing	not firing	500	none	0:33	0:00
22-Aug-2015	4		14:51	15:05	Sperm whale	visually	08.53500	-057.77400	1858	4	700	not firing	not firing	700	none	0:00	0:00
23-Aug-2015		1014	0:26	0:28	Unidentifiable dolphin	acoustically	09.18782	-057.47913	2789	1	500	full power while on survey line	full power while on survey line	500	none	0:02	0:00

Date	Visual Det. #	Acoustic Det. #	Time at Initial Det.	Time at Last Det.	Common Name	Detection Method	Latitude	Longitude	Water Depth (m)	No. of Animals	Range when First Detected	Source Activity at First Det.	Source Activity at Last Det.	Closest distance to source (m)	Mitigation Actions	Total Duration Animals Observed inside EZ	Total Duration of Production Loss
24-Aug-2015	5		12:23	12:25	Sperm whale	visually	08.67267	-057.67067	2195	4	30	full power while on survey line	full power while on survey line	120	none	0:02	0:00
25-Aug-2015	6	1015	20:26	21:28	Unidentifiable dolphin	visually and acoustically	08.58800	-057.78500	1966	50	1000	not firing	not firing	500	delayed start of firing	0:31	0:09
28-Aug-2015		1016	2:11	2:12	Unidentifiable dolphin	acoustically	08.89212	-057.32488	2740	1	500	full power while on survey line	full power while on survey line	500	none	0:01	0:00
28-Aug-2015	7		19:44	19:56	Short-finned pilot whale	visually	08.38517	-057.49167	1750	10	300	not firing	not firing	600	none	0:00	
02-Sep-2015		1017	7:50	9:40	Unidentifiable dolphin	acoustically	08.45103	-057.47260	1931	4	500	not firing	not firing	500	None	1:50	0:00
05-Sep-2015		1018	6:00	6:39	Unidentifiable dolphin	acoustically	09.21905	-057.13223	2503	7	1342	not firing	not firing	500	None	0:13	0:00
05-Sep-2015	8		14:23	14:24	Unidentifiable dolphin	visually	08.65183	-057.41883	2441	3	300	full power while on survey line	full power while on survey line	700	None	0:00	
05-Sep-2015	9		20:09	20:56	Spinner dolphin	visually	08.32167	-057.50083	1552	10	400	not firing	not firing	800	None	0:00	
05-Sep-2015		1019	21:51	0:10	Unidentifiable dolphin	acoustically	08.41005	-057.53445	1751	10	1320	not firing	not firing	333	Delayed start of firing	2:19	6:18
06-Sep-2015		1020	3:57	4:01	Unidentifiable dolphin	acoustically	08.44833	-057.57648	1848	1	500	not firing	not firing	500	None	0:04	0:00
06-Sep-2015		1021	7:45	8:29	Unidentifiable dolphin	acoustically	08.67262	-057.41407	2420	3	500	not firing	not firing	500	None	0:44	0:00
06-Sep-2015		1022	23:18	23:31	Unidentifiable dolphin	acoustically	08.79262	-057.31035	2740	1	500	not firing	not firing	500	None	0:13	0:00
07-Sep-2015		1023	3:45	4:03	Unidentifiable dolphin	acoustically	08.49943	-057.45878	2221	1	500	full power while on a survey line	full power while on a survey line	500	None	0:18	0:00
07-Sep-2015		1024	5:34		Unidentifiable dolphin	acoustically	08.38515	-057.51537	2200	2	500	full power while on a survey line	full power while on a survey line	500	None	0:33	0:00
07-Sep-2015	10		20:28	20:33	Spinner dolphin	visually	08.44320	-057.16280	2642	15	600	full power while on a survey line	full power while on a survey line	600	None	0:00	0:00
08-Sep-2015		1025	3:31	3:36	Unidentifiable dolphin	acoustically	09.18232	-057.09012	2882	1	500	not firing	not firing	500	None	0:05	0:00
08-Sep-2015		1026	4:15	4:25	Unidentifiable dolphin	acoustically	09.15390	-057.13107	2880	1	146	not firing	not firing	331	None	0:10	0:00
09-Sep-2015		1027	0:28	1:45	Unidentifiable dolphin	acoustically	08.25095	-057.51753	922	10	500	full power while on a survey line	full power while on a survey line	500	None	1:47	0:00
09-Sep-2015		1028	3:09	6:15	Unidentifiable dolphin	acoustically	08.42433	-057.42923	1914	10	500	full power while on a survey line	full power while on a survey line	500	None	3:06	0:00
10-Sep-2015		1029	0:44	1:15	Unidentifiable dolphin	acoustically	08.61807	-057.38715	2730	5	500	full power while on a survey line	full power while on a survey line	500	None	0:26	0:00

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10-Sep-2015		1030	8:47	9:10	Unidentifiable dolphin	acoustically	08.12568	-057.66637	850	8	407	not firing	not firing	407	None	0:23	0:00
11-Sep-2015	11		21:02	21:14	Pantropical spotted dolphin	visually	08.11667	-057.65633	4316	10	400	not firing	not firing	400	None	6:00	0:00
11-Sep-2015		1031	22:42	22:45	Unidentifiable dolphin	acoustically	08.09720	-057.57962	438	10	338	not firing	not firing	337	none	0:03	0:00
12-Sep-2015		1032	5:12	6:15	Unidentifiable dolphin	acoustically	08.55130	-057.35698	920	5	500	full power while on a survey line	full power while on a survey line	500	None	1:03	0:00
14-Sep-2015		1033	8:10	8:20	Unidentifiable dolphin	acoustically	09.16730	-057.04782	3024	4	359	not firing	not firing	359	None	0:10	0:00
16-Sep-2015		1034	23:50	23:59	Unidentifiable dolphin	acoustically	08.64438	-057.30863	2526	1	500	not firing	not firing	500	Delayed start of firing	0:09	0:20
17-Sep-2015	12		18:05	18:07	Green sea turtle	visually	08.59483	-057.37996	2354	1	50	full power while on a survey line	full power while on a survey line	421	None	0:02	0:00
18-Sep-2015		1035	2:34	2:45	Unidentifiable dolphin	acoustically	08.15653	-057.62753	605	4	500	not firing	not firing	500	None	0:11	0:00
18-Sep-2015		1036	4:06	4:08	Unidentifiable dolphin	acoustically	08.08700	-057.63545	122	2	500	not firing	not firing	500	None	0:02	0:00
19-Sep-2015		1037	22:50	23:09	Unidentifiable dolphin	acoustically	08.40208	-057.41120	1943	5	1000	full power while on a survey line	full power while on a survey line	500	None	0:01	0:00
20-Sep-2015		1038	0:25	1:02	Unidentifiable dolphin	acoustically	08.51187	-057.35605	2231	5	500	full power while on a survey line	full power while on a survey line	500	None	0:07	0:00
21-Sep-2015		1039	3:58	4:28	Unidentifiable dolphin	acoustically	08.12010	-057.64147	225	3	500	not firing	not firing	500	None	0:14	0:00
21-Sep-2015		1040	5:23	6:16	Unidentifiable dolphin	acoustically	08.06973	-057.58560	127	5	500	not firing	not firing	500	None	0:20	0:00
22-Sep-2015	13		16:53	17:04	Spinner dolphin	visually	08.11443	-057.63953	132	10	500	not firing	not firing	500	None	0:08	0:00
24-Sep-2015		1041	23:22	23:33	Sperm Whale	acoustically	09.14933	-057.08477	3028	1	1000	not firing	not firing	350	None	0:03	0:00
29-Sep-2015		1042	8:35	9:25	Unidentifiable dolphin	acoustically	09.14770	-057.07647	3032	3	1000	not firing	not firing	500	None	0:10	0:00
03-Oct-2015		1043	3:21	3:33	Unidentifiable dolphin	acoustically	08.98752	-057.01937	3002	3	1000	soft-start / ramp-up	full power while not on a survey line	750	None	0:00	
05-Oct-2015		1044	0:39	1:32	Unidentifiable dolphin	acoustically	08.30182	-057.36012	1735	2	1000	full power while on a survey line	full power while on a survey line	750	None	0:00	
05-Oct-2015		1045	8:30	8:45	Unidentifiable dolphin	acoustically	08.18663	-057.47893	1056	10	500	full power while on a survey line	full power while on a survey line	500	None	0:15	0:00
08-Oct-2015		1046	4:03	5:21	Unidentifiable dolphin	acoustically	08.01672	-057.49263	123	5	500	not firing	not firing	500	None	1:15	0:00

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09-Oct-2015	14		13:11	13:15	Unidentifiable dolphin	visually	08.28333	-057.35000	1738	20	2000	full power while on a survey line	full power while on a survey line	1400	None	0:00	
09-Oct-2015		1047	21:56	22:20	Sperm whale	acoustically	08.26367	-057.42602	1476	1	1369	full power while on a survey line	full power while on a survey line	1105	None	0:00	
10-Oct-2015		1048	23:15	23:52	Sperm whale	acoustically	08.44087	-057.27262	2169	2	600	full power while on a survey line	full power while on a survey line	300	None	0:25	0:00
12-Oct-2015		1049	4:45	5:05	Unidentifiable dolphin	acoustically	08.93798	-057.01742	2976	10	1000	full power while on a survey line	full power while on a survey line	500	None	0:12	0:00
12-Oct-2015	15		13:42	14:14	Pantropical spotted dolphin	visually	08.41557	-057.28070	2136	20	60	full power while on a survey line	full power while on a survey line	442	None	0:31	0:00
13-Oct-2015	16	1050	21:26	21:41	Unidentifiable dolphin	visually and acoustically	08.73333	-057.10000	2792	5	200	full power while on a survey line	full power while on a survey line	430	None	0:15	0:00
14-Oct-2015	17		18:52	19:04	Sperm whale	visually	08.52390	-057.27819	2372	5	1500	full power while on a survey line	full power while on a survey line	500	None	0:07	0:00
15-Oct-2015		1051	4:27	4:52	Sperm whale	acoustically	09.12403	-056.96693	3110	3	600	not firing	not firing	374	None	0:02	0:00
15-Oct-2015	18		12:58	13:04	Unidentifiable whale	visually	08.59878	-057.17948	2581	3	1800	full power while on a survey line	full power while on a survey line	2240	None	0:00	0:00
15-Oct-2015	19		13:27	13:32	Unidentifiable whale	visually	08.57330	-057.19220	2531	4	2000	full power while on a survey line	full power while on a survey line	2440	None	0:00	0:00
15-Oct-2015	20		15:43	16:07	Pantropical spotted dolphin	visually	08.44278	-057.25804	2210	100	800	full power while on a survey line	full power while on a survey line	442	None	0:22	0:00
18-Oct-2015		1052	2:02	2:25	Unidentifiable dolphin	acoustically	08.95842	-057.04987	2972	3	750	not firing	not firing	750	None	0:00	
18-Oct-2015	21		21:05	21:16	Short-finned pilot whale	visually	08.03112	-057.41902	486	5	700	not firing	not firing	400	None	0:06	0:00
19-Oct-2015		1053	0:21	0:23	Unidentifiable dolphin	acoustically	08.15270	-057.00508	984	2	500	soft-start / ramp-up	soft-start / ramp-up	500	None	0:02	0:00
19-Oct-2015		1054	5:01	6:01	Unidentifiable dolphin	acoustically	08.46072	-057.29995	2225	10	500	full power while on a survey line	not firing	500	None	0:43	0:00
19-Oct-2015		1055	22:17	22:27	Unidentifiable dolphin	acoustically	08.59060	-057.11205	2619	4	750	full power while on a survey line	full power while on a survey line	750	None	0:00	
21-Oct-2015		1056	4:23	4:26	Unidentifiable dolphin	acoustically	08.82142	-056.99062	2926	3	750	full power while on a survey line	full power while on a survey line	750	None	0:00	
27-Oct-2015		1057	3:07	3:14	Unidentifiable dolphin	acoustically	08.84043	-056.97112	2932	2		full power while on a survey line	full power while on a survey line	500	None	0:07	0:00
28-Oct-2015		1058	6:53	9:15	Unidentifiable dolphin	acoustically	08.77717	-057.05850	2410	2		full power while not on a survey line	not firing	500	None	0:44	0:00

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29-Oct-2015		1059	7:26	7:55	Unidentifiable dolphin	acoustically	08.88080	-057.00790		8		full power while on a survey line	full power while on a survey line	500	None	0:29	0:00
29-Oct-2015	22		13:30	13:33	Unidentifiable whale	visually	08.60700	-057.13767	2631	1	850	full power while on a survey line	full power while on a survey line	1250	None	0:00	0:00
29-Oct-2015	23		15:48	15:49	Loggerhead sea turtle	visually	08.75417	-057.05917	2825.2	1	15	full power while on a survey line	full power while on a survey line	350	None	0:00	0:00
31-Oct-2015		1060	3:18	8:23	Unidentifiable dolphin	acoustically	08.88362	-056.99505	2854	1		full power while on a survey line	full power while on a survey line	500	None	0:05	0:00
02-Nov-2015		1061	5:06	5:34	Unidentifiable dolphin	acoustically	08.19388	-057.27792	1142	4	500	full power while on a survey line	full power while on a survey line	500	None	0:28	0:00
02-Nov-2015	24		13:45	13:46	Unidentifiable shelled sea turtle	visually	08.23450	-057.30733	2792	1	100	full power while on a survey line	full power while on a survey line	400	None	0:01	0:00
02-Nov-2015		1062	21:35	23:36	Unidentifiable dolphin	acoustically	08.69015	-057.08478	2763	4	453	full power while on a survey line	full power while on a survey line	453	None	2:01	0:00
03-Nov-2015		1063	4:27	4:43	Unidentifiable dolphin	acoustically	08.01915	-057.33055	1501	2	500	full power while on a survey line	full power while on a survey line	500	None	0:16	0:00
06-Nov-2015		1064	8:06	8:43	Unidentifiable dolphin	acoustically	08.39257	-057.16237	2200	2	500	full power while on a survey line	full power while on a survey line	500	None	0:36	0:00
06-Nov-2015		1065	22:29	23:04	Unidentifiable dolphin	acoustically	08.36418	-057.23382	2001	3	500	full power while on a survey line	full power while on a survey line	500	None	0:35	0:00
09-Nov-2015	25		9:51	9:57	Pantropical spotted dolphin	visually	07.95917	-057.41783	121	12	15	not firing	not firing	400	None	0:06	0:00
10-Nov-2015		1066	1:36	2:10	Unidentifiable dolphin	acoustically	08.95882	-056.92400	3036	10	383	not firing	not firing	383	None	0:34	0:00
10-Nov-2015		1067	8:19	9:23	Unidentifiable dolphin	acoustically	08.32000	-057.04570	2200	1	500	full power while on a survey line	full power while on a survey line	500	None	1:05	0:00
11-Nov-2015		1068	3:50	4:23	Unidentifiable dolphin	acoustically	08.54578	-057.13402	2531	10	500	full power while on a survey line	full power while on a survey line	500	None	0:33	0:00
12-Nov-2015		1069	22:12	22:33	Unidentifiable dolphin	acoustically	08.55805	-057.80012	1901	6	500	not firing	not firing	500	None	0:31	0:00
13-Nov-2015		1070	0:49	0:55	Unidentifiable dolphin	acoustically	08.71340	-057.73418	2079	2	500	soft-start / ramp-up	soft-start / ramp-up	500	None	0:06	0:00
13-Nov-2015		1071	4:17	4:50	Unidentifiable dolphin	acoustically	08.92755	-057.62565	2611	2	500	full power while on a survey line	full power while on a survey line	500	None	0:33	0:00
14-Nov-2015		1072	4:06	7:30	Unidentifiable dolphin	acoustically	08.66088	-057.76525	2127	10	500	not firing	not firing	500	Delayed start of firing	3:24	6:30
14-Nov-2015		1073	23:55	0:05	Unidentifiable dolphin	acoustically	09.20032	-057.42403	2920	1	500	other reduced power firing	other reduced power firing	500	None	0:10	0:00
17-Nov-2015		1074	6:46	8:25	Unidentifiable dolphin	acoustically	09.25777	-057.40563	2522	2	500	not firing	not firing	500	None	1:22	0:00

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17-Nov-2015	26		15:39	15:47	Spinner dolphin	visually	08.70400	-057.67617	2241	30	1500	full power while on a survey line	full power while on a survey line	400	None	0:06	0:00
18-Nov-2015		1075	21:34	23:05	Unidentifiable dolphin	acoustically	08.65553	-057.78728	2147	10	500	not firing	full power while on a survey line	355	Delayed start of firing	0:45	0:00
19-Nov-2015	27		14:12	14:14	Unidentifiable shelled sea turtle	visually	09.05638	-057.51774	2755	1	50	full power while on a survey line	full power while on a survey line	200	None	0:02	0:00
19-Nov-2015		1076	21:26	21:50	Unidentifiable dolphin	acoustically	08.56820	-057.76073	1979	3	750	not firing	not firing	750	None	0:00	
20-Nov-2015	28		11:09	11:27	Unidentifiable dolphin	visually	09.32019	-057.48297	3057	15	1500	not firing	not firing	1942	None	0:00	
21-Nov-2015	29		20:54	21:00	Pantropical spotted dolphin	visually	09.24086	-057.43351	2843	5	5	not firing	not firing	420	None	0:06	
22-Nov-2015		1077	5:38	5:44	Unidentifiable dolphin	acoustically	08.74820	-057.68258	2283	2	750	full power while on a survey line	full power while on a survey line	750	None	0:00	
23-Nov-2015		1078	0:27	1:08	Unidentifiable dolphin	acoustically	09.06267	-057.59407	2710	2	750	full power while on a survey line	full power while on a survey line	750	None	0:00	
23-Nov-2015		1079	3:41	4:02	Unidentifiable dolphin	acoustically	09.25142	-057.49875	2909	5	500	full power while on a survey line	not firing	500	None	0:12	0:00
23-Nov-2015		1080	7:44	8:09	Unidentifiable dolphin	acoustically	09.27097	-057.42252	2804	10	500	not firing	not firing	500	Delayed start of firing	0:11	0:50
24-Nov-2015	30		11:48	11:58	Unidentifiable dolphin	visually	09.22631	-057.39363	2938	8	800	not firing	not firing	1242	None	0:00	0:00
24-Nov-2015	31		13:59	14:00	Unidentifiable dolphin	visually	09.12170	-057.44577	2862	3	3000	full power while on a survey line	full power while on a survey line	3440	None	0:00	0:00
25-Nov-2015		1081	7:07	7:26	Unidentifiable dolphin	acoustically	08.97973	-057.64765	2693	4	750	full power while on a survey line	full power while on a survey line	750	None	0:00	
26-Nov-2015		1082	7:15	7:33	Unidentifiable dolphin	acoustically	08.65577	-057.85497	2100	4	750	not firing	not firing	750	None	0:00	
26-Nov-2015	32		11:07	11:15	Unidentifiable whale	visually	08.90997	-057.73462	2562	1	1000	full power while on a survey line	full power while on a survey line	1000	None	0:00	
27-Nov-2015		1083	6:50	6:58	Unidentifiable dolphin	acoustically	09.02320	-057.62645	2646	2	500	full power while on a survey line	full power while on a survey line	318	None	0:08	0:00
27-Nov-2015	33		18:38	18:40	Unidentifiable whale	visually	08.80333	-057.79269	2386	1	2000	full power while on a survey line	full power while on a survey line	2000	None	0:00	0:00
27-Nov-2015	34		19:15	19:34	Unidentifiable whale	visually	08.84745	-057.77071	2411	2	1500	full power while on a survey line	full power while on a survey line	1500	None	0:00	0:00
27-Nov-2015	35		20:35	20:35	Unidentifiable whale	visually	08.92152	-057.73368	2555	1	2000	full power while on a survey line	full power while on a survey line	2440	None	0:00	0:00
28-Nov-2015		1084	3:50	4:06	Unidentifiable dolphin	acoustically	09.39188	-057.55263	3030	2	750	not firing	not firing	750	None	0:00	

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28-Nov-2015	36		15:45	15:45	Unidentifiable whale	visually	08.88180	-057.70027	2543	1	800	full power while on a survey line	full power while on a survey line	1240	None	0:00	0:00
28-Nov-2015	37		15:59	16:09	Unidentifiable baleen whale	visually	08.87042	-057.70625	2525	1	200	full power while on a survey line	full power while on a survey line	490	None	0:00	0:00
30-Nov-2015		1085	3:22	5:25	Unidentifiable dolphin	acoustically	08.59388	-057.80985	2027	3	750	not firing	not firing	500	None	0:06	0:00
01-Dec-2015		1086	5:25	5:53	Unidentifiable dolphin	acoustically	08.77293	-057.76179	2294	2	500	full power while on a survey line	full power while on a survey line	500	None	0:28	0:00
01-Dec-2015		1087	22:18	23:02	Unidentifiable dolphin	acoustically	09.42600	-057.56707	3062	4	500	not firing	not firing	500	None	0:44	0:00
02-Dec-2015		1088	1:23	2:11	Unidentifiable dolphin	acoustically	09.34757	-057.48392	3090	5	200	other reduced power firing	not firing	200	None	0:31	0:00
02-Dec-2015	38		16:20	16:31	Pantropical spotted dolphin	visually	08.91807	-057.69172	1941	12	200	not firing	not firing	400	None	0:10	0:00
14-Dec-2015		1089	3:24	4:00	Unidentifiable dolphin	acoustically	09.21040	-057.60275	2969	10	750	full power while on a survey line	full power while on a survey line	500	None	0:07	0:00
14-Dec-2015	39		11:08	11:20	Unidentifiable baleen whale	visually	09.06485	-057.62260	2693	1	900	full power while on a survey line	full power while on a survey line	900	None	0:00	
16-Dec-2015		1090	7:32	7:58	Unidentifiable dolphin	acoustically	09.25063	-057.53803	2968	10	500	soft-start / ramp-up	full power while on a survey line	100	None	0:26	0:00
17-Dec-2015		1091	6:30	7:02	Unidentifiable dolphin	acoustically	09.36972	-057.55643	2935	3	500	not firing	not firing	500	None	0:32	0:00
18-Dec-2015		1092	7:53	8:07	Unidentifiable dolphin	acoustically	09.30182	-057.57132	2950	6	500	not firing	not firing	500	None	0:14	0:00
19-Dec-2015		1093	0:08	0:36	Unidentifiable dolphin	acoustically	08.63513	-057.91538	2453	1	500	not firing	not firing	500	None	0:15	0:00
25-Dec-2015		1094	5:36	5:42	Unidentifiable dolphin	acoustically	09.35305	-057.52217	3140	3	223	not firing	not firing	223	None	0:06	0:00
26-Dec-2015	40		16:42	16:42	Unidentifiable shelled sea turtle	visually	08.97607	-057.63832	2600	1	250	soft-start / ramp-up	soft-start / ramp-up	300	None	0:01	0:00
28-Dec-2015		1095	9:51	10:02	Unidentifiable dolphin	acoustically	08.73075	-057.86927	2120	1	500	full power while on a survey line	full power while on a survey line	500	None	0:11	0:00
02-Jan-2016		1096	5:47	6:00	Unidentifiable dolphin	acoustically	09.18667	-057.63637	2070	5	500	full power while on a survey line	full power while on a survey line	500	None	0:13	0:00
02-Jan-2016		1097	22:54	1:10	Unidentifiable dolphin	acoustically	08.57063	-057.99030	1916	2	500	not firing	not firing	500	None	1:19	0:00
03-Jan-2016		1098	8:12	8:56	Unidentifiable dolphin	acoustically	09.13872	-057.66220	2567	5	500	full power while on a survey line	full power while on a survey line	500	None		0:00
05-Jan-2016		1099	2:43	9:55	Unidentifiable dolphin	acoustically	08.73105	-058.00340	2147	5	233	full power while on a survey line	not firing	134	None	6:21	0:00

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08-Jan-2016		1100	2:37	5:40	Unidentifiable dolphin	acoustically	09.25820	-057.61100	2932	5	500	full power while on a survey line	full power while on a survey line	134	None	2:57	0:00
10-Jan-2016		1101	4:25	4:42	Unidentifiable dolphin	acoustically	09.02477	-057.74255	2198	1	500	full power while on a survey line	full power while on a survey line	500	None	0:18	0:00
10-Jan-2016		1102	8:33	9:39	Unidentifiable dolphin	acoustically	09.26178	-057.61925	2725	3	500	full power while on a survey line	full power while on a survey line	500	None		0:00
11-Jan-2016		1103	5:17	5:36	Unidentifiable dolphin	acoustically	08.54360	-058.13680	1725	3	500	not firing	not firing	500	None	0:19	0:00
11-Jan-2016	41		12:21	12:27	Unidentifiable dolphin	visually	08.80942	-057.85178	2389	15	3500	full power while on a survey line	full power while on a survey line	3940	None	0:00	0:00
11-Jan-2016		1104	21:50	22:09	Unidentifiable dolphin	acoustically	09.42273	-057.65097	2995	1	500	not firing	not firing	500	None	0:19	0:00
12-Jan-2016		1105	21:41	22:30	Unidentifiable dolphin	acoustically	09.28750	-057.61505	2936	5	500	full power while on a survey line	not firing	500	None	0:49	0:00
13-Jan-2016		1106	0:09	0:15	Unidentifiable dolphin	acoustically	09.41852	-057.66805	2850	2	500	not firing	not firing	500	None	0:06	0:00
13-Jan-2016	42		16:52	17:23	Unidentifiable baleen whale	visually	08.78913	-057.87182	2433	5	5000	full power while on a survey line	full power while on a survey line	5000	None	0:00	0:00
13-Jan-2016	43		18:12	18:23	Unidentifiable dolphin	visually	08.87162	-057.83352	2456	5	350	full power while on a survey line	full power while on a survey line	400	None	0:06	0:00
14-Jan-2016	44		17:44	17:52	Bryde's whale	visually	08.65883	-057.94017	3246	1	500	not firing	not firing	300	None	0:08	0:00
14-Jan-2016	45		21:59	22:10	Unidentifiable baleen whale	visually	08.93992	-057.80128	2602	2	4000	full power while on a survey line	full power while on a survey line	4300	None	0:00	0:00
15-Jan-2016		1107	3:15	3:40	Unidentifiable dolphin				2998		500	full power while on a survey line	full power while on a survey line	500	None	0:25	0:00
15-Jan-2016		1108	5:29	6:50	Unidentifiable dolphin				2810		500	not firing	not firing	500	None	0:50	0:00
15-Jan-2016		1109	21:52	3:15	Unidentifiable dolphin				2278		500	full power while on a survey line	full power while on a survey line	500	None	5:23	0:00
16-Jan-2016		1110	22:23	0:00	Unidentifiable dolphin				1997		500	not firing	not firing	500	Delayed start of firing	1:05	5:35
17-Jan-2016		1111	7:39	8:08	Unidentifiable dolphin				2227		500	full power while on a survey line	full power while on a survey line	500	None	0:29	0:00
17-Jan-2016	46		10:47	11:25	Unidentifiable dolphin				2706		4000	full power while on a survey line	full power while on a survey line	4000	None	0:00	0:00
19-Jan-2016		1112	4:02	5:08	Unidentifiable dolphin				2599		327	full power while on a survey line	full power while on a survey line	224	None	1:06	0:00
19-Jan-2016	47		18:41	18:51	Unidentifiable baleen whale				2698		2000	full power while on a survey line	full power while on a survey line	2400	None	0:00	0:00

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19-Jan-2016		1113	23:01	0:03	Unidentifiable dolphin				2811		500	not firing	not firing	500	None	1:02	0:00
22-Jan-2016	48	1114	21:41	22:09	Fraser's dolphin				2257		1500	full power while on a survey line	full power while on a survey line	600	None	0:00	
23-Jan-2016	49		21:31	21:36	Unidentifiable dolphin				2767		2000	full power while on a survey line	full power while on a survey line	2400	None	0:00	
26-Jan-2016		1115	0:47	0:51	Unidentifiable dolphin				2115		600	full power while on a survey line	full power while on a survey line	600	None	0:00	
27-Jan-2016		1116	5:23	5:55	Unidentifiable dolphin				2501		600	not firing	not firing	600	None	0:00	
29-Jan-2016		1117	8:17	8:35	Unidentifiable dolphin				2877		500	not firing	not firing	500	None	0:18	0:00
29-Jan-2016	50		19:22	20:57	Unidentifiable baleen whale	visually	08.98860	-057.80987	2469	1	4000	full power while on a survey line	full power while on a survey line	2400	None	0:00	
02-Feb-2016	51		21:38	21:44	Unidentifiable dolphin	visually	09.02032	-057.80798	2451	15	1500	full power while on a survey line	full power while on a survey line	1300	None	0:00	0:00
03-Feb-2016	52		17:59	17:59	Unidentifiable baleen whale	visually	09.26725	-057.80270	2800	1	2000	full power while on a survey line	full power while on a survey line	2400	None	0:00	0:00
03-Feb-2016		1118	22:00	22:33	Unidentifiable dolphin	acoustically	09.39725	-057.64078	2897	3	500	not firing	not firing	500	None	0:02	0:00
04-Feb-2016		1119	5:24	5:42	Unidentifiable dolphin	acoustically	08.93837	-057.86118	2466	2	600	full power while on a survey line	full power while on a survey line	600	None	0:00	0:00
04-Feb-2016	53		13:01	13:03	Loggerhead sea turtle	visually	08.54941	-058.04350	1784	1	20	not firing	not firing	150	None	0:03	0:00
05-Feb-2016		1120	0:51	2:45	Unidentifiable dolphin	acoustically	09.31858	-057.78522	2881	5	600	full power while on a survey line	not firing	600	None	0:00	
05-Feb-2016		1121	3:39	5:10	Sperm whale	acoustically	09.42168	-057.65608	2985	3	1000	not firing	not firing	500	None	1:11	0:16
05-Feb-2016	54		19:14	19:15	Unidentifiable dolphin	visually	08.55120	-058.05164	1781	6	350	not firing	not firing	370	None	0:01	0:00
06-Feb-2016		1122	4:41	4:57	Sperm whale	acoustically	09.11672	-057.88290	2706	1	1000	full power while on a survey line	full power while on a survey line	600	None	0:00	0:00
09-Feb-2016		1123	0:05	2:04	Unidentifiable dolphin	acoustically	09.41593	-057.74115	2909	10	300	not firing	not firing	100	None	0:24	0:00
10-Feb-2016		1124	7:16	7:35	Unidentifiable dolphin	acoustically	09.36637	-057.76788	2847	10	500	full power while on a survey line	not firing	100	None	0:19	0:00
10-Feb-2016		1125	8:54	9:33	Unidentifiable dolphin	acoustically	09.44592	-057.71917	2954	3	600	not firing	not firing	600	None	0:00	
11-Feb-2016		1126	22:53	23:29	Unidentifiable dolphin	acoustically	08.62942	-058.11560	1959	3	1000	not firing	not firing	1000	None	0:00	0:00

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12-Feb-2016		1127	5:21	6:39	Unidentifiable dolphin	acoustically	08.99613	-057.95902	2592	10	600	full power while on a survey line	full power while on a survey line	100	None	0:47	0:00
15-Feb-2016		1128	6:50	7:15	Unidentifiable dolphin	acoustically	09.47290	-057.70115	2923	5	1000	not firing	not firing	500	None	0:03	0:00
16-Feb-2016		1129	7:57	8:16	Unidentifiable dolphin	acoustically	09.19907	-057.87067	2751	5	500	full power while on a survey line	full power while on a survey line	500	None	0:19	0:00
16-Feb-2016	55		13:49	14:19	Bryde's whale	visually	09.40503	-057.73413	2891	1	500	not firing	not firing	375	None	0:22	0:00
17-Feb-2016	56		20:16	20:36	Bryde's whale	visually	09.30907	-057.81919	2829	5	3000	full power while on a survey line	not firing	350	None	0:11	0:00
Stabroek 3D *CGG Geo Celtic*																	
13-Jul-2015	1		12:36	12:41	Pantropical spotted dolphin	Visually	07.60667	-056.22050	1427	6	100	not firing	not firing		none	0:05	0:00
14-Jul-2015	2		22:11	22:11	Unidentified dolphin	Visually	09.30017	-057.50767	3030	1	50	not firing	not firing		none	0:01	0:00
20-Jul-2015	3		12:27	13:01	Bryde's whale	Visually	08.20433	-057.25233	1611	2	2500	full power while on survey line	full power while on survey line	2000	none	0:00	
21-Jul-2015		1	7:50	8:40	Sperm whale	Acoustically	08.85870	-056.82468	2924	3	1200	not firing	not firing	1200	none	0:00	
21-Jul-2015	4		15:58	16:04	Sperm whale	Visually	08.63817	-057.03200	2725	1	1000	full power while on survey line	full power while on survey line	1500	none	0:00	0:00
22-Jul-2015		2	8:23	8:51	Sperm whale	Acoustically	08.05523	-057.22383	1117	3	122	soft start / ramp-up	full power while on survey line	222	none	0:12	0:00
24-Jul-2015	5		15:18	15:21	Pantropical spotted dolphin	Visually	08.62217	-057.02433	2714	15	1000	full power while on survey line	full power while on survey line	700	none	0:00	
31-Jul-2015	6		15:31	15:39	Bryde's whale	Visually	08.64968	-057.00645	2746	1	1500	full power while on survey line	full power while on survey line	2000	none	0:00	
04-Aug-2015	7		21:17	21:53	Unidentified dolphin	Visually	08.81022	-056.87942	2084	9	1000	not firing	not firing	500	none	0:06	0:00
06-Aug-2015	8		17:31	17:36	Melon-headed whale	Visually	08.86733	-056.88033	2971	20	350	not firing	not firing	400	none	0:02	0:00
13-Aug-2015		3	4:12	4:22	Unidentified dolphin	Acoustically	08.22350	-057.08743	2799		500	full power while on survey line	full power while on survey line	500	none	0:10	0:00
15-Aug-2015		4	5:14	5:21	Unidentified dolphin	Acoustically	07.94860	-057.29223	401		500	not firing	not firing	500	none	0:07	
16-Aug-2015		5	0:54	1:04	Unidentified dolphin	Acoustically	08.66362	-056.95570	2759		500	full power while on survey line	full power while on survey line	500	none	0:10	
16-Aug-2015		6	5:45	5:51	Unidentified dolphin	Acoustically	08.34687	-057.11478	1935			full power while on survey line	full power while on survey line	500	none		

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16-Aug-2015		7	23:46	23:52	Unidentified dolphin	Acoustically	08.64960	-056.86345	1938			full power while on survey line	full power while on survey line	500	none		
18-Aug-2015		8	1:08	1:22	Unidentified dolphin	Acoustically	07.93547	-057.27138	1567			not firing	not firing	500	none	0:10	
20-Aug-2015		9	3:29	3:35	Unidentified dolphin	Acoustically	08.51128	-057.02087	2539			full power while on survey line	full power while on survey line	500	none	0:06	
23-Aug-2015		10	3:38	3:54	Unidentified dolphin	Acoustically	08.92945	-056.78423	1877			not firing	not firing	500	none	0:11	
23-Aug-2015	9		20:01	20:28	spinner dolphin	Visually	07.99855	-057.30675	676	6	70	not firing	not firing	350	none	0:25	
25-Aug-2015	10		20:48	20:51	Sperm Whale	Visually	08.06923	-057.24155	1132	2	700	full power while on survey line	full power while on survey line	1100	none	0:00	0:00
27-Aug-2015		11	2:16	2:21	Unidentified dolphin	acoustically	08.16987	-057.03950	1953			not firing	not firing		none		
28-Aug-2015	11		21:28	21:40	Sperm Whale	visually	08.35993	-056.95387	2336	2	1200	full power while on survey line	full power while on survey line	1600	none	0:00	
28-Aug-2015		12	23:35	23:39	Unidentified dolphin	acoustically	08.67388	-057.00000	1938			full power while on survey line	full power while on survey line		none		
29-Aug-2015		13	4:42	5:12	Unidentified dolphin	acoustically	07.85503	-057.18397	754		500	not firing	not firing	392	none	0:03	0:00
29-Aug-2015		14	21:40	21:41	Unidentified dolphin	acoustically	08.67388	-056.76073			500	Not firing	Not firing		none		0:00
01-Sep-2015	12		11:54	12:08	Unidentified dolphin	visually	08.18255	-057.01922	1887	30	2300	full power while on survey line	full power while on survey line	1900	none	0:00	0:00
04-Sep-2015	13		19:18	19:31	Spinner dolphin	visually	09.09712	-056.71303	3195	40	400	not firing	not firing		none	0:00	0:00
06-Sep-2015		15	4:58	5:09	Unidentified dolphin	acoustically	08.57487	-056.85153	2665			full power while on survey line	full power while on survey line		none		
06-Sep-2015		16	6:38	6:50	Unidentified dolphin	acoustically	08.69658	-056.83220	2455			not firing	not firing		none		
06-Sep-2015		17	8:05	8:08	Unidentified dolphin	acoustically	08.66855	-056.75297	2805			not firing	not firing		none		
07-Sep-2015		18	0:21	0:56	Unidentified dolphin	acoustically	08.01387	-057.13650				full power while not on survey line	full power while on survey line		none		
07-Sep-2015		19	3:16	4:14	Unidentified dolphin	acoustically	08.20857	-057.03802	1988			full power while on survey line	full power while on survey line		none		
08-Sep-2015		20	2:31	3:22	Unidentified dolphin	acoustically	07.80817	-057.24317	104			not firing	not firing		none		
08-Sep-2015		21	6:28	6:42	Unidentified dolphin	acoustically	08.02537	-057.07737	1768			full power while on survey line	full power while on survey line		none		

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09-Sep-2015		22	4:00	4:31	Unidentified dolphin	acoustically	07.79208	-057.09225	1855			not firing	not firing		none		
11-Sep-2015	14		16:43	17:00	Pantropical spotted dolphin	visually	08.09942	-057.02707	1700	25	1100	full power while on survey line	full power while on survey line	400	none	0:10	0:00
11-Sep-2015	15		17:44	17:48	Sperm whale	visually	08.17018	-056.99213	1917	1		full power while on survey line	full power while on survey line	630	none	0:00	
12-Sep-2015		23	6:11	6:20	Unidentified dolphin	acoustically	08.31147	-056.81557	1508			full power while on survey line	full power while on survey line		none		
13-Sep-2015	16		17:26	17:52	Risso's dolphin	visually	07.86913	-057.03428	919	4		full power while on survey line	full power while on survey line	540	none	0:08	0:00
14-Sep-2015		24	1:18	1:21	Unidentified dolphin	acoustically	08.10058	-057.01753	1899			full power while on survey line	full power while on survey line		none		
14-Sep-2015		25	23:42	0:21	Unidentified dolphin	acoustically	07.79044	-057.06839	2184			not firing	not firing		none		
15-Sep-2015	17		12:24	13:30	Spinner dolphin	visually	08.53735	-056.79117	2656	30		full power while on survey line	not firing	400	none	0:40	0:00
16-Sep-2015		26	0:57	1:12	Unidentified dolphin	acoustically	07.97797	-056.97057	1586			full power while on survey line	full power while on survey line		none		
16-Sep-2015		27	4:03	4:11	Unidentified dolphin	acoustically	07.78223	-057.06783	1233			not firing	not firing		none		
17-Sep-2015		28	8:16	8:17	Unidentified dolphin	acoustically	07.27117	-057.06772	155		1100	not firing	not firing	500	none		
18-Sep-2015		29	23:34	0:40	Unidentified dolphin	acoustically	08.39273	-056.85323	2464		550	full power while on survey line	full power while on survey line	166	none	0:04	0:00
21-Sep-2015		30	0:42	1:07	Unidentified dolphin	acoustically	07.81638	-057.13172	212			not firing	soft start / ramp-up		none		
30-Sep-2015	18		18:53	18:58	Pantropical spotted dolphin	visually	07.96317	-056.93150	1457	8	1700	full power while on survey line	full power while on survey line	600	none	0:00	
02-Oct-2015		31	4:51	4:56	Unidentified dolphin	acoustically	07.60242	-057.02920	439			not firing	not firing		none	0:00	0:00
02-Oct-2015		32	9:30	9:34	Unidentified dolphin	acoustically	07.79998	-057.10415	318			not firing	not firing	500	none	0:04	0:00
03-Oct-2015		33	3:00	3:02	Unidentified dolphin	acoustically	08.56353	-056.59932	2790		600	not firing	not firing	500	none	0:00	0:00
04-Oct-2015	19		18:46	19:16	Melon-headed whale	visually	07.83033	-056.98933	850	15		full power while on survey line	full power while on survey line	400	none	0:01	0:00
05-Oct-2015		34	1:40	2:03	Unidentified dolphin	acoustically	07.96310	-057.11443	1388			full power while on survey line	full power while on survey line	268	none	0:07	0:00
07-Oct-2015		35	0:33	1:23	Unidentified dolphin	acoustically	08.13062	-056.84512	1918	3		full power while on survey line	full power while on survey line	500	none	0:12	0:00

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07-Oct-2015		36	2:00	2:58	Unidentified dolphin	acoustically	08.04267	-056.88077	1648	2		not firing	not firing		none	0:00	0:00
07-Oct-2015		37	3:30	3:48	Unidentified dolphin	acoustically	07.95915	-056.91913	1473	2		not firing	soft start / ramp-up		none	0:00	0:00
07-Oct-2015		38	23:49	23:59	Unidentified dolphin	acoustically	08.59402	-056.67885	2767	4		not firing	not firing	500	none	0:10	0:00
11-Oct-2015	20		14:51	15:19	Spinner dolphin	visually	08.16017	-056.80217	2049	23	2000	full power while on survey line	full power while on survey line	1200	none	0:00	
12-Oct-2015		39	5:30	6:14	Unidentified dolphin	acoustically	07.85208	-056.85037	1155	1		full power while on survey line	full power while on survey line		none	0:00	0:00
15-Oct-2015	21		14:10	14:12	Unidentified dolphin	visually	08.25883	-056.73400	2283	4	2500	full power while on survey line	full power while on survey line	2800	none	0:00	
18-Oct-2015		40	4:35	5:23	Unidentified dolphin	acoustically	08.41775	-056.61290	2627	6		not firing	not firing	91	none	0:11	0:00
19-Oct-2015	22		13:05	13:26	Pantropical spotted dolphin	visually	08.28647	-056.60217	2412	8	2000	not firing	not firing	900	none	0:00	
19-Oct-2015	23		15:18	15:35	Unidentified dolphin	visually	08.16267	-056.66383	2207	4	1500	full power while on survey line	full power while on survey line	1200	none	0:00	
23-Oct-2015		41	23:59	0:25	Unidentified dolphin	acoustically	08.23862	-086.61222	2346			full power while on survey line	full power while on survey line		none		
24-Oct-2015		42	7:04	7:38	Unidentified dolphin	acoustically	07.78198	-056.84243	1889			full power while on survey line	full power while on survey line		none		
27-Oct-2015		43	3:25	3:26	Unidentified dolphin	acoustically	07.86668	-056.79000	1099			full power while on survey line	full power while on survey line		none		
27-Oct-2015		44	5:34	5:39	Unidentified dolphin	acoustically	07.71652	-056.86600	1201			full power while on survey line	full power while on survey line		none		
29-Oct-2015		45	4:45	4:45	Unidentified dolphin	acoustically	07.65978	-056.88998	1037			full power while on survey line	full power while on survey line		none		
29-Oct-2015		46	5:57	6:40	Unidentified dolphin	acoustically	07.58553	-056.92792	1233			full power while on survey line	full power while on survey line		none		
31-Oct-2015	24		11:20	11:32	Spinner dolphin	visually	07.93313	-056.74172	1727	30	700	full power while on survey line	full power while on survey line	800	none	0:00	
31-Oct-2015	25		13:13	13:27	Spinner dolphin	visually	07.80727	-056.80727	1274	20	1200	full power while on survey line	full power while on survey line	1500	none	0:00	
03-Nov-2015		47	22:25	22:28	Unidentified dolphin	acoustically	08.41632	-056.46133	2672			not firing	not firing		none		
05-Nov-2015		48	3:52	4:15	Unidentified dolphin	acoustically	08.36812	-056.53823	1899			not firing	not firing		none		
05-Nov-2015		49	6:26	6:34	Unidentified dolphin	acoustically	08.19742	-056.56077	1029			full power while on survey line	full power while on survey line		none		

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09-Nov-2015		50	22:46	22:58	Unidentified dolphin	acoustically	08.23267	-056.56398	2400			soft-start / ramp-up	soft-start / ramp-up		none		
10-Nov-2015		51	2:07	4:08	Unidentified dolphin	acoustically	08.03747	-056.66157	1890			full power while on a survey line	full power while on a survey line		none		
10-Nov-2015		52	4:58	6:14	Unidentified dolphin	acoustically	07.87063	-056.74725	1230			full power while on a survey line	full power while on a survey line		none		
10-Nov-2015		53	7:58	8:03	Unidentified dolphin	acoustically	07.69500	-056.83497	1098			not firing	not firing		none		
10-Nov-2015		54	8:43	8:58	Unidentified dolphin	acoustically	07.69500	-056.83497	933			not firing	not firing		none		
11-Nov-2015		55	2:02	2:16	Unidentified dolphin	acoustically	07.83748	-056.87770	1117			full power while on a survey line	full power while on a survey line		none		
11-Nov-2015		56	4:05	4:10	Unidentified dolphin	acoustically	07.96932	-056.81335	1988			full power while on a survey line	full power while on a survey line		none		
13-Nov-2015		57	20:45	20:48	Unidentified dolphin	acoustically	07.99315	-056.70533	1888			full power while on a survey line	full power while on a survey line		none		
16-Nov-2015		58	1:10	1:16	Unidentified dolphin	acoustically	07.89363	-056.63023	660			not firing	not firing		none		
18-Nov-2015		59	1:58	2:02	Unidentified dolphin	acoustically	07.47978	-056.93305	69			not firing	not firing		none		
20-Nov-2015		60	5:12	5:40	Unidentified dolphin	acoustically	08.02847	-056.54880	2082			full power while on a survey line	full power while on a survey line	60	none	0:05	0:00
20-nov-2015	26		12:49	12:53	Pantropical spotted dolphin	visually	07.60975	-056.76030	354	3	200	full power while on a survey line	full power while on a survey line	500	None	0:04	0:00
22-Nov-2015	27		16:00	16:03	Unidentified dolphin	visually	07.72223	-056.79850	1012	3	100	full power while on a survey line	full power while on a survey line	500	None	0:03	0:00
23-Nov-2015		61	6:42	6:50	Unidentified dolphin	acoustically	08.02463	-056.54223	2065			full power while on a survey line	full power while on a survey line	500	None	0:01	0:00
23-Nov-2015		62	22:00	22:08	Unidentified dolphin	acoustically	07.72385	-056.78882	1042			full power while on a survey line	full power while on a survey line	500	None	0:02	0:00
24-Nov-2015	28		18:53	19:00	Spinner dolphin	visually	07.60555	-056.74868	354	6	250	full power while on a survey line	full power while on a survey line	600	None	0:00	
26-Nov-2015		63	2:29	2:35	Unidentified dolphin	acoustically	07.58505	-056.75477	118			full power while on a survey line	full power while on a survey line	500	None	0:03	0:00
26-Nov-2015		64	23:25	23:39	Unidentified dolphin	acoustically	08.15307	-056.46447	2376			full power while on a survey line	full power while on a survey line	500	None	0:08	0:00
01-Dec-2015		65	5:33	5:48	Unidentified dolphin	acoustically	07.61903	-056.72003	568			full power while on a survey line	full power while on a survey line		None		
04-Dec-2015		66	2:08	2:37	Unidentified dolphin	acoustically	07.57792	-056.83318	105			not firing	not firing	500	None	0:18	0:00

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05-Dec-2015	29		13:07	13:25	Unidentified dolphin	visually	08.04855	-056.41083	2353	30	1000	not firing	not firing	1400	None	0:00	
06-Dec-2015		67	23:08	23:09	Unidentified dolphin	acoustically	08.25187	-056.43815	2357			other reduced power firing	other reduced power firing		None	0:00	
07-Dec-2015		68	6:18	6:35	Unidentified dolphin	acoustically	07.83805	-056.58882	1747			full power while on a survey line	full power while on a survey line		None		
08-Dec-2015		69	5:45	5:55	Unidentified dolphin	acoustically	08.23802	-056.42053	2554			not firing	not firing		None		
08-Dec-2015		70	7:07	7:17	Unidentified dolphin	acoustically	08.15310	-056.43042	2419			not firing	not firing		None		
09-Dec-2015		71	1:04	1:13	Unidentified dolphin	acoustically	07.62438	-056.79972	384			full power while on a survey line	full power while on a survey line	500	None	0:09	
10-Dec-2015	30		19:44	19:51	Bryde's whale	visually	07.64177	-056.89598	108	1	2500	not firing	not firing	2500	None	0:00	
11-Dec-2015		72	3:31	3:53	Unidentified dolphin	acoustically	07.61323	-056.80063	829			full power while on a survey line	full power while on a survey line		None		
12-Dec-2015		73	4:33	5:05	Unidentified dolphin	acoustically	08.23237	-056.48737	2500			not firing	not firing	500	None	0:07	0:00
12-Dec-2015	31		19:53	20:01	Unidentified dolphin	visually	07.39123	-056.86523	61	1	3500	not firing	not firing	3000	None	0:00	
13-Dec-2015		74	1:04	1:05	Unidentified dolphin	acoustically	07.71405	-056.74670	1136			full power while on a survey line	full power while on a survey line	500	None	0:01	0:00
13-Dec-2015		75	1:21	1:38	Unidentified dolphin	acoustically	07.73217	-056.73752	1240			full power while on a survey line	full power while on a survey line		None		
13-Dec-2015		76	4:50	5:08	Unidentified dolphin	acoustically	07.96230	-056.62072	1948			full power while on a survey line	full power while on a survey line		None		
14-Dec-2015	32		13:11	13:17	Bryde's Whale	Visually	07.99662	-056.59930	1998	1	1500	full power while on a survey line	full power while on a survey line	1300	None	0:00	0:00
15-Dec-2015		77	3:24	3:33	Unidentified dolphin	acoustically	07.68190	-056.64597	1196			full power while on a survey line	full power while on a survey line	500	None	0:01	0:00
15-Dec-2015		78	6:36	6:38	Unidentified dolphin	acoustically	07.47328	-056.75178	80			full power while on a survey line	full power while on a survey line		None		
16-Dec-2015		79	4:07	4:08	Unidentified dolphin	acoustically	08.11353	-056.42775	2398			not firing	not firing	98	None	0:05	
16-Dec-2015	33		12:16	12:19	Pantropical spotted dolphin	visually	07.60367	-056.68063	670			full power while on a survey line	full power while on a survey line	450	None	0:03	
18-Dec-2015		80	5:03	5:06	Unidentified dolphin	acoustically	07.61032	-056.78712	890			full power while on a survey line	full power while on a survey line		None	0:03	
19-Dec-2015		81	0:56	1:32	Unidentified dolphin	acoustically	07.82755	-056.56463	1302	3		full power while on a survey line	full power while on a survey line	500	None		

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19-Dec-2015		82	4:12	5:23	Unidentified dolphin	acoustically	07.63088	-056.66412	889	1		full power while on a survey line	full power while on a survey line	500	None		
19-Dec-2015		83	21:13	21:19	Unidentified dolphin	acoustically	07.71777	-056.65807	1309	5		not firing	not firing	1500	None		
20-Dec-2015		84	5:50	5:56	Unidentified dolphin	acoustically	07.59125	-056.78597	1099	1		soft-start / ramp-up	soft-start / ramp-up	1000	None		
22-Dec-2015		85	2:50	3:19	Unidentified dolphin	acoustically	07.91055	-056.38272	1088			not firing	not firing	500	None		
24-Dec-2015		86	6:25	6:51	Unidentified dolphin	acoustically	08.20438	-056.44178	1306			not firing	not firing	500	None		
24-Dec-2015		87	23:06	23:21	Unidentified dolphin	acoustically	07.99050	-056.58660	1899			full power while on a survey line	full power while on a survey line	500	None		
29-Dec-2015	34		16:45	16:46	Unidentified dolphin	visually	08.64070	-056.77875	2765	1	250	not firing	not firing		None	0:00	0:00
07-Jan-2016		88	23:00	23:04	Unidentified dolphin	acoustically	07.59452	-056.67487	2304	1		full power while on a survey line	full power while on a survey line	1500	None		
08-Jan-2016		89	0:23	0:25	Unidentified dolphin	acoustically	07.68625	-056.62702	2216	1		full power while on a survey line	full power while on a survey line	500	None		
09-Jan-2016	35		19:34	19:38	Pantropical spotted dolphin	visually	07.79715	-056.49132	1777	8	400	full power while on a survey line	full power while on a survey line	600	None	0:00	
11-Jan-2016	36		13:35	13:45	Bryde's whale	visually	07.79320	-056.56128	1649	1	150	full power while on a survey line	full power while on a survey line	380	None	0:07	
11-Jan-2016		90	23:28	23:33	Unidentified dolphin	acoustically	07.96468	-056.39753	252	1	500	full power while on a survey line	full power while on a survey line	500	None		
13-Jan-2016		91	2:10	2:50	Unidentified dolphin	acoustically	07.87522	-056.44013	446	5	500	full power while on a survey line	full power while on a survey line	500	None		
13-Jan-2016	37		15:25	15:30	Unidentified dolphin	visually	07.61243	-056.64640	882	5	5000	full power while on a survey line	full power while on a survey line	5500	None	0:00	0:00
14-Jan-2016	38		18:38	18:45	Pantropical spotted dolphin	visually	07.65023	-056.62297	1111	15	600	full power while on a survey line	full power while on a survey line	600	None	0:00	0:00
16-Jan-2016		92	3:09	3:30	Unidentified dolphin	acoustically	07.92925	-056.47488	367	1		full power while on a survey line	full power while on a survey line		None		
17-Jan-2016		93	3:50	4:20	Unidentified dolphin	acoustically	07.77890	-056.54897	664	1		full power while on a survey line	full power while on a survey line		None		
17-Jan-2016	39		20:38	21:14	Spinner dolphin	visually	07.59259	-056.56273	828	40	4000	full power while on a survey line	full power while on a survey line	1100	None	0:00	0:00
17-Jan-2016	40		20:38	20:43	Sperm whale	visually	07.59259	-056.56273	828	1	4000	full power while on a survey line	full power while on a survey line	4500	None	0:00	0:00

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17-Jan-2016	41		21:17	21:18	Sperm whale	visually	07.55542	-056.58175	496	1	3000	full power while on a survey line	full power while on a survey line	3000	None	0:00	0:00
18-Jan-2016		94	3:42	3:54	Unidentified dolphin	acoustically	07.55280	-056.57818		3	500	full power while on a survey line	full power while on a survey line	500	None		
20-Jan-2016	42		20:18	20:26	Unidentified baleen whale	visually	07.57283	-056.63638	537	1	1200	full power while on a survey line	full power while on a survey line	1500	None	0:00	0:00
20-Jan-2016		95	21:35	21:37	Unidentified dolphin	acoustically	07.65657	-056.59522	678	1	800	full power while on a survey line	full power while on a survey line	800	None		
21-Jan-2016		96	1:19	1:32	Unidentified dolphin	acoustically	07.91010	-056.46873	576	3	1000	full power while on a survey line	full power while on a survey line	1000	None		
22-Jan-2016		97	6:28	6:32	Unidentified dolphin	acoustically	07.86007	-056.48872	898	2	500	full power while on a survey line	full power while on a survey line	500	None		
23-Jan-2016		98	0:52	1:19	Unidentified dolphin	acoustically	07.50032	-056.58780	123	3	1000	full power while on a survey line	full power while on a survey line	1000	None		
23-Jan-2016	43		10:49	10:56	Spinner dolphin	visually	688.98333	-056.57243	450	15	500	full power while on a survey line	full power while on a survey line	450	None	3:00	0:00
26-Jan-2016		99	2:50	3:26	unidentified dolphin	acoustically	07.56685	-056.61857	489	3	1000	full power while on a survey line	full power while on a survey line	1000	None		
26-Jan-2016		100	22:50	0:30	unidentified dolphin	acoustically	07.62162	-056.51397	1049	5	1000	full power while on a survey line	full power while on a survey line	250	None		
30-Jan-2016		101	20:13	20:18	unidentified dolphin	acoustically	08.03940	-056.38148	2355	3	1000	not firing	not firing	800	None		
31-Jan-2016		102	3:25	3:34	unidentified dolphin	acoustically	07.56065	-056.61190	445	1	1000	full power while on a survey line	full power while on a survey line	500	None		
01-Feb-2016		103	0:10	0:19	Unidentified dolphin	acoustically	07.56907	-056.53042	686	1	1000	full power while on a survey line	full power while on a survey line	500	None		
01-Feb-2016		104	1:33	1:42	Unidentified dolphin	acoustically	07.63507	-056.49682	1049	1	500	full power while on a survey line	full power while on a survey line	500	None		
01-Feb-2016		105	5:00	5:10	Unidentified dolphin	acoustically	07.82620	-056.40653	2009	1	1000	full power while on a survey line	full power while on a survey line	500	None		
04-Feb-2016		106	23:14	0:08	Unidentified dolphin	acoustically	07.91117	-056.34532	980	3	1000	not firing	not firing	1000	None		
08-Feb-2016		107	23:54	23:58	Unidentified dolphin	acoustically	07.68675	-056.43133	899	3	1000	full power while on a survey line	full power while on a survey line	1000	None		
09-Feb-2016		108	3:20	3:33	Unidentified dolphin	acoustically	07.90452	-056.21250	1766	NA	NA	not firing	not firing	100	None		
14-Feb-2016		109	3:08	4:12	Unidentified dolphin	acoustically	07.59007	-056.34805	1033	5	1500	full power while on a survey line	full power while on a survey line	1000	None		

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14-Feb-2016		110	22:56	23:03	Unidentified dolphin	acoustically	07.69835	-056.29043	1488		1000	full power while on a survey line	full power while on a survey line	1000	None		
15-Feb-2016		111	3:02	4:08	Unidentified dolphin	acoustically	07.48422	-056.39773	502		2000	full power while on a survey line	full power while on a survey line	1000	None		
17-Feb-2016		112	5:41	5:50	Unidentified dolphin	acoustically	07.62690	-056.42300	1242	2	1500	full power while on a survey line	full power while on a survey line	1500	None		
17-Feb-2016		113	22:00	22:27	Unidentified dolphin	acoustically	07.50063	-056.37557	770	5	1000	full power while on a survey line	full power while on a survey line	300	None		
19-Feb-2016		114	3:22	3:26	Unidentified dolphin	acoustically	07.55490	-056.43820	102	2	500	full power while on a survey line	full power while on a survey line	500	None		
LIZA AUV Survey																	
21-Dec-2015	1		19:31	19:31	Short-finned pilot whale	visually	07.80372	-057.15685	400	1	20	not firing	not firing		none	00:00	
25-Dec-2015	2		10:16	10:26	Common bottlenose dolphin	visually	08.10027	-057.01693	1702	8	100	full power while on survey line	full power while on survey line		none	00:10	00:00
25-Dec-2015	3		13:44	14:23	Pantropical spotted dolphin	visually	08.10938	-057.02723	1718	10	20	full power while on survey line	full power while on survey line		none	00:39	00:00
29-Dec-2015	4		13:27	13:29	Common bottlenose dolphin	visually	07.49228	-057.57785	48	4	10	not firing	not firing		none	00:02	00:00
01-Jan-2016	5		20:47	20:48	Pantropical spotted dolphin	visually	08.08897	-057.02958	343	20	400	not firing	not firing		none	00:01	00:00
06-Jan-2016	6		18:19	18:26	Pantropical spotted dolphin	visually	08.11558	-057.02025	1752	50	100	full power while on survey line	full power while on survey line		none	00:05	00:00
07-Jan-2016	7		19:25	19:59	Short-finned pilot whale	visually	07.92542	-057.10417	1200	22	100	not firing	not firing		none	00:19	00:00
10-Jan-2016	8		13:43	13:49	Common bottlenose dolphin	visually	08.05623	-057.05670	1550	32	10	full power while on survey line	full power while on survey line		none	00:05	00:00
12-Jan-2016	9		14:00	14:10	Pantropical spotted dolphin	visually	08.08613	-056.91308	1811	10	20	not firing	not firing		none	00:07	00:00
14-Jan-2016	10		19:18	19:43	Pantropical spotted dolphin	visually	07.91857	-057.05837	1200	55	10	not firing	not firing		none	00:14	00:00
18-Jan-2016	11		17:04	17:05	Green Sea Turtle	visually	08.01568	-056.86687	1657	1	10	full power while on survey line	full power while not on survey line		none	00:01	00:00
27-Jan-2016	12		12:34	12:36	Common bottlenose dolphin	visually	08.00553	-056.84902	1554	10	2	not firing	not firing		none	00:02	00:00
28-Jan-2016	13		21:21	21:24	Common bottlenose dolphin	visually	07.35323	-057.45280	41	10	20	full power while not on survey line	full power while not on survey line		none	00:02	00:00
29-Jan-2016	14		10:05	10:05	Unidentifiable dolphin	visually	07.97517	-056.95390	1467	5	2	not firing	not firing		none	00:01	00:00

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29-Jan-2016	15		16:40	16:51	Sperm whale	visually	07.85222	-057.03092	1209	4	800	full power while on survey line	full power while on survey line		none	00:00	
29-Jan-2016	16		19:56	20:13	Unidentifiable dolphin	visually	07.94035	-056.98360	1313	10	1500	full power while on survey line	full power while on survey line		none	00:00	
05-Feb-2016	17		13:10	13:15	Pantropical spotted dolphin	visually	08.10133	-056.89590	1850	20	4	full power while on survey line	full power while on survey line		none	00:05	00:00
08-Feb-2016	18		10:03	10:10	Common bottlenose dolphin	visually	07.68338	-057.28462	75	10	2	not firing	not firing		none	00:07	00:00
08-Feb-2016	19		12:45	13:08	Common bottlenose dolphin	visually	07.45865	-057.52113	51	15	400	not firing	not firing		none	00:23	00:00
13-Feb-2016	20		19:30	19:36	Melon-headed whale	visually	08.06668	-057.12560	1093	50	200	not firing	not firing		delayed start of firing	00:06	00:00
03-Mar-2016	21		20:30	20:32	Hawksbill sea turtle	visually	07.80083	-057.81800	60	1	30	not firing	not firing		none	02:00	00:00
03-Mar-2016	22		21:05	21:08	Pantropical spotted dolphin	visually	07.48217	-057.49083	50	1	150	not firing	not firing		none	03:00	00:00
05-Mar-2016	23		15:04	15:05	Hawksbill sea turtle	visually	07.65150	-057.21100	71	1	30	other reduced power firing	other reduced power firing		none	01:00	00:00
06-Mar-2016	24		15:05	15:08	Sperm whale	visually	07.90298	-057.09298	1000	1	1000	other reduced power firing	other reduced power firing		none	00:00	00:00
11-Mar-2016	25		10:58	11:02	Unidentifiable baleen whale	visually	07.92797	-056.54735	1820	1	1500	other reduced power firing	other reduced power firing		none	00:00	00:00
11-Mar-2016	26		13:25	13:35	Bryde's whale	visually	07.89517	-056.83417	1500	1	200	other reduced power firing	other reduced power firing		none	10:00	00:00
17-Mar-2016	27		20:44	20:50	Bryde's whale	visually	08.29683	-057.35317	1896	1	600	other reduced power firing	other reduced power firing		none	00:00	00:00
21-Mar-2016	28		17:40	17:45	Common bottlenose dolphin	visually	07.71488	-057.16995	90	2	10	other reduced power firing	other reduced power firing		none	00:05	00:00
Canje 3D Survey																	
20-Mar-2016	1		13:05	13:07	Unidentifiable dolphin	visually	07.97825	-056.17697	2278	10	250	not firing	not firing	842	none		00:00
29-Mar-2016	2		21:11	21:13	Sperm whale	visually	07.92200	-056.19385	2160	1	3700	not firing	not firing	4000	none		00:00
02-Apr-2016	3		16:35	19:15	Fraser's dolphin	visually	07.92298	-056.23653	2218	1	50	full power while on survey line	full power while on survey line	590	none		00:00
03-Apr-2016	4		15:00	16:50	Fraser's dolphin	visually	07.85427	-056.23342	2018	1	150	full power while on survey line	full power while on survey line	560	none		00:00
04-Apr-2016	5		11:37	11:45	Unidentifiable baleen whale	visually	08.64020	-057.56457	3128	2	1500	full power while on survey line	full power while on survey line	1600	none		00:00

Date	Visual Det. #	Acoustic Det. #	Time at Initial Det.	Time at Last Det.	Common Name	Detection Method	Latitude	Longitude	Water Depth (m)	No. of Animals	Range when First Detected	Source Activity at First Det.	Source Activity at Last Det.	Closest distance to source (m)	Mitigation Actions	Total Duration Animals Observed inside EZ	Total Duration of Production Loss
05-Apr-2016	6		15:57	15:58	Sperm whale	visually	08.25383	-056.22693	2756	1	800	full power while on survey line	full power while on survey line	1440	none		00:00
13-Apr-2016	7		9:48	9:49	Unidentifiable dolphin	visually	08.80603	-056.29915	3214	11	20	not firing	not firing	637	none		00:00
16-Apr-2016	8		10:29	10:44	Bryde's whale	visually	08.72498	-056.10738	3149	1	1200	not firing	not firing	1337	none		00:00
17-Apr-2016	9		16:16	16:16	Unidentifiable dolphin	visually	08.79703	-056.17315	3172	1	200	not firing	not firing	620	none		00:00
19-Apr-2016	10		20:25	20:41	Bryde's whale	visually	08.57515	-056.10538	3012	1	2500	full power while on survey line	full power while on survey line	2700	none		00:00
24-Apr-2016	11		18:17	18:21	Pantropical spotted dolphin	visually	08.74803	-056.18900	3146	50	300	not firing	not firing	737	none		00:00
26-Apr-2016		1	19:50	19:54	Unidentifiable dolphin	acoustically	08.75265	-056.19203	3152	3	1500	not firing	not firing	1500	none		00:00
26-Apr-2016		2	23:20	23:51	Unidentifiable dolphin	acoustically	08.48763	-056.18960	2977	1	1500	full power while on survey line	full power while on survey line	1500	none		00:00
27-Apr-2016	12		10:07	10:22	Unidentifiable baleen whale	visually	07.79478	-056.47098	1816	1	1000	not firing	not firing	595	none		00:00
30-Apr-2016		3	22:30	22:40	Unidentifiable dolphin	acoustically	08.08677	-056.26832	2546	3	1000	full power while on survey line	full power while on survey line	1000	none		00:00
01-May-2016	13		13:50	13:56	Unidentifiable beaked whale	Visually	08.63773	-056.28852	3106	1	300	full power while on survey line	full power while on survey line	837	none		00:00
10-May-2016	14		11:45	12:11	Pantropical spotted dolphin	Visually	07.89978	-056.42068	2137	100	1400	full power while on survey line	full power while on survey line	1500	none		
12-May-2016		4	22:28	22:30	Unidentifiable dolphin	Acoustically	07.70700	-056.32828	1345	2	1500	full power while on survey line	full power while on survey line	1500	none		00:00
12-May-2016		5	23:03	23:08	Unidentifiable dolphin	Acoustically	07.66883	-056.35267	1466	2	1500	not firing	not firing	1500	none		00:00
19-May-2016		6	4:09	4:11	Unidentifiable dolphin	Acoustically	08.45215	-056.34965	2677	2	1800	full power while on survey line	full power while on survey line	1800	none		00:00
20-May-2016		7	7:10	7:37	Unidentifiable dolphin	acoustically	08.84265	-056.37600	2897	4	1000	not firing	not firing	1000	none		00:00
22-May-2016		8	22:24	23:23	Unidentifiable dolphin	acoustically	08.45418	-056.65300	2530	4	1000	not firing	not firing	1000	none		00:00
03-June-2016	15		12:29	12:30	Unidentifiable dolphin	visually	08.89283	-056.65928	3044	2	300	not firing	not firing	580	none	00:00	00:00
06-June-2016	16		14:56	14:58	Spinner dolphin	visually	08.46977	-056.66849	2793	80	600	full power while on survey line	full power while on survey line	600	none	00:00	00:00
10-Jun-2016		9	6:44	6:47	Unidentifiable dolphin	acoustically	08.81343	-056.48455	3045	2	1500	not firing	not firing	1500	none	00:00	00:00

Date	Visual Det. #	Acoustic Det. #	Time at Initial Det.	Time at Last Det.	Common Name	Detection Method	Latitude	Longitude	Water Depth (m)	No. of Animals	Range when First Detected	Source Activity at First Det.	Source Activity at Last Det.	Closest distance to source (m)	Mitigation Actions	Total Duration Animals Observed inside EZ	Total Duration of Production Loss
12-Jun-2016	17		12:29	12:32	Pantropical spotted dolphin	visually	08.59130	-056.68162	2767	10	100	full power while on survey line	full power while on survey line	680	none	00:00	00:00
15-Jun-2016	18		22:15	22:17	Unidentifiable whale	visually	08.20167	-056.60167	2322	1	1000	full power while on survey line	full power while on survey line	1500	none	00:00	00:00
18-Jun-2016		10	3:03	3:07	Unidentifiable dolphin	acoustically	07.97215	-056.50000	2127	1	1000	full power while on survey line	full power while on survey line	1000	none		00:00
18-Jun-2016	19		12:29	12:33	Unidentifiable whale	visually	08.39858	-056.60995	2599	1	2000	full power while on survey line	full power while on survey line	1000	none	00:00	00:00
27-Jun-2016	20		14:13	14:36	Pantropical spotted dolphin	visually	08.55483	-056.53190	2815	30	100	full power while on survey line	full power while on survey line	580	none	00:00	00:00
27-Jun-2016	21		15:43	16:32	Pantropical spotted dolphin	visually	08.42527	-056.53418	2666	30	350	full power while on survey line	full power while on survey line	485	none	00:00	00:00
29-Jun-2016	22		20:20	20:25	Sperm whale	visually	08.68422	-056.55772	2913	1	300	full power while on survey line	full power while on survey line	780	none	00:00	00:00
01-Jul-2016	23		15:24	15:25	Spinner dolphin	visually	08.20915	-056.50747	2430	15	650	full power while on survey line	full power while on survey line	860	none	00:00	00:00
11-Jul-2016		11	1:10	1:34	Unidentifiable dolphin	acoustically	08.65758	-056.70718	2899	4	1500	full power while on survey line	full power while on survey line	1500	none	00:00	00:00
15-Jul-2016		12	1:19	1:32	Unidentifiable dolphin	acoustically	08.67695	-056.72610	2821	3	1500	full power while on survey line	full power while on survey line	1500	none	00:00	00:00
15-Jul-2016		13	2:15	2:20	Unidentifiable dolphin	acoustically	08.60683	-056.72640	2467	3	1200	full power while on survey line	full power while on survey line	1200	none	00:00	00:00
15-Jul-2016		14	3:47	4:02	Unidentifiable dolphin	acoustically	08.48968	-056.72717	2636	4	1000	full power while on survey line	full power while on survey line	1000	none	00:00	00:00
18-Jul-2016		15	0:34	0:40	Unidentifiable dolphin	acoustically	08.64185	-056.74250	2788	2	1500	full power while on survey line	full power while on survey line	1500	none	00:00	00:00
18-Jul-2016		16	3:15	3:29	Unidentifiable dolphin	acoustically	08.42110	-056.74078	2433	4	1500	full power while on survey line	full power while on survey line	1500	none	00:00	00:00
18-Jul-2016	24		10:55	11:03	Unidentifiable beaked whale	visually	08.53655	-056.85025	2615	1	2500	full power while on survey line	full power while on survey line	3100	none		00:00
20-Jul-2016	25		11:07	11:39	Spinner dolphin	visually	08.65650	-056.81087	2762	100	2000	full power while on survey line	full power while on survey line	1070	none		00:00
20-Jul-2016	26		14:50	14:53	Unidentifiable dolphin	visually	08.91803	-056.81168	3027	4	2000	full power while on survey line	full power while on survey line	2300	none		00:00
21-Jul-2016		17	4:32	4:36	Unidentifiable dolphin	acoustically	08.13485	-056.73510	2675	3	1200	not firing	not firing	1200	none		00:00
22-Jul-2016	27		11:52	12:58	Bryde's whale	visually	09.10263	-056.98917	3087	2	1800	not firing	not firing	2200	none		00:00

Date	Visual Det. #	Acoustic Det. #	Time at Initial Det.	Time at Last Det.	Common Name	Detection Method	Latitude	Longitude	Water Depth (m)	No. of Animals	Range when First Detected	Source Activity at First Det.	Source Activity at Last Det.	Closest distance to source (m)	Mitigation Actions	Total Duration Animals Observed inside EZ	Total Duration of Production Loss
02-Aug-2016	28		19:52	19:56	Sperm whale	visually	08.59483	-056.99615	2661	2	5000	not firing	not firing	5430	none		00:00
04-Aug-2016		18	1:50	2:09	Unidentifiable dolphin	acoustically	08.88523	-056.87285	2899	3	1500	full power while on a survey	full power while on a survey line	1500	none		00:00
11-Aug-2016		19	1:11	1:29	Unidentifiable dolphin	acoustically	08.89125	-056.92425	2844	3	1500	full power while on a survey	full power while on a survey	1500	none		0:00
12-Aug-2016		20	2:21	2:47	Unidentifiable dolphin	acoustically	08.67013	-057.00000	2679	2	1200	not firing	not firing	1200	none		0:00
12-Aug-2016		21	5:50	6:11	Unidentifiable dolphin	acoustically	08.95213	-057.08207	2855	4	1000	full power while on a survey line	full power while on a survey line	1000	none		0:00
17-Aug-2016	29		18:14	18:33	Melon-headed whale	visually	08.94688	-056.97955	3033	15	700	full power while on a survey	full power while on a survey	700	none		0:00

APPENDIX K – Marine Fish of Guyana

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Appendix K. Finfish species from Zone (McConnell, 1962)

Scientific Name
Abudefduf sp.
Acanthurus hepatus
Alutera monoceros
Alutera schoepfi
Alutera ventralis
Anisotremus virginicus
Antennarius scaber
Antigonia capros
Balistes carolinensis
Balistes vetula
Bathystoma aurolineatum
Bathystoma rimator
Bathystoma striatum
Bellator militaris
Bodianus sp.
Bothus sp.
Calamus proridens
Caulolatilus guppyi
Chaetodon bimaculatus
Chaetodon sp.
Carcharhinus acronatus
Coryphaena hippurus
Cryptomus sp.
Cubiceps sp.
Cyclopsetta fimbriata
Dactylopterus volitans
Decapterus punctatus
Decapturus macarellus
Diplectrum formosum
Diplectrum radiale
Diplectrum sp.
Eqeus lanceolatus
Eucinostomus gula
Fistularia petimba
Gymnachirus sp.
Gymnothorax ocellatus
Haemulon melanurum
Haemulon sciurus
Haemulon steindachneri
Halichoeres sp.
Halieutichthys sp.
Hippocampus longirostris
Holocanthus tricolor

Holocentrus ascensionis
Holocentrus bullisi
Lactophrys tricornis
Lutjanus analis
Lutjanus aya
Lutjanus spp.
Lutjanus synagris
Monocanthus ciliatus
Monocanthus hispidus
Mullus sp.
Mustelus sp.
Ocyurus p.
Ogocephalus vespertilio
Pomacanthus arcuatus
Pomacanthus paru
Priacanthus arenatus
Prionodes phoebe
Prionotus sp.
Psenes sp.
Rhinobatos percellens
Rhomboplites aurorubens
Rypticus sp.
Saurida sp.
Scoliodon sp.
Scoliodon terrae-novae
Scorpaena agassizii
Scorpaena brasiliensis
Scorpaena plumieri
Scorpaena sp.
Selar crumenophthalmus
Spariosoma aqualidum
Sphoeroides dorsalis
Sphoeroides marmoratus
Syacium papillosum
Synodus foetens
Synodus intermedius
Synodus poeyi
Trachinocephalus myops
Trachurus lathami
Upeneus maculatus
Upeneus parvus

APPENDIX L – Air Quality Modeling Report

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Appendix L-Air Quality Modeling Report

The business of sustainability

ERM

TABLE OF CONTENTS

1.0 INTRODUCTION 1
1.1 PURPOSE 1
2.0 AIR QUALITY MODELING METHODOLOGY 2
2.1 MODEL INPUTS: SOURCE CHARACTERISTICS AND EMISSIONS 2
2.2 RECEPTORS 5
2.3 MODEL SELECTION 6
2.4 METEOROLOGICAL DATA 7
3.0 MODEL RESULTS 10
3.1 AMBIENT AIR QUALITY GUIDELINES AND CONCENTRATIONS 10
3.2 MODEL RESULTS 10

LIST OF TABLES

Table 2-1 Source Parameters for Model Input
Table 2-2 Flare Calculations
Table 2-3 Annual Air Emissions Summary
Table 3-1 WHO Ambient Air Quality Guidelines
Table 3-2 Modeling Results Summary at Potential Onshore Receptor Locations

LIST OF FIGURES

Figure 1-1 Air Quality Modeling Domain
Figure 2-1 Air Quality Modeling Receptor Locations
Figure 2-2 Wind Roses: 10 meter Level
Figure 2-3 Wind Roses: 240 meter Level

LIST OF ACRONYMS

AM3	Actual cubic meters
AOI	Area of Influence
Cal/sec	Calories/second
CALPUFF	CALifornia PUFF model
CO	Carbon Monoxide
DC	Drill Centre
EEPGL	Esso Exploration and Production Guyana Limited
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
ERM	Environmental Resources Management
FPSO	Floating Production Storage and Offloading (Vessel)
H_2S	Hydrogen Sulfide
HHV	Higher Heating Value
K	Degrees Kelvin
kbd	Thousand barrels per day
m	Meters
m^3	Cubic Meters
MMBtu	Million British Thermal Units
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
PDA	Project Development Area

PM10	Particulate Matter (less than 10 microns)
PM25	Particulate Matter (less than 2.5 microns)
ppb	Parts Per Billion
ppg	Pounds Per Gallon
ppm	Parts Per Million
SO_2	Sulfur Dioxide
TOR	Terms Of Reference
VOC	Volatile Organic Compounds
$\mu g/m^3$	Micrograms per cubic meter
UTM	Universal Transverse Mercator (East or North)
WHO	World Health Organization
WRF	Weather Research and Forecasting (meteorological model)

1.0 INTRODUCTION

1.1 Purpose

For the production of an Environmental Impact Assessment (EIA) of the Liza Phase 1 Development Project (the Project), Esso Exploration and Production Guyana Limited (EEPGL) commissioned ERM to perform modeling of air emissions from the Project, to estimate concentrations at locations onshore where exposure to these concentrations may occur. This Appendix provides a description of modeling methodology including source characteristics and emissions, receptor locations, model selection, meteorological data development, and results. Figure 1-1 displays the modeling domain used in this analysis, showing the locations of the main Project point sources (the FPSO and Drill Centers DC1 and DC2), and of the area sources (including support vessels, construction vessels, and other sources without a fixed location), as configured for the modeling. Terrain elevations used in the modelling are also depicted on this figure.

Figure 1-1 Air Quality Modeling Domain



2.0 AIR QUALITY MODELING METHODOLOGY

2.1 Model Inputs: Source Characteristics and Emissions

Emissions generated by the Project generally emanate from two source categories: a) specific point sources such as the power generating units and diesel engines on drill ships and on the FPSO, flares used (non-routinely) to combust produced gas when not consumed as fuel gas on the FPSO or re-injected, vents and onboard incineration of wastes; and b) general area sources such as support vessels, construction vessels, tug boats, and helicopters. Such emissions contribute to increases in the ambient air concentrations of certain pollutants at onshore receptors.

Modeling stack sources involves first calculating plume rise, i.e. how high the plume rises due to momentum and buoyancy of the release. Plume rise is added to the physical stack height to determine final plume height, and the plume is tracked as it is transported downwind and dispersed by atmospheric turbulence. Stack parameters needed for model input include the physical stack height, internal diameter, exhaust velocity, elevation of the base of the stack, and exhaust temperature. Table 2-1 displays the values of the parameters that were used in this analysis, along with the stack locations in UTM coordinates. Table 2-1 also displays area source characteristics. These values are based on current knowledge of the Project design. If the parameters change as a result of final design considerations, the modeling will be reviewed to determine if additional analysis is necessary. It should be noted that due to the distance from Project sources to onshore receptors, modeled concentrations are not very sensitive to changes in physical parameters.

Table 2-1 Source Parameters for Model Input

Name	UTME	UTMN	Base Elevation	Height	Exhaust Flow	Exhaust Temp	Diameter	Exhaust Velocity
	m	m	m	m	Am3/hour	K	m	m/s
FPSO Sources								
Combustion Turbines	501000	885512	30	28.00	638,716	803.15	3.100	23.507
Flare - HP Normal Flaring (Note 1)	501000	885512	30	136.29	n/a	1273.00	0.243	20.000
Flare - LP Normal Flaring (Note 1)	501000	885512	30	135.72	n/a	1273.00	0.133	20.000
Flare - HP Full Flaring (Note 1)	501000	885512	30	194.51	n/a	1273.00	13.378	20.000
Flare - LP Full Flaring (Note 1)	501000	885512	30	162.48	n/a	1273.00	5.962	20.000
Auxiliary Boiler (Heaters)	501000	885512	30	24.40	98,457	681.15	1.150	26.330
Essential Services Gens	501000	885512	30	15.50	14,791	578.15	0.305	56.234

Emergency Generators	501000	885512	30	3.20	15,229	719.15	0.300	59.845
Incinerator	501000	885512	30	10.00	5,000	600.00	0.500	7.074
Deck Cranes	501000	885512	30	28.90	7,360	795.55	0.522	9.539
Export Tanker	501000	885512	30	24.40	98,457	681.15	1.150	26.330
Drill Center Sources								
Drill Center1	502901	891211	0	22.00	73,470	682.60	0.800	40.601
Drill Center2	505105	898442	0	22.00	73,470	682.60	0.800	40.601
Area Sources								
Support Vessels Project Area	Note 2		0	10.00	n/a	n/a	n/a	n/a
Support Vessels FPSO shore to Project Area								
Helicopters	Note 2		0	300.00	n/a	n/a	n/a	n/a
General Project Area (Construction)	Note 3		0	10.00	n/a	n/a	n/a	n/a

Notes

1. Effective height/diameter calculated based on heat release to maintain buoyancy flux
2. Area sources to distribute emissions between shore and Project area
3. General area Source in Project area

Flares associated with the Project are modeled as stack sources, with adjustments made to account for and maintain buoyancy of the hot plume. Table 2-2 displays the inputs and results of the calculations that were conducted to estimate an effective diameter and an effective stack height that accomplishes this goal.

Table 2-2 Flare Calculations

Description	Gas Usage	Gas HHV	Total heat release	Total heat release	Sensible heat release	Effective stack diameter[1]	Physical Stack Height	Effective Release Height[1]
	MMscf/hr	Btu/scf	MMBtu/hr	cal/sec	cal/sec	m		m
Purge and Pilot Gas								
HP	1.50E-03	1284.6	1.9	1.35E+05	6.07E+04	0.243	135	136.29
LP	3.35E-04	1707.4	0.6	4.00E+04	1.80E+04	0.133	135	135.72
Max Flaring (Commissioning, Non Routine)								
HP	4.53	1284.6	5,820.7	4.07E+08	1.83E+08	13.378	135	194.51
LP	0.68	1707.4	1,156.1	8.09E+07	3.64E+07	5.962	135	162.48

NOTES

1 - Effective diameter and effective stack height calculated based on U.S. EPA guidance, using 20 m/s exit velocity and 1273 K exhaust temp

Emissions to air from the Project have been estimated based on a number of factors including activity levels, fuel type, equipment capacities, and standard emission factors that are published by the USEPA in the publication *AP-42: Compilation of Air Pollutant Emission* Factors (AP-42). As described in AP-42, an emission factor is a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., milligrams of NO_x emitted per cubic meter of natural gas combusted). The use of these factors allows estimation of emissions from various sources of air pollution. In most cases, these factors are averages of available data of an acceptable quality, and are generally assumed to be representative of long-term averages for a particular type of source. Table 2-3 provides a summary of expected annual emissions from various Project activities for three time periods: 2018-2019 (Drilling, SURF Installation, and operation of related support and installation vessels); 2020-2021 (Drilling, operation of related support vessels, FPSO startup and associated temporary non-routine flaring, tanker loading); and 2022-2040 (production operations following cessation of drilling, including temporary non-routine flaring, operation of related support vessels and tanker loading). For each of the time periods, the annual emissions summarized in Table 2-3 represent the overall maximum anticipated for any one year during that time period for the source category indicated. While there are some differences in emissions for different years within the time periods, they are relatively minor and the use of maximum emissions for the impact assessment provides a degree of conservatism in the results. Detailed listings of emissions by year are displayed in Table 2-4 (found at the end of this report).

Table 2-3 Annual Air Emissions Summary

Pollutant	Source Category	Annual Emissions (tonnes)		
		2018-2019	2020-2021	2022-2040
Nitrogen Oxides (NOx)	FPSO	0.0	1,637.2	1,542.9
	FPSO Flaring (temporary, non-routine)	0.0	372.8	171.9
	Tanker Loading	0.0	131.1	136.5
	Area Sources	2,382.9	1,122.5	1,122.5
	Drill ship	1,253.0	1,670.1	0.0
	Total	3,635.9	4,933.6	2,973.9
Sulfur Oxides (SO_2)	FPSO	0.0	45.0	47.1
	FPSO Flaring (temporary, non-routine)	0.0	0.0	3.8
	Tanker Loading	0.0	109.9	114.5
	Area Sources	81.4	38.7	38.7

Pollutant	Source Category	Annual Emissions (tonnes)		
		2018-2019	2020-2021	2022-2040
	Drill ship	42.3	56.0	0.0
	Total	123.7	249.6	204.0
Particulate Matter (PM)	FPSO	0.0	40.2	33.6
	FPSO Flaring (temporary, non-routine)	0.0	10.7	4.9
	Tanker Loading	0.0	9.2	9.6
	Area Sources	167.5	78.9	78.9
	Drill ship	88.1	117.4	0.0
	Total	255.6	256.4	127.0
Carbon Monoxide (CO)	FPSO	0.0	422.4	402.8
	FPSO Flaring (temporary, non-routine)	0.0	2,028.3	935.6
	Tanker Loading	0.0	27.3	28.4
	Area Sources	496.4	233.9	233.9
	Drill ship	261.0	347.9	0.0
	Total	757.5	3,059.8	1,600.6
Hydrogen Sulfide (H_2S)	FPSO Flaring (temporary, non-routine)	n/a	0.0	0.1
Volatile Organic Compounds (VOCs)	All Sources	92.6	10,248.6	10,717.5
Greenhouse Gasses (GHGs [kilotonnes CO_2-equivalents])	All Sources	190.2	1,508.5	976.7

Notes:

1. The years indicated for the various Project stages reflect the current project execution plan, and remain subject to adjustment.
2. VOC and GHG emissions are shown in this table but were not included in the impact assessment modeling, as no ambient air quality criteria have been established for these substances.
3. PM emissions represent total PM; for the purpose of the impact assessment, the total PM values were used for modeling of both PM_{10} and $PM_{2.5}$ emissions (producing conservatively high modelling results).
4. The emission rates in this table reflect annual totals. In some cases, the activities generating the emission are not continuous during the year, or do not operate at full capacity throughout the year. For these sources, the annual emissions reflect this non-continuous operation over the year. However, for the purpose of modeling conducted to compare with short-term (up to 24-hour) guidelines, activities were assumed to be operating at full capacity for the simulated period, to reflect maximum short-term emission rates.

2.2 Receptors

A grid of potential receptor points was established for onshore areas in the AOI. The intent of this grid was to identify maximum predicted pollutant concentrations

generated by the Project across the onshore portion of the AOI. The methodology utilized was to predict maximum concentrations at all of the onshore grid points using the dispersion model, and then to compare these maximum values to concentrations that may potentially result in significant impacts; if the maximum predicted concentrations are determined to be not significant, it follows that air quality impacts on any specific receptors throughout the onshore AOI also would be not significant. For this reason specific locations of sensitive receptors were not identified at the onset of modeling. Figure 2-1 illustrates the locations of the receptor points modeled. For each receptor, terrain elevations were specified and are used by CALPUFF to model plume interaction with onshore terrain.

Figure 2-1 Air Quality Modeling Receptor Locations



2.3 Model Selection

The CALPUFF model (a non-steady-state model used in the U.S. and around the globe for long-range transport and complex wind modeling) was selected for use in the

assessment. CALPUFF is a Lagrangian "puff" model that treats a plume as a series of puffs that it tracks as the wind carries the plume towards potential receptor locations. The selection of CALPUFF was based on the long distance between the principal Project-related sources and the receptors. As shown in Figure 2-1, the distance from the PDA to the closest shoreline is greater than 190 kilometers. At this distance, emission plumes released from Project point sources would travel for 10 hours, assuming an average wind speed of 5 meters/second (typical for the area). During this transport time winds can change direction and speed. Accordingly, prediction of plume dispersion is most appropriately accomplished with a non-steady state model. Additionally, due to the vast differences in surface characteristics between open water and land, coastal areas frequently experience a classic meteorological phenomenon known as the land-sea breeze circulation (LSBC). This phenomenon is due to the diurnal surface temperature differences that develop between the land and the open water. LSBC effects can play an important role in the dispersion modeling analysis of the emission sources as plumes interact with the onshore receptors; CALPUFF, combined with gridded meteorological data, is capable of accounting for the LSBC phenomenon. The modeling was conducted with CALPUFF (Version 7.2.1, level 150618). CALPUFF was run for each source individually, and post-processing was used to calculate pollutant-specific totals for applicable averaging periods.

2.4 Meteorological Data

The Weather Research and Forecasting (WRF) model was used to develop hourly meteorology inputs for CALPUFF for one year – calendar year 2014. WRF is a prognostic meteorological model that creates profiles of winds and temperature at grid points across a domain. The grid spacing chosen for this analysis was 12 km, so that a two-dimensional profile of hourly winds and temperature was developed every 12 km within the domain shown in Figure 2-1. The profiles were used by CALPUFF to simulate the transport and dispersion of emission plumes from Project sources, allowing the model to calculate ambient constituent concentrations at potential receptor locations accounting for changes in meteorology as the plumes travel downwind.

Illustrations of how WRF accounts for the effects on meteorological variables of height above the surface and underlying land use characteristics (i.e. overland and overwater) are provided in Figures 2-2 and 2-3. These figures display the locations of the 12 km grid points (WRF created profiles of wind and temperature for each of these locations). At every other grid point, wind roses were created to illustrate wind direction and speed frequencies at that location. Wind roses shown in Figure 2-2 were created from the profile level 10 meters above the surface; the wind roses shown in Figure 2-3 were created from the profile level 240 meters above the surface (240 meters is representative of typical plume heights for the larger Project sources). At a height of 240 meters, the effects of the land surface on winds is considerably less pronounced than the effects at 10 meters. Figure 2-2 (10 meter level) shows a pronounced effect on wind speed over land where surface friction acts to slow down the wind.

Figure 2-2 Wind Roses: 10 meter Level

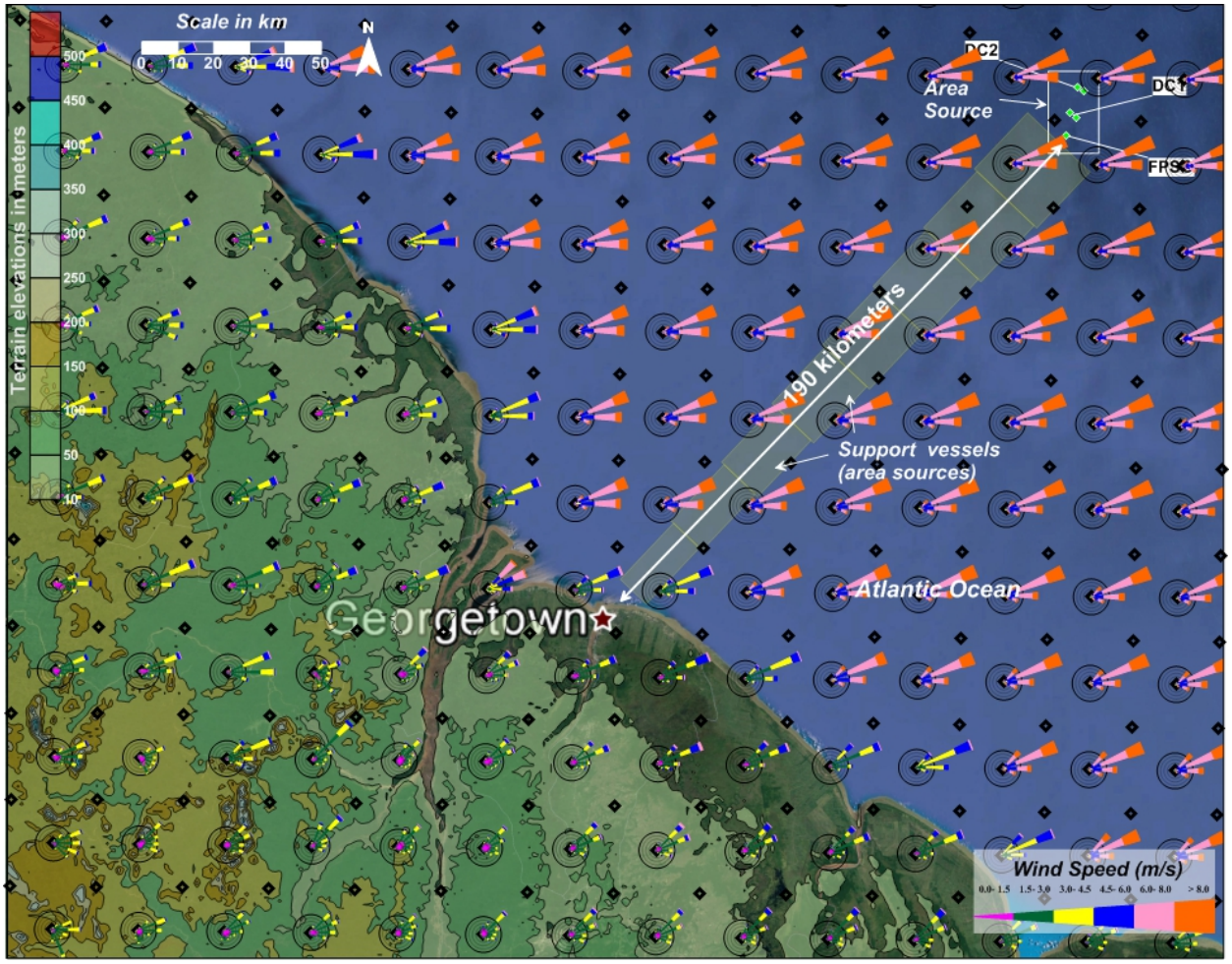
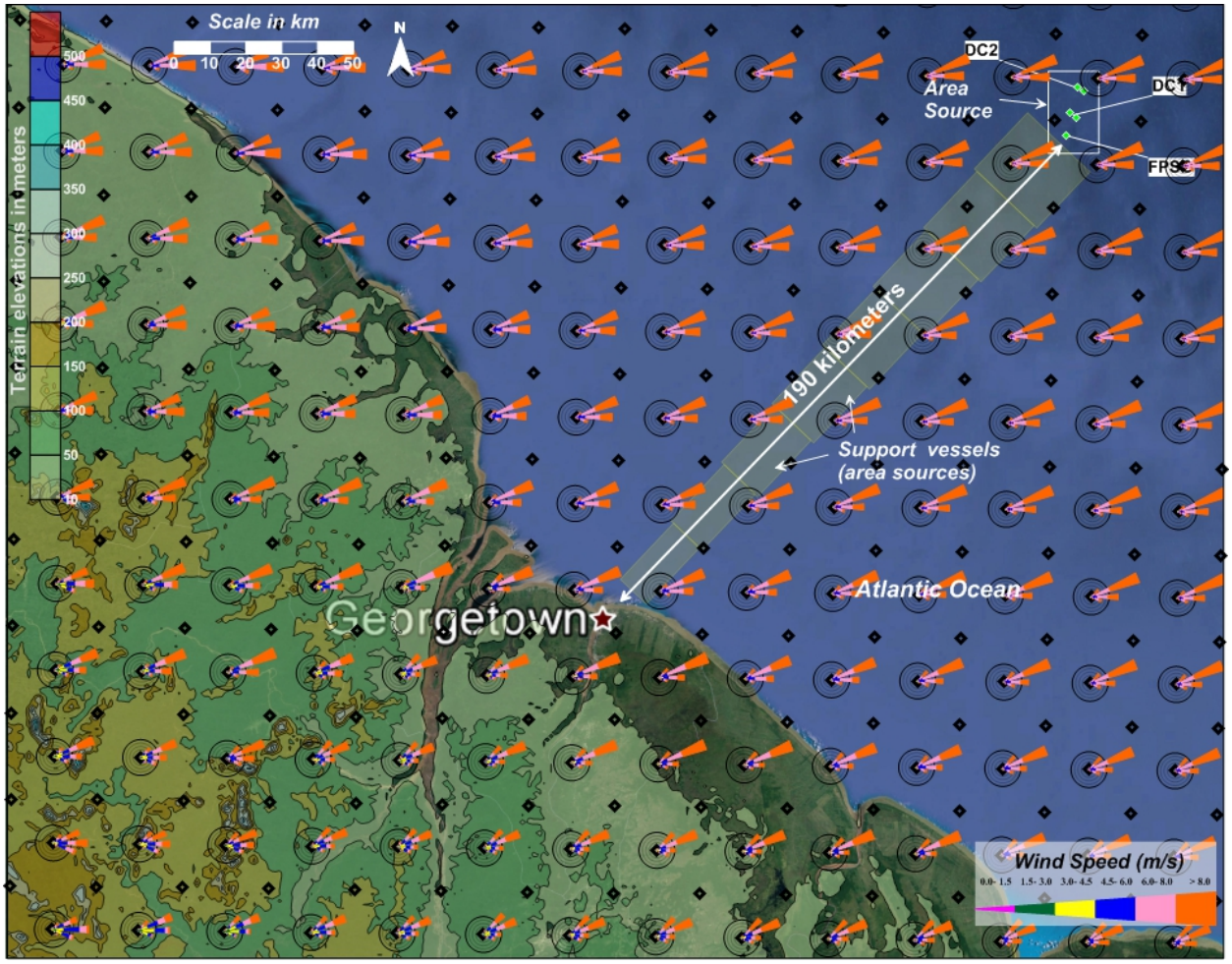


Figure 2-3 Wind Roses: 240 meter Level



3.0 MODEL RESULTS

3.1 Ambient Air Quality Guidelines and Concentrations

Ambient air quality guidelines are concentration levels in air that are established by governing authorities to protect human health in locations where exposure can occur. These generally include a margin of safety to ensure that vulnerable individuals are also protected. Guyana has not established specific ambient air quality standards; therefore, the guidelines used for reference in this assessment were those established by the World Health Organization (WHO). The WHO guidelines are summarized in Table 3-1. These guidelines were published in *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide - Global Update 2005* (WHO, 2005) except for CO and H_2S, which were published in WHO *Air Quality Guidelines for Europe, 2nd edition, 2000* (WHO, 2000).

Table 3-1 WHO Ambient Air Quality Guidelines

Pollutant	Averaging Period	Guideline Concentration (µg/m³)
NO_2	1-hour	200
	Annual	40
SO_2	10-minute	500
	24-hour	20
PM_{10}	24-hour	50
	Annual	20
$PM_{2.5}$	24-hour	25
	Annual	10
CO	1-hour	30,000
	8-hour	10,000
H_2S	30-minute	7

3.2 Model Results

Using the methodology described above, modeling was conducted with CALPUFF to estimate maximum ambient concentrations of Project-generated constituents of interest at potential onshore receptor locations. Model results were developed for each modeled constituent, for each averaging period with an associated WHO guideline concentration (Table 3-1). Results are summarized in Table 3-2.

Table 3-2 Modeling Results Summary at Potential Onshore Receptor Locations

Pollutant	Averaging Period	Guideline Concentration (µg/m³)	Maximum Predicted Concentration (µg/m³)			Percent of WHO Guideline		
			2018-2019	2020-2021	2022-2040	2018-2019	2020-2021	2022-2040
NO_2	1-hour	200	1.3	2.1	1.5	0.6%	1.0%	0.7%
	Annual	40	0.1	0.2	0.1	0.3%	0.4%	0.2%
SO_2	10-minute	500	0.1	0.7	0.6	0.0%	0.1%	0.1%
	24-hour	20	0.0	0.2	0.2	0.1%	0.9%	0.9%
PM_{10}	24-hour	50	0.0	0.1	0.0	0.1%	0.1%	0.1%
	Annual	20	0.0	0.0	0.0	0.1%	0.1%	0.0%
$PM_{2.5}$	24-hour	25	0.0	0.1	0.0	0.2%	0.2%	0.1%
	Annual	10	0.0	0.0	0.0	0.1%	0.1%	0.0%
CO	1-hour	30,000	0.3	2.6	2.6	0.0%	0.0%	0.0%
	8-hour	10,000	0.3	1.5	1.4	0.0%	0.0%	0.0%
H_2S	30-minute	7	n/a	n/a	0.00002	n/a	n/a	0.0002%

As shown in this table, maximum modeled concentrations at any onshore receptor are less than or equal to 1% of the applicable guideline for all pollutants and averaging periods. This result is consistent with the expectation that air quality impacts would be minimal, based on the distance of Project emissions sources from the nearest receptor on-shore.

Table 2-4a NOx Emissions By Year

Source Sector	Emissions (tonnes) Modeled for Each Time Period			Emissions (tonnes) Per Year																						
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.00	1509.21	1509.21	0.00E+00	0.00E+00	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03	1.51E+03
Flare - HP Normal Flaring (Note 1)	0.00	0.12	0.06	0.00E+00	0.00E+00	1.23E-01	5.11E-02	5.35E-02	5.55E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.69E-02	5.64E-02	5.69E-02
Flare - LP Normal Flaring (Note 1)	0.00	0.18	0.09	0.00E+00	0.00E+00	1.84E-01	7.64E-02	8.00E-02	8.29E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.51E-02	8.43E-02	8.51E-02
Flare - HP Full Flaring (Note 1)	0.00	324.00	149.45	0.00E+00	0.00E+00	3.24E+02	1.34E+02	1.40E+02	1.46E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.49E+02	1.48E+02	1.49E+02
Flare - LP Full Flaring (Note 1)	0.00	48.46	22.35	0.00E+00	0.00E+00	4.85E+01	2.01E+01	2.10E+01	2.18E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.24E+01	2.21E+01	2.24E+01
Auxiliary Boiler (Heaters)	0.00	14.26	14.26	0.00E+00	0.00E+00	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01	1.43E+01
Essential Services Gens	0.00	101.68	7.84	0.00E+00	0.00E+00	1.02E+02	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00	7.84E+00
Emergency Generators	0.00	0.20	0.20	0.00E+00	0.00E+00	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01	1.96E-01
Incinerator	0.00	1.87	1.44	0.00E+00	4.32E-01	1.87E+00	1.87E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00	1.44E+00
Deck Cranes	0.00	9.94	9.94	0.00E+00	0.00E+00	4.97E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00	9.94E+00
Export Tanker	0.00	131.06	136.54	0.00E+00	0.00E+00	5.89E+01	1.31E+02	1.36E+02	1.36E+02	1.37E+02	1.24E+02	1.18E+02	9.95E+01	8.54E+01	6.93E+01	5.70E+01	4.86E+01	4.26E+01	3.78E+01	3.50E+01	3.26E+01	2.74E+01	2.21E+01	1.88E+01	1.66E+01	1.51E+01
Drill Center1	626.49	835.04	0.00	2.78E+02	6.26E+02	8.35E+02	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	626.49	835.04	0.00	2.78E+02	6.26E+02	8.35E+02	1.04E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	579.41	740.36	740.36	1.93E+02	5.79E+02	7.40E+02	7.40E+02	7.40E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02	4.75E+02
Support Vessels FPSO shore to Project Area	289.71	370.18	370.18	9.66E+01	2.90E+02	3.70E+02	3.70E+02	3.70E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02	2.37E+02
Helicopters	17.43	11.98	11.98	5.81E+00	1.74E+01	1.20E+01	1.20E+01	1.20E+01	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00	2.18E+00
General Project Area (Construction)	1496.33	0.00	0.00	0.00E+00	1.50E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	3635.86	4933.59	2973.89	852	3636	4856.4	3160.1	2962.7	2561.1	2565.7	2552.8	2547.3	2528.7	2514.6	2498.5	2486.2	2477.8	2471.8	2467.0	2464.2	2461.8	2456.6	2451.3	2448.0	2444.2	2444.3

Table 2-4b SO_2 Emissions By Year

Source Sector	Maximum emissions by source sector			Emissions (tonnes) Per Year																						
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.0	39.9	45.3	0.00E+00	0.00E+00	3.99E+01	3.99E+01	3.99E+01	3.99E+01	4.00E+01	4.08E+01	4.15E+01	4.24E+01	4.36E+01	4.48E+01	4.34E+01	4.38E+01	4.43E+01	4.43E+01	4.43E+01	4.43E+01	4.48E+01	4.45E+01	4.46E+01	4.53E+01	4.52E+01
Flare - HP Normal Flaring (Note 1)	0.0	0.0	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.87E-05	2.12E-04	3.68E-04	5.72E-04	8.52E-04	1.13E-03	8.03E-04	9.19E-04	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.15E-03	1.06E-03	1.09E-03	1.25E-03	1.23E-03
Flare - LP Normal Flaring (Note 1)	0.0	0.0	0.0	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.79E-05	3.17E-04	5.50E-04	8.55E-04	1.27E-03	1.69E-03	1.20E-03	1.37E-03	1.55E-03	1.54E-03	1.54E-03	1.54E-03	1.72E-03	1.59E-03	1.62E-03	1.87E-03	1.84E-03
Flare - HP Full Flaring (Note 1)	0.0	0.0	3.3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.90E-02	5.57E-01	9.66E-01	1.50E+00	2.24E+00	2.98E+00	2.11E+00	2.41E+00	2.71E+00	2.71E+00	2.70E+00	2.71E+00	3.01E+00	2.79E+00	2.85E+00	3.29E+00	3.22E+00
Flare - LP Full Flaring (Note 1)	0.0	0.0	0.5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.33E-03	8.33E-02	1.44E-01	2.25E-01	3.34E-01	4.45E-01	3.15E-01	3.61E-01	4.06E-01	4.06E-01	4.04E-01	4.05E-01	4.51E-01	4.17E-01	4.27E-01	4.92E-01	4.82E-01
Auxiliary Boiler (Heaters)	0.0	0.0	0.1	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.54E-03	1.75E-02	3.03E-02	4.71E-02	7.02E-02	9.34E-02	6.62E-02	7.57E-02	8.52E-02	8.51E-02	8.49E-02	8.49E-02	9.46E-02	8.76E-02	8.96E-02	1.04E-01	1.01E-01
Essential Services Gens	0.0	3.4	0.3	0.00E+00	0.00E+00	3.41E+00	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01	2.63E-01
Emergency Generators	0.0	0.0	0.0	0.00E+00	0.00E+00	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03	4.59E-03
Incinerator	0.0	1.3	1.0	0.00E+00	3.11E-01	1.35E+00	1.35E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00	1.04E+00
Deck Cranes	0.0	0.3	0.3	0.00E+00	0.00E+00	1.67E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01	3.33E-01
Export Tanker	0.0	109.9	114.5	0.00E+00	0.00E+00	4.93E+01	1.10E+02	1.14E+02	1.14E+02	1.14E+02	1.04E+02	9.90E+01	8.34E+01	7.16E+01	5.81E+01	4.78E+01	4.08E+01	3.57E+01	3.16E+01	2.93E+01	2.73E+01	2.30E+01	1.85E+01	1.58E+01	1.39E+01	1.26E+01
Drill Center1	21.2	28.0	0.0	9.33E+00	2.10E+01	2.80E+01	3.50E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	21.2	28.0	0.0	9.33E+00	2.10E+01	2.80E+01	3.50E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	19.4	24.8	24.8	6.48E+00	1.94E+01	2.48E+01	2.48E+01	2.48E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01	1.59E+01
Support Vessels FPSO shore to Project Area	9.7	12.4	12.4	3.24E+00	9.71E+00	1.24E+01	1.24E+01	1.24E+01	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00	7.96E+00
Helicopters	2.1	1.5	1.5	7.08E-01	2.12E+00	1.46E+00	1.46E+00	1.46E+00	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01	2.66E-01
General Project Area (Construction)	50.2	0.0	0.0	0.00E+00	5.02E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	123.7	249.6	204.0	29	124	188.9	197.4	194.0	180.0	180.3	170.9	167.5	153.3	143.6	132.1	119.4	113.3	109.1	105.0	102.6	100.6	97.2	92.1	89.5	88.9	87.4

Table 2-4c H_2S Emissions By Year

Source Sector	Maximum emissions by source sector			Emissions (tonnes) Per Year																					
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Flare - HP Normal Flaring (Note 1)	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.74E-07	3.11E-06	5.40E-06	8.39E-06	1.25E-05	1.66E-05	1.18E-05	1.35E-05	1.52E-05	1.52E-05	1.51E-05	1.51E-05	1.68E-05	1.56E-05	1.59E-05	1.84E-05
Flare - LP Normal Flaring (Note 1)	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.09E-07	4.65E-06	8.06E-06	1.25E-05	1.87E-05	2.49E-05	1.76E-05	2.01E-05	2.27E-05	2.26E-05	2.26E-05	2.26E-05	2.52E-05	2.33E-05	2.38E-05	2.75E-05
Flare - HP Full Flaring (Note 1)	0.00	0.00	0.05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.19E-04	8.17E-03	1.42E-02	2.20E-02	3.28E-02	4.37E-02	3.09E-02	3.54E-02	3.98E-02	3.98E-02	3.97E-02	3.97E-02	4.42E-02	4.09E-02	4.19E-02	4.82E-02
Flare - LP Full Flaring (Note 1)	0.00	0.00	0.01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.08E-04	1.22E-03	2.12E-03	3.29E-03	4.91E-03	6.53E-03	4.62E-03	5.29E-03	5.96E-03	5.95E-03	5.93E-03	5.94E-03	6.61E-03	6.12E-03	6.26E-03	7.22E-03
Auxiliary Boiler (Heaters)	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Essential Services Gens	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Emergency Generators	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Incinerator	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Deck Cranes	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Export Tanker	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center1	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels FPSO shore to Project Area	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Helicopters	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
General Project Area (Construction)	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	0.0	0.0	0.1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008	0.0094	0.0163	0.0253	0.0377	0.0502	0.0356	0.0407	0.0458	0.0458	0.0456	0.0457	0.0509	0.0471	0.0482	0.0555

Table 2-4d PM Emissions By Year

Source Sector	Maximum emissions by source sector			Emissions (tonnes) Per Year																					
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.0	31.1	31.1	0.00E+00	0.00E+00	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01	3.11E+01
Flare - HP Normal Flaring (Note 1)	0.0	0.0	0.0	0.00E+00	0.00E+00	3.53E-03	1.46E-03	1.53E-03	1.59E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.63E-03	1.61E-03	1.63E-03
Flare - LP Normal Flaring (Note 1)	0.0	0.0	0.0	0.00E+00	0.00E+00	5.27E-03	2.18E-03	2.29E-03	2.37E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.43E-03	2.41E-03	2.43E-03
Flare - HP Full Flaring (Note 1)	0.0	9.3	4.3	0.00E+00	0.00E+00	9.26E+00	3.84E+00	4.02E+00	4.16E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.27E+00	4.23E+00	4.27E+00
Flare - LP Full Flaring (Note 1)	0.0	1.4	0.6	0.00E+00	0.00E+00	1.39E+00	5.74E-01	6.01E-01	6.23E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.39E-01	6.33E-01	6.39E-01
Auxiliary Boiler (Heaters)	0.0	1.1	1.1	0.00E+00	0.00E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00	1.08E+00
Essential Services Gens	0.0	7.1	0.6	0.00E+00	0.00E+00	7.15E+00	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01	5.51E-01
Emergency Generators	0.0	0.0	0.0	0.00E+00	0.00E+00	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02	1.38E-02
Incinerator	0.0	0.1	0.1	0.00E+00	3.04E-02	1.32E-01	1.32E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01	1.01E-01
Deck Cranes	0.0	0.7	0.7	0.00E+00	0.00E+00	3.49E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01	6.99E-01
Export Tanker	0.0	9.2	9.6	0.00E+00	0.00E+00	4.14E+00	9.21E+00	9.54E+00	9.58E+00	9.60E+00	8.69E+00	8.30E+00	6.99E+00	6.01E+00	4.87E+00	4.01E+00	3.42E+00	3.00E+00	2.65E+00	2.46E+00	2.29E+00	1.93E+00	1.55E+00	1.32E+00	1.17E+00	1.06E+00
Drill Center1	44.0	58.7	0.0	1.96E+01	4.40E+01	5.87E+01	7.34E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	44.0	58.7	0.0	1.96E+01	4.40E+01	5.87E+01	7.34E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	40.7	52.0	52.0	1.36E+01	4.07E+01	5.20E+01	5.20E+01	5.20E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01	3.34E+01
Support Vessels FPSO shore to Project Area	20.4	26.0	26.0	6.79E+00	2.04E+01	2.60E+01	2.60E+01	2.60E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01	1.67E+01
Helicopters	1.2	0.8	0.8	4.08E-01	1.23E+00	8.42E-01	8.42E-01	8.42E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01	1.53E-01
General Project Area (Construction)	105.2	0.0	0.0	0.00E+00	1.05E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	255.6	256.4	127.0	59.9	255.6	251.0	140.8	126.6	98.2	98.3	97.4	97.0	95.7	94.7	93.6	92.7	92.1	91.7	91.4	91.2	91.0	90.6	90.3	90.0	89.8	89.8

Table 2-4e CO Emissions By Year

Source Sector	Maximum emissions by source sector			Emissions (tonnes) Per Year																						
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.0	386.7	386.7	0.00E+00	0.00E+00	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02	3.87E+02
Flare - HP Normal Flaring (Note 1)	0.0	0.7	0.3	0.00E+00	0.00E+00	6.71E-01	2.78E-01	2.91E-01	3.02E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.10E-01	3.07E-01	3.10E-01
Flare - LP Normal Flaring (Note 1)	0.0	1.0	0.5	0.00E+00	0.00E+00	1.00E+00	4.16E-01	4.35E-01	4.51E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.63E-01	4.59E-01	4.63E-01
Flare - HP Full Flaring (Note 1)	0.0	1763.0	813.2	0.00E+00	0.00E+00	1.76E+03	7.30E+02	7.64E+02	7.92E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.13E+02	8.06E+02	8.13E+02
Flare - LP Full Flaring (Note 1)	0.0	263.7	121.6	0.00E+00	0.00E+00	2.64E+02	1.09E+02	1.14E+02	1.19E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.22E+02	1.20E+02	1.22E+02
Auxiliary Boiler (Heaters)	0.0	12.0	12.0	0.00E+00	0.00E+00	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01
Essential Services Gens	0.0	21.2	1.6	0.00E+00	0.00E+00	2.12E+01	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00	1.63E+00
Emergency Generators	0.0	0.0	0.0	0.00E+00	0.00E+00	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02	4.08E-02
Incinerator	0.0	0.4	0.3	0.00E+00	9.00E-02	3.90E-01	3.90E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01	3.00E-01
Deck Cranes	0.0	2.1	2.1	0.00E+00	0.00E+00	1.04E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00	2.07E+00
Export Tanker	0.0	27.3	28.4	0.00E+00	0.00E+00	1.23E+01	2.73E+01	2.83E+01	2.84E+01	2.84E+01	2.58E+01	2.46E+01	2.07E+01	1.78E+01	1.44E+01	1.19E+01	1.01E+01	8.88E+00	7.87E+00	7.28E+00	6.78E+00	5.71E+00	4.61E+00	3.92E+00	3.47E+00	3.14E+00
Drill Center1	130.5	174.0	0.0	5.80E+01	1.30E+02	1.74E+02	2.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	130.5	174.0	0.0	5.80E+01	1.30E+02	1.74E+02	2.17E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	120.7	154.2	154.2	4.02E+01	1.21E+02	1.54E+02	1.54E+02	1.54E+02	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01	9.89E+01
Support Vessels FPSO shore to Project Area	60.4	77.1	77.1	2.01E+01	6.04E+01	7.71E+01	7.71E+01	7.71E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01	4.95E+01
Helicopters	3.6	2.5	2.5	1.21E+00	3.63E+00	2.50E+00	2.50E+00	2.50E+00	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01	4.54E-01
General Project Area (Construction)	311.7	0.0	0.0	0.00E+00	3.12E+02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	757.5	3059.8	1600.6	177.5	757.5	3043.7	1547.9	1544.4	1491.7	1515.6	1512.9	1511.8	1507.9	1505.0	1501.6	1499.0	1497.3	1496.0	1495.0	1494.4	1493.9	1492.9	1491.8	1491.1	1481.8	1490.3

Table 2-4f VOC Emissions By Year

Source Sector	Emissions (tonnes) Modeled for Each Time Period			Emissions (tonnes) Per Year																						
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.00	7.91	7.91	0.00E+00	0.00E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00	7.91E+00
Flare - HP Normal Flaring (Note 1)	0.00	0.27	0.30	0.00E+00	0.00E+00	6.49E-01	2.69E-01	2.81E-01	2.92E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.99E-01	2.96E-01	2.99E-01
Flare - LP Normal Flaring (Note 1)	0.00	0.40	0.45	0.00E+00	0.00E+00	9.69E-01	4.02E-01	4.20E-01	4.36E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.47E-01	4.43E-01	4.47E-01
Flare - HP Full Flaring (Note 1)	0.00	706.32	786.29	0.00E+00	0.00E+00	1.70E+03	7.06E+02	7.39E+02	7.66E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.86E+02	7.79E+02	7.86E+02
Flare - LP Full Flaring (Note 1)	0.00	105.54	117.49	0.00E+00	0.00E+00	2.55E+02	1.06E+02	1.10E+02	1.14E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.17E+02	1.16E+02	1.17E+02
Auxiliary Boiler (Heaters)	0.00	0.41	0.41	0.00E+00	0.00E+00	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01	4.13E-01
Essential Services Gens	0.00	0.20	0.20	0.00E+00	0.00E+00	2.60E+00	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01	2.01E-01
Emergency Generators	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Incinerator	0.00	0.00	0.00	0.00E+00	1.09E-03	4.72E-03	4.72E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03
Deck Cranes	0.00	0.25	0.25	0.00E+00	0.00E+00	1.27E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01	2.54E-01
Export Tanker	0.00	3.35	3.49	0.00E+00	0.00E+00	1.51E+00	3.35E+00	3.47E+00	3.49E+00	3.49E+00	3.16E+00	3.02E+00	2.55E+00	2.19E+00	1.77E+00	1.46E+00	1.24E+00	1.09E+00	9.66E-01	8.95E-01	8.33E-01	7.02E-01	5.66E-01	4.82E-01	4.26E-01	3.86E-01
Drill Center1	16.03	2.67	0.00	7.12E+00	1.60E+01	2.14E+01	2.67E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	16.03	2.67	0.00	7.12E+00	1.60E+01	2.14E+01	2.67E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	14.83	18.95	12.15	4.94E+00	1.48E+01	1.89E+01	1.89E+01	1.89E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01	1.22E+01
Support Vessels FPSO shore to Project Area	7.41	9.47	6.08	2.47E+00	7.41E+00	9.47E+00	9.47E+00	9.47E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00	6.08E+00
Helicopters	0.01	0.01	0.00	2.70E-03	8.11E-03	5.57E-03	5.57E-03	5.57E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03	1.01E-03
General Project Area (Construction)	38.30	0.00	0.00	0.00E+00	3.83E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	92.61	10249.27	10718.21	22	93	6261.5	10249.3	10611.5	10679.3	10718.2	9792.3	9399.0	8063.5	7055.3	5898.5	5018.7	4417.9	3988.3	3637.7	3436.9	3265.1	2897.7	2516.7	2281.8	2115.7	2011.9

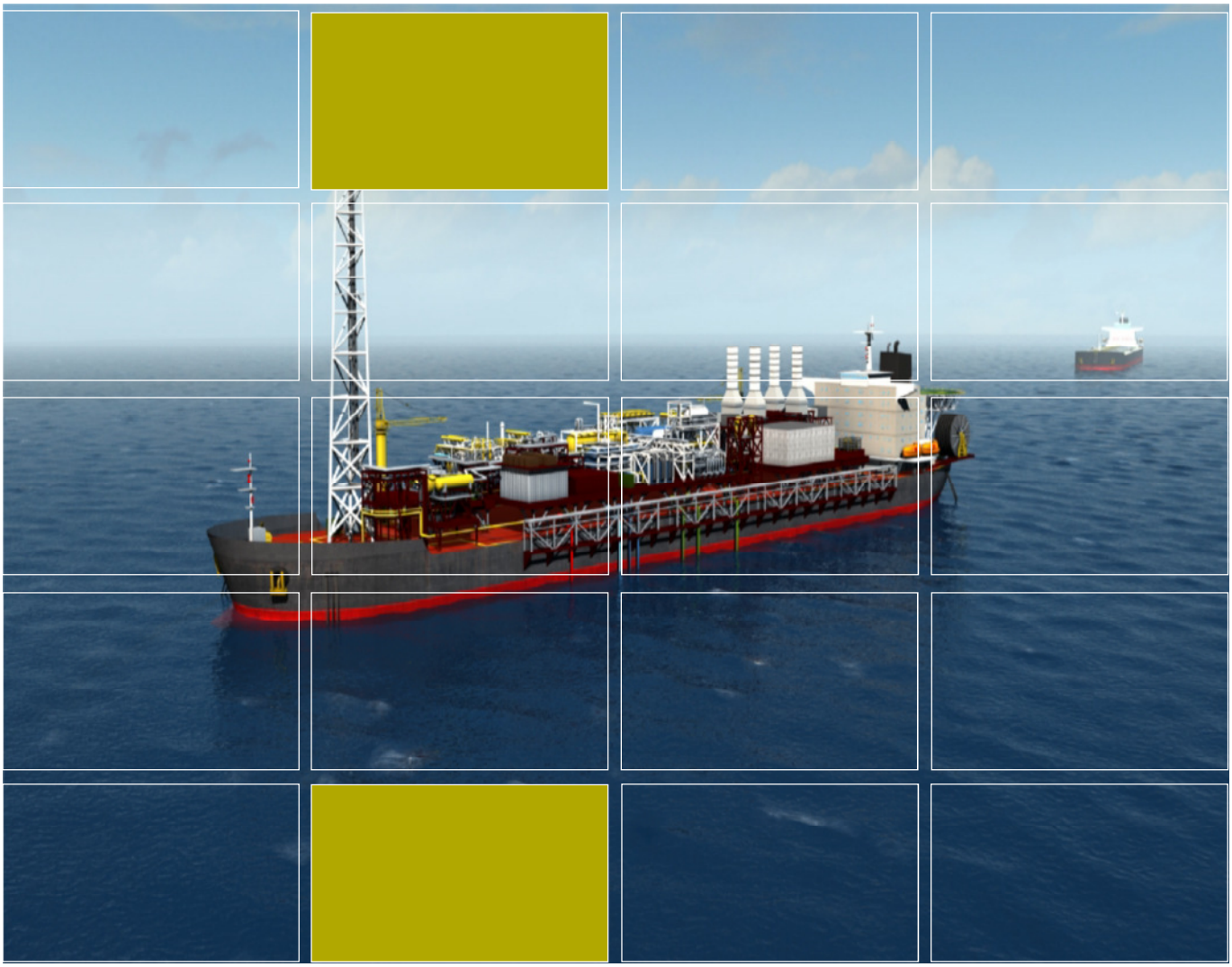
Table 2-4g GHG (kilotonnes CO_2-equivalents) Emissions By Year

Source Sector	Emissions (Tonnes) for Each Time Period			Emissions (tonnes) Per Year																							
	const.	oper/drill	operations	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Combustion Turbines	0.00	513.98	513.98	0.00E+00	0.00E+00	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02	5.14E+02
Flare - HP Normal Flaring (Note 1)	0.00	0.27	0.12	0.00E+00	0.00E+00	2.70E-01	1.12E-01	1.17E-01	1.21E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.25E-01	1.23E-01	1.25E-01
Flare - LP Normal Flaring (Note 1)	0.00	0.40	0.19	0.00E+00	0.00E+00	4.04E-01	1.67E-01	1.75E-01	1.82E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.86E-01	1.85E-01	1.86E-01
Flare - HP Full Flaring (Note 1)	0.00	709.63	327.32	0.00E+00	0.00E+00	7.10E+02	2.94E+02	3.08E+02	3.19E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.27E+02	3.24E+02	3.27E+02
Flare - LP Full Flaring (Note 1)	0.00	106.14	48.96	0.00E+00	0.00E+00	1.06E+02	4.40E+01	4.60E+01	4.77E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.90E+01	4.85E+01	4.90E+01
Auxiliary Boiler (Heaters)	0.00	9.47	9.47	0.00E+00	0.00E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00	9.47E+00
Essential Services Gens	0.00	5.25	0.40	0.00E+00	0.00E+00	5.25E+00	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01	4.05E-01
Emergency Generators	0.00	0.00	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Incinerator	0.28	1.22	0.94	0.00E+00	2.82E-01	1.22E+00	1.22E+00	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01	9.41E-01
Deck Cranes	0.00	0.26	0.51	0.00E+00	0.00E+00	2.57E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01	5.13E-01
Export Tanker	0.00	3.04	7.05	0.00E+00	0.00E+00	3.04E+00	6.77E+00	7.00E+00	7.04E+00	7.05E+00	6.38E+00	6.10E+00	5.14E+00	4.41E+00	3.58E+00	2.94E+00	2.51E+00	2.20E+00	1.95E+00	1.80E+00	1.68E+00	1.42E+00	1.14E+00	9.73E-01	8.59E-01	7.78E-01
Drill Center1	32.33	43.11	0.00	1.44E+01	3.23E+01	4.31E+01	5.39E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Drill Center2	32.33	43.11	0.00	1.44E+01	3.23E+01	4.31E+01	5.39E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Support Vessels Project Area	29.91	38.22	24.51	9.97E+00	2.99E+01	3.82E+01	3.82E+01	3.82E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01	2.45E+01
Support Vessels FPSO shore to Project Area	14.96	19.11	12.26	4.99E+00	1.50E+01	1.91E+01	1.91E+01	1.91E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01	1.23E+01
Helicopters	3.11	2.14	0.39	1.04E+00	3.11E+00	2.14E+00	2.14E+00	2.14E+00	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01	3.89E-01
General Project Area (Construction)	77.25	0.00	0.00	0.00E+00	7.72E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sum	190.17	1508.54	976.68	45	190	1508.5	970.2	976.2	967.0	976.7	973.1	971.6	966.5	962.6	958.2	954.8	952.5	950.8	949.5	948.7	948.0	946.6	945.2	944.2	940.1	943.2

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APPENDIX M – Water Quality Modeling Report

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Technical Report: Water Modelling; Liza Well Development

The business of sustainability

ERM

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 PURPOSE 1

1.2 SCOPE OF WORK 2

2.0 DRILL CUTTINGS AND MUD DEPOSITION MODELLING 3

2.1 APPROACH 3

2.1.1 Simulation Design 3

2.1.2 Drill Cuttings and Mud Deposition Software 6

2.1.3 Environmental Data 7

2.2 SCENARIOS 15

2.2.1 Depositional Thickness 15

2.2.2 Total Suspended Solids 16

2.3 ADHERED OIL 16

2.4 RESULTS 16

2.4.1 Depositional thickness 17

2.4.2 Total Suspended Solids 20

2.4.3 Oil Deposits on the Sediment 25

2.5 CONCLUSIONS 28

3.0 OFFSHORE DISCHARGES MODELLING 30

3.1 APPROACH 30

3.2 SCENARIO SELECTION 32

3.2.1 Discharge Velocity 33

3.2.2 Discharge Properties 33

3.2.3 Ambient Currents 35

3.2.4 Ambient Temperatures 37

3.2.5 Scenarios 38

3.3 STANDARDS AND THRESHOLDS 40

3.4 RESULTS 41

3.4.1 Cooling Water 42

3.4.2 Produced Water 45

3.4.3 Sulfate Removal & Potable Water Processing Brines 47

3.4.4 Hydrostatic Test Water 48

3.4.5 Gas Injection Line Commissioning Fluids 49
3.5 CONCLUSIONS 50
4.0 REFERENCES 53

LIST OF ACRONYMS

AOP	Asphaltene Onset Pressure
AMS	Alarm Management System
AUV	Autonomous Underwater Vehicle
BFROC	Base fluid retention on cuttings
BOD	Biological Oxygen Demand
BOP	Blowout Preventer
BOPD	Barrels of Oil Per Day
CARICOM	Caribbean Community
CCR	Central Control Room
CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPACC	Caribbean Planning for Adaptation to Climate Change
DC	Drill Centre
EEPGL	Esso Exploration and Production Guyana Limited
EIA	Environmental Impact Assessment
EITI	Extractive Industries Transparency Initiative
EPA	Environmental Protection Agency
ERM	Environmental Resources Management
ESMP	Environmental and Social Management Plan

F&G	Fire and Gas
FA	Flow Assurance
FLET	Flowline End Termination
FPSO	Floating Production, Storage, and Offloading
GA	General Alarm
GGMC	Guyana Geology and Mines Commission
GI	Gas Injection
GIFT	Generalized Integrated Fate and Transport
GRA	Guyana Revenue Authority
H2S	Hydrogen Sulfide
HP	High Pressure
HVAC	Heating, Ventilating, and Air Conditioning
ICSS	Integral Control and Safety System
ICZM	Integrated Coastal Zone Management
ILO	International Labour Organization
IFC	International Finance Corporation
IMF	International Monetary Fund
IP	Intermediate Pressure
kbd	Thousand barrels per day
LMRP	Lower Marine Riser Package
LP	Low Pressure
m	Meters

m3	Cubic Meters
MARAD	Maritime Administration
MDBML	Mean Depth Below Mud Line
MeOH (or CH3OH)	Methanol
mi	Miles
MoNRE	Ministry of Natural Resources and Environment
MPV	Multi-Purpose Vessel
MSCFD (or mscfd)	Million Standard Cubic Feet per Day
MSWT	Mean Sea Water Temperature
NABF	Non-Aqueous Base Fluid
NADF	Non-Aqueous Drilling Fluid
nm	nautical miles
NMVOC	Non-Methane Volatile Organic Compounds
NOx	Nitrogen Oxide
OBR	Onboard Representative
OIMS	Operations Integrity Management System
OSRP	Oil Spill Response Plan
P&A	Plugging and Abandonment
PA	Public Address
PCS	Process Control System
PE	Parabolic Equation
PLET	Production Line End Termination

PM (2.5 or 10)	Particulate Matter
POB	Persons On Board
ppb	Parts per Billion
ppg	Pounds per Gallon
ppm	Parts per Million
psi (or psia)	Pounds per Square Inch (Atmospheric)
PSV	Platform Supply Vessel
ROC	Residual On Cuttings
ROV	Remotely Operated Underwater Vehicle
SCM	Subsea Control Module
SCSSV	Surface-Controlled Subsurface Safety Valve
SDU	Subsea Distribution Unit
SIMOPS	Simultaneous Operations
SIS	Safety Instrumented System
SITP	Shut In Tubing Pressure
SO2	Sulfur Dioxide
SOT	Safe Operating Temperature
SSHE	Safety, Security, Health, and Environment
SRU	Sulfate Removal Unit
SURF	Subsea Umbilicals Risers and Flowlines
TD	Total Depth
TEG	Tri-ethylene Glycol

TOR	Terms Of Reference
TSS	Total Suspended Solids
TV	Tug Vessel
UTA	Umbilical Termination Assembly
UPS	Uninterruptible Power Supply
TVD	True Vertical Depth
VLCC	Very Large Crude Carrier
VOC	Volatile Organic Compounds
VSP	Vertical Seismic Profile
WAT	Wax Appearance Temperature
WBM	Water Based Mud
WI	Water Injection

1.0 INTRODUCTION

1.1 Purpose

For the production of an Environmental Impact Assessment (EIA) of the Liza Phase 1 Development Project, Esso Exploration and Production Guyana Limited (EEPGL) commissioned ERM to perform modelling of discharges into the marine environment related to planned drilling and oil production in the Stabroek Petroleum Prospecting License Area offshore Guyana (Figure 1-1). These models included simulations of drill cuttings and mud deposition, and discharges of cooling water, sulfate removal and potable water process brines, produced water, and hydrotest fluid.

For the purposes of this report, the Stabroek Petroleum Prospect License Area will be referred to as the "Stabroek Block."

Figure 1-1 Stabroek Petroleum Prospecting License Area (ERM, 2016)



1.2 Scope of work

This technical report describes the modeling study performed to understand the potential impacts from offshore releases in two sections. Section 2.0 describes the discharges related to drilling operations and Section 3.0 describes the operational and maintenance discharges. A separate report describing accidental discharges related to oil spills is provided in Volume 4. The selection of these discharges for the modeling were done based on the review of the project description, proposed project related activities and an understanding of accidental releases that could occur from proposed project activities. Computational models were used to estimate the potential extent of the discharge plumes based on estimated discharges and facility plans.

2.0 DRILL CUTTINGS AND MUD DEPOSITION MODELLING

2.1 Approach

In this study, the discharge of drill cuttings is evaluated. It is assumed that there will be a direct discharge of cuttings during drilling of the riserless open hole section followed by discharge near the surface of cuttings with a small fraction of adhered residual base oil from material removed in the lower well sections after treatment on the FPSO.

For the impact assessment, the modelling was performed to determine three key endpoints:

- the amount of suspended sediment concentrations added to water column background concentrations;
- the seabed accumulation (thickness) of the adhered muds and drill cuttings over an area of seafloor (the footprint) for assessment of impacts to benthic organisms; and
- the amount of hydrocarbons settled upon the seafloor.

2.1.1 Simulation Design

Released material will pass vertically through the water column because cuttings and muds are denser than the receiving water. Released material will also migrate horizontally due to advection by local and regional currents. The dispersion of cuttings and muds dispersion therefore is fundamentally a three-dimensional phenomenon requiring three-dimensional hydrodynamic fate and transport modelling.

There are four well centre locations. Two of these centres were modelled representing the shallowest and the deepest wells. These are DC1-I at a depth of 1688 m and DC2-I at a depth of 1853 meters.

At each of these wells, the top hole (Section 1) and conductor (Section 2) will be jetted and drilled with water-based muds (WBM) to a depth of 956 m below the mud line (BML). The subsequent three sections (with hole diameters sizes 17.5”and 12.25”followed by a hole 8.5” by 9.875”) will be drilled with non-aqueous drilling fluid (NADF) until a total depth (TD) is reached at approximately 6,628 m BML. The discharge pipe from the drill platform will release treated cuttings 11 m below mean sea level (MSL). Table 2-1 summarizes the proposed well profile.

To develop the three required endpoints, three model grids were used: a particle grid, a depositional grid, and a concentration grid. The movement of the discharged cuttings and muds using Lagrangian particles was computed within the particle grid (

Table 2-2 Grid dimensions

Grid	Horizontal Dimensions	Vertical Dimensions

Grid	Horizontal Dimensions	Vertical Dimensions
Particle grid	50 m x 50 m	N/A
Depositional grid	38 m x 38 m	N/A
Concentration grid	Variable – smallest 25 m x 25 m at center	Variable – smallest 10 m at top and bottom

Figure 2-1). This particle grid is square approximately 55 km on each side, with each cell approximately 50 m by 50 m in length and width. Each grid cell contains an interpolated depth value derived from the bathymetry data described in Section 3.1.3.1. Particles are free to move horizontally and vertically within this grid's domain, independently of the grid except for movement past the grid boundaries on the seafloor (as defined by the bathymetry) and shorelines.

For computation of the mass deposition on the seafloor, the model used a smaller and finer square, two-dimensional (2-D) depositional grid, with each grid centered on a well. The depositional grid is a 20 km square grid with 520 cells on each side, each cell approximately 38 m in length and width (Figure 2-2).

The concentration grid, used for computations of total suspended solids (TSS), is three-dimensional with the same horizontal dimensions as the depositional grid. Vertically, the cells are 10 m thick at the surface and bottom regions where the maximum suspended solids are predicted to occur. The cell thicknesses expand in size towards the middle of the water column region. See Table 2-2 for a summary of these three grids' dimensions.

Table 2-1 Well profile

Section	Diameter (inches)	Well Interval (m)
Section 1 – Structural (Top Hole, Jet)	36″	82
Section 2 – Conductor	26″	1,065
Section 3 – Surface	17 ½″	1,530
Section 4 – Production	12 ¼″	3,150
Section 5 - Open	8 ½″ x 9 7/8″	1,000

Table 2-2 Grid dimensions

Grid	Horizontal Dimensions	Vertical Dimensions
Particle grid	50 m x 50 m	N/A
Depositional grid	38 m x 38 m	N/A
Concentration grid	Variable – smallest 25 m x 25 m at center	Variable – smallest 10 m at top and bottom

Figure 2-1 Particle grid

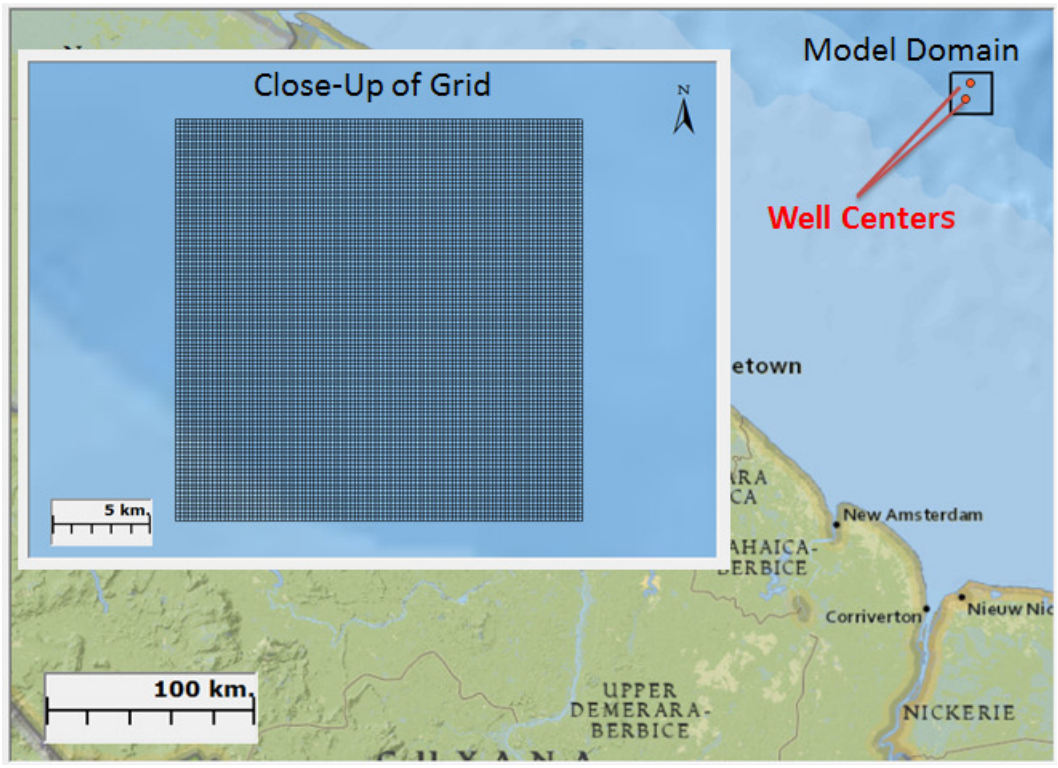
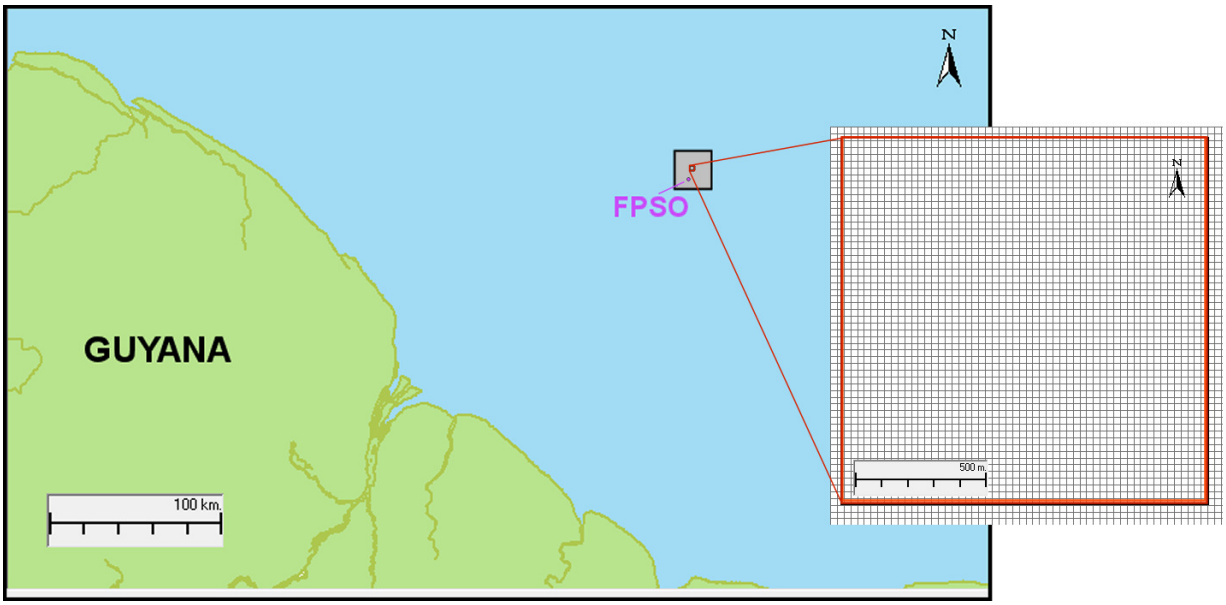


Figure 2-2 Depositional and Concentration grid



2.1.2 Drill Cuttings and Mud Deposition Software

The modelling was performed using GEMSS® (Generalized Environmental Modelling System for Surfacewaters) and its drill cuttings and muds discharge module, GIFT (Generalized Integrated Fate and Transport) (Kolluru and Spaulding, 1993; Kolluru, et al., 1998; Fichera and Kolluru, 2007; Fichera, et al., 2013; Prakash and Kolluru, 2014). GIFT simulates the fate of dissolved and particulate material discharged during dredging operations, disposal of mine tailings, well drill cuttings and muds, and release of produced water. This three-dimensional particle-based model uses Lagrangian algorithms in conjunction with currents, specified mass load rates, release times and locations, particle sizes, settling velocities, and shear stress values. The modelling methodology is based on a deterministic mode of simulation. In deterministic, single event simulations, the starting date and current speed and direction at each time step are chosen from a database of properties in the selected periods.

Drill cuttings and muds were modelled as particles. Movement in the vertical direction resulted in the settling and deposition of cuttings on the seabed. The combined action of erosion and deposition, based on particle size distribution and the intensity of release, resulted in the net accumulation of drill cuttings on the seabed.

Modelling data requirements included:

- drill section sizes and schedule;
- drilling mud types;
- cuttings and mud grain size distribution;
- mud and cuttings densities; and

- mud and cuttings release rates, durations, and discharge depths.

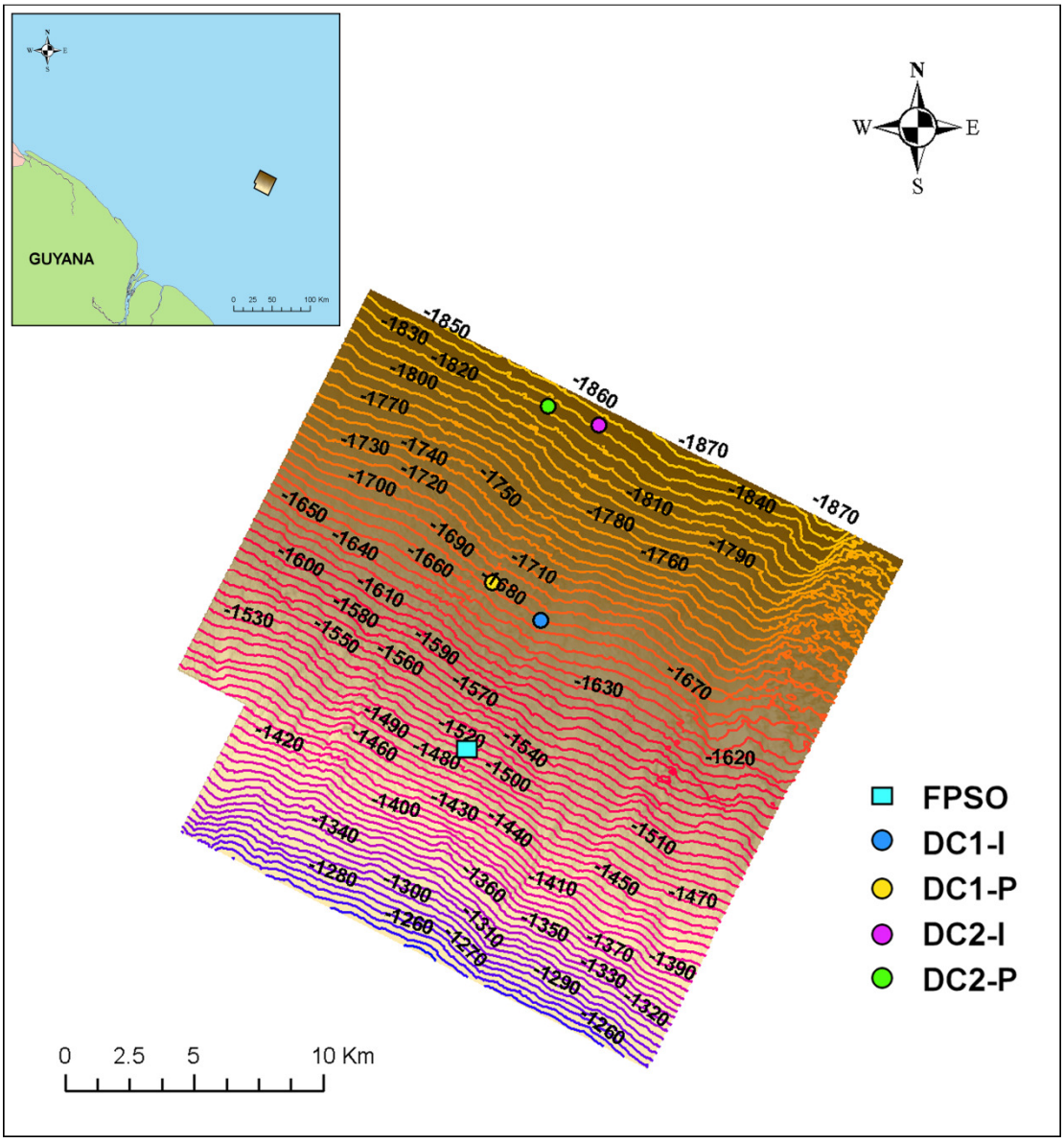
2.1.3 Environmental Data

Model inputs were assembled and formatted for use with GIFT. The environmental data used by the model include bathymetric data, ocean current, water temperature and salinity data. Spatially and temporally varying oceanic data were collected to characterize this area and determine appropriate simulation periods (see Section 6.1.4).

2.1.3.1 Bathymetry

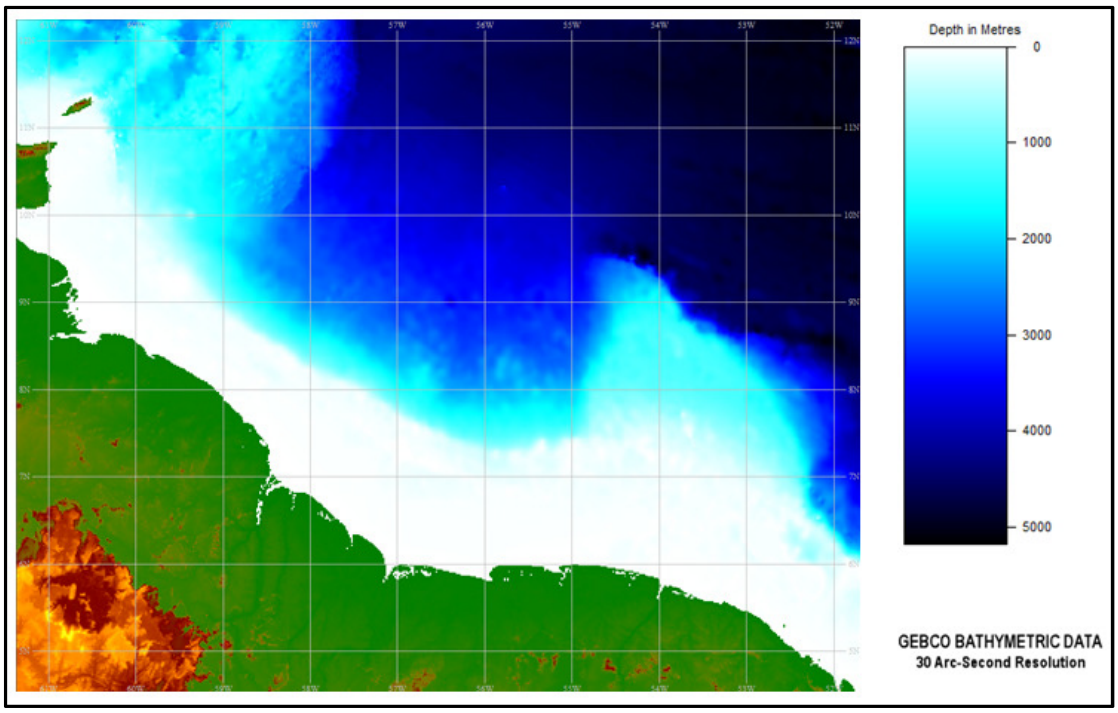
The primary spatial dataset is the bathymetric data, used to describe the depth and shape of the seafloor. Bathymetric data are used to develop the shape and depth of the lower boundary of the modelling grids. Two datasets were used. The primary source of bathymetry was the 2016 bathymetric survey performed by Fugro (Fugro, 2016). This dataset was provided as a set of depth contour lines covering a region approximately 23 km by 22 km within the block (Figure 2-3).

Figure 2-3 Bathymetric data (Fugro, 2016)



The bathymetry data provided by Fugro were supplemented by data from the General Bathymetric Chart of the Oceans (GEBCO), a publicly-available source (BODC, 2014). Data from this source provided bathymetric values beyond the Fugro database towards the north. The database used for this study is the GEBCO_08 Grid which has a 30 arc-second resolution. GEBCO bathymetry offshore Guyana is shown in Figure 2-3 Figure 2-4.

Figure 2-4 GEBCO Data Region



A polyline shapefile of the Guyanese coastline acts as boundary in the model domain between land and water. The coastlines were obtained from Esri's World Boundaries and Places Alternate product.

2.1.3.2 *Time Varying Data: Ocean Current, Temperature and Salinity Data*

The time-varying data for the drill cuttings deposition modelling include ocean current speed and direction, water temperature, and salinity. Deposition modelling requires time-varying currents on a three-dimensional grid. Hourly depth-varying and spatially-varying currents were obtained from ExxonMobil Upstream Research Company using the SAT-OCEAN model combined with currents from the HYCOM (HYbrid Coordinate Ocean Model) global ocean circulation hindcast model (hycom.org). Currents were obtained every three hours from 2005 through 2014. The model extended from 56° W to 58° W longitude and 7°N to 11°N latitude over 128 by 128 grid cells and 22 depth bins at 0, 5, 10, 20, 30, 40, 50, 75, 100, 125, 150, 200, 300, 400, 500, 1000, 1500, 2000, 2500, 3000, 3500,and 4000 m depths. Depth-varying temperature and salinity values were obtained directly from HYCOM model output.

Monthly-averaged, depth-averaged current speeds were computed across the 2005 to 2014 period of record. Through a statistical analysis of these current speeds at the well locations, the months with the minimum and maximum average current speeds were determined. Modelling was performed assuming drill cuttings deposition occurs

starting on the first day of these two months: March 2006 (maximum speed) and August 2013 (minimum speed). Simulations performed during these two months will provide the full range of depositional patterns from a larger and thinner footprint when the current speeds are highest to a thicker, smaller footprint when the speeds are smallest.

Example current vector plots for March 2006 and August 2013 are shown below in Figure 2-5 and Figure 2-7 at the surface (0 m) and in Figure 2-6 and Figure 2-8 in deeper water (1000 m).

Figure 2-5 Example current vector diagram, March 1, 2006 (surface)

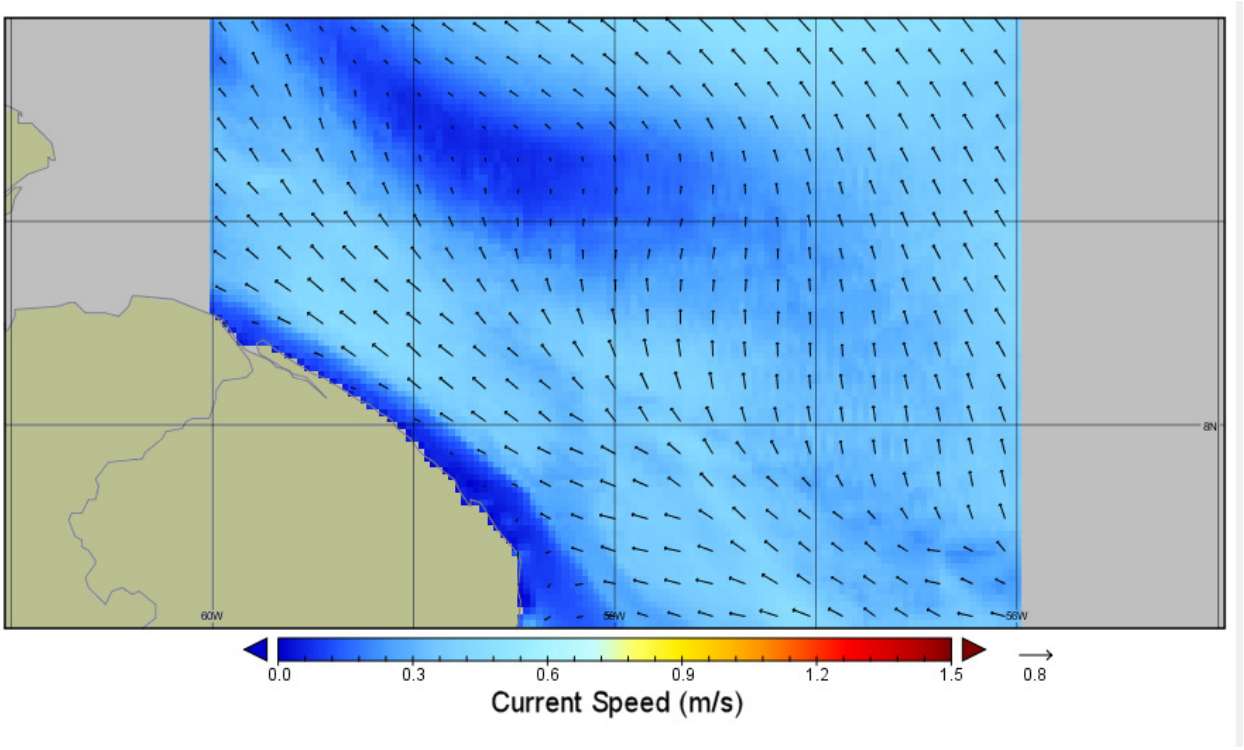


Figure 2-6 Example current vector diagram, March 1, 2006 (1,000 m depth)

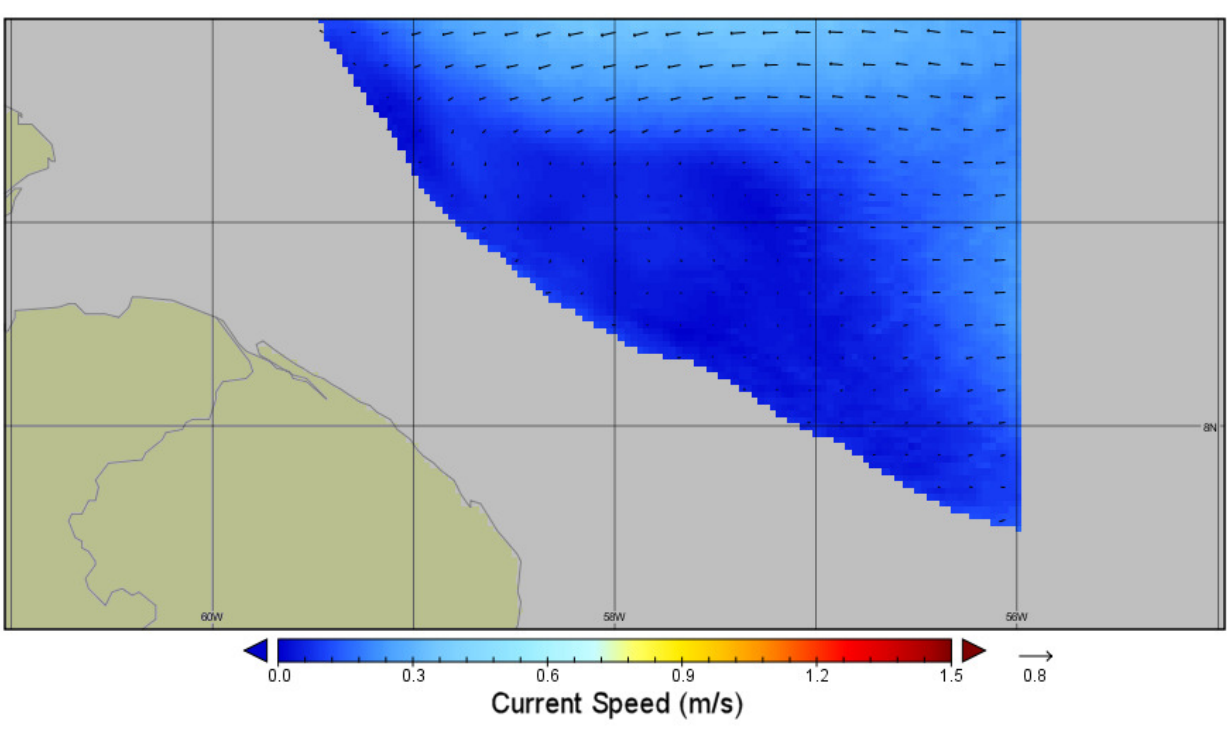


Figure 2-7 Example current vector diagram, August 1, 2013 (surface)

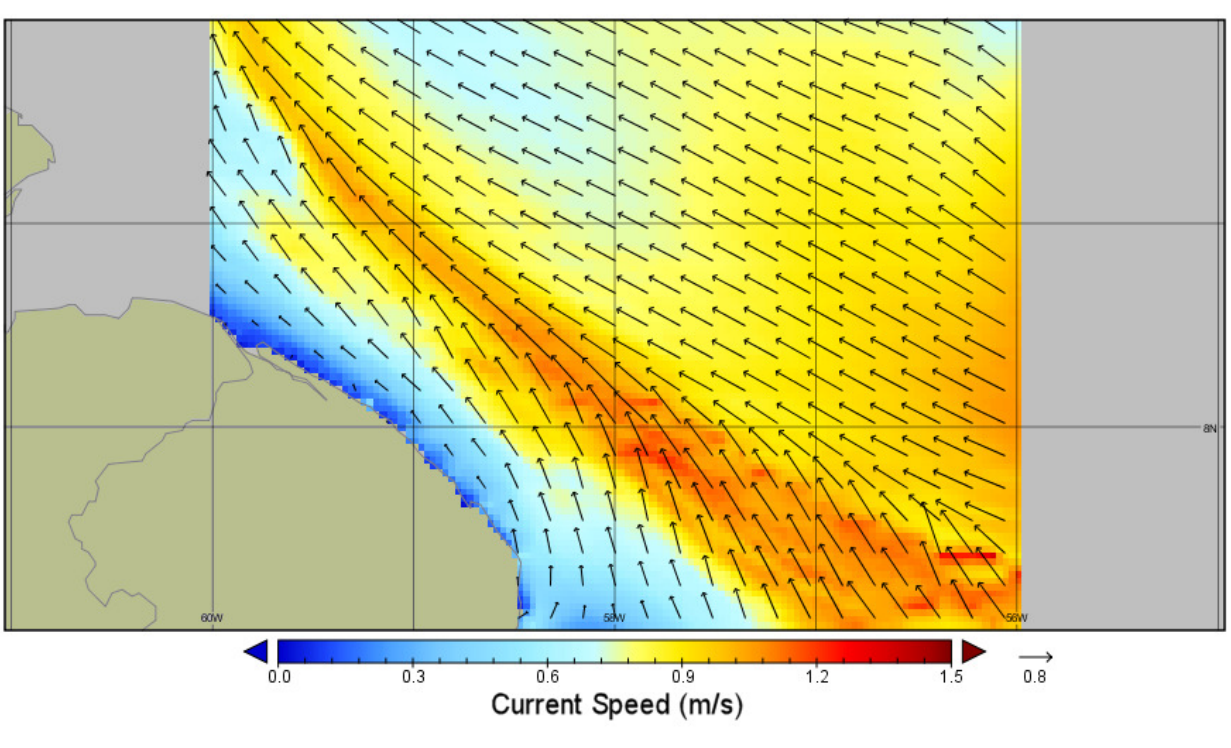
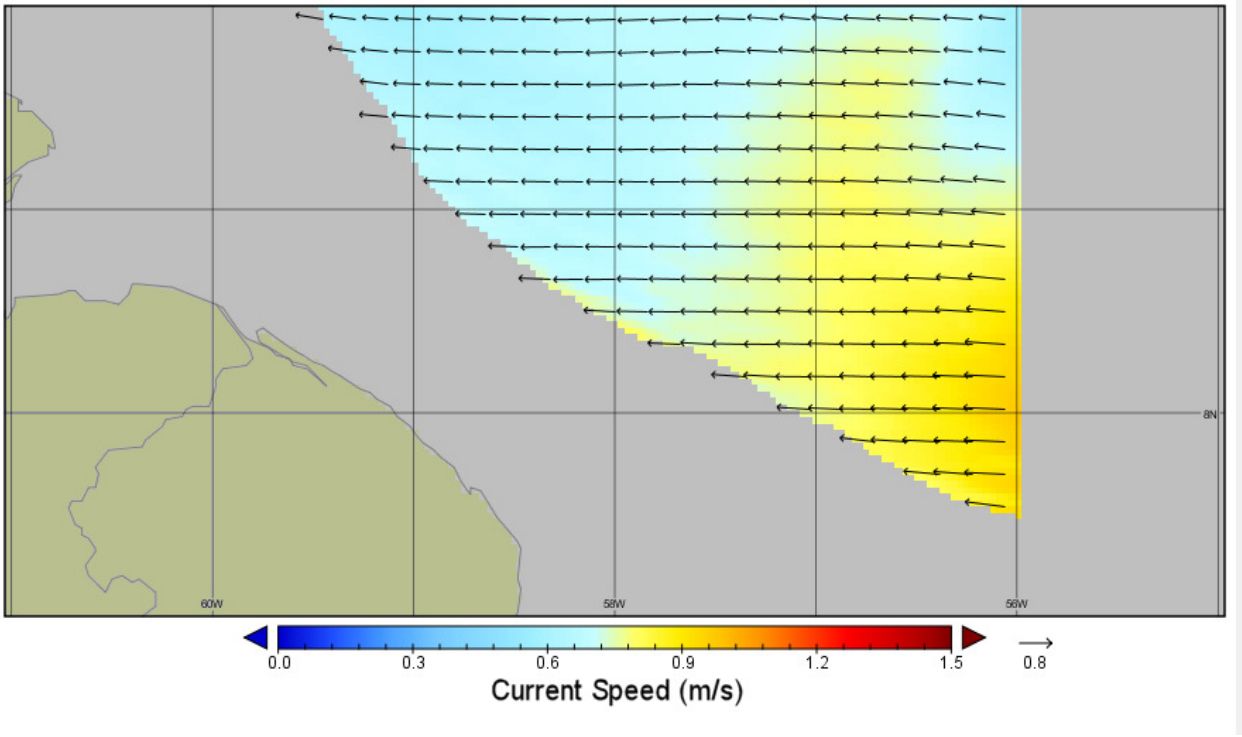


Figure 2-8 Example current vector diagram, August 1, 2013 (1,000 m depth)



2.1.3.3 *Drill cuttings and mud volumes and properties*

Estimated quantities of anticipated drill cuttings and muds to be discharged during drilling are provided in Table 2-3. The estimated times to drill each section were provided by EEPGL. For the top hole sections, only WBM are expected to be used. The volume of WBM discharged in Sections 1 and 2 are 5-times and 8-times the volume of the drill cuttings, respectively. In the subsequent sections, the cuttings with a small percentage of adhered non-aqueous muds will be disposed at 11 m below sea level. No non-aqueous drilling muds are to be directly discharged. Adhered muds will not exceed 6.9% of the cuttings mass on average.

Table 2-3 Discharge description

Hole Diameter (inches)	Volume of Cuttings Discharged (bbl)	Volume of Mud to be Discharged (bbl)	Type of Mud	Estimated Drilling Duration (days)
36″	339	1,694	WBM	0.5

Hole Diameter (inches)	Volume of Cuttings Discharged (bbl)	Volume of Mud to be Discharged (bbl)	Type of Mud	Estimated Drilling Duration (days)
26″	2,295	18,356	WBM	1.5
17 ½″	1,493	248	NADF	3
12 ¼″	1,507	251	NADF	6
8 ½″ x 9 7/8″	303	56	NADF	4
TOTAL	**5,936**	**28.5**	**-**	**15**

Though the actual drilling of the well may take longer to complete, the model simulation of the discharges to the sea was run for 23 days assuming 15 days of drilling with a nominal one-day pause of discharges between well sections for a conservative estimate of TSS, and model performance efficiency.

2.1.3.4 Cuttings and Mud Volumes and Properties

The grain size properties of the drill cuttings and muds were provided by EEPGL. The distribution of particle sizes and associated fall velocities used in this study are listed in Table 2-4 for cuttings in Section 1 and 2, Table 2-5 for WBM and Table 2-6 for treated cuttings released from Section 3 through 5 with adhered non-aqueous drilling fluid (NADF). Cuttings density was assumed to be 2.6 g/mL. The WBM density was assumed to be 11 ppg. The density of NADF was reported by EEPGL to range between 9 and 13.2 ppg; 9 ppg was used for a conservative assumption since it would result in slower settling and a larger footprint of deposition.

Table 2-4 Cuttings when water based mud is used

Mass Fraction (Wt %)	Fall Velocity (cm/s)	Estimated Diameter (cm)
2	0.00003	0.00005
3	0.0001	0.0001
5	0.0003	0.0002
10	0.0046	0.0006
10	0.0695	0.0007

Mass Fraction (Wt %)	Fall Velocity (cm/s)	Estimated Diameter (cm)
20	0.4460	0.0059
20	1.8300	0.0363
10	6.9300	0.1350
10	14.3000	0.3730
5	19.8000	0.6680
3	23.4000	0.9510
2	26.1000	1.2200

Table 2-5 WBM grain size distribution

Mass Fraction (Wt %)	Fall Velocity (cm/s)	Estimated Diameter (cm)
7	0.0027	0.0005
8	0.0061	0.0007
5	0.0148	0.0011
10	0.0300	0.0015
13.3	0.0434	0.0018
13.3	0.0511	0.0020
19.2	0.0640	0.0007
19.2	0.0823	0.0008
4	0.4270	0.0058
1	1.1200	0.0250

Table 2-6 Treated cuttings with adhered NADF grain size distribution

Mass Fraction (Wt %)	Fall Velocity (cm/s)	Estimated Diameter (cm)
43	0.02	0.00
1.01	0.20	0.01
4.99	2.00	0.04
5.55	8.00	0.16
7.99	14.00	0.36
10.99	19.00	0.62
13.01	21.99	0.83

Mass Fraction (Wt %)	Fall Velocity (cm/s)	Estimated Diameter (cm)
6.81	23.99	1.00
3.69	26.99	1.32
2.47	30.97	1.89
0.49	124.97	*

* Fall velocity outside the range of available correlations; computed by GIFT model

2.2 Scenarios

Modelling was performed for four scenarios representing the shallowest and deepest wells (DC1-I and DC2-I, respectively) and for the minimum and maximum of the monthly-averaged, depth-averaged current speeds (Table 2-7). The water depth at the two well varied between 1,688 m at DC1-I and 1,853 m at DC2-I.The same drilling and mud discharge schedule described in Table 2-3 was assumed at both wells.

Table 2-7 Drill cuttings and mud deposition scenarios

Well Centre	Scenario Name	Ambient Currents	Water Depth (m)
DC1-I	1a	Minimum Monthly Avg	1,688
	1b	Maximum Monthly Avg	1,688
DC2-I	2a	Minimum Monthly Avg	1,853
	2b	Maximum Monthly Avg	1,853

These scenarios provide output that is presented in terms of depositional thickness, TSS concentrations, and deposition of adhered oil.

2.2.1 Depositional Thickness

Drill cuttings and adhered mud discharges will create a footprint on the seabed. The deposition of cuttings and adhered muds may result in physical damage and habitat loss or disruption over a defined area of the seabed. The discharge of muds and cuttings may affect seabed habitats through physical smothering.

Burial by drilling muds and cuttings may cause physical impacts upon benthic communities. The specific thickness of burial which may cause an impact can vary depending on the benthic species and the amount of oxygen depletion which may occur, causing anoxic conditions beneath the depositional layer.

The severity of burial impacts depends on the sensitivity of the benthic organism, the thickness of deposition, the amount of oxygen depleting material, and the duration of the burial. Thickness thresholds vary by species and sediment impermeability. A

suggested threshold thickness value of 5 cm above a substratum for a month deposition impacting benthic communities is recommended based on publications by Ellis and Heim (1985) and MarLIN (2011). Smaller threshold values as low as 1 mm have been reported (e.g., Smit et al., 2006), however they are associated with instantaneous burials on benthic species, not gradual smothering effects.

2.2.2 Total Suspended Solids

Increases in concentration of TSS will occur due to discharges of drill cuttings and mud. The highest concentration increases will exist at the point of discharge from the drillship or at the seafloor during upper well section drilling, and decrease over time and distance as the suspended solids plume dissipates and settles. Larger particles will settle out more quickly than fine particles, such that the TSS plume of tiny particles may linger and travel further than plumes of larger grain-sizes. As such, elevated TSS may form in regions where tiny suspended particles linger in a cloud and mix with subsequent discharges. Impacts related to elevated TSS may occur if light penetration is impeded significantly for long periods of time reducing the ability of plants and phytoplankton to photosynthesize. Increases in TSS may also decrease water clarity and clog fish gills. A commonly used guidance value for TSS effluent discharges in the marine environment recommended by MARPOL of 35 mg/L was used as a threshold (IMO, 2006).

2.3 Adhered Oil

Discharges of cuttings after use of NADF must be treated through the on-board systems (shakers and dryers). The non-aqueous base fluid (NABF) portion of the NADF that remains will be reduced to approximately 6.9% base fluid retention on cuttings (BFROC) by mass. These hydrocarbons, once settled to the seafloor, can degrade over time, and may enter the pore water within the sediments or become dissolved in the water column, depending on each specific hydrocarbon's tendency to remain partitioned to the solids.

2.4 Results

The results of the modelling are illustrated in the following sections as contour plots. The plots presented indicate the location of the drill cuttings release point, taken at or above the well. The results are presented for the following parameters:

bottom thickness at the end of the simulation;

maximum TSS at any time in the simulation at the surface and bottom; and

mass of hydrocarbons per unit area deposited on the seafloor.

Based on the above parameters, the following set of threshold criteria has been applied in this analysis:

- Criterion 1 - The maximum allowable increase in total suspended solids should be no greater than 35 mg/L above ambient;
- Criterion 2 – The maximum allowable thickness deposited should not exceed 5 cm for the duration of one month; and

There are no available criteria applicable for the mass of hydrocarbons deposited on the seafloor.

2.4.1 Depositional thickness

When the first two sections are jetted and drilled before the riser is installed, cuttings and water based muds are discharged directly to the seabed resulting in mound of material deposited around the well.

The material discharged at the seabed is deposited in the area directly adjacent to the well head and results in the thickest layers of deposited material, which can be described as a footprint of cuttings with the majority of the material above 1 mm thick concentrated in a 1.5 km radius from the well. In three of the four scenarios, a small region close to the well exceeded the depositional thickness threshold value of 50 mm (5 cm) during the month. This exceedance ranged from roughly a 21 m to 43 m radius around the well. The maximum thickness reached was 753 mm (Scenario 2b: DC2-I, maximum currents), but slope failure (i.e. sudden collapse of the depositional mound) and resuspension of the particles are likely to reduce the height of the deposited materials over time.

Figure 2-9 through Figure 2-12 show the expected thicknesses of the cuttings and adhered mud layer on the seabed as a result of the drilling activities at the end of the model simulation (when all deposition had occurred) from both surface and bottom releases. Figure 2-9 and Figure 2-10 show the results of Scenario 1a and 1b. Figure 2-11 and Figure 2-12 show the results of Scenario 2a and 2b

In Scenario 1, at Well DC1-I, the maximum thickness predicted by the model was 660 mm, located in the vicinity surrounding the well. Jetting and top hole drilling deposited the majority of the deposited mound's peak (658.3 mm of the final 660 mm). The majority of the depositions (98.6% to 99.6%) were 1 cm thick or less.

In Scenario 2, at Well DC2-I, the maximum thickness predicted by the model was 753 mm, located in the vicinity surrounding the well. Jetting and top hole drilling deposited the majority of the deposited mound's peak (701.2 mm of the final 703 mm). The majority of the depositions (98.2% to 99.8%) were 1 cm thick or less.

Table 2-8 Depositional Thickness Summary

Scenario	Maximum Depositional Thickness (mm)	Area (m²) with Thickness > 50 mm threshold
1a DC1-I Min Currents	660	4,575
1b DC1-I Max Currents	186	5,815
2a DC2-I Min Currents	703	1,442
2b DC2-I Max Currents	753	1,590

Figure 2-9 Maximum Depositional Thickness – Scenario 1a DC1-I minimum currents

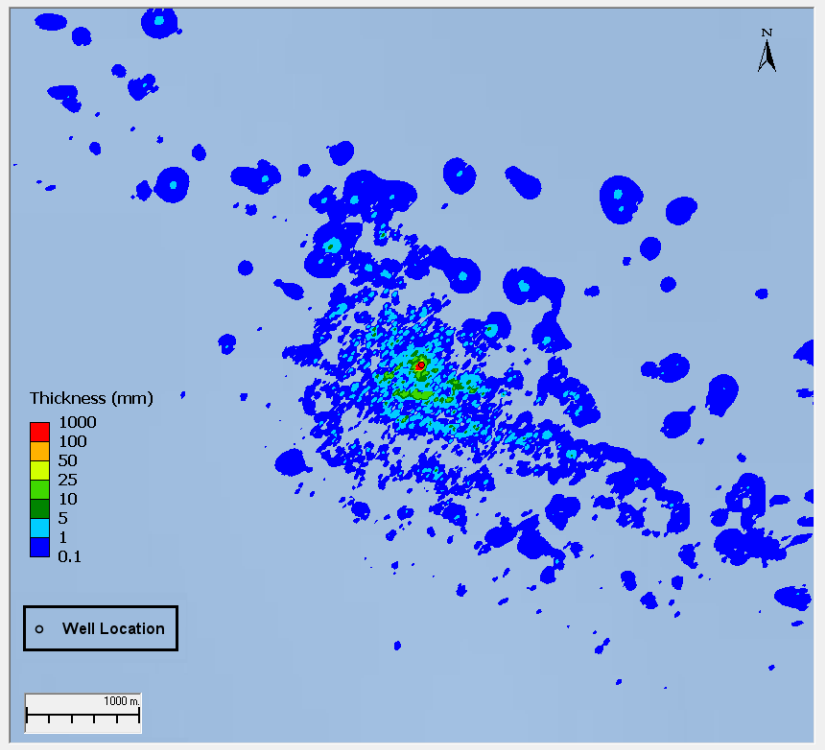


Figure 2-10 Maximum Depositional Thickness – Scenario 1b DC1-I maximum currents

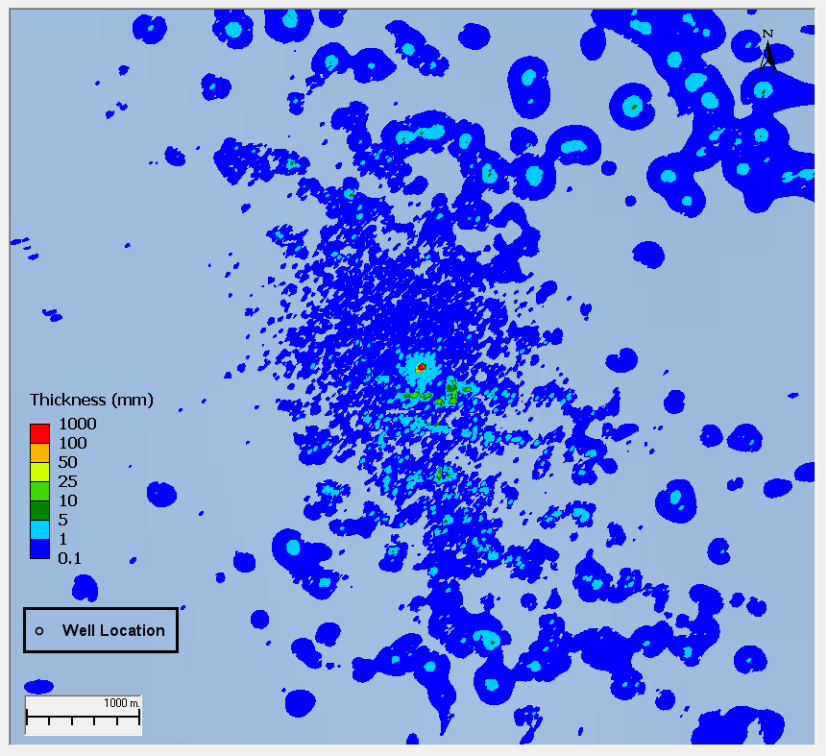


Figure 2-11 Maximum Depositional Thickness – Scenario 2a DC2-I minimum currents

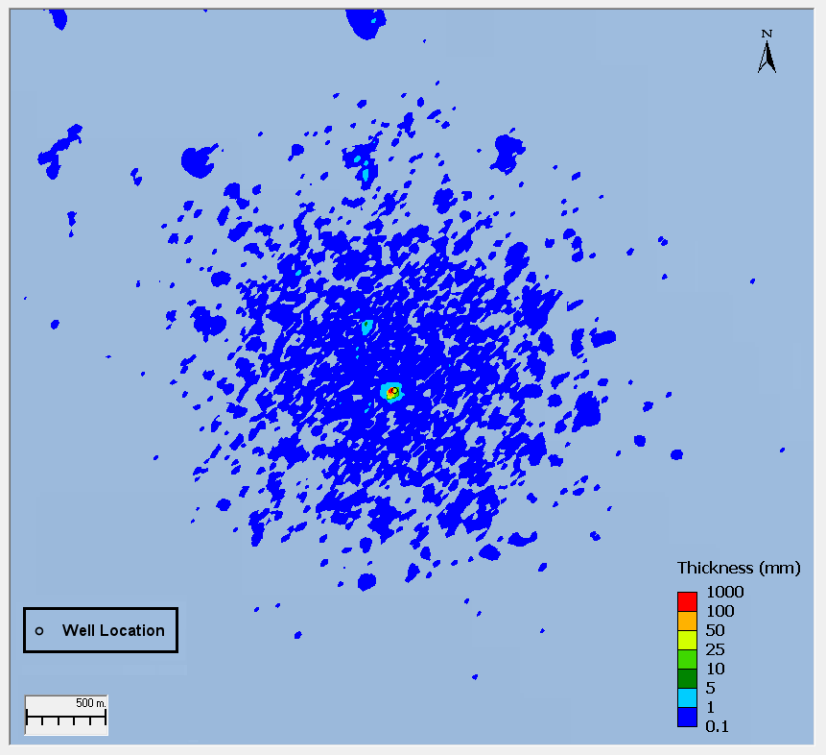
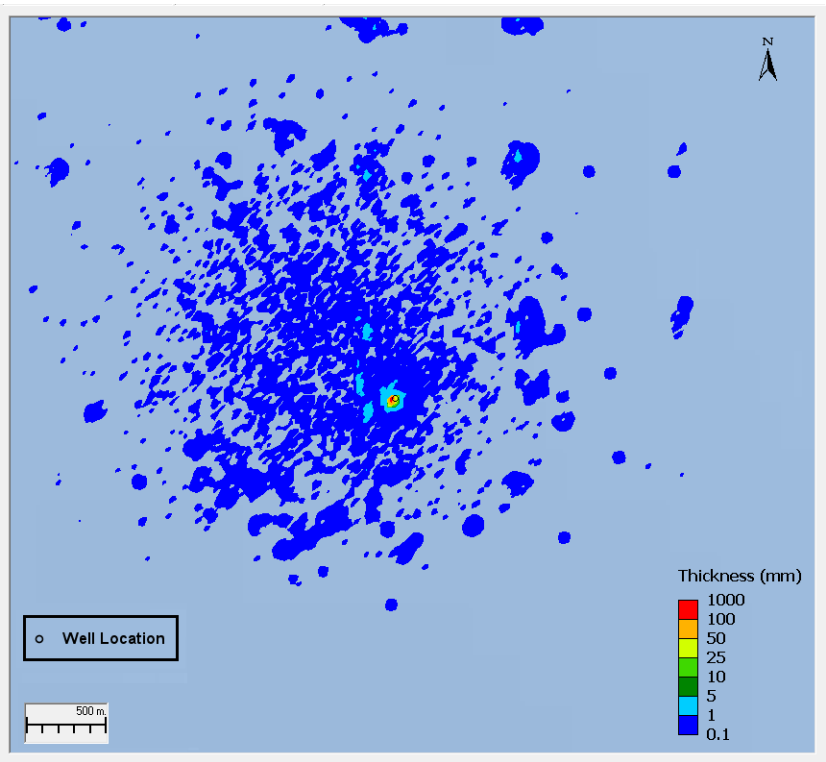


Figure 2-12 Maximum Depositional Thickness – Scenario 2b DC2-I maximum currents



2.4.2 Total Suspended Solids

The maximum TSS concentration added above ambient as a result of jetting and top hole drilling near the seafloor was 9,737 mg/L in Scenario 2b. The maximum TSS concentration added above ambient as a result of surface discharges was 5.3 mg/L in Scenario 2b. The 35 mg/L threshold is not predicted to be exceeded at the surface, where inhibition of photosynthesis would be a concern. At the sea floor, a maximum of approximately 0.168 km² of water is predicted to show concentrations that exceed the 35 mg/L threshold during drilling of the first two well sections. These maxima occur at the sea floor and are below the photic zone (the zone where high TSS could impact some organisms). Therefore the inhibition of light is not a concern at these depths.

In Scenario 1 at DC1-I, the maximum TSS ranged between 222 mg/L and 4,323 mg/L at the sea floor. In Scenario 2 at DC2-I, the maximum TSS ranged between 233 mg/L and 5,260 mg/L at the sea floor.

Note that in the following figures, the estimated maximum TSS concentrations may be slightly offset from the discharge location as the simulation's floating small particles suspended in the water column may concentrate together at various locations. Larger particles do not remain suspended but quickly settle to the seafloor.

Scenario	Maximum TSS (mg/L)		Area (km²) with TSS > 35 mg/L threshold	
	Surface	Bottom	Surface	Bottom
1a DC1-I Min Currents	2.1	4,323	0	0.094
1b DC1-I Max Currents	2.9	5,517	0	0.168
2a DC2-I Min Currents	1.6	5,260	0	0.091
2b DC2-I Max Currents	5.3	9,737	0	0.088

Figure 2-13 Maximum TSS at surface – Scenario 1a DC1-I minimum currents



Figure 2-14 Maximum TSS at bottom – Scenario 1a DC1-I minimum currents

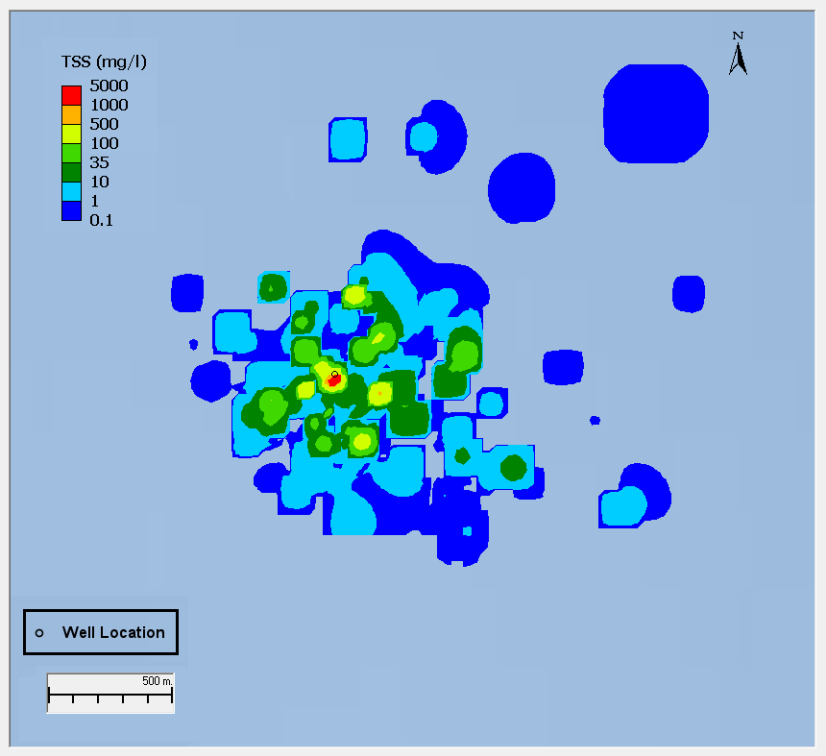


Figure 2-15 Maximum TSS at surface – Scenario 1b DC1-I maximum currents

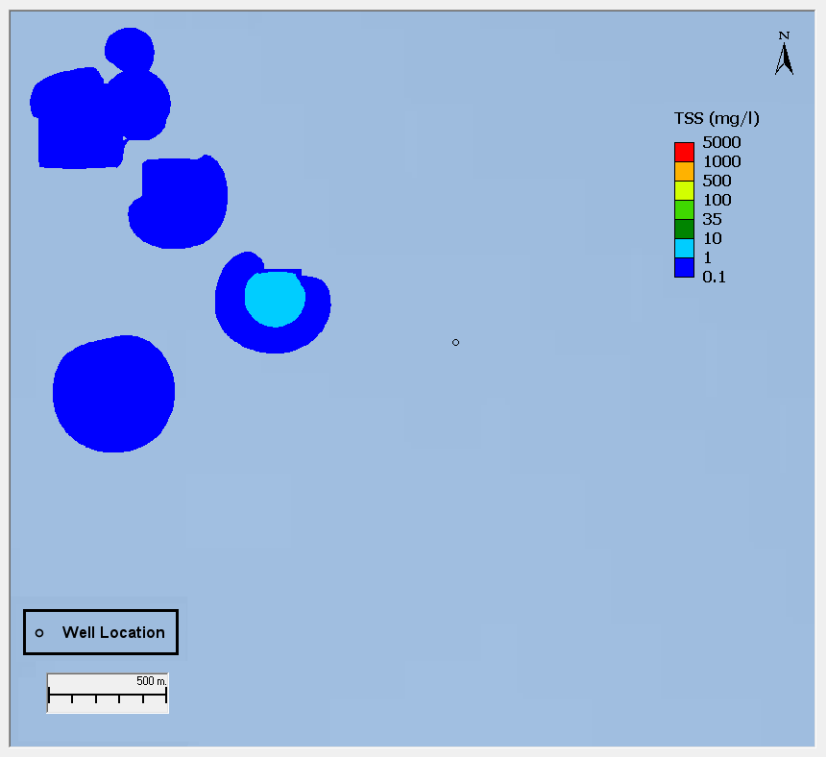


Figure 2-16 Maximum TSS at the bottom – Scenario 1b DC1-I maximum currents

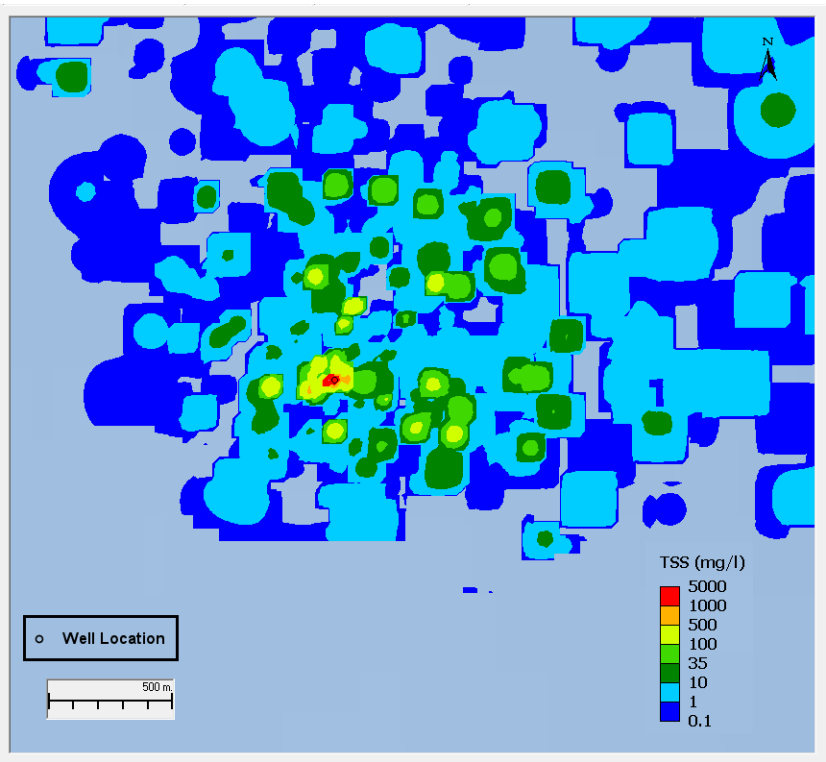


Figure 2-17 Maximum TSS at surface – Scenario 2a DC2-I minimum currents

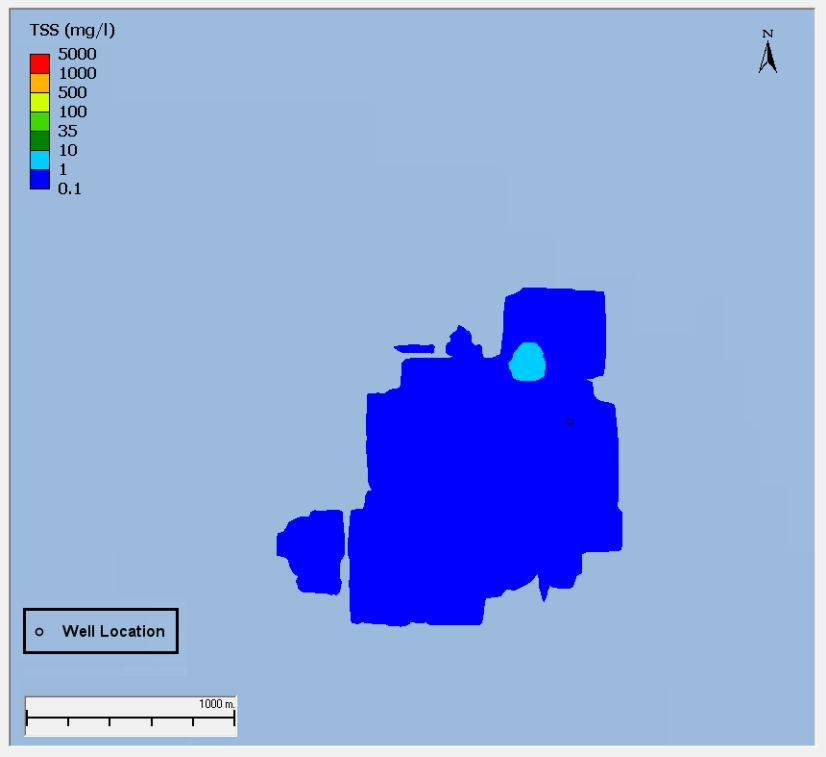


Figure 2-18 Maximum TSS at the bottom– Scenario 2a DC2-I minimum currents

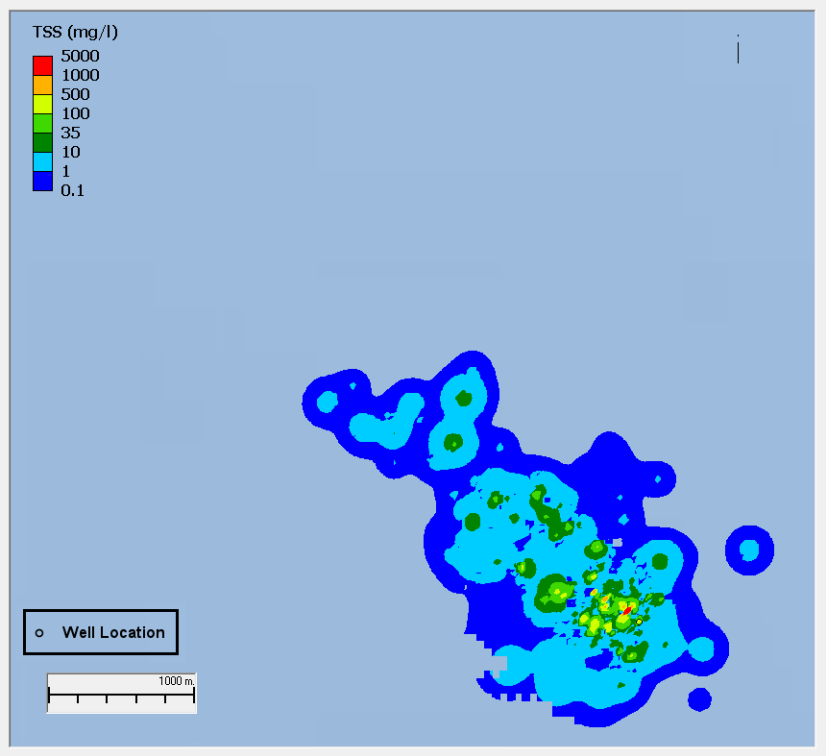


Figure 2-19 Maximum TSS at surface – Scenario 2b DC2-I maximum currents

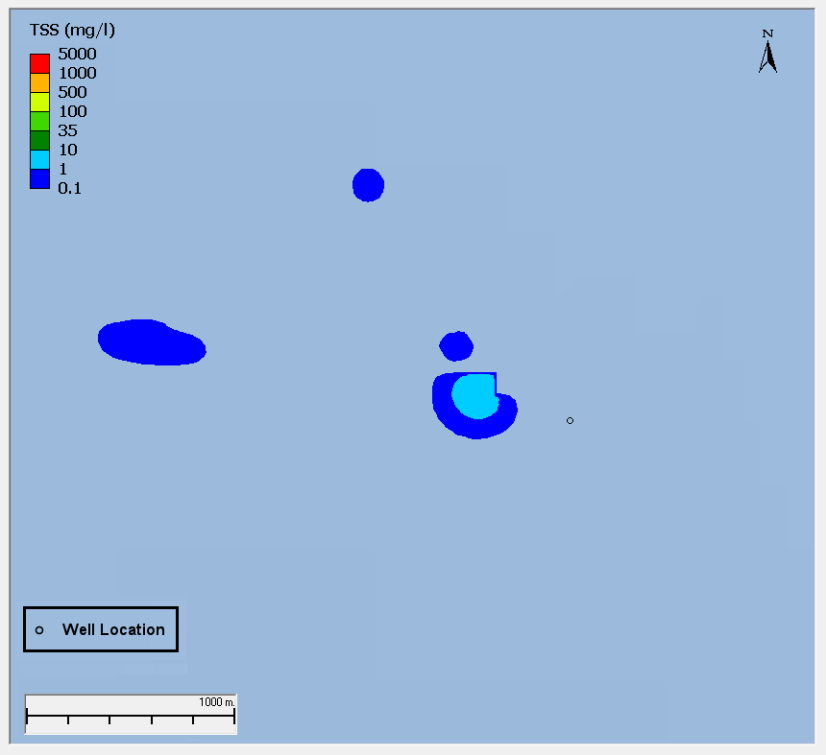
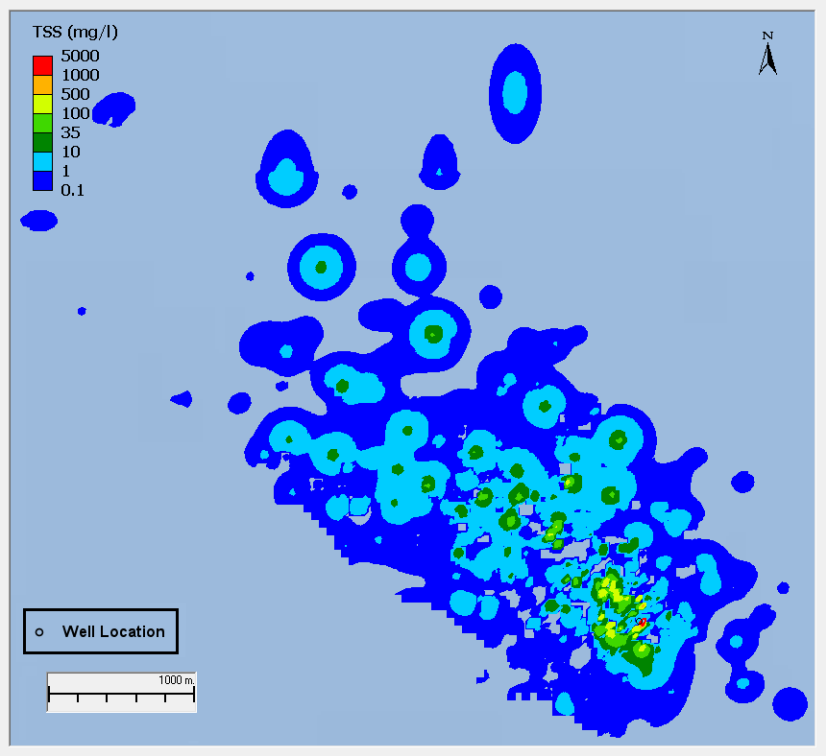


Figure 2-20 Maximum TSS at the bottom – Scenario 2b DC2-I maximum currents



2.4.3 Oil Deposits on the Sediment

At the end of the simulation, NABF adhered to the cuttings settled primarily within approximately a 2 km radius region in all four scenarios. Within that region, the total hydrocarbon concentration reached a maximum of 334.7 g/m² in Scenario 1b.

In Scenario 1 at DC1-I, concentrations above 5 g/m² occupied an area between 10.4 km² and 10.6 km². In Scenario 2 at DC2-I, concentrations above 5 g/m² occupied an area between 8.0 km² and 10.1 km².

Table 2-9 Hydrocarbon Deposition Summary

Scenario	Maximum Hydrocarbon Deposition (g/m²)	Area (km²) with Hydrocarbons > 5 g/m²
1a DC1-I Min Currents	278.5	10.4
1b DC1-I Max Currents	334.7	10.6
2a DC2-I Min Currents	307.9	8.0
2b DC2-I Max Currents	234.4	10.1

Figure 2-21 Total Deposited Adhered Oil – Scenario 1a DC1-I minimum currents

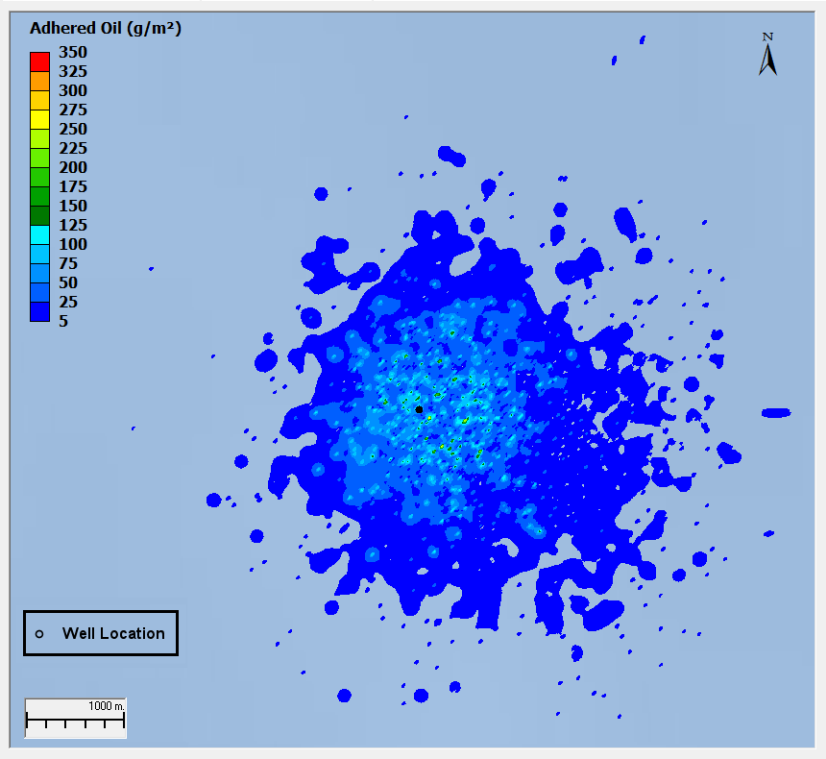


Figure 2-22 Total Deposited Adhered Oil – Scenario 1b DC1-I maximum currents

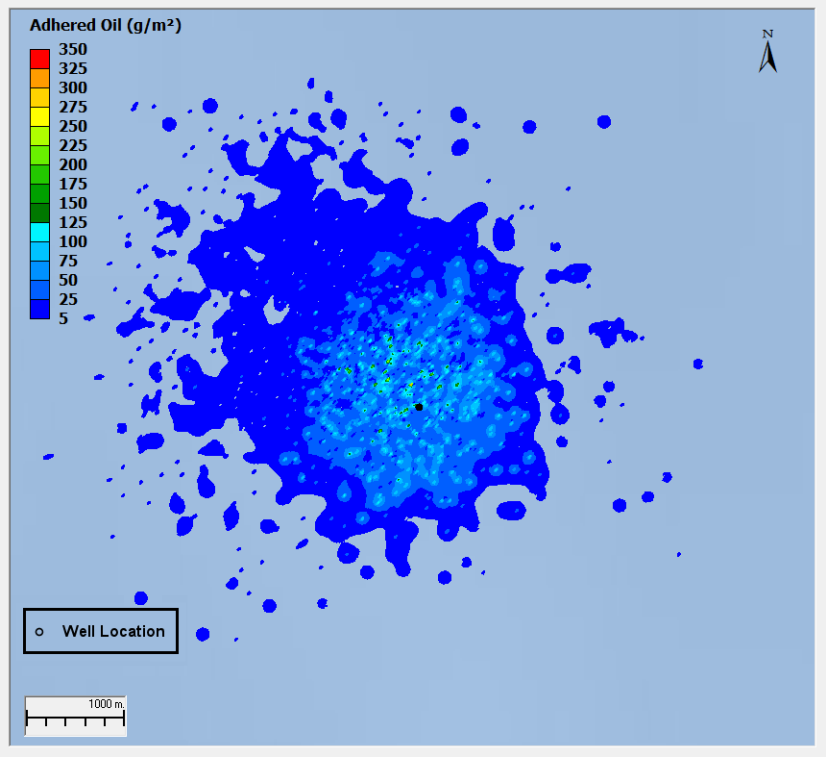


Figure 2-23 Total Deposited Adhered Oil – Scenario 2a DC2-I minimum currents

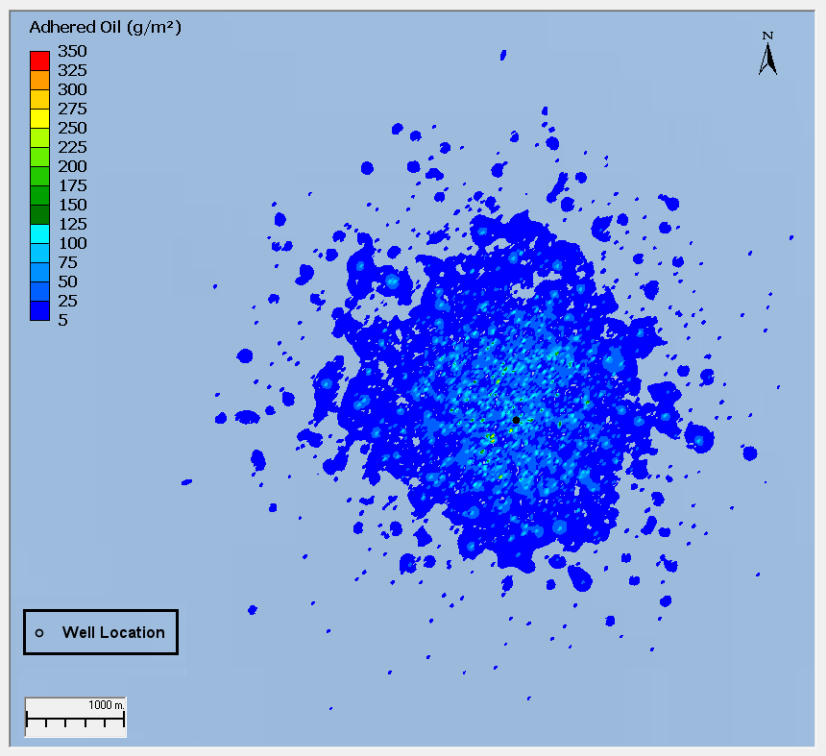
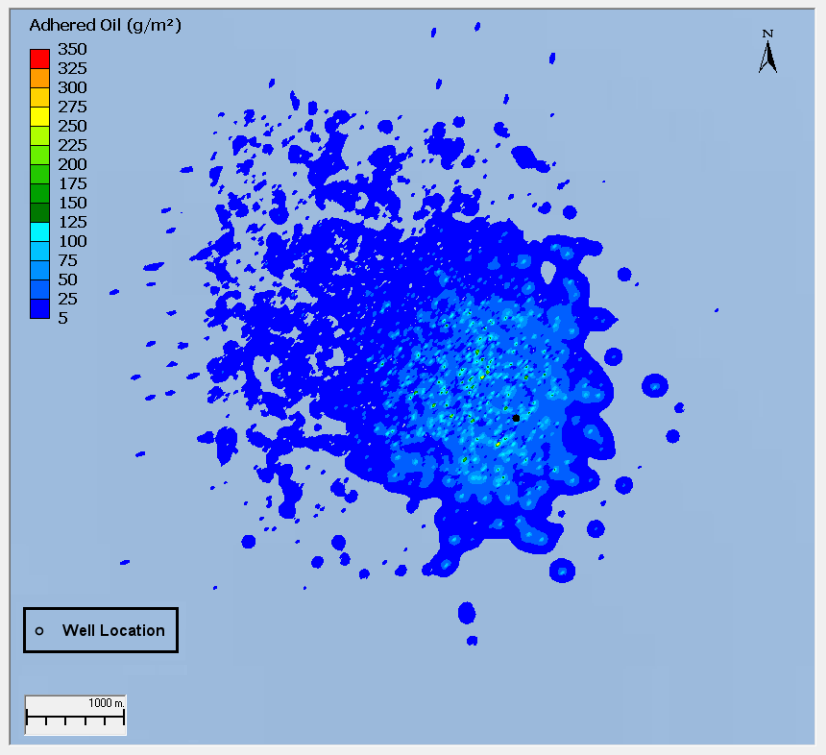


Figure 2-24 Total Deposited Adhered Oil – Scenario 2b DC2-I maximum currents



2.5 Conclusions

Modelling was performed using GEMSS® and its drill cuttings and muds deposition module, GIFT. Four simulations were made representing the shallowest and deepest well locations (DC1-I and DC2-I, respectively) and two ambient current conditions (minimum and maximum monthly-averaged, depth-averaged current speeds over a ten year period of record). At the beginning of the simulation, during a two day period, cuttings and WBM were discharged directly at the seabed while jetting and drilling the first two well sections. Drill cuttings and adhered NADF muds from the subsequent three sections were simulated to be release 11 m below sea level over 13 days.

Output from the drill cutting modelling included estimations of the total thickness of materials deposited on the sea floor, and maximum increased total suspended solids concentrations above ambient conditions. The concentration of hydrocarbons adhered to the cuttings that deposited on the sea floor was estimated in terms of mass per unit area. The results of the modelling are shown below in Table 2-10.

Table 2-10 Model Results Summary

Scenario	Maximum Depositional Thickness (mm)	Area (m^2) with Thickness > 50 mm threshold	Maximum TSS (mg/L) Surface/Bottom	Area (km^2) with TSS > 35 mg/L threshold Surface/Bottom	Maximum Adhered Oil Deposition (g/m^2)	Area (km^2) with Adhered Oil > 5 g/m^2
1a DC1-I Min Currents	660	4,575	2.1 / 4,323	0 / 0.094	278.5	10.4
1b DC1-I Max Currents	186	5,815	2.9 / 5,517	0 / 0.168	334.7	10.6
2a DC2-I Min Currents	703	1,442	1.6 / 5,260	0 / 0.091	307.9	8.0
2b DC2-I Max Currents	753	1,590	5.3 / 9,737	0 / 0.088	234.4	10.1

According to the model results, the thickness of drill cuttings and adhered muds deposited on the seafloor may exceed the threshold value of 50 mm within a 43 m radius from the well. This depositional mound is primarily due to the cuttings and muds discharged during the jetting and drilling of the top two sections. The maximum

TSS concentration in the water column directly above the well during the bottom releases may be initially high (over 9,700 mg/L) at the point of release, although in water depths below the photic zone in areas where light inhibition is not a concern and the population of biota is relatively low. At the surface where photosynthesis inhibition is more of a concern, TSS increases from discharges were below the 35 mg/L threshold. The maximum TSS concentration in the water column from the surface release is 5.3 mg/L. Hydrocarbons deposited on the seafloor had a maximum concentration of 334.7 g/m^2 with deposits generally settled in an area 10.4 km^2 at concentrations over 5 g/m^2.

Note that the variations in the current speeds are the primary cause for the variations in the model results provided. Scenario 2 has a higher maximum thickness and higher bottom TSS concentrations compared to the pair of simulations in Scenario 1. At the bottom depth of DC2-I, the currents are slower than at DC1-I allowing for a higher peak deposition, more compact deposition area, and more concentrated TSS. Though Scenario 2b had higher average currents compared to Scenario 2a, the bottom currents where most of the deposition occurs during drilling of the riserless sections were slower in Scenario 2b. Higher in the water column the current speeds in Scenario 2b were higher than in Scenario 2a. The areas of deposits with adhered oil show the opposite effect as the near surface currents in Scenario 1 were higher than in Scenario 2, causing a larger scatter of particles and resulting footprint area of the oily SOBM particles once they reached the seafloor.

3.0 OFFSHORE DISCHARGES MODELLING

3.1 Approach

The Project will have several planned discharges to water associated with SURF & FPSO installation and commissioning activities as well as production operations. These discharges, based on the preliminary design information, are listed in Table 11.

Table 11 List of operational and maintenance discharges from the Liza FPSO

Type of Discharge and Effluent Characteristics	**Expected Discharge Volume/Rate**
Ballast Water (FPSO initial deballasting)	≤ 500,000 bbl total
Hydrostatic Test Water • Biocide: ≤ 500 ppm • Oxygen scavenger ≤ 100 ppm • Corrosion inhibitor ≤ 100 ppm	25,000 bbl (total volume for all flowlines and risers, occurring throughout SURF commissioning phase)
Gas Injection Line Commissioning Fluids • Hydrate inhibitor (e.g., methanol or ethylene glycol)	400 bbl total
Produced Water • Oil & Grease • Temperature (40-50 °C at point of discharge) • Residual production and water treatment chemicals	≤ 100,000 bpd
Cooling Water • Hypochlorite: ≤ 5 ppm	≤ 700,000 bpd
Sulfate Removal & Potable Water Processing Brines • Hypochlorite: ≤ 1 ppm • Electrolyte: ≤ 1 ppm • Biocide: ≤ 5 ppm • Oxygen Scavenger: ≤ 10 ppm • Scale Inhibitor: ≤ 5 ppm	≤ 100,000 bpd
Subsea Hydraulic Fluid Discharge • Water soluble, low-toxicity	≤ 5 bpd
FPSO Bilge Water	1,800 bpd
Inert Gas Generator Cooling Water	Negligible
FPSO Slop Tank Water	Negligible
Miscellaneous Discharges including Boiler Blowdown, Desalinization Blowdown, Lab	<10 bpd

Type of Discharge and Effluent Characteristics	Expected Discharge Volume/Rate
Sink Drainage	
Tanker Ballast Water	1,100,000 bbl total (at each tanker crude loading)
BOP System Testing Water-Soluble Low-Toxicity Hydraulic Fluid	30 bbl every two weeks
Rain Water/Deck Drainage/Wash Down Water	Rainfall dependent
Gray Water	5,000 bpd
Black Water (sewage)	4,000 bpd
Food Preparation Wastes	<30 bpd

Cooling water, produced water, and brines from the Sulfate Removal Unit (SRU) and freshwater Reverse Osmosis (RO) system (all associated with the production operations stage) are the main operational discharges that are significant enough to require an assessment of the extent of the discharge plume. Additionally, although the discharge of hydrotest water and commissioning fluids will occur over only a short time period during the installation and SURF commissioning stage, they were also included in the offshore discharge modelling as a conservative measure.

The constituents considered from these discharges are listed in Table 12.

Table 12 Operational and maintenance offshore discharges and their constituents modelled

Discharge	Modeled Constituents
Cooling Water	• Temperature • Residual Chlorine
Produced Water	• Oil & Grease (O&G) • Residual production and water treatment chemicals (e.g., scale and corrosion inhibitors)
Sulfate Removal and Potable Water Processing Brines	• Hypochlorite • Electrolyte • Biocide • Oxygen Scavenger • Scale Inhibitor
Hydrotest Water	• Biocides

Discharge	Modeled Constituents
	• Oxygen Scavenger • Corrosion Inhibitor
Gas Injection Line Commissioning Fluid	• Hydrate inhibitor (e.g., methanol or ethylene glycol)

As the standards applicable to marine discharges are typically at the end of the mixing zone, modelling of the near-field mixing zone is necessary. The model used for the mixing zone calculations is USEPA's CORMIX dilution model. CORMIX is a design tool routinely used by regulatory agencies to estimate the size and configuration of proposed and existing mixing zones resulting from wastewater discharges. CORMIX is primarily a near-field model, i.e., it applies to the region adjacent to the discharge structure in which the wastewater plume is recognizable as separate from the ambient water and its trajectory is dominated by the discharge rate, effluent density, and geometry of the discharge structure.

The CORMIX calculation is based on defining the various hydraulic zones the effluent plume traverses in the receiving waterbody, then applying an analytical solution or empirical relationship to compute the plume trajectory and dilution rate in each zone. Each of these analytical solutions and empirical relationships has been validated by the developers and other researchers against laboratory and field studies. CORMIX has been applied to many cases (http://www.cormix.info) and is recognized by the USEPA and other national regulatory agencies as an appropriate model for computing trajectories, dilution rates and mixing zone dimensions.

3.2 Scenario Selection

Understanding the mixing characteristics of the various discharges and assessing compliance with applicable regulatory standards requires an understanding the properties of the receiving (ambient) water. The properties of the ambient water in combination with the discharge port configuration (pipe or diffuser) control the near-field mixing and dilution of the discharge. Properties of the ambient water relevant to the current analysis are velocities, temperature and salinity. While the ambient velocity (and its strength relative to the discharge/exit velocity) determines the level of initial mixing, temperature and salinity influence the behaviour of the discharge plume and its relative configuration due to density differences (i.e., buoyancy effects). Significant density differences between the discharge and ambient water will impede mixing. Balancing that effect, significant differences between discharge velocity and ambient

current increases entrainment of the ambient water into the discharge plume resulting in rapid mixing.

3.2.1 Discharge Velocity

Discharge velocity is directly related to the pipe diameter used for the various effluent streams. Smaller pipe diameters result in higher exit velocities facilitating increased mixing. However, engineering constraints may require a minimum pipe diameter. Since the front end engineering and design (FEED) for the project has not been completed, the maximum pipe diameter for each discharge that assured compliance with applicable regulatory standards was chosen by testing a number of diameters using CORMIX. Pipe diameters that are smaller than the ones shown here will result in increased mixing and smaller plumes. In addition, a variety of vertical discharge locations was considered to further ensure compliance with applicable regulatory standards. The range of pipe configurations considered for the four discharge streams considered are listed in Table 13.

Table 13 Pipe diameters considered for the four offshore discharges

Type of Discharge	Pipe Diameter	Vertical Location Relative to Sea Level
Produced Water	18″	1m to 10m
Cooling Water	24″ to 40″	1m to 10m
Sulfate Removal and Potable Water Process Brines	12″	1m
Hydrostatic Test Water	2″, 6″	Seafloor
Hydrate Control Fluid	2″, 6″	Seafloor

3.2.2 Discharge Properties

Ranges of anticipated discharge rates for the various operational discharges were available from the preliminary design (see Table 11). Furthermore, the pipeline volumes for the various pipelines were available. The most conservative (highest) rates were used for the modelling. Expected concentrations of the constituents were also available. The selected discharge rates and constituent concentrations are shown in Table 14.

Table 14 Modelled discharges and selected discharge rates

Type of Discharge	Discharge Rate	Constituent Concentrations

Type of Discharge	Discharge Rate	Constituent Concentrations
Produced Water	105,000 bpd (conservative)	• Oil & Grease: 42 mg/l (daily maximum) • Residual production and water treatment chemicals (100 ppm scale inhibitor and 200 ppm corrosion inhibitor used as examples)
Cooling Water	See Table 15	• Temperature: 125 F • Hypochlorite: ≤ 5 ppm
Sulfate Removal & Potable Water Processing Brines	100,000 bpd	• Hypochlorite: ≤ 1 ppm • Electrolyte: ≤ 1 ppm • Biocide: ≤ 5 ppm • Oxygen Scavenger: ≤ 10 ppm • Scale Inhibitor: ≤ 5 ppm
Hydrostatic Test Water	25,000 barrels (bbl) (total volume for all flowlines and risers, occurring across approximately one year)	• Biocide: 500 ppm • Oxygen Scavenger: 100 ppm • Corrosion Inhibitor: 100 ppm
Hydrate Control Fluid	2,500 bbl (may be as low as 400 bbl)	• Concentrated methanol or ethylene glycol

The cooling water discharge was evaluated in more detail due to anticipated changes in operational discharge rates. The cooling water discharge consists of two individual streams: cooling exchangers and produced water cooling. It is possible that both of these streams may be released through two separate pipes or through a combined pipe. A range of discharge rates based on the various phases of the project were available. Statistical summaries of these rates were used to bound the discharge plume using minimum and maximum rates as shown in Table 15.

Table 15 Statistical summary of cooling water discharge rates (kbpd: thousand barrels per day)

Source	Minimum (kbpd)	Maximum (kbpd)

Combined Pipe		
Cooling Med Exchangers & Produced Water Cooler	269.6	739.2
Separate Pipes		
Cooling Med Exchangers	133.6	566.4
Produced Water Cooler	66.4	288

3.2.3 Ambient Currents

Ambient currents for the region were available from ExxonMobil Upstream Research Company using the SAT-OCEAN (2.1.3.2) and analysed in order to select appropriate values for the specific locations for the operational discharges at the FPSO and for the hydrotest discharge (largest single discharge) at the DC2-I location. Although the operational discharges occur near the surface, the hydrotest release occurs near the seabed. Therefore, the ambient currents were analysed to select appropriate values at the FPSO near the surface and at DC2-I near the seabed.

The ambient currents were analysed for the period of May 2008 to September 2016. A frequency distribution analysis was performed to evaluate the magnitude and exceedance percentages of the currents. The ambient currents selected for modelling consisted of bounding cases (5% and 95%) and typical (50%). The frequency distributions for the two locations are shown in Figure 25 and Figure 26. The selected current magnitudes are shown in Table 16.

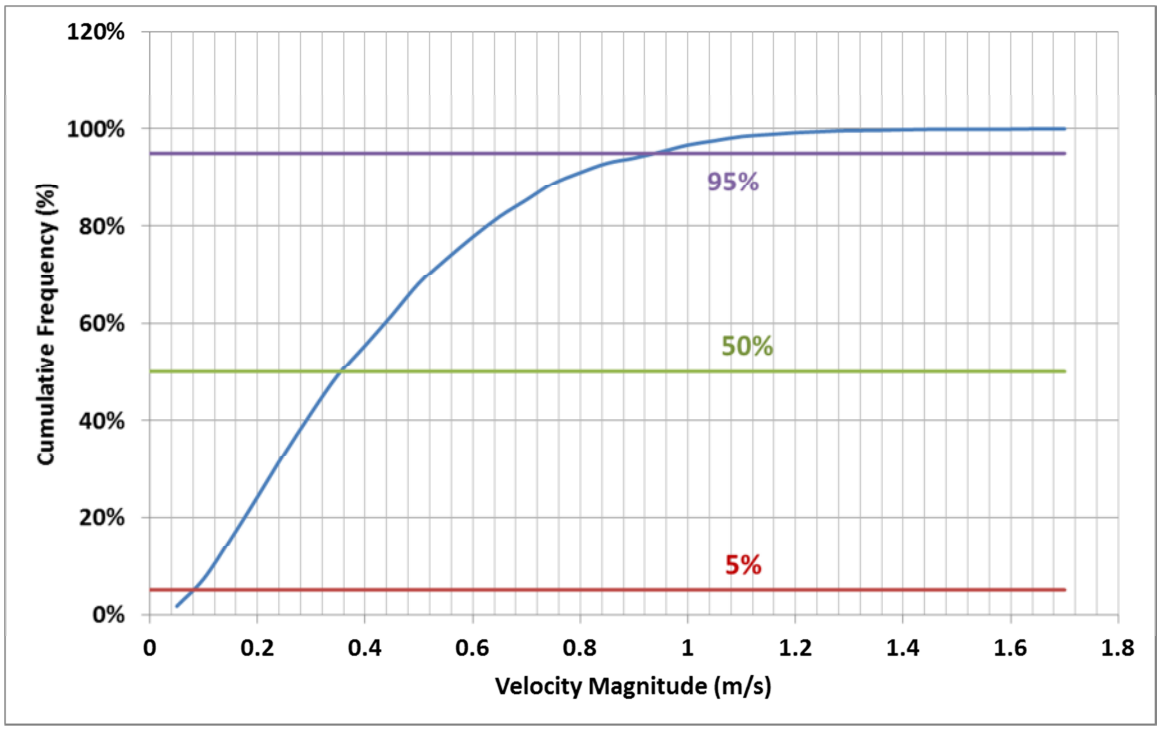


Figure 25 Cumulative frequency distribution at FPSO (near surface)

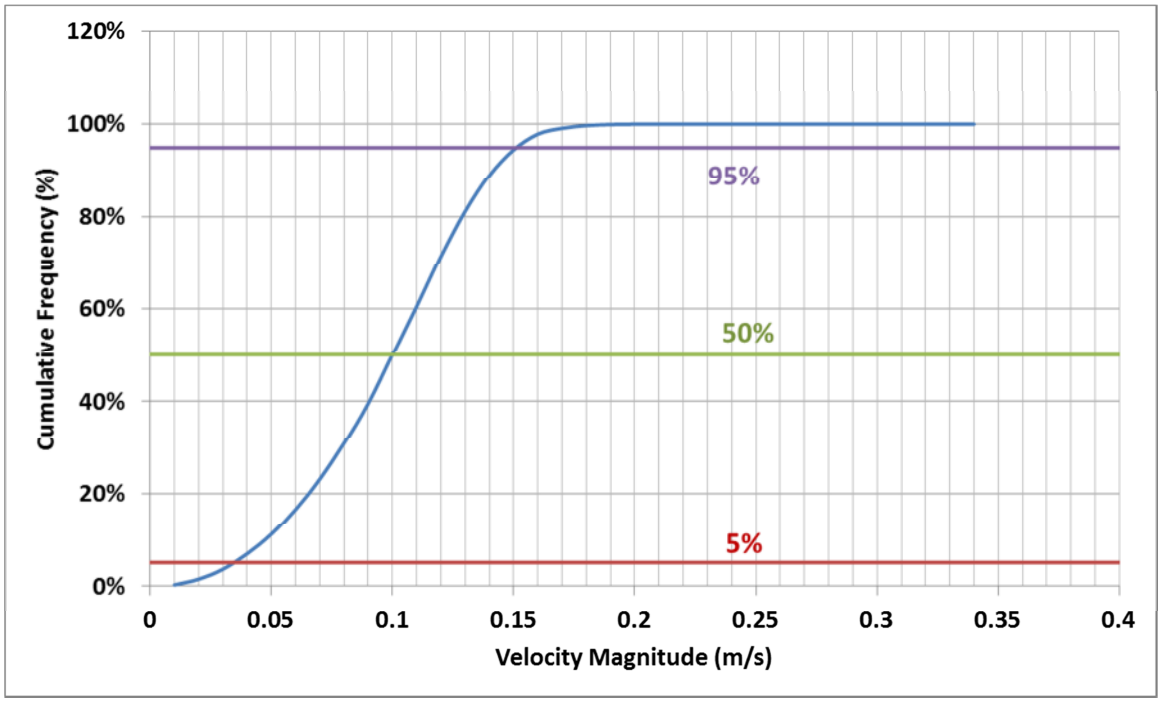


Figure 26 Cumulative frequency distribution at DC2-I (near seabed)

Table 16 Selected ambient current magnitudes (m/s)

Cumulative Frequency	FPSO	DC2-I
Low (5%)	0.08	0.035
Typical (50%)	0.36	0.10
High (95%)	0.94	0.15

3.2.4 Ambient Temperatures

An analysis of ambient temperatures for the FPSO location was conducted based on data available from ExxonMobil Upstream Research Company using the SAT-OCEAN (2.1.3.2). Since the ambient temperatures do not vary significantly within the Stabroek Licensing Area, only the FPSO location, not the DC2-I location, was considered. As with the velocity data, the temperature data are available for a period of May 2008 to September 2016. A frequency distribution analysis was done to evaluate the temperatures and exceedance percentages. Selected ambient temperatures consisted of two bounding cases (1% and 99%) and a typical case (50%). Only the cooling water discharge whose plume is influenced by the ambient temperatures was considered for the bounding cases and all remaining discharges were run for the typical case. The frequency distribution is shown in Figure 2 and the selected temperatures are shown in Table 5.

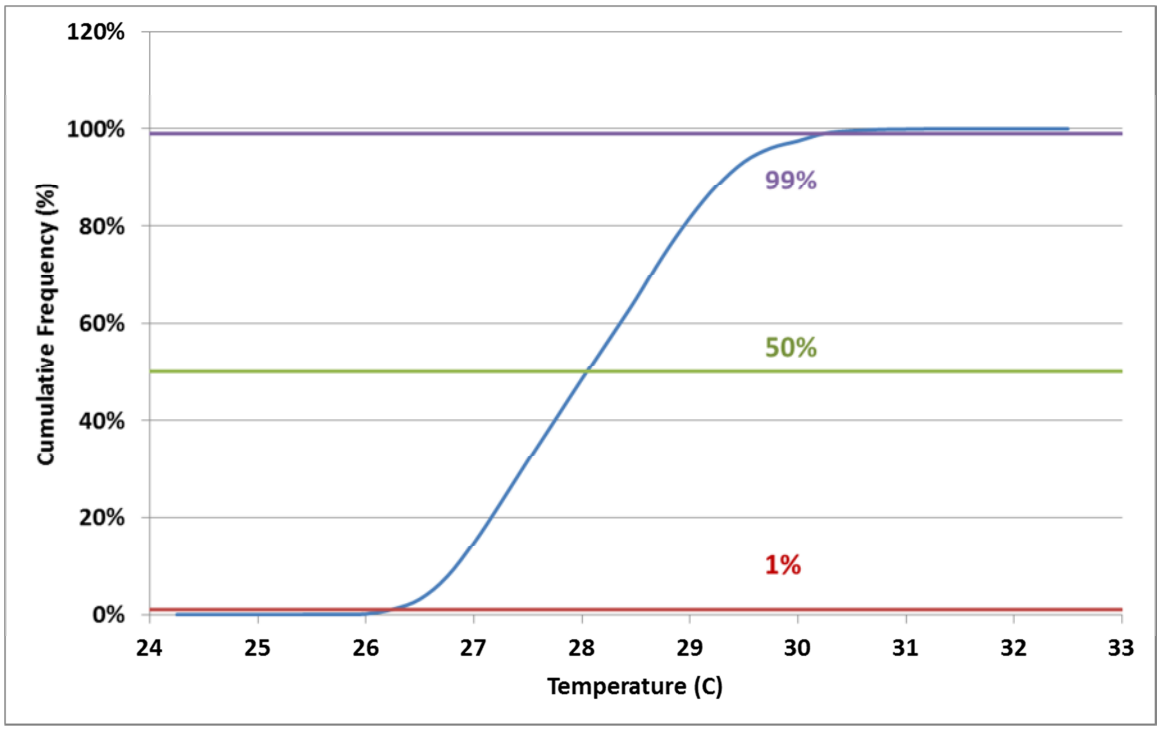


Figure 27 Cumulative frequency distribution at FPSO (near surface)

Cumulative Frequency	FPSO
Low (1%)	0.08
High (99%)	0.94

3.2.5 Scenarios

A combination of the discharges, ambient properties (currents and temperatures) and discharge velocities (pipe diameter) were used to develop a comprehensive list of scenarios for simulation with CORMIX (Table 17). Pipe diameters selected for these scenarios were the largest diameters shown in Table 13. Demonstration runs were done by selecting the worst scenario (largest plume) to show that the selection of smaller diameter will result in smaller plume.

Table 17 List of modelled scenarios

No	Discharge	Scenario Name	Ambient Currents	Ambient Temperature	Location
1	Cooling Water - Thermal	T Sc 01	Low (5%)	High (99%)	FPSO
		T Sc 02	Typical (50%)	High (99%)	FPSO
		T Sc 03	High (95%)	High (99%)	FPSO

No	Discharge	Scenario Name	Ambient Currents	Ambient Temperature	Location
		T Sc 04	Low (5%)	Low (1%)	FPSO
		T Sc 05	Typical (50%)	Low (1%)	FPSO
		T Sc 06	High (95%)	Low (1%)	FPSO
2	Cooling Water - Hypochlorite	C Sc 01	Low (5%)	High (99%)	FPSO
		C Sc 02	Typical (50%)	High (99%)	FPSO
		C Sc 03	High (95%)	High (99%)	FPSO
		C Sc 04	Low (5%)	Low (1%)	FPSO
		C Sc 05	Typical (50%)	Low (1%)	FPSO
		C Sc 06	High (95%)	Low (1%)	FPSO
3	Sulfate Removal & Potable Water Processing Brines	W Sc 01	Low (5%)	Typical (50%)	FPSO; 1m above Surface
		W Sc 02	Typical (50%)	Typical (50%)	FPSO; 1m above Surface
		W Sc 03	High (95%)	Typical (50%)	FPSO; 1m above Surface
4	Produced Water	P Sc 01	Low (5%)	Typical (50%)	FPSO; 1m below Surface
		P Sc 02	Typical (50%)	Typical (50%)	FPSO; 1m below Surface
		P Sc 03	High (95%)	Typical (50%)	FPSO; 1m below Surface
5	Hydrostatic Test Water	H Sc 01	Low (5%)	Typical (50%)	DC2-I; Seabed
		H Sc 02	Typical (50%)	Typical (50%)	DC2-I; Seabed
		H Sc 03	High (95%)	Typical (50%)	DC2-I; Seabed
6	Hydrate Control Fluid -	Methanol Sc01 2in	Low (5%)	Typical (50%)	DC2-I; Seabed
		Methanol	High (95%)	Typical (50%)	DC2-I; Seabed

No	Discharge	Scenario Name	Ambient Currents	Ambient Temperature	Location
	Methanol	Sc03 2in			
		Methanol Sc01 6in	Low (5%)	Typical (50%)	DC2-I; Seabed
		Methanol Sc03 6in	High (95%)	Typical (50%)	DC2-I; Seabed
7	Hydrate Control Fluid – ethylene glycol	MEG Sc01 2in	Low (5%)	Typical (50%)	DC2-I; Seabed
		MEG Sc03 2in	High (95%)	Typical (50%)	DC2-I; Seabed
		MEG Sc01 6in	Low (5%)	Typical (50%)	DC2-I; Seabed
		MEG Sc03 6in	High (95%)	Typical (50%)	DC2-I; Seabed

3.3 Standards and Thresholds

The cooling water discharges are typically regulated regionally with consideration of native aquatic species. These standards are more stringent in coastal and inland waters due to the presence of sensitive aquatic receptors and the limited area available for mixing. In offshore waters, such standards are usually absent. For this study, an internationally recognized thermal standard of 3°C maximum temperature change at 100 meters from the point of discharge was used. Hypochlorite, added to avoid biofouling, is either regulated as an end of pipe concentration or at the end of a mixing zone (100 m in this case). However, the residual chlorine from the hypochlorite only poses risk to aquatic species if they are exposed to elevated concentrations for extended periods of time (72-96 hours).

The scenarios designed in this study are highly conservative, i.e., they assume extended periods of time during which ambient conditions (primarily currents, salinity and temperature) persist. This approach assumes a static plume which, in reality, will be transient in extent and configuration. For instance, the small ambient currents (5%) will only exist for a short duration suggesting that the resulting plumes will continue to evolve and devolve as currents change direction and magnitude. Figure 28 shows a schematic of such transient plume suggesting that the existence of maximum concentrations calculated through this conservative approach will exist only for a short duration and result in considerably reduced exposure times.

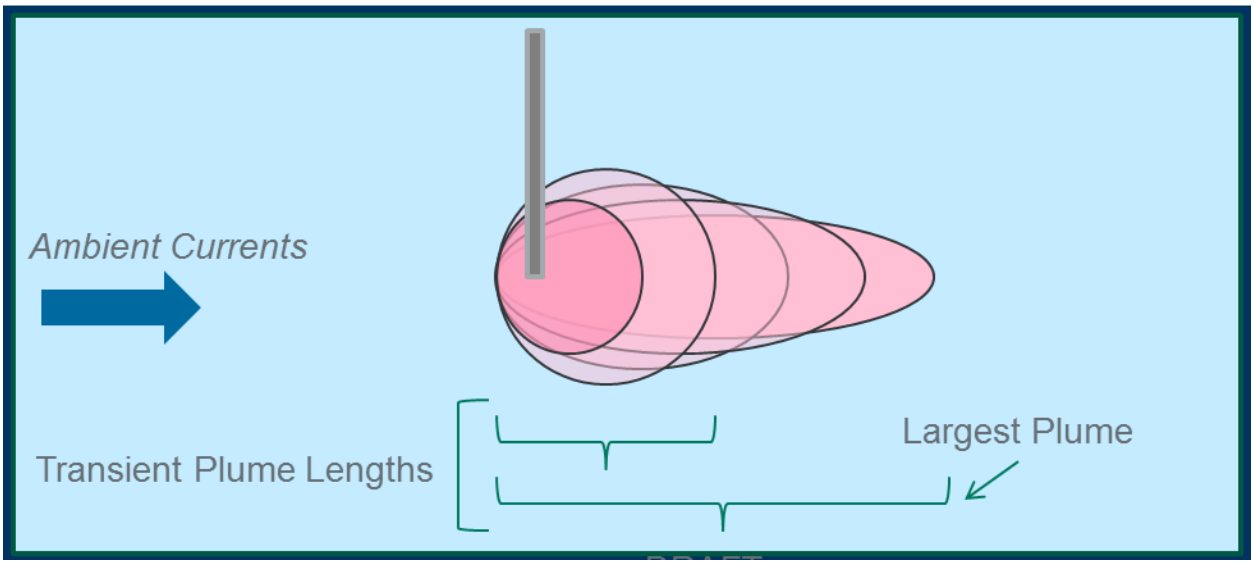


Figure 28 Transient discharge plume from various offshore releases

Discharges such as produced water, hydrotest or sulfate removal & potable water processing brines are not subject to any regulatory standards for ambient water quality. The total concentration of oil & grease at the end of pipe is regulated by MARPOL standards at maximum monthly average of 29 mg/l and a daily maximum of 42 mg/l. Furthermore, the USEPA compliance guidance document for the Gulf of Mexico (Final NPDES General Permit for New and Existing Sources and New Discharges in the Offshore Subcategory of the Oil and Gas Extraction Category for the Western Portion of the Outer Continental Shelf of the Gulf of Mexico (GMG290000)) requires treatment chemicals such as biocides, corrosion inhibitors, or other chemicals used to prevent corrosion or fouling of piping or equipment to be limited by the following constraints:

- The maximum concentration and any other conditions specified in the EPA product registration labelling, or
- The maximum manufacturer's recommended concentration, or
- 500 mg/l

At the time of the study, no manufacturer's recommended limits are available for constituents within the SRU processing brines, produced water or hydrotest water. It is noted that the maximum concentrations of any treatment chemicals will be less than 500 mg/l.

Since no ambient water quality standards exist or are applicable to the various offshore discharge streams except for the cooling water discharge, only dilution values are reported at a reference distance of 100 m.

3.4 Results

Each CORMIX simulation codes its results in a prediction (*.prd) file that consists of the plume centerline coordinates (0,0,0 at the discharge location), dilution (S) and

concentrations. For thermal discharge (cooling water), concentration refers to the temperature rise above ambient and includes heat loss from the surface. For all other constituents, the dilution value without any decay is used to obtain a conservative result. Note that inclusion of a decay term would result in a smaller plume. Since the concentrations are always the highest at the plume centerline, the results discussed here are shown as centerline concentrations with distance from the discharge.

3.4.1 Cooling Water

The cooling water discharge consists of two separate streams: cooling exchangers and produced water cooler. At this early stage of the project, it is undecided if these two streams will be combined and released through a single pipe or released separately. The project design will only consider pipe configurations that allow compliance with the thermal standard of temperature rise within 100 m of the discharge to be less than 3°C. To obtain this level of performance, several limiting pipe configurations were evaluated and design options developed such that compliance is achieved. Pipe diameters ranging from 24″ to 40″ were considered. Since larger pipes result in reduced exit velocity resulting in reduced mixing, deeper releases were considered to compensate for this reduction in mixing. Two ambient temperatures (1% and 99%) were selected for simulation because different in ambient temperatures will influence the plume behaviour and the effluent temperature rise.

Based on the initial assessments, Scenario 06 (winter – low ambient temperature and low ambient currents) was found to be limiting. Using this scenario, the minimum depth necessary for the combined release to achieve compliance was determined as shown in Table 18. Each of these pipe configurations (combination of pipe diameter and release depth) will ensure compliance with applicable thermal standards under both minimum and maximum flow rates (Table 15). Similarly, Table 19 shows the pipe configuration for the separate discharges that will ensure compliance. Figure 29 shows the temperature rise diminishing with distance from the discharge showing compliance with 3°C within 15 m from the discharge.

Table 18 Release depth needed to ensure compliance with the ≤3 deg. C temperature difference at 100 m standard for various pipe diameters (combined discharge)

Pipe Diameter	Discharge Depth (m)
40 inch	7
38 inch	6
36 inch	6
34 inch	5
32 inch	4

Pipe Diameter	Discharge Depth (m)
30 inch	3
28 inch	2
24 inch	1

Table 19 Release depth needed to ensure compliance with the ≤3 deg. C temperature difference at 100 m standard for various pipe diameters (separate discharges)

Pipe Diameter	Discharge Depth (m)
40 inch	
Cooling Med Exchangers	6
Produced Water Cooler	7
38 inch	
Cooling Med Exchangers	6
Produced Water Cooler	6
36 inch	
Cooling Med Exchangers	6
Produced Water Cooler	6
34 inch	
Cooling Med Exchangers	6
Produced Water Cooler	5
32 inch	
Cooling Med Exchangers	5
Produced Water Cooler	5
30 inch	
Cooling Med Exchangers	5
Produced Water Cooler	5

Pipe Diameter	Discharge Depth (m)
28 inch	
Cooling Med Exchangers	4
Produced Water Cooler	4
24 inch	
Cooling Med Exchangers	3
Produced Water Cooler	4

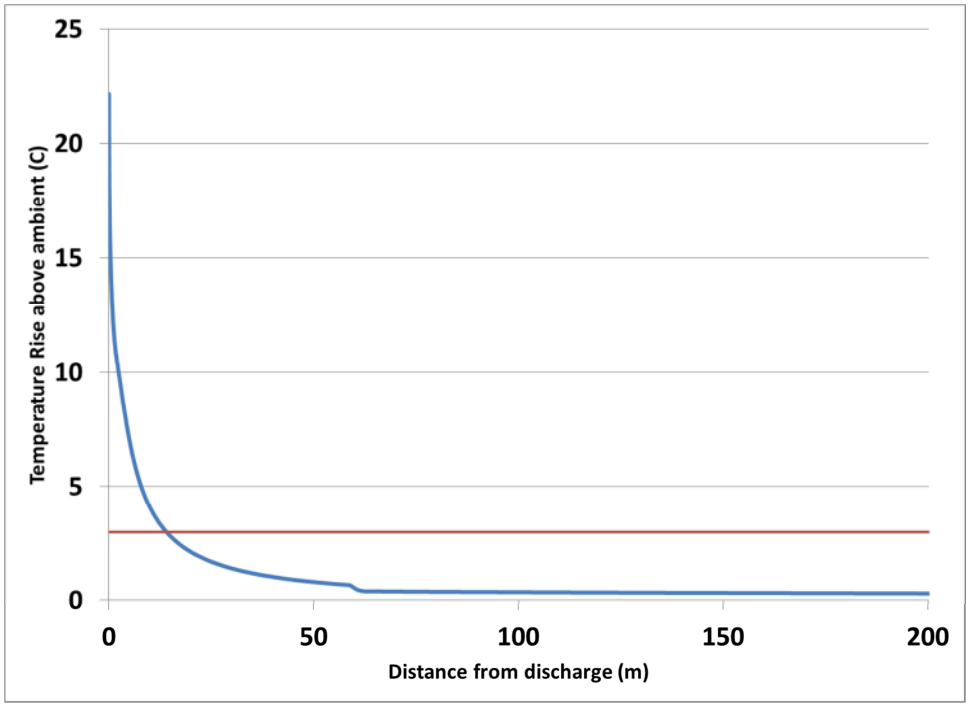


Figure 29 Temperature rise above ambient versus distance downstream for winter, low ambient current scenario; 40 inch diameter pipe and combined cooling water release

Compliance with the thermal discharge standard requires sufficient mixing within the immediate vicinity of the discharge. The pipe configurations designed to ensure compliance for thermal standards will therefore result in adequate mixing for the hypochlorite discharge as well. Since the thermal mixing at 100 m results in the reduction of concentrations by a factor 8.8 (=26.4 C/3C), the residual chlorine resulting concentrations from hypochlorite addition will reduce by the same factor. For hypochlorite dosing resulting of 5 ppm, the highest dosing expected, residual chorine concentrations at 100 m will be 0.57 ppm. As noted earlier, these concentrations are the most conservative estimates (i.e., peak values) and will be transient in nature. In

contrast, any risk to aquatic species from residual chlorine requires sustained exposure for 72 to 96 hours.

3.4.2 Produced Water

Produced water consists of oil & grease and residual production and water treatment chemicals. Scale inhibitor and corrosion inhibitor were modelled at discharge concentrations of 100 ppm and 200 ppm, respectively, as examples of residual production chemicals that may exist as constituents in the produced water discharge. It was assumed that the pipe diameter will be 18". Selection of pipe diameters less than 18" during the FEED will result in increased mixing and a smaller plume. Of the constituents of concern in produced water, only oil & grease end-of-pipe concentrations are regulated under MARPOL. The applicable standard is a maximum monthly average of 29 mg/l and a daily maximum of 42 mg/l released at the end of pipe. These standards are applied prior to the release of produced water. The daily maximum value of 42 mg/l was used for this analysis. No ambient water quality standards exist for any other constituents.

Concentrations of oil & grease, scale inhibitor and corrosion inhibitor are shown for the three scenarios in Figure 30, Figure 31 and Figure 32, respectively. Oil & grease concentration decreases to less 3.2 mg/l within 100 m while scale inhibitor and corrosion inhibitor drop to less than 7.6 ppm and 15.3 ppm, respectively, within 100 m. Releasing the same discharge approximately 10m below the water surface will result in further mixing and a smaller plume. While a near surface release is currently planned, the FEED study may recommend release of produced water 10 m below sea surface. A demonstration run for the worst case scenario (low ambient currents) was performed for this configuration. The plumes will shrink under this condition. Each constituent (oil & grease, scale inhibitor and corrosion inhibitor) shows lower concentrations at 100 m. For instance, corrosion inhibitor concentration at 100 m was 7.6 ppm when released at the surface, whereas it decreases to 2.4 ppm when released 10 m below surface.

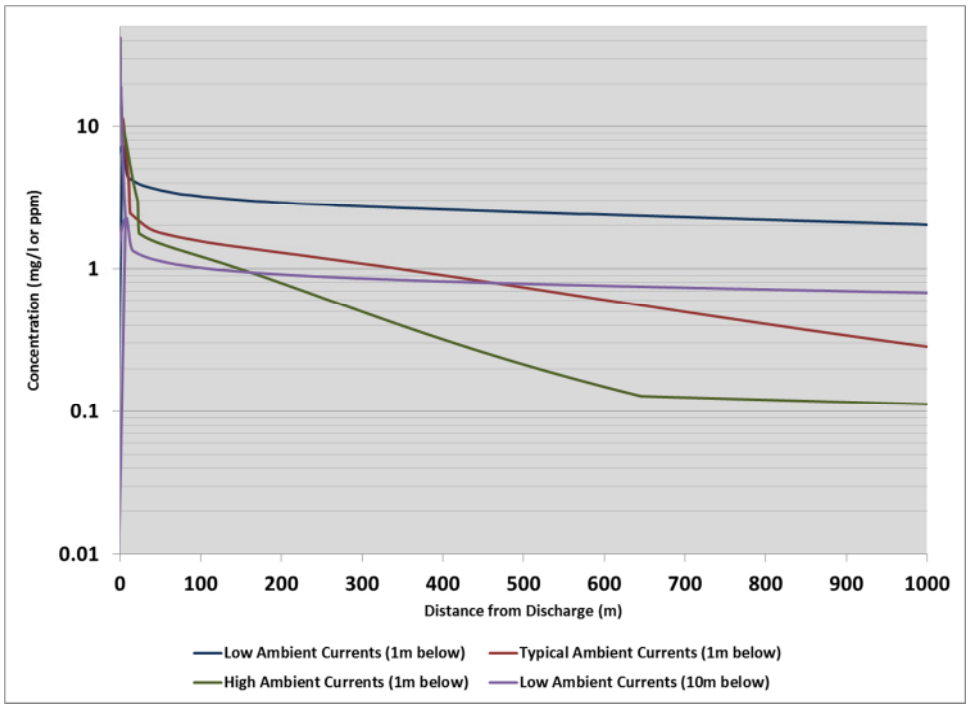


Figure 30 Concentration of oil and grease (mg/l) with distance (m) from the discharge for the three scenarios modelled

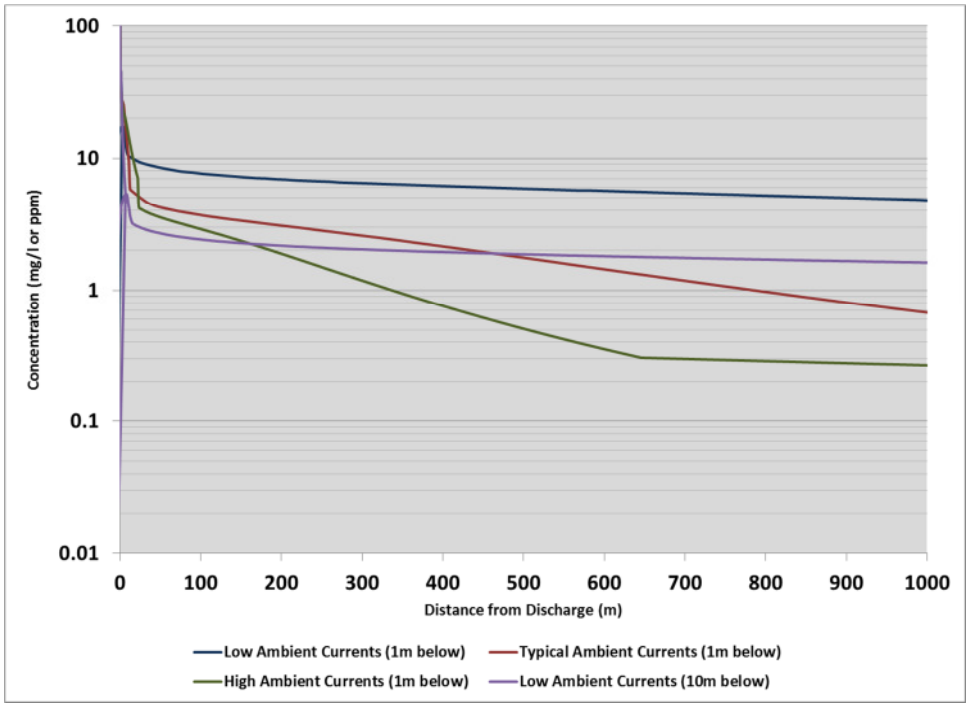


Figure 31 Concentration of scale inhibitor (ppm) with distance (m) from the discharge for the three scenarios modelled

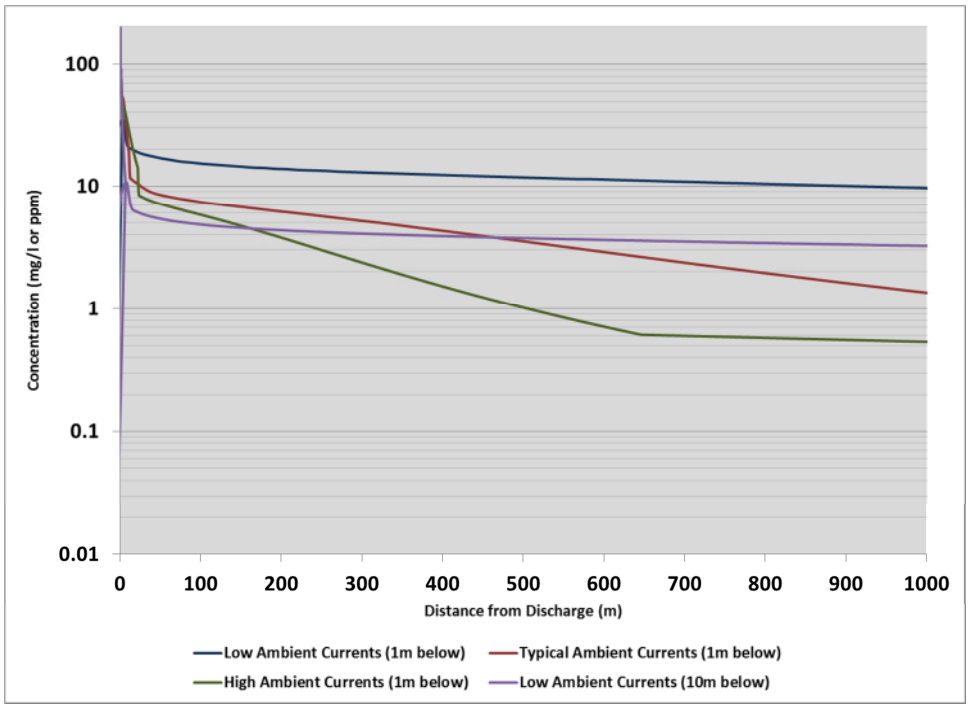


Figure 32 Concentration of corrosion inhibitor (ppm) with distance (m) from the discharge for the three scenarios modelled

3.4.3 Sulfate Removal & Potable Water Processing Brines

Effluent waste stream consists of the combination of processing brines from the SRU and freshwater RO. The main constituent are hypochlorite, electrolytes, biocides, oxygen scavenger and scale inhibitor. No ambient water quality standards exist of any of these constituents. It was also assumed that the discharge pipe will not exceed a diameter of 12 inches. Any pipe of smaller diameter will result in increased mixing and smaller plume.

The results for biocides concentrations for the three scenarios are shown in Figure 33. The biocide concentration decreases to 0.07 mg/l within 100 m (98.6% reduction) even for the worst case scenario (high ambient currents). All other constituents will follow the same mixing pattern and experience the same percent reduction as summarized in Table 20.

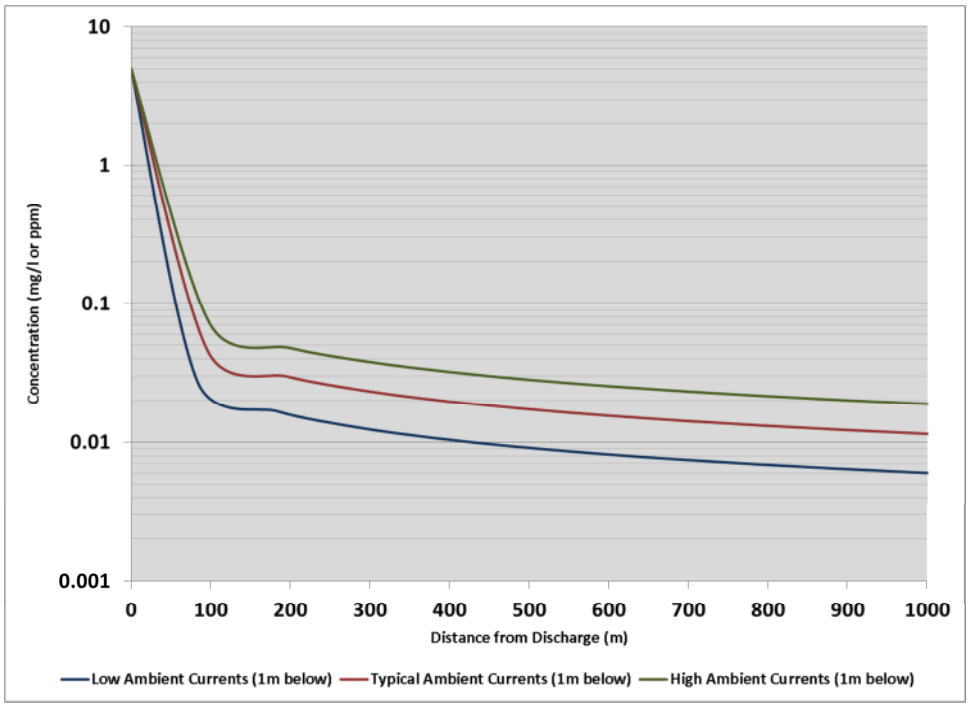


Figure 33 Concentration of biocide (ppm) with distance (m) from the discharge for the three scenarios modelled

3.4.4 Hydrostatic Test Water

Hydrotesting will be conducted routinely for various pipeline and risers. All pipeline and riser volumes were considered for this analysis and the largest single release was selected. It was assumed that once testing is complete, the total volume will be released within 60 minutes. Since the pipelines and risers are of different diameters, all three scenarios were run for pipe diameter of 2″ and 6″. Results for all three scenarios showing reduction in biocide concentration with the bounding pipe diameter cases are shown in Figure 34. For the worst case (H Sc 01 with 6″ pipe), biocide decreases to 5.5 ppm within 100 m of the discharge. The other constituents (oxygen scavenger and corrosion inhibitor) will follow the same mixing pattern and experience the same percent reduction.

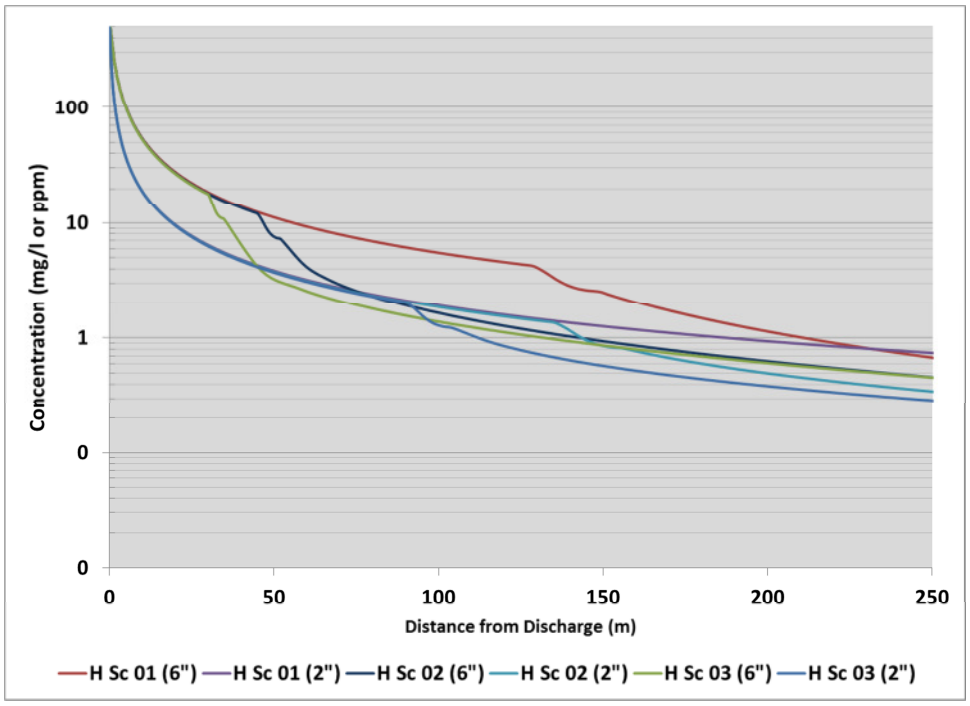


Figure 34 Concentration of biocide (ppm) with distance (m) from the discharge for the three scenarios and two pipe diameters

3.4.5 Gas Injection Line Commissioning Fluids

As part of the gas injection line commissioning, a hydrate control fluid (concentrated methanol or ethylene glycol) will be discharged at the seafloor. The most probable volume for the hydrate control fluid will be 400 bbl, but a very conservative value of 2,500 bbl was assumed for the modelling analysis. Since the pipelines and risers are of different diameters, all three scenarios were run for pipe diameter of 2″ and 6″. Figure 35 shows the results for both methanol and ethylene glycol under the low and high ambient currents and 2″ and 6″ pipe diameters.

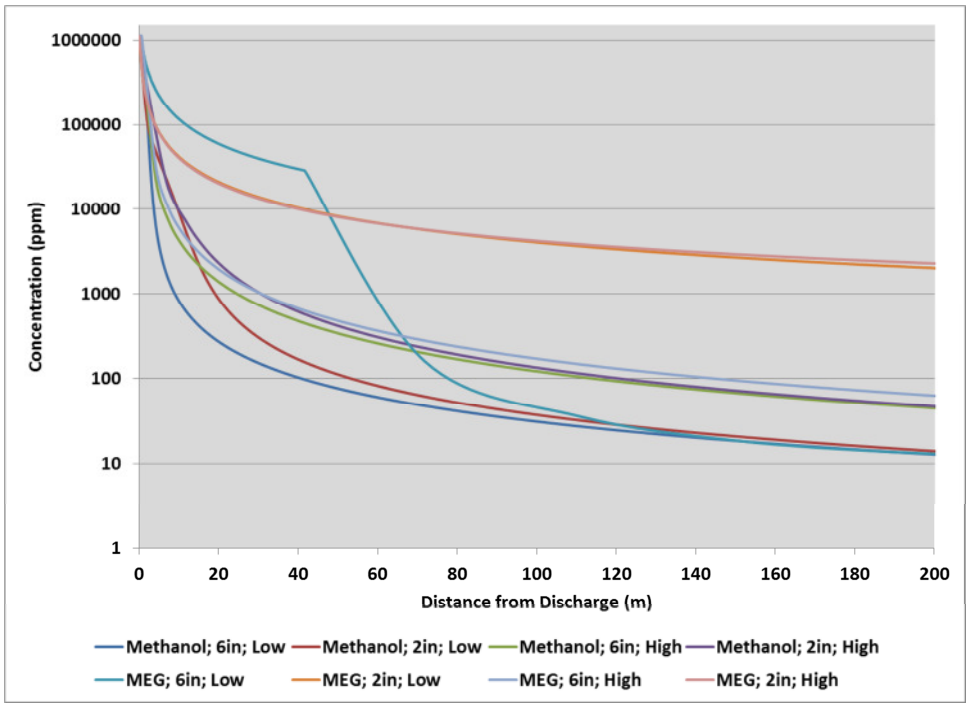


Figure 35 Concentration of methanol or MEG (ppm) with distance (m) from the discharge for the low and high currents and 2″ and 6″ pipe diameters

3.5 Conclusions

The various operational and maintenance discharges and activities identified in the proposed project description were modelled to estimate the extent of the discharge plume. Extreme conditions and maximum expected discharge rates and concentrations were considered in this conservative analysis. The only relevant regulatory standard related to ambient water quality is for the thermal discharges: temperature rises within 100 m of the discharge point are required to be less than 3°C. Since the project is in the pre-FEED phase, design specifications for the various discharge ports were not available. To address this lack of specific information, conservative estimates of the largest pipe diameter were made that allow the standard to be met. The final FEED will ensure that the designed discharge pipes will not exceed these conservative pipe diameters by using these, or smaller, pipe diameters.

CORMIX, a near-field mixing zone model approved by USEPA, was used to simulate the size and configuration of the mixing zones of the various discharges. It was found that even under the extreme conditions, discharge plumes were small and subject to rapid mixing within the first 100 m. Although only thermal discharges are subject to regulatory limits, the reference distance of 100 m is used for reporting purposes for all the discharges to demonstrate the rapid mixing that the discharge plumes experience.

Table 20 summarizes the results of the modelling study for offshore discharges.

Table 20 Results summary of offshore discharges and concentrations at 100 m reference distance

No'	Discharge	Scenario Name	Concentrations at 100 m[1]
1	**Thermal**	**Worst Case**	Temperature Rise: <3°C
2	**Hypochlorite**	**Worst Case**	Residual Chlorine: 0.57 ppm
3	**Sulfate Removal & Potable Water Processing Brines**	**W Sc 01**	Hypochlorite: 0.005 ppm Electrolyte: 0.005 ppm Biocide: 0.027 ppm Oxygen Scavenger: 0.055 ppm Scale Inhibitor: 0.027 ppm
		W Sc 02	Hypochlorite: 0.009 ppm Electrolyte: 0.009 ppm Biocide: 0.045 ppm Oxygen Scavenger: 0.09 ppm Scale Inhibitor: 0.045 ppm
		W Sc 03	Hypochlorite: 0.014 ppm Electrolyte: 0.014 ppm Biocide: 0.07 ppm Oxygen Scavenger: 0.14 ppm Scale Inhibitor: 0.07 ppm
4	**Produced Water**	**P Sc 01**	Oil & Grease: 3.2 mg/l Scale Inhibitor: 7.64 ppm Corrosion Inhibitor: 15.27 ppm
		P Sc 02	Oil & Grease: 1.52 mg/l

[1] Note: Except for the thermal discharge (temperature rise), no standards exist for any discharge constituents. The distance of 100 m is used as a widely accepted reference distance and should not be interpreted as a criterion for regulatory compliance.

No'	Discharge	Scenario Name	Concentrations at 100 m[1]
			Scale Inhibitor: 3.64 ppm Corrosion Inhibitor: 7.27 ppm
		P Sc 03	Oil & Grease: 1.21 mg/l Scale Inhibitor: 2.89 ppm Corrosion Inhibitor: 5.78 ppm
5	**Hydrotest**	**H Sc 01**	Biocide (6″ pipe): 5.50 ppm Biocide (2″ pipe): 1.89 ppm
		H Sc 02	Biocide (6″ pipe): 1.70 ppm Biocide (2″ pipe): 1.84 ppm
		H Sc 03	Biocide (6″ pipe): 1.51 ppm Biocide (2″ pipe): 1.28 ppm
6	**Hydrate Control Fluid**	**Methanol Sc01 2in**	Methanol (2″ pipe): 37.5 ppm
		Methanol Sc03 2in	Methanol (2″ pipe): 136.3 ppm
		Methanol Sc01 6in	Methanol (6″ pipe): 31.1 ppm
		Methanol Sc03 6in	Methanol (6″ pipe): 121.8 ppm
		MEG Sc01 2in	MEG (2″ pipe): 4,031.1 ppm
		MEG Sc03 2in	MEG (2″ pipe): 4,190.2 ppm
		MEG Sc01 6in	MEG (6″ pipe): 70.3 ppm
		MEG Sc03 6in	MEG (6″ pipe): 171.5 ppm

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APPENDIX N – Underwater Noise Modeling Report (JASCO)

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Underwater Sound Associated with Liza Phase 1 Project Activities

Offshore Guyana Stabroek Block

Submitted to:

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ExxonMobil Exploration Co.
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Contents

EXECUTIVE SUMMARY 1
1. INTRODUCTION 2
1.1. Modeled Scenarios 3
2. ACOUSTIC EFFECTS CRITERIA 9
3. METHODS 10
3.1. Modeling Acoustic Source Levels 10
3.1.1. Vessels 10
3.1.2. Vertical Seismic Profile Source 11
3.1.3. Impact Pile Driving 12
3.2. Modeling Sound Propagation 13
3.3. Calculating Distances to Acoustic Effect Thresholds 14
4. MODEL PARAMETERS 15
4.1. Acoustic Source Parameters 15
4.1.1. Vessels 15
4.1.2. Vertical Seismic Profile Source 17
4.1.3. Impact Pile Driving 18
4.2. Environmental Parameters 18
4.2.1. Bathymetry 18
4.2.2. Geoacoustics 18
4.2.3. Ocean Sound Speed Profile 19
4.3. Sound Propagation Modeling Zones 20
5. RESULTS 21
5.1. Source Levels 21
5.1.1. Vessels 21
5.1.2. Vertical Seismic Profile Source 23
5.1.3. Impact Pile Driving 25
5.2. Sound Fields 26
5.2.1. Vessels 26
5.2.2. Vertical Seismic Profile Source 27
5.2.3. Impact Pile Driving 28
6. DISCUSSION 35
GLOSSARY 36
LITERATURE CITED 42
APPENDIX A. UNDERWATER ACOUSTICS A-1

Figures

Figure 1. Overview of the Guyana Stabroek project area. 2
Figure 2. Scenario 1: Location of modeled vessels. 5
Figure 3. Scenario 2: Location of modeled vessels. 6
Figure 4. Scenarios 3 and 4: Location of modeled vessels and the VSP source at Drill Center 2. 7
Figure 5. Scenarios 5 and 6: Location of modeled underwater impact pile driving operations at Drill Center 2-P and the FPSO (Area 2). 8
Figure 6. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). 12
Figure 7. Example of an area ensonified to an arbitrary sound level showing R_{max} and $R_{95\%}$ radii. 14
Figure 8. Layout of the High-performance Magnum six-gun array (1200 in^3 total volume, 4.5 m depth) 17
Figure 9. Mean monthly sound speed profiles (left: top 200 m; right: entire water column) at the FPSO location 20
Figure 10. Estimated source level spectra for the FPSO. 21
Figure 11. Estimated source level spectrum for the drill ship. 21
Figure 12. Estimated source level spectrum for the pipelaying vessel. 22
Figure 13. Estimated source level spectra for the tugs. 22
Figure 14. Estimated source level spectra for the various support vessels. 22
Figure 15. Predicted source level details for the 1200 in^3 array. 23
Figure 16. Directionality of the predicted horizontal source levels for the 1200 in^3 array, 10–25,000 Hz. 24
Figure 17. Force at the top of a pile during impact driving of a 25-m long, 5-m wide cylindrical steel pile with the MENCK 500T (underwater) hammer 25
Figure 18. Predicted overpressure signature of three monopoles along the modeled pile: top (in water), center (in water), and bottom (in substrate). 25
Figure 19. Scenario 4: Sound level contour map showing the extend of the maximum-over-depth M-weighted SEL_{24h} from the VSP source for marine mammal injury thresholds based on Southall et al. (2007) and Finneran (2015) 27
Figure 20. Scenario 5: Sound level contour map showing the extend of the maximum-over-depth M-weighted SEL_{24h} from impact pile driving for marine mammal injury thresholds based on Southall et al. (2007) and Finneran (2015). 29
Figure 21. Scenario 5: Estimated M-weighted SEL_{24h} based on Southall et al. (2007), propagating south of the pile at Drill Center 2-P 30
Figure 22. Scenario 5: Estimated M-weighted SEL_{24h} based on Finneran (2015), propagating south of the pile at Drill Center 2-P. 31
Figure 23. Scenario 6: Sound level contour map showing the extend of the maximum-over-depth M-weighted SEL_{24h} from impact pile driving for marine mammal injury thresholds based on Southall et al. (2007) and Finneran (2015). 32
Figure 24. Scenario 6: Estimated M-weighted SEL_{24h} based on Southall et al. (2007), propagating south of the FPSO anchor mooring piles. 33
Figure 25. Scenario 6: Estimated M-weighted SEL_{24h} based on Finneran (2015), propagating south of the FPSO anchor mooring piles. 34

Figure A-1. One-third-octave-bands shown on a linear frequency scale and on a logarithmic scale. A-2
Figure A-2. A power spectrum and the corresponding 1/3-octave-band sound pressure levels of example ambient noise shown on a logarithmic frequency scale. A-3
Figure A-3. Auditory weighting functions for functional marine mammal hearing groups as recommended by Southall et al. (2007). A-7

Figure A-4. Auditory weighting functions for functional marine mammal hearing groups as recommended by Finneran (2015). A-8
Figure A-5. The N×2-D and maximum-over-depth modeling approach used by MONM. A-9
Figure A-6. Peak and SPL and per-pulse SEL versus range from a 20 in^3 air gun array. A-10

Tables

Table 1. List of vessels for each modeled scenario. 4
Table 2. Marine mammal injury (Permanent Threshold Shift (PTS) onset) thresholds based on Southall et al. (2007), and Finneran (2015). 9
Table 3. Specifications of proposed and surrogate vessels used to estimate source levels. 16
Table 4. Relative positions of the elements within the 1200 in^3 array. 18
Table 5. Geoacoustic properties of the sub-bottom sediments as a function of depth 19
Table 6. Source level specifications in the horizontal plane for the 1200 in^3 array 23
Table 7. Scenarios 1–3: Distances (m) to marine mammal injury for non-impulsive sources. 26
Table 8. Scenario 4: Distances (m) to marine mammal injury thresholds for the VSP source. 27
Table 9. Scenario 5: Distances (m) to marine mammal injury thresholds for the underwater pile driving operations at Drill Center 2-P 28
Table 10. Scenario 6: Distances (m) to marine mammal injury thresholds for the underwater pile driving operations at the FPSO location. 32

Table A-1. Parameters for the auditory weighting functions recommended by Southall et al. (2007). A-7
Table A-2. Parameters for the auditory weighting functions recommended by Finneran (2015) A-8

Executive Summary

This underwater sound modeling study predicts underwater sound levels associated with the Liza Phase 1 Development Project (hereinafter referred to as the Project). The Project is designed to develop and produce oil in the ExxonMobil Liza field, located within the Stabroek Block, approximately 190 km offshore central Guyana. The modeled Project activities include drilling development wells, installing and operating a Floating Production Storage and Offloading (FPSO) vessel, and installing Subsea, Umbilical, Riser, and Flowline (SURF) equipment. Sound footprints from representative sound sources, including vessels, a vertical seismic profile (VSP) source, and underwater impact pile driving equipment, were considered. The model results were used to estimate distances to marine mammal injury thresholds, based on best available science.

The underwater sound fields were modeled for water column sound speed profiles representative of April. This time corresponds with lowest surface temperatures, which lead to upward sound refraction and longer-distance sound propagation. The obtained results therefore ensure cautionary estimates of the distances to received sound level thresholds.

Six scenarios were modeled to simulate the following:

1. The operation of a Floating Production Storage and Offloading (FPSO) vessel,
2. The installation of the FPSO vessel, which includes the associated installation and support vessels,
3. The operation of a drill ship and a pipelaying vessel at one of the two drill centers, approximately 13 km north of the FPSO,
4. The operation of a VSP source in the vicinity of the drill centers,
5. Underwater impact pile driving of SURF equipment piles at one of the two drill centers, approximately 13 km north of the FPSO, and
6. Underwater impact pile driving of anchor mooring piles at the FPSO location.

The models produced estimates of the sound fields in M-weighted SEL_{24h} and peak sound pressure levels (PK). The sound fields account for source-specific sound emission characteristics (Section 4.1) and site-specific environmental parameters (Section 4.2). The estimated sound fields are applicable to other locations within the Project area, where site-specific environmental parameters are similar.

For scenarios 1 through 3, the distances to injury thresholds from vessels are small (<10 m). Distances to low- and mid-frequency cetacean injury thresholds for the VSP source were estimated for three sets of acoustic effects criteria. The distances vary from ≤35 m for mid-frequency cetaceans to ≤143 m for low-frequency cetaceans. Distances to the same thresholds for underwater impact pile driving operations are the longer than for the other scenarios. The distances vary from 100 to 762 m for mid-frequency cetaceans and from 1,025 to 1,375 m for low-frequency cetaceans. The sound levels at or above injury thresholds for impact pile driving were found close to the ocean bottom, at depths >1,000 m.

1. Introduction

JASCO Applied Sciences (JASCO) carried out a modeling study for Esso Exploration and Production Guyana Limited (EEPGL) to predict underwater sound levels associated with the Liza Phase 1 Development Project (hereinafter referred to as the Project) located within the Stabroek Block, approximately 190 km offshore central Guyana (Figure 1). The Project activities include installing and operating a Floating Production, Storage, and Offloading (FPSO) vessel, installing and operating Subsea Umbilical, Riser, and Flowline (SURF) equipment, as well as associated development drilling at two drill centers in the Liza field. Each drill center consists of an underwater injection (I) and a production (P) component, tied to the FPSO by the SURF equipment. Installing this Project infrastructure will require the use of multiple vessels, including drill ships, pipelaying vessels, tugs, barges, support, and supply vessels of various sizes. During production operations, the FPSO will be moored. Hydrocarbons produced from the wells will be offloaded onto tankers. This offloading operation may also require the use of tugs, while supply vessels will regularly dock alongside the FPSO.

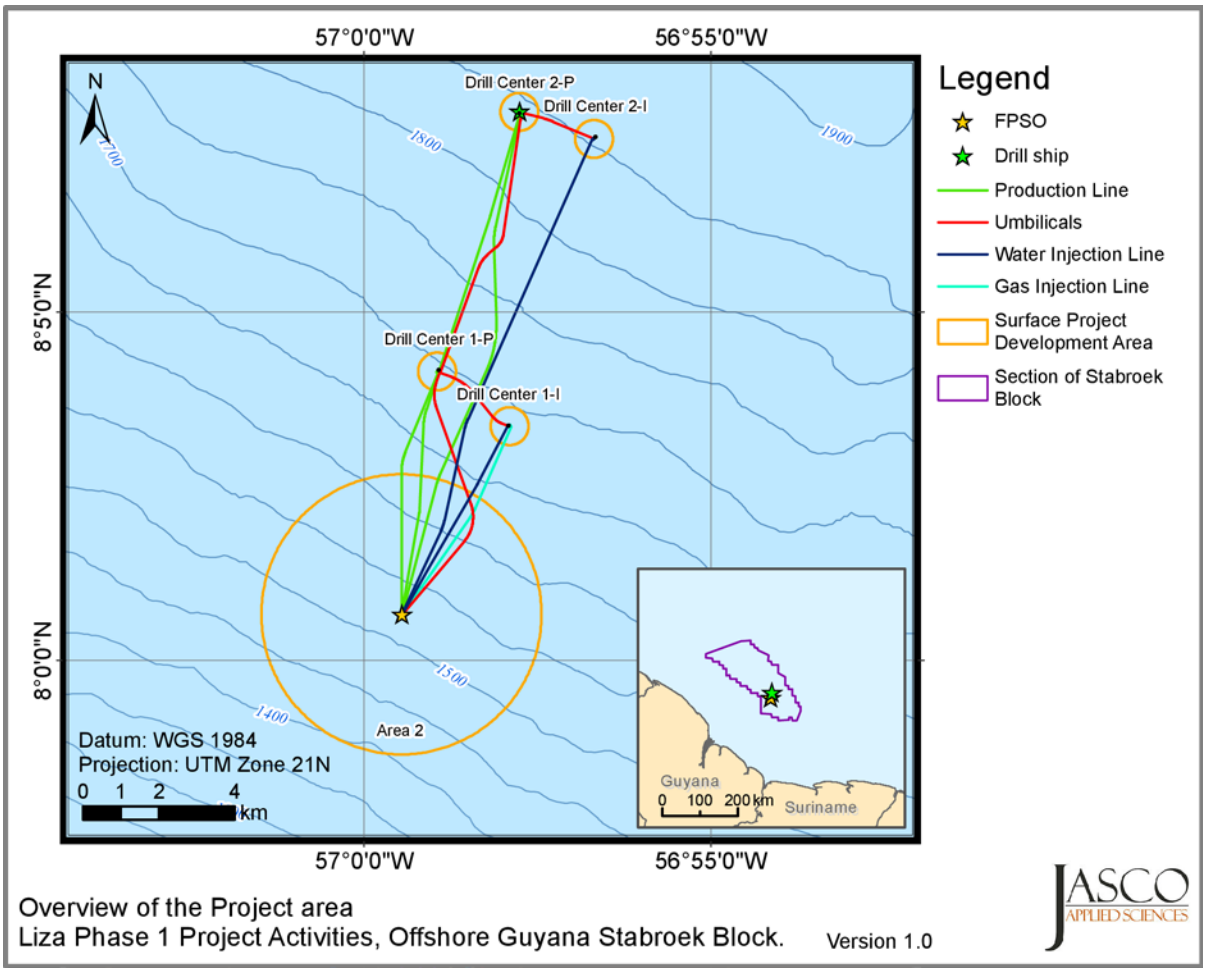


Figure 1. Overview of the Guyana Stabroek project area.

Six scenarios were considered in this modeling study, which include:

1. The operation of an FPSO vessel,
2. The installation of the FPSO vessel, which includes mooring the FPSO, and using several installation and service vessels, and
3. The installation of subsea flowlines and risers and operation of Drill Center 2-P, approximately 13 km north of the FPSO, which includes the operation of a drill ship, a pipelaying vessel, and multiple service vessels,
4. The operation of a VSP source in the vicinity of Drill Centers 2-P and 2-I,
5. The installation of piles for SURF equipment at Drill Center 2-P through underwater impact pile driving, and
6. The installation of anchor mooring piles at the FPSO location through underwater impact pile driving.

The specific vessels, the characteristics of the VSP source, as well as the specifications of the piles and driving hammer are at present unknown. Measurements from surrogate vessels, including the FPSO, drill ship, pipelaying vessel, tugs, and support vessels, were used to derive the acoustic characteristics of the vessels that will likely be used in the operations. The VSP source considered here is a six-element air gun array with a total volume of 1200 in^3. The source pressure signature of this array was modeled with JASCO's Airgun Array Source Model (AASM). This model accounts for individual element volume and position within the array. All modeled piles were 25 m in length, and 5 m in diameter. The modeled impact hammer model is the MENCK 500T, with underwater settings. It was assumed that it will take 5 hours to drive each pile, and that one pile will be driven per 24 hour period. The forcing function transferred from the hammer to the pile was modeled using the GRLWEAP model (GRLWEAP, Pile Dynamics 2010); the sound signature along the pile was modeled using JASCO's pile vibration and near-field sound radiation model (MacGillivray 2014).

Sound propagation was modeled with JASCO's Marine Operations Noise Model (MONM) and JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM). These models produced depth, range, and azimuth dependent sound fields associated with environmental parameters, including bathymetry, that are specific to the Stabroek Block area.

The sound footprint for each scenario was modeled to estimate distances to sound level thresholds based on injurious criteria prescribed by Southall et al. (2007) and Finneran (2015). The sound footprints were calculated as frequency-weighted (M-weighted) sound exposure levels (SEL) for 24 hours of operation.

Section 2 describes the acoustic effect criteria for this study. Definitions of the different metrics associated with the criteria are provided in Appendix A.1. Section 3 discusses the methodology for predicting the source levels and modeling the sound propagation. Section 4 describes the various input parameters pertinent to this study. Section 5 presents the results in two formats: tables of maximum and 95% distances to sound level thresholds and a sound field contour map showing the directivity of the various sound level threshold contours for the VSP source and impact pile driving operations. Section 6 presents an analysis of the results.

1.1. Modeled Scenarios

Various vessels were involved in the first three scenarios, including tugs, supply vessels, and support vessels. At the time of this study, the exact location and description of each vessel were unknown. The modeled scenarios represent an estimate of the general location of each vessel for a 24 hour period; the surrogate vessels provide estimates of the sound emission levels for the proposed vessel fleet. Table 1 and Figures 2–4 list the vessels, their operational state, and their location. Scenario 4 involves a VSP source operating near Drill Center 2-P (Table 1; Figure 4). Scenarios 5 and 6 represent the installation of SURF equipment and FPSO anchor mooring piles using an underwater impact pile driver (Table 1; Figure 5).

Table 1. List of vessels for each modeled scenario. FPSO: Floating Production Storage and Offloading; VSP: Vertical Seismic Profile.

Scenario	Vessel/Source type	Operational state	Location		UTM Coordinates	
			Latitude (°)	Longitude (°)	Easting (m)	Northing (m)
1	FPSO	Moored, not using main engines	8.010982	−56.990920	501000	885512
	Tanker	Idle, held in position by tugs	8.010955	−56.984305	501729	885509
	2 x tugs	Using dynamic positioning	8.010276, 8.011651	−56.987445, −56.987427	501383, 501385	885434, 885586
	Large tug	Using dynamic positioning	8.010955	−56.983479	501820	885509
	Supply vessel	Using dynamic positioning	8.011326	−56.991873	500895	885550
2	FPSO	Using main engine	8.010982	−56.990920	501000	885512
	2 x FPSO supply barges	Using dynamic positioning	8.000010, 8.010665	−56.991447, −56.991719	500942, 500912	884299, 885477
	2 x tugs	Using dynamic positioning	8.010213, 8.000769	−56.991447, −56.991447	500942, 500942	885427, 884383
	FPSO major work vessel	Using dynamic positioning	8.010629	−56.989732	501131	885473
	2 x supply vessels	Using dynamic positioning	8.011326, 7.993162	−56.991873, −56.983788	500895, 501786	885550, 883542
	3 x support vessels	Using dynamic positioning	8.011724, 7.989020, 8.010286	−56.989187, −56.996910, −56.989586	501191, 500340, 501147	885594, 883084, 885435
	Fast supply vessel	Using dynamic positioning	8.010673	−56.969304	503382	885478
	Light construction vessel	Using dynamic positioning	8.011299	−56.989777	501126	885547
3	Drill ship	Drilling and maintenance work	8.131187	−56.962605	504119	898801
	Large crane vessel	Using dynamic positioning	8.130906	−56.963123	504062	898770
	Light construction vessel	Using dynamic positioning	8.131431	−56.963277	504045	898828
	Multiple service vessel	Using dynamic positioning	8.134623	−56.958293	504594	899181
	Pipelaying vessel	Laying pipe	8.117347	−56.964095	503955	897271
	2 x barges	Towed by tugs	8.117428, 8.101734	−56.963841, −56.962799	503983, 504098	897280, 895545
	2 x tugs	Using dynamic positioning	8.117546, 8.102494	−56.963705, −56.962798	503998, 504098	897293, 895629
	2 x supply vessels	Using dynamic positioning	8.130734, 8.117799	−56.963059, −56.964268	504069, 503936	898751, 897321
	3 x support vessels	Using dynamic positioning	8.134479, 8.114625, 8.141861	−56.966644, −56.968507, −56.975277	503674, 503469, 502723	899165, 896970, 899981
	Field intervention vessel	Using dynamic positioning	8.141768	−56.949605	505551	899971
4	VSP source	Up to 40 pulses in 24 hours	8.128535	−56.953837	505085	898508
	VPS support vessel	Using dynamic positioning; deploying the VSP source	8.128535	−56.953837	505085	898508
5	Underwater impact pile driving	Driving SURF equipment piles at Drill Center 2-P	8.131187	−56.962605	504119	898801
6	Underwater impact pile driving	Driving FPSO anchor mooring piles at the FPSO	8.010982	−56.990920	501000	885512

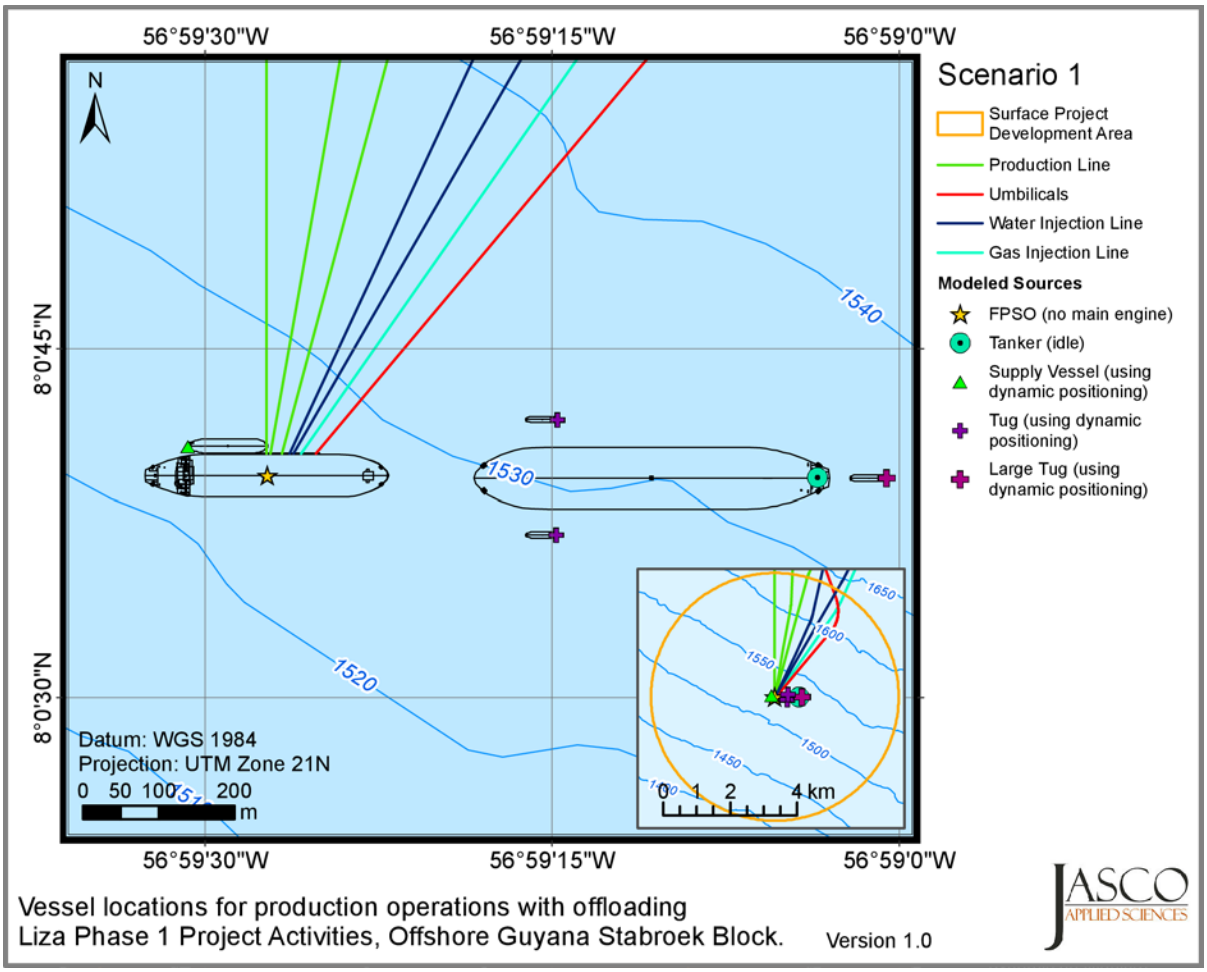


Figure 2. Scenario 1: Location of modeled vessels.

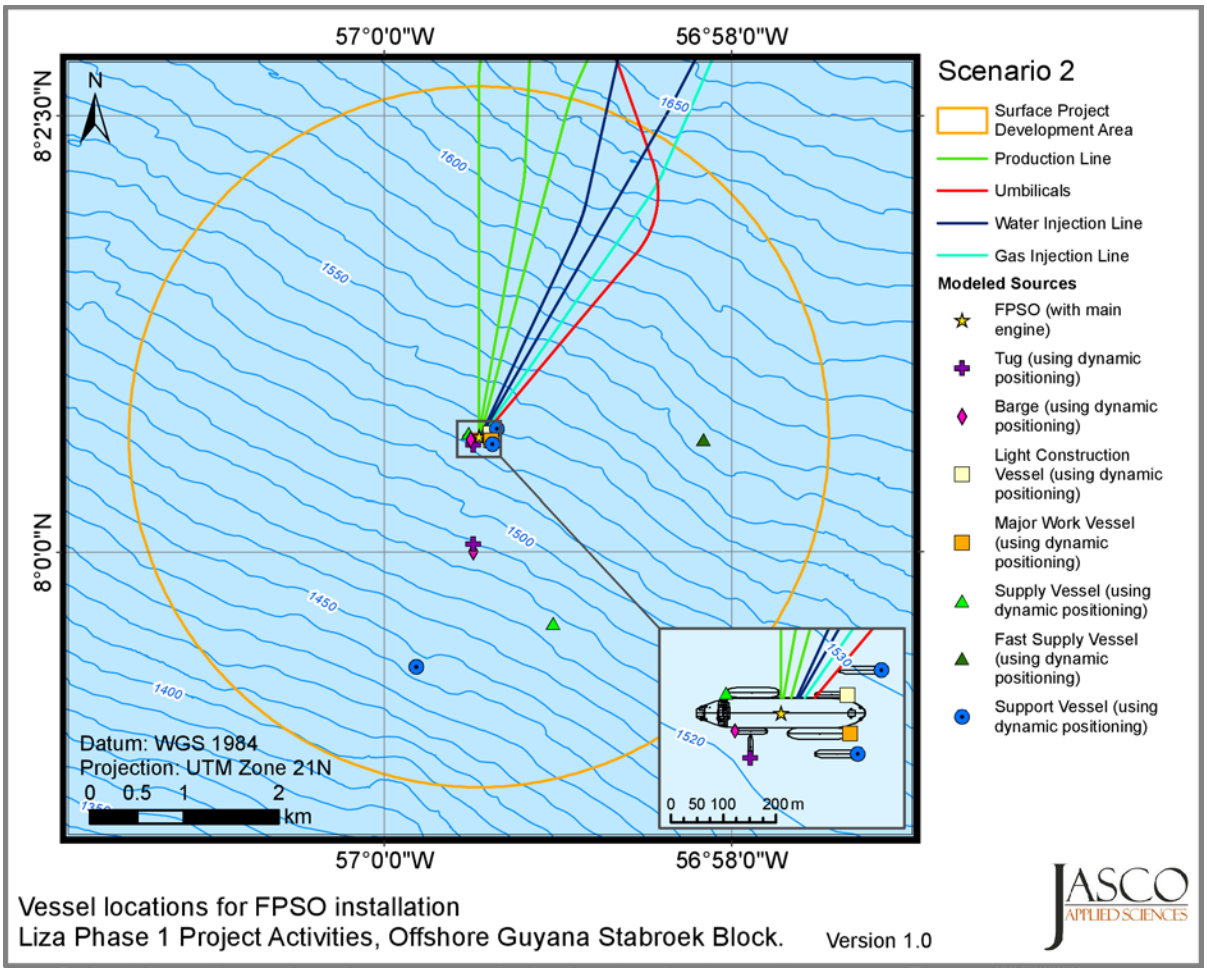


Figure 3. Scenario 2: Location of modeled vessels.

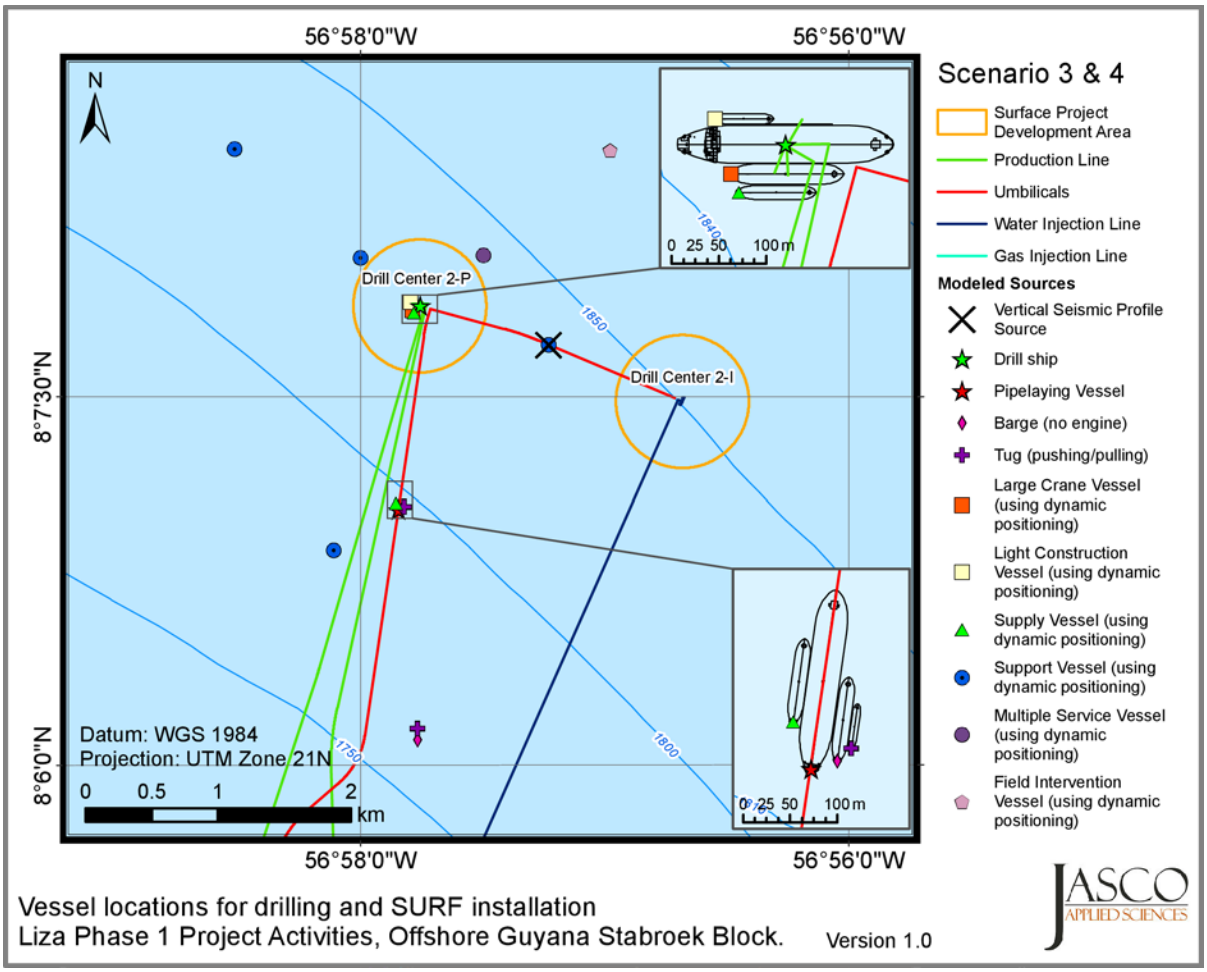


Figure 4. Scenarios 3 and 4: Location of modeled vessels and the VSP source at Drill Center 2.

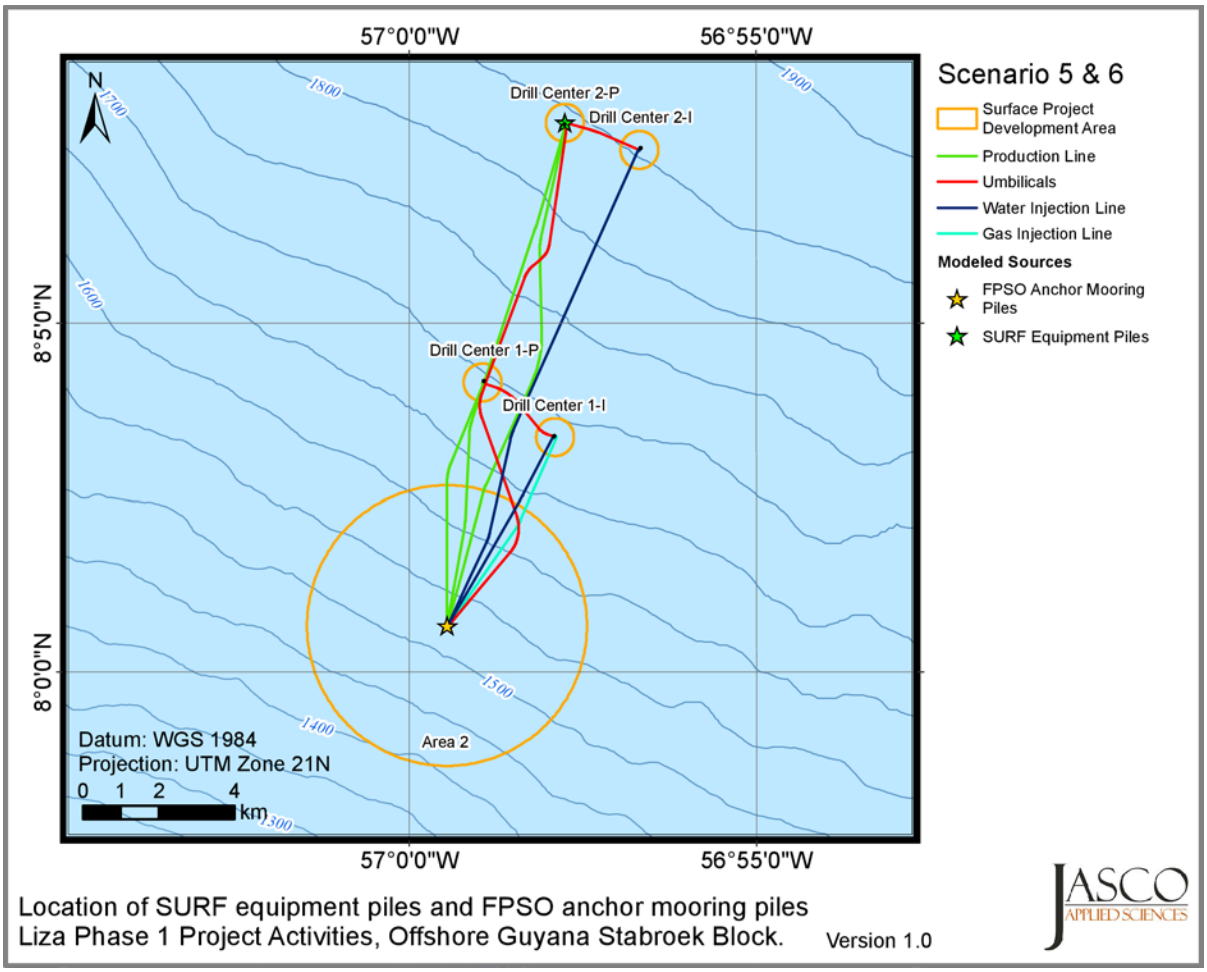


Figure 5. Scenarios 5 and 6: Location of modeled underwater impact pile driving operations at Drill Center 2-P and the FPSO (Area 2).

2. Acoustic Effects Criteria

Underwater sound can affect marine fauna in various ways. The question of which acoustic exposure levels might cause injury to marine mammals is still an active research. Since 2007, several expert groups have investigated SEL and peak pressure-based assessment approaches for injury using methods similar to those applied for humans, and a few key papers have been published on the topic. Those publications are reviewed, and the relative criteria discussed, in Appendix A.2. In the present section we propose specific thresholds used in other recent studies that are the most likely candidates for more widespread use; we caution readers, however, that assessment criteria are likely to evolve in the near future as research is progressing rapidly in this field.

Results of this modeling study are presented in terms M-weighted sound exposure level (SEL; $L_{E,24h}$) and peak pressure level (PK; L_{pk}) thresholds for injury to low- and mid-frequency cetaceans, based on two sets of criteria (Table 2): Southall et al. (2007) and Finneran (2015). These criteria have been chosen to include standard thresholds and thresholds suggested by the best available science, as reviewed and discussed in Appendix A.2. Low-frequency cetaceans, including baleen whales, and mid-frequency cetaceans, including dolphins and small whales, have been observed within or near the Project area. This study therefore focuses only on these marine mammal hearing groups.

Table 2. Marine mammal injury (Permanent Threshold Shift (PTS) onset) thresholds based on Southall et al. (2007), and Finneran (2015). PK and SPL in dB re 1 µPa; weighted SEL (24 hours) in dB re 1 µPa²·s.

Hearing group	Impulsive source				Non-impulsive source		
	Southall et al. (2007)		Finneran (2015)		Southall et al. (2007)		Finneran (2015)
	PK	Weighted SEL_{24h}	PK	Weighted SEL_{24h}	PK	Weighted SEL_{24h}	Weighted SEL_{24h}
Low-frequency cetaceans	230	198	230	192	230	215	207
Mid-frequency cetaceans	230	198	230	187	230	215	199

3. Methods

Underwater acoustic field for the studied vessels were modeled using JASCO's Marine Operations Noise Model (MONM), which is based on source levels derived from measurements of surrogate vessels.

Three complementary acoustic models were used to predict the underwater acoustic field for the studied seismic source. The pressure signatures and directional source levels of the VSP source were predicted with JASCO's Air gun Array Source Model (AASM). The acoustic fields around the array, in terms of M-weighted SEL_{24h}, were modeled with MONM. JASCO's Full Waveform Range-dependent Acoustic Model (FWRAM) was used to determine peak pressure levels as a function of azimuth, depth, and range from the array.

The acoustic source signature for impact pile driving operations was modeled using JASCO's physical model of pile vibration and near-field sound radiation (MacGillivray 2014), in conjunction with the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010). The acoustic fields, in terms of M-weighted SEL_{24h} and peak pressure levels, were modeled with JASCO's FWRAM.

M-weighting was applied for two hearing groups to weight the importance of received sound levels according to their constituent frequencies.

3.1. Modeling Acoustic Source Levels

3.1.1. Vessels

Several types of vessels were modeled in this study, including an FPSO, a drill ship, a pipelaying vessel, tugs, barges, supply vessels, and support vessels. The vessels characteristics are presented in Section 4.1.1. Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation (Ross 1976, §8.6), with a small fraction produced by sound transmitted through the hull, such as sound from engines, gearing, and other mechanical systems (Spence et al. 2007). Sound levels thus tend to be the highest when propulsion systems are used at high power. For example, during dynamic positioning in high currents or winds, or transiting at high speeds. A vessel's sound signature depends on the vessel's size, power output, and propulsion system characteristics (e.g., blade shape and size). Vessels produce broadband acoustic energy with most of the energy emitted below a few kilohertz. Sound from onboard machinery, particularly sound below 200 Hz, dominates the sound spectrum before cavitation begins—normally around 8 to 12 knots on many commercial vessels (Spence et al. 2007).

At the time of this study, the specific vessels engaged in installing and operating at the drill centers were unknown. Generalized source spectra were computed by comparing the expected specifications of the vessels to that of surrogate vessels for which source levels were available. Source levels for the surrogate were derived from measured received levels during various operational states. To account for the differences between the specification of the modeled and surrogate vessels, the spectra of the surrogates were corrected by the power ratings of the modeled and reference vessels:

$$S(f, P) = S_0(f) + 10\log\left(\frac{P}{P_0}\right) \quad (1)$$

where S_0 is the reference spectrum and P_0 is the reference power rating (Ross 1976, §8.6). When needed, surrogate spectra were extrapolated using −2 dB per decade at frequencies below 100 Hz and −1 dB per decade at frequencies above 1000 Hz (Ross 1976, §8.6).

3.1.2. Vertical Seismic Profile Source

The VSP source considered here is a six-element air gun array with a 1200 in^3 total volume. The source characteristics are presented in Section 4.1.2. The source levels and directivity of the VSP array were predicted with JASCO's Air gun Array Source Model (AASM; MacGillivray 2006a). This model is based on the physics of oscillation and radiation of air gun bubbles described by Ziolkowski (1970). The model solves the set of parallel differential equations that govern bubble oscillations. AASM also accounts for nonlinear pressure interactions between air guns, port throttling, bubble damping, and generator-injector (GI) gun behavior that are discussed by Dragoset (1984), Laws et al. (1990), and Landro (1992). AASM includes four empirical parameters that were tuned so model output matches observed air gun behavior. The model parameters fit to a large library of empirical data using a "simulated annealing" global optimization algorithm. These data are measurements of the signatures of Bolt 600/B guns ranging in volume from 5 to 185 in^3 (Racca and Scrimger 1986).

While air gun signatures are highly repeatable at low frequencies, which are used for seismic imaging, at higher frequencies their sound emissions have a large random component that cannot be predicted using a deterministic model. Therefore, AASM uses a stochastic simulation to predict the high-frequency (560−25,000 Hz) sound emissions of individual air guns, using a data-driven multiple-regression model. The multiple-regression model is based on a statistical analysis of a large collection of high quality seismic source signature data recently obtained from the Joint Industry Program (JIP) on Sound and Marine Life (Mattsson and Jenkerson 2008). The stochastic model uses a Monte-Carlo simulation to simulate the random component of the high-frequency spectrum of each element in an array. The mean high-frequency spectra from the stochastic model augment the low-frequency signatures from the physical model, allowing AASM to predict source levels at frequencies up to 25,000 Hz.

AASM produces a set of "notional" signatures for each array element based on:

- Array layout
- Volume, tow depth, and firing pressure of each air gun
- Interactions between different elements in the array

These notional signatures are the pressure waveforms of the individual elements at a standard reference distance of 1 m; they account for the interactions with the other elements in the array. The signatures are summed with the appropriate phase delays to obtain the far-field source signature of the entire array in all directions. This far-field array signature is filtered into 1/3-octave-bands to compute the source levels of the array as a function of frequency band and azimuthal angle in the horizontal plane (at the source depth), after which it is considered to be a directional point source in the far field.

A seismic array consists of many sources and the point-source assumption is invalid in the near field where the array elements add incoherently. The maximum extent of the near field of an array (R_{nf}) is:

$$R_{nf} < \frac{l^2}{4\lambda} \tag{1}$$

where λ is the sound wavelength and l is the longest dimension of the array (Lurton 2002, §5.2.4). For example, an array length of l = 2 m yields a near-field range of 1.5 m at 2 kHz. Beyond this R_{nf} range, the array is assumed to radiate like a directional point source and is treated as such for propagation modeling.

The interactions between individual elements of the array create directionality in the overall acoustic emission. Generally, this directionality is prominent mainly at frequencies in the mid-range between tens of hertz to several hundred hertz. At lower frequencies, with acoustic wavelengths much larger than the separation distances between array elements, the directionality is small. At higher frequencies, the pattern of lobes is too finely spaced to be resolved and the effective directivity is less.

3.1.3. Impact Pile Driving

A physical model of pile vibration and near-field sound radiation is used to calculate source levels of piles. The physical model employed in this study computes the underwater vibration and sound radiation of a pile by solving the theoretical equations of motion for axial and radial vibrations of a cylindrical shell. These equations of motion are solved subject to boundary conditions, which describe the forcing function of the hammer at the top of the pile and the soil resistance at the base of the pile (Figure 6). Damping of the pile vibration due to radiation loading is computed for Mach waves emanating from the pile wall. The equations of motion are discretised using the finite difference (FD) method and are solved on a discrete time and depth mesh.

In order to model the sound emissions of the piles, it was also necessary to model the force of the pile driving hammers. The force at the top of the pile was computed using the GRLWEAP 2010 wave equation model (GRLWEAP, Pile Dynamics 2010), which includes a large database of simulated hammers—both impact and vibratory—based on the manufacturer's specifications. The forcing functions from GRLWEAP were used as inputs to the FD model to compute the resulting pile vibrations.

The sound radiating from the pile itself is simulated using a vertical array of discrete point sources. The point sources are centered on the pile axis. Their amplitudes are derived using an inverse technique, such that their collective particle velocity—calculated using a near-field wave-number integration model—matches the particle velocity in the water at the pile wall. The sound field propagating away from the vertical source array is then calculated using a time-domain acoustic propagation model (e.g., FWRAM; Appendix A.5.3). MacGillivray (2014) describes the theory behind the physical model in more detail.

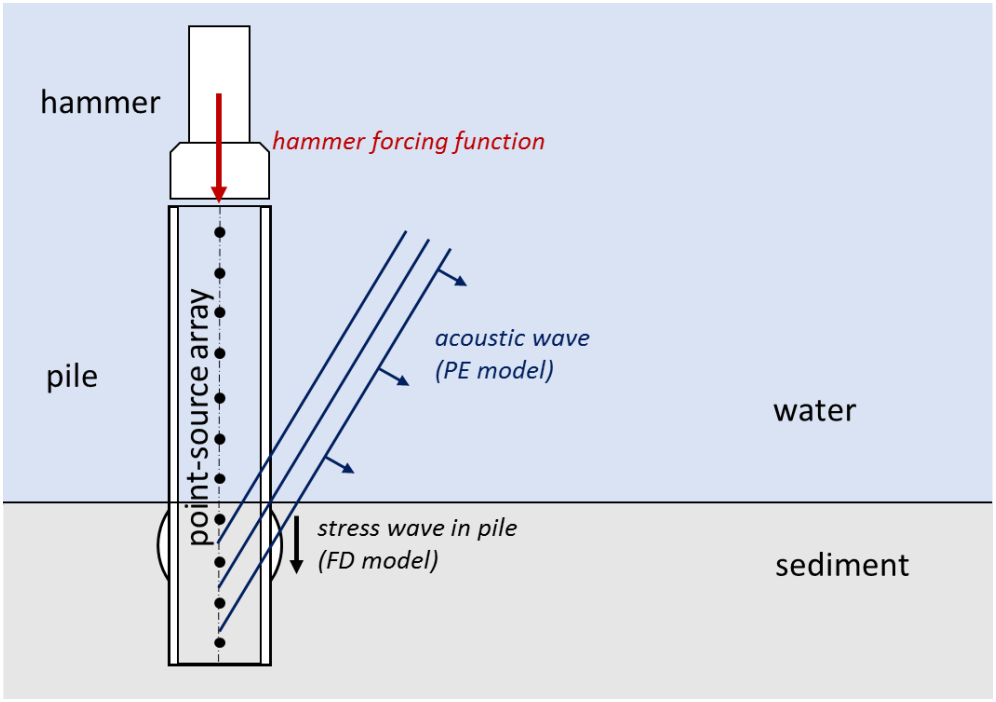


Figure 6. Physical model geometry for impact driving of a cylindrical pile (vertical cross-section). The hammer forcing function is used with the finite difference (FD) model to compute the stress wave vibration in the pile. A vertical array of point sources is used with the parabolic equation (PE) model to compute the acoustic waves that the pile wall radiates.

3.2. Modeling Sound Propagation

Underwater sound propagation (i.e., transmission loss) for the vessels and the VSP source exposure levels was predicted with JASCO's MONM (see Appendix A.5.2). The model computes received SEL (per-pulse SEL for impulsive sources) for directional sources located at a specified depth. It incorporates site-specific environmental properties including a bathymetric grid of the modeled area, in-water sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor. The model computes acoustic fields in three dimensions by modeling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source.

MONM treats frequency dependence by computing acoustic transmission loss at the center frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, from 10 Hz to 32 kHz, are modeled to include the majority of acoustic energy emitted by the source. Sound propagation at frequencies from 5 to 32 kHz was modeled by modifying the transmission loss at 5 kHz with the frequency- and range-dependent absorption coefficient for sea water (François and Garrison 1982a). Although mostly insignificant at lower frequencies, absorption coefficients were also applied from 10 Hz to 5 kHz for consistency. The broadband underwater sound field, expressed in terms of M-weighted per-pulse SEL, was computed by filtering and summing the received 1/3-octave-band levels.

JASCO's FWRAM (see Appendix A.5.3) was used to determine peak pressure levels from the VSP source and per-pulse SEL from pile driving operations. FWRAM uses the same computational algorithm as MONM, but computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source such as an underwater pile (MacGillivray and Chapman 2012).

The parabolic equation (PE) approximation used in FWRAM (Appendix A.5.3) is valid for sound propagating within a vertical angle range of at least 45° above and below the horizontal plane at the source depth (the exact angle depends on the environment). In the case of underwater impact pile driving, where the pile extends only over a fraction of the water column, the received levels above the pile (propagating at a >45° angle from the horizontal plane) may be underestimated using this model. The main acoustic waves around the pile propagate, however, at an angle of ~17° from the horizontal plane (Reinhall and Dahl 2011). FWRAM therefore provides a valid estimate of the distances to injury thresholds, which occur well within the PE approximation angle.

This approach, combined with the pile driving source model, accurately estimates spectral levels within the 10–800 Hz band where most of the energy from impact pile driving is concentrated. An extrapolation method (Zykov et al. 2016) was used to extend the modeled levels in 1/3-octave-bands up to 25 kHz, by applying a −2 dB per 1/3-octave-band roll-off coefficient to the per-pulse SEL value starting at the 800 Hz band. The acoustic energy levels at these higher frequencies are required to correctly assess the acoustic fields against Finneran (2015) criteria. The broadband underwater sound field, expressed in terms of M-weighted per-pulse SEL, was computed by filtering and summing the received 1/3-octave-band levels.

The injury thresholds evaluated here account for the total acoustic energy a marine mammal is subjected to within a defined period (24 hours in the present case). In the present study, the M-weighted SEL_{24h} were obtained by assuming a stationary scenario. With this simplified approach the acoustic energy (SEL) for 1 sec (for non-impulsive sources) or a single pulse (for impulsive sources) at a particular location was replicated in situ to estimate the cumulative metric. For a given number (N) of source activity seconds or of acoustic pulse events over a 24-hour period, SEL_{24h} was thus computed using the basic formula:

$$\mathrm{SEL}_{24\mathrm{h}} = \mathrm{SEL} + 10\log_{10}(N)\ . \qquad (2)$$

By assuming stationary sources, the method provides conservative estimates of the maximum extent of each sound level isopleth. This approach also yields notional values that are not strongly dependent on the environment or on the position of each source, which simplifies comparisons between different source types and acoustic effect criteria.

Although a more complex analysis would be outside the scope of this study, an important consideration that qualifies the cumulative received level estimates is that individuals of most species do not remain stationary throughout the exposure period. Their dose accumulation, therefore, depends on their movement and would likely be lower than for a stationary receiver. A second issue is that animals tend to recover from the sub-injurious effects of sound exposure over time; the paradigm of a strictly dosimetric accumulation is not therefore altogether correct, but the recovery period of most species is unknown.

3.3. Calculating Distances to Acoustic Effect Thresholds

The underwater sound fields predicted by the propagation models were sampled so that the received sound level at each location in the horizontal plane was taken to be the maximum value over all modeled depths for that location. Two distances from the source are reported for each sound level: 1) R_{max}, the maximum range at which the given sound level was encountered in the modeled maximum-over-depth sound field over all azimuths, and 2) $R_{95\%}$, the maximum range at which the given sound level was encountered after the 5% farthest such points were excluded (Figure 7). The $R_{95\%}$ is used because the maximum-over-depth sound field footprint is often non-circular and can include anomalous protrusions along a few azimuths. Regardless of the geometric shape of the maximum-over-depth footprint, $R_{95\%}$ is the predicted range encompassing at least 95% of the area (in the horizontal plane) that would be exposed to sound at or above that level. The difference between R_{max} and $R_{95\%}$ depends on the source directivity and the heterogeneity of the acoustic environment. The $R_{95\%}$ excludes ends of protruding areas or small isolated acoustic foci not representative of the nominal ensonification zone.

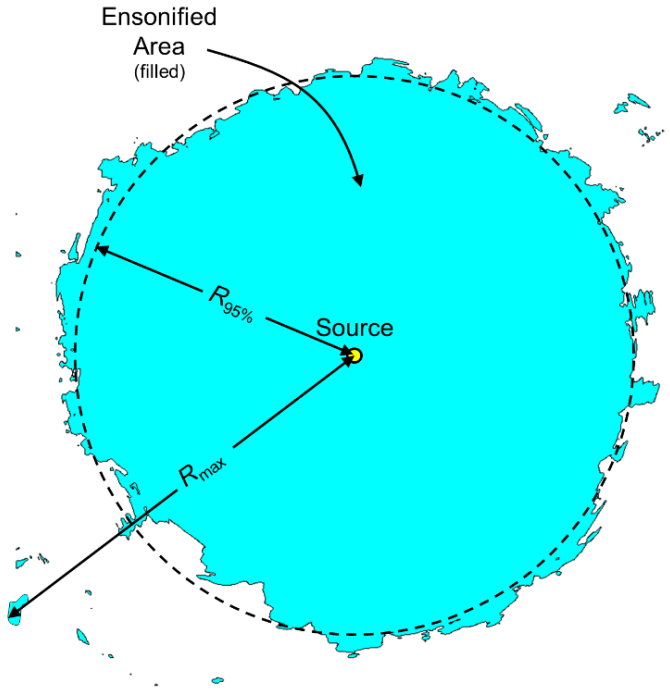


Figure 7. Example of an area ensonified to an arbitrary sound level showing R_{max} and $R_{95\%}$ radii.

4. Model Parameters

4.1. Acoustic Source Parameters

4.1.1. Vessels

A surrogate source vessel was chosen to represent each of the proposed vessels modeled in this study (Table 3). For vessels where the surrogate was significantly different in length, width, draft, or power, the surrogate's spectrum was adjusted based on the ratio of available power between the proposed and surrogate vessel (Section 3.1.1).

In Scenario 1 (Table 1; Figure 2), three tugs held the tanker in position (i.e., the tanker's main engine and propulsion system were idling or off). Thus, the sound levels from the tanker were neglected in the modeled scenario because they will be significantly lower (by at least 10 dB) than sounds from the tugs.

In Scenario 2 (Table 1; Figure 3), sound levels from the fast supply vessel, a small craft approximately 19 m long with a draft of less than 1 m, were also expected to be significantly lower (~150 dB re 1 µPa @ 1 m; Funk et al. 2008 §3.7) than sound levels from the adjacent vessels. This vessel was excluded from the modeled scenario.

The specific characteristics of the Floating Production Storage and Offloading (FPSO) that will be used in this project are unknown at present. The spectra used in Scenarios 1 and 2 were derived from the recordings of six FPSOs during various operational stages (Erbe et al. 2013). In Scenario 1, the FPSO was expected to be moored and operating; its spectrum was modeled using the 5th percentile 1/3-octave-band spectrum derived from all the FPSO source spectra recorded. In Scenario 2, tugs positioned the FPSO during installation and mooring. Such operations were expected to be noisier than in Scenario 1; the FPSO spectrum was modeled using the 95th percentile 1/3-octave-band spectrum derived from all the source spectra recorded.

Since the tugs in each scenario will be engaged in various activities (e.g., transiting at various speed, pulling and pushing vessels, handling cables and anchors), the spectra of the surrogate tug, recorded during transit at half and full speed and during anchor pulling, were averaged to produce a mean 1/3-octave-band spectrum.

The source depth for vessels other than the drill ship was based on the depth at which cavitation from the propulsion system was expected to occur. Gray and Greenley (1980) estimate that the center of the cavitation volume occurs below the propeller blade arc, by an amount equal to ~15% of the propeller diameter. The modeled source depth was estimated by:

$$Z_s = D - 0.85 \times \phi_{prop} \tag{3}$$

where Z_s is the source depth, D is the depth at the bottom of the propeller (often equal to the draft) of the proposed vessel, and $\varnothing_{\text{prop}}$ is the diameter of its propeller.

During drilling operations, sound will be generated at many locations along the drill shaft. For the purpose of this study, the sound was assumed to be concentrated at the top of the drill shaft; the source depth was equal to the operational draft of the drill ship (12 m).

Table 3. Specifications of proposed and surrogate vessels used to estimate source levels.

Vessel type	Proposed vessel								Surrogate vessel							
	Name	Length (m)	Breadth (m)	Draft (m)	Max. power (kW)	Bollard pull (t)	Main propulsion	Propeller diameter (m)	Name	Length (m)	Breadth (m)	Draft (m)	Max. power (kW)	Bollard pull (t)	Main propulsion	Reference
FPSO	Unknown	Unknown	Unknown	Unknown, assumed 10 and 16	Unknown	n/a	Unknown	Unknown, assumed 5.5	Average between	209–340	Unknown	10.8–16	n/a	n/a	n/a	Erbe et al. (2013)
FPSO major work vessel	*Normand Installer*	124	28	7.3	31360	n/a	4 x tunnel thrusters, 1 x retractable azimuth thruster, 2 x controllable pitch propellers in nozzles	4.5	DSV *Fu Lai*	107.1	19.4	Unknown	7400	56	4 x thrusters, 2 x controllable pitch propellers	MacGillivray (2006b)
FPSO supply barge Supply vessel Support vessel	*Hannah Chouest*	85	18	6	7200	n/a	Unknown	Unknown, assumed 3.2								
Light construction vessel Field intervention vessel	MEO *Ranger*	64	16	5.4	5000	n/a	2 x tunnel thrusters, 2 x Z-drive propeller	2.7								
Large crane vessel	*Normand Installer*	124	28	7.3	31360	n/a	4 x tunnel thrusters, 1 x retractable azimuth thruster, 2 x controllable pitch propellers in nozzles	4.5								
Multiple service vessel	*7 Pacific*	134	24	6.75	17300	n/a	3 x stern azimuth thrusters, 1 x retractable bow azimuth thruster, 2 x bow tunnel thrusters	3.2								
Tug	Unknown	Unknown	Unknown	Unknown, assumed 5.5	Unknown	80	Azimuth stern drive	Unknown, assumed 3.2	*Britoil 51*	45	12	5.5	6600	90	2 x fixed pitch nozzeled propellers	Hannay et al. (2004)
Tug (large)	Unknown	Unknown	Unknown	Unknown, assumed 5.4	Unknown	120	Azimuth stern drive	Unknown, assumed 3.2	*Britoil 61*	51	13	5.4	10500	130	2 x controllable pitch nozzeled propellers	Adjusted from *Britoil 51* based on power
Drill ship	*Stenna Carron*	228	42	12	Unknown	n/a	6 x thrusters	n/a	*Stena Forth*	228	41	12	1750	n/a	6 x thrusters	Kyhn et al. (2009)
Pipelaying vessel	*7 Borealis*	182	46	8.5–11.35	45622	n/a	4 x azimuth thrusters, 1 x tunnel thruster	3	*Castoro*	191	35	10	Unknown	n/a	2 x variable pitch propellers, 1 x bow thruster	MacGillivray (2006b)

4.1.2. Vertical Seismic Profile Source

The Schlumberger High-performance Magnum six-gun array (1200 in³ total volume) was modeled as a surrogate VSP source in Scenario 4. The array consists of two vertically-triangular air gun clusters with in-line separations of 2 m. The first cluster has three 150 in³ elements with 0.9 m separation, the second cluster has three 250 in³ elements with a 1.1 m separation. In both clusters, the center air gun is shallower. The elements are fired simultaneously at 2000 psi air pressure. The array was modeled at a 4.5 m depth (the center of the clusters). It is estimated that the VSP source will produce 20–40 pulses within 6–12 hours of operation. Figure 8 illustrates the element distribution in the horizontal (*x*-*y*) plane, and Table 4 shows the array specifications.

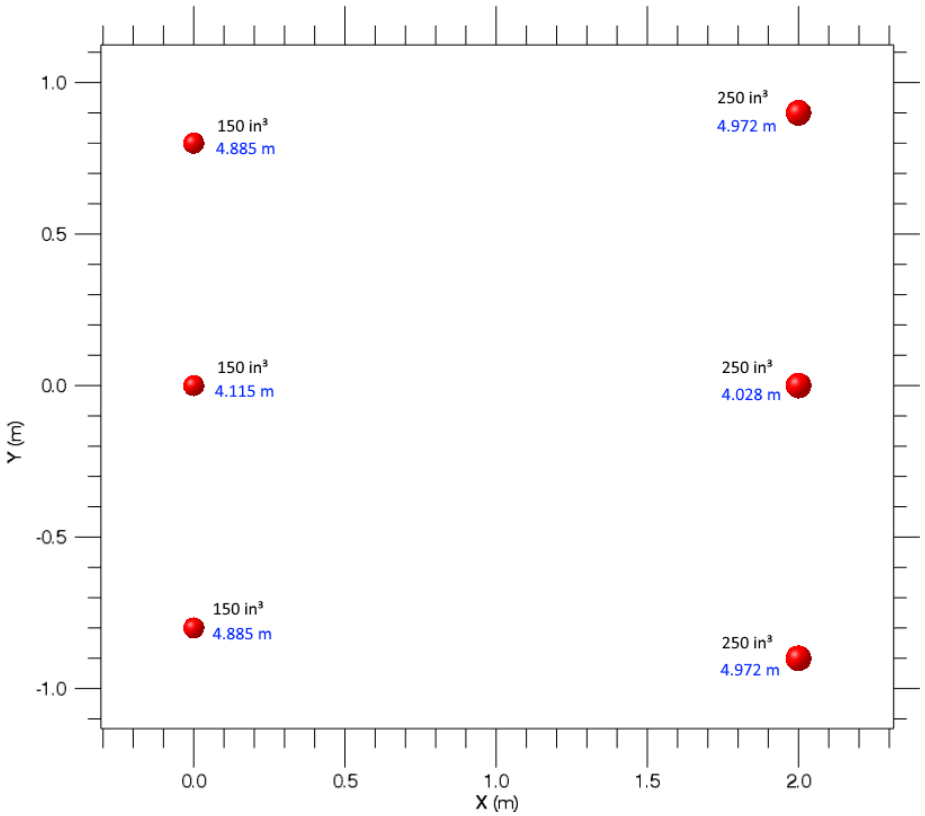


Figure 8. Layout of the High-performance Magnum six-gun array (1200 in³ total volume, 4.5 m depth), composed of 6 elements. Black labels indicate element volume in cubic inches; blue labels indicate the depth of the element relative to the sea surface.

Table 4. Relative positions of the elements within the 1200 in^3 array.

Element	*x* (m)	*y* (m)	*z* (m)	Volume (in^3)
1	0.0	0.000	4.115	150
2	0.0	−0.445	4.885	150
3	0.0	0.445	4.885	150
4	−2.0	0.000	4.028	250
5	−2.0	−0.545	4.972	250
6	−2.0	−0.545	4.972	250

4.1.3. Impact Pile Driving

Impact pile driving of cylindrical steel piles was modeled at two locations (Scenarios 5 and 6; Table 1). At both locations, the water depth was much deeper (1524.4 m and 1842.7 m) than the length of the pile (25 m long; 5 m in diameter). The MENCK 500T underwater hammer was used as the impact pile driver. A generic pile helmet, with a weight 1/5 that of the hammer (Parola 1970), was assumed with the default parameters of the hammer in the GRLWEAP 2010 wave equation model.

Information on the penetration rate per blow was unknown at the time of this study. The maximum number of strikes per minute (38) for the modeled hammer was assumed over a driving period of 5 hours. One driving period was assumed to occur every 24 hours.

4.2. Environmental Parameters

4.2.1. Bathymetry

Bathymetry data, covering an area of approximately 23 × 21 km centered on the modeled sites, was provided by EEPGL. For the long-range modeling (up to 100 km from the FPSO and the drill ship), this grid was extended using data from SRTM15+ (v1.0; Becker et al. 2009, Sandwell et al. 2014) global bathymetry grid, with a resolution of 30 arc-seconds (~460 × 460 m at the studied latitude), to produce a 150 × 150 km region. The data were re-gridded, by minimum curvature gridding, onto a Universal Transverse Mercator (UTM) Zone 21 coordinate projection with a regular grid spacing of 100 × 100 m.

4.2.2. Geoacoustics

The geoacoustic properties of surficial seabed layers depend on the sediment type. As the porosity decreases, the compressional sound speed, sediment bulk density, and compressional attenuation increase. For each modeled location, MONM assumes a single geoacoustic profile of the seafloor for the entire modeled area. The acoustic properties required by MONM are:

- Sediment bulk density,
- Compressional-wave (or P-wave) speed,
- P-wave attenuation in decibels per wavelength,
- Shear-wave (or S-wave) speed, and
- S-wave attenuation, also in decibels per wavelength.

Along the Guyana coast, suspended Amazonian sediments and fluvial mud from various Guyana rivers are transported eastward with the Guiana Current. This large volume of sediment deposition results in a thick (estimated up to 30 m; Rucker 1967) and fairly uniform layer of fine-grained sediment (Maxon

Consulting Inc. 2014). This surficial sediment layer, also characterized by a low concentration of organic carbon (Maxon Consulting Inc. 2014), overlays a mixture of sand and clay ~30–100 m thick (Rucker 1967).

The estimated geoacoustic profile (Table 5) was based on empirical formulas presented by Hamilton (1980). Without information from recent boreholes, a generic geoacoustic profile for silt-clay sediments was used with a 1.3 m/s per meters below the seafloor (mbsf) sound-speed gradient. The density and P-wave attenuation coefficients were taken from Hamilton (1980).

Table 5. Geoacoustic properties of the sub-bottom sediments as a function of depth, in meters below the seafloor (mbsf). Within each depth range, each parameter varies linearly within the stated range.

Depth (mbsf)	Material	Density (g/cm³)	P-wave speed (m/s)	P-wave attenuation **(dB/λ)**	S-wave speed (m/s)	S-wave attenuation **(dB/λ)**
0–30	Silt-clay	1.45–1.49	1500–1539	0.17–0.18	200	3.0
30–100	Sand-clay	1.83–2.00	1623–1700	1.21–2.00		
100–500	Sand-clay	2.00	1700–2100	2.00		
>500	Sand-clay	2.00	2100	2.00		

4.2.3. Ocean Sound Speed Profile

The ocean sound speed profiles for the modeled sites were derived from temperature and salinity profiles from the U.S. Naval Oceanographic Office's *Generalized Digital Environmental Model V 3.0* (GDEM; Teague et al. 1990, Carnes 2009). GDEM provides an ocean climatology of temperature and salinity for the world's oceans on a latitude-longitude grid with 0.25° resolution, with a temporal resolution of one month, based on global historical observations from the U.S. Navy's Master Oceanographic Observational Data Set (MOODS). The climatology profiles include 78 fixed depth points to a maximum depth of 6800 m (where the ocean is that deep). The GDEM temperature-salinity profiles were converted to sound speed profiles according to the equations of Coppens (1981):

$$\begin{aligned} c(z,T,S,\phi) &= 1449.05 + 45.7t - 5.21t^2 - 0.23t^3 \\ &\quad + \left(1.333 - 0.126t + 0.009t^2\right)(S-35) + \Delta \\ \Delta &= 16.3Z + 0.18Z^2, \quad Z = \frac{z}{1000}\left[1 - 0.0026\cos(2\phi)\right], \quad t = \frac{T}{10} \end{aligned} \tag{4}$$

where z is water depth (m), T is temperature (°C), S is salinity (psu), and ϕ is latitude (radians).

Mean monthly sound speed profiles were derived from the GDEM profiles at the FPSO and drill ship locations. There are no significant variations in sound speed with geographical location. Monthly variations in sound speed are also minimal, although the profile in April tends to be mostly upward refracting in the top 100 m (Figure 9). This month is therefore expected to promote longest range propagation and was used for all modeled scenarios.

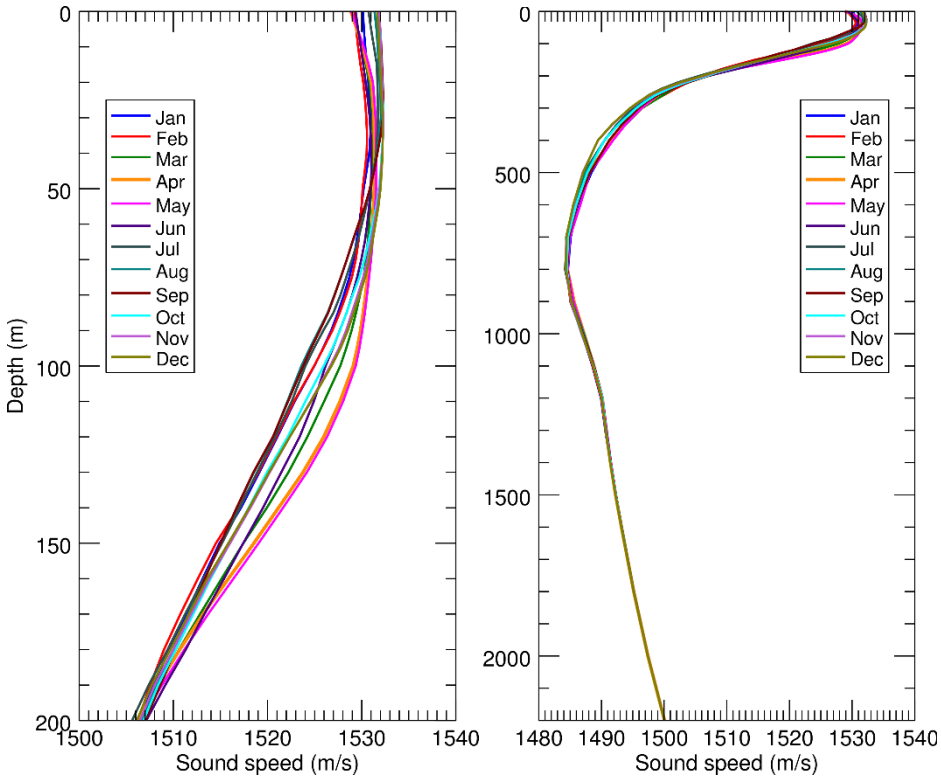


Figure 9. Mean monthly sound speed profiles (left: top 200 m; right: entire water column) at the FPSO location (08° 00' 39.53" N, 056° 59' 27.31" W) derived from data obtained from *GDEM V 3.0* (Teague et al. 1990, Carnes 2009).

4.3. Sound Propagation Modeling Zones

For the purposes of assessing sound levels with MONM, the sound field was modeled up to distances of 2 and 20 km from the FPSO (Scenarios 1 and 2) and the drill ship (Scenario 3), with a horizontal separation of 5 and 20 m between receiver points along the modeled radials. The horizontal angular separation between radials was 2.5°, for a total of N = 144 radial planes. Receiver depths were chosen to span the entire water column over the modeled areas, from 1 to 5000 m, with step sizes increasing with depth.

FWRAM modeled synthetic pulses of the VSP source up to 20 km, along four radials (0, 90, 180, and 270° from the tow direction) to compute peak pressure levels. The horizontal range step was set at 20 m. The tow direction was 293°. The same parameters were used to model sound from pile driving operations, the range step was however adjusted to 2 m up to 200 m from the source, and 25 m thereafter.

5. Results

5.1. Source Levels

5.1.1. Vessels

Figures 10–14 show the estimated 1/3-octave-band source levels for the modeled vessels. The broadband (10 Hz to 32 kHz) source levels vary from 173.4 dB re 1 µPa for the light construction and field intervention vessel to 196.1 dB re 1 µPa for the large tug. Although source levels may vary substantially during different operations, these modeled spectra represent a conservative average over a 24 hour period.

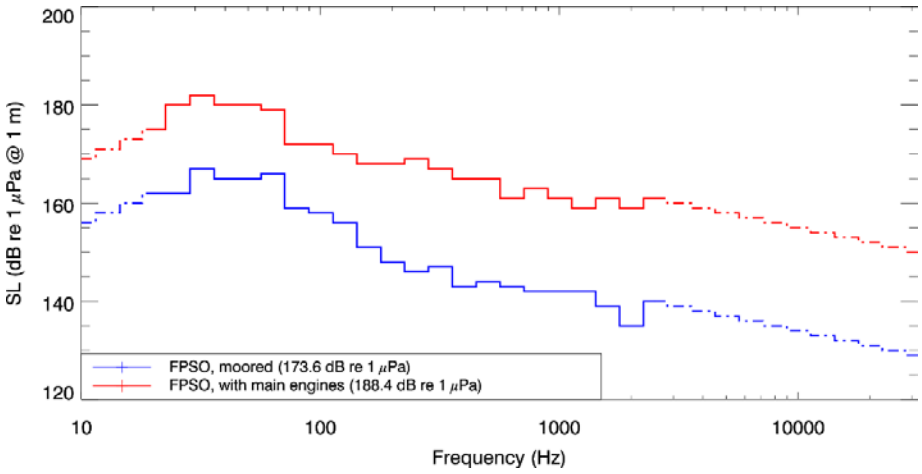


Figure 10. Estimated source level spectra for the FPSO. Dashed lines represent extrapolated levels based on Ross' spectrum (Ross 1976).

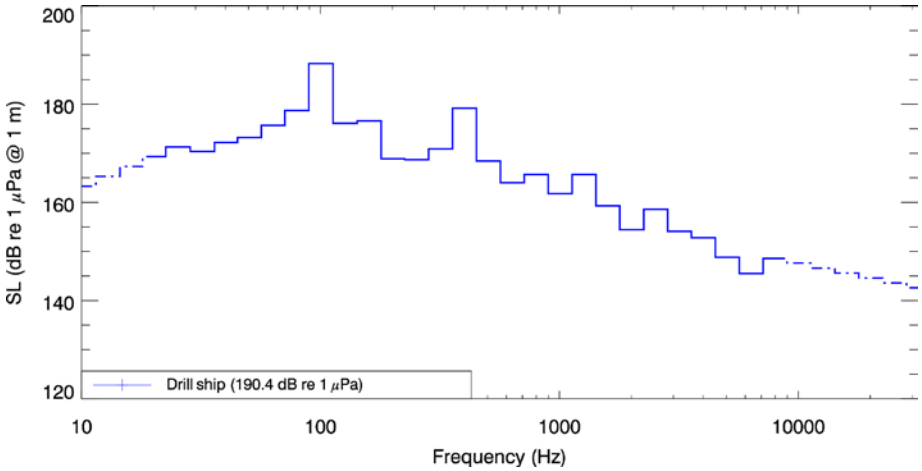


Figure 11. Estimated source level spectrum for the drill ship. Dashed lines represent extrapolated levels based on Ross' spectrum (Ross 1976).

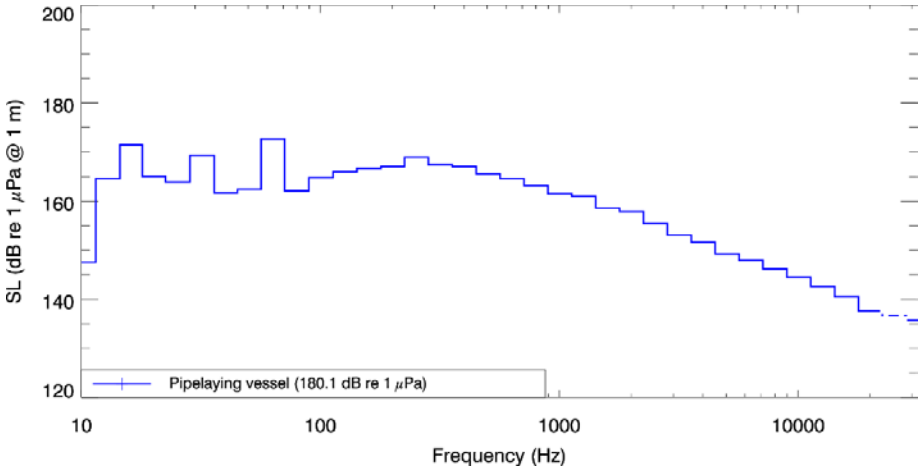


Figure 12. Estimated source level spectrum for the pipelaying vessel. Dashed lines represent extrapolated levels based on Ross' spectrum (Ross 1976).

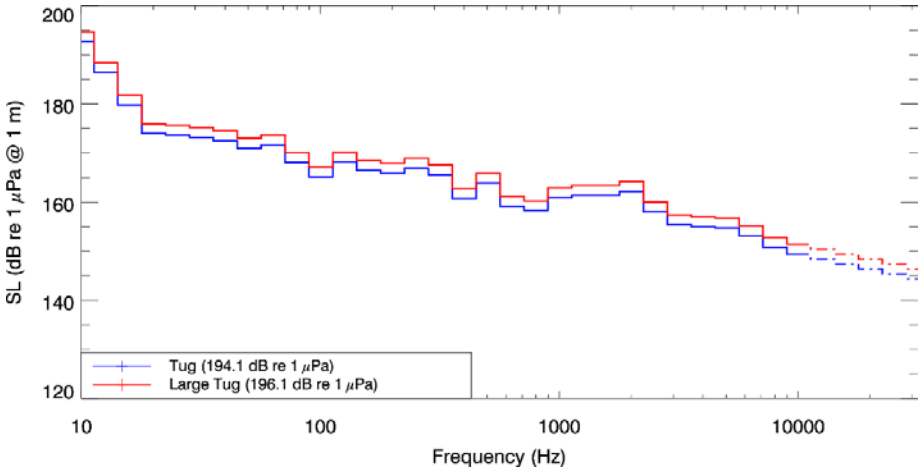


Figure 13. Estimated source level spectra for the tugs. Dashed lines represent extrapolated levels based on Ross' spectrum (Ross 1976).

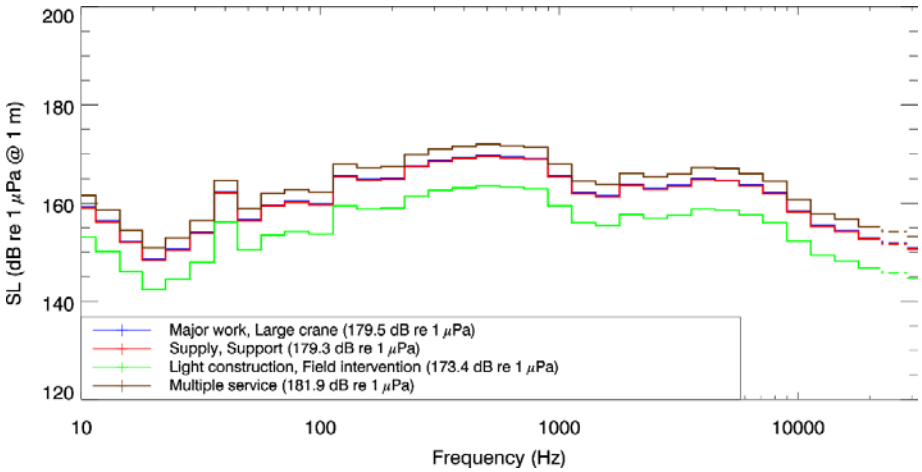


Figure 14. Estimated source level spectra for the various support vessels. Dashed lines represent extrapolated levels based on Ross' spectrum (Ross 1976).

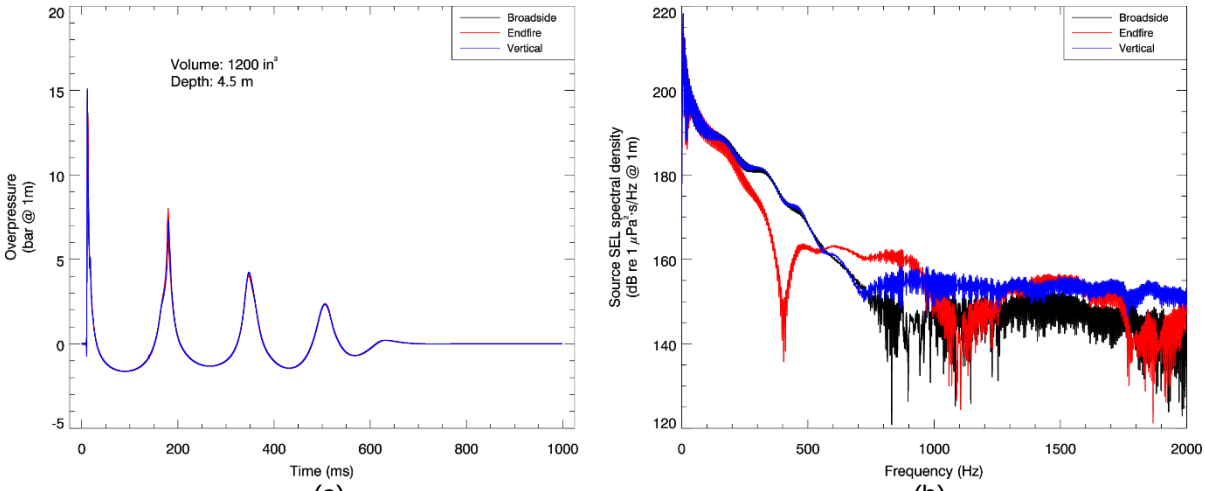
5.1.2. Vertical Seismic Profile Source

The pressure signatures of the individual array elements and the composite 1/3-octave-band source levels of the array, as functions of azimuthal angle (in the horizontal plane), were modeled with AASM (Section 3.1.2). While effects of surface reflected signals on bubble oscillations and inter-bubble interactions are accounted for in the notional pressure signatures of each element by AASM, the surface-reflected signal (i.e., surface ghost) is not shown in the far-field source signature plots below. The acoustic propagation models account for those surface reflections, which are a property of the propagating medium rather than the source.

Figure 15 shows the horizontal overpressure signatures (broadside–perpendicular to the tow direction, and endfire–parallel to the tow direction), the vertical overpressure signature, and corresponding power spectrum levels for the 1200 in^3 array at a 4.5 m tow depth. The signatures consist of a strong primary peak, related to the initial release of high-pressure air, followed by a series of pulses associated with bubble oscillations. Most energy is produced at frequencies below 600 Hz. Frequency-dependent peaks and nulls in the spectrum result from interference among elements in the array, and depend on the volumes and relative locations of the element.

Table 6 shows the broadband SPL and unweighted per-pulse SEL source levels.

Horizontal 1/3-octave-band source levels are shown as a function of band center frequency and azimuth (Figure 16). As discussed in Section 3.1.1, directivity in the sound field is most noticeable at frequencies from ~316 to 2000 Hz.



(a) (b)

Figure 15. Predicted source level details for the 1200 in^3 array. (a) The overpressure signature and (b) the power spectrum in the broadside (perpendicular to tow direction), endfire (directly aft of the array), and downward (vertical) directions.

Table 6. Source level specifications in the horizontal plane for the 1200 in^3 array, for a 4.5 m tow depth.

Direction	Peak pressure level (dB re 1 **µPa @ 1** m)	SPL (dB re 1 **µPa** @ 1 m)	Unweighted per-pulse SEL (dB re 1 **µPa**^{2}·s @ 1 m)	
			10–2000 Hz	2000–25000 Hz
Broadside (no surface ghost)	243.5	225.7	219.4	172.8
Endfire (no surface ghost)	242.6	225.6	219.3	176.9
Vertical (no surface ghost)	243.6	225.7	219.4	176.4
Vertical (with surface ghost)	243.6	224.3	219.8	179.4

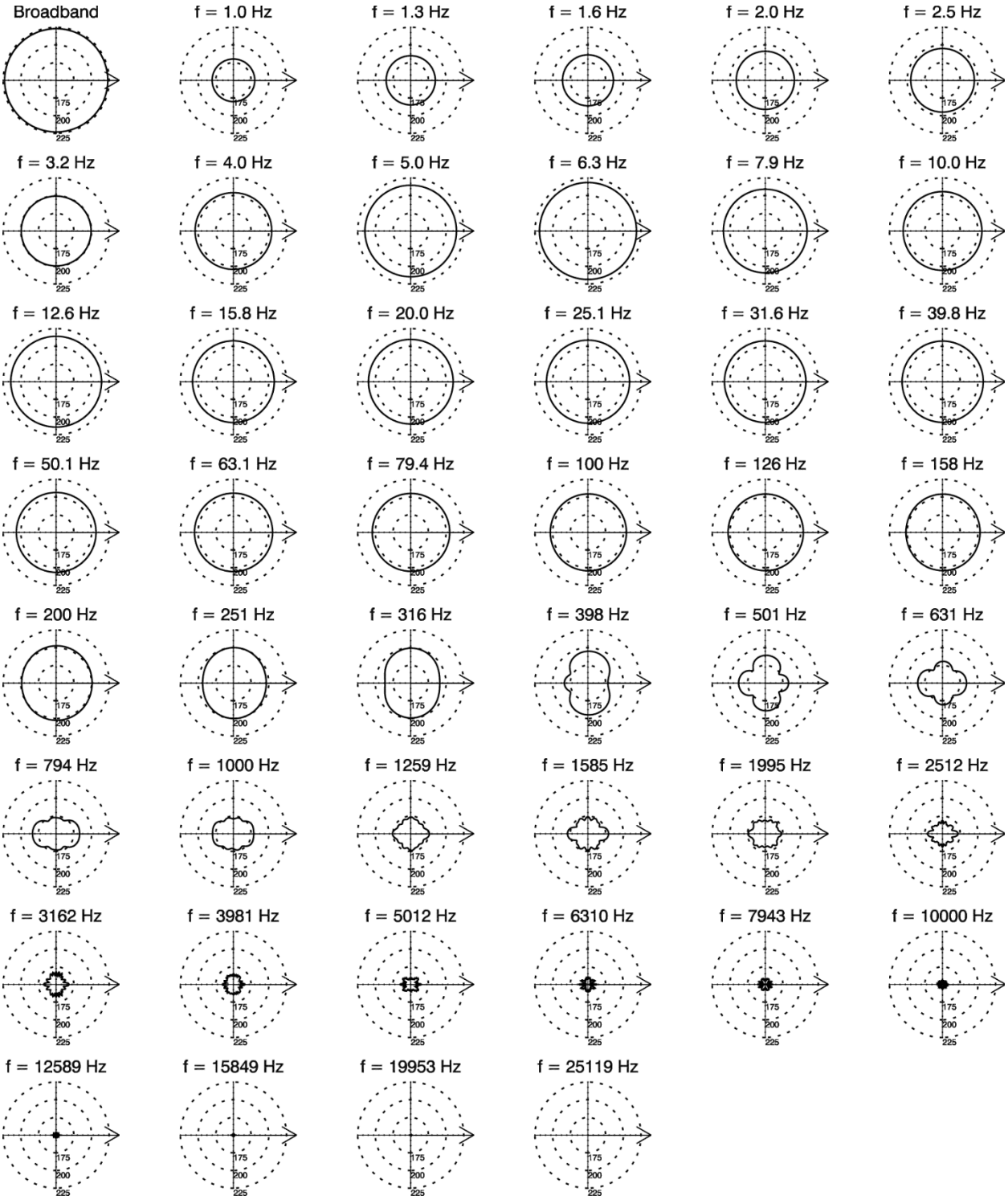


Figure 16. Directionality of the predicted horizontal source levels for the 1200 in^3 array, 10–25,000 Hz.Source levels (in dB re 1 µPa^2·s) are shown as a function of azimuth for the center frequencies of the 1/3-octave-bands modeled; frequencies are shown above the plots. Tow direction is to the right and tow depth is 4.5 m.

5.1.3. Impact Pile Driving

The forcing function at the top of the pile (Figure 17) was modeled using the GRLWEAP 2010 wave equation model. The forcing function consists of a strong primary peak, related to the initial contact of the ram and helmet, followed by a series of pulses associated with the ram-helmet oscillations. JASCO's pile driving source model estimated equivalent source signatures every 2 m along the pile. Figure 18 presents the signature of the monopoles at the top, center, and bottom of the pile. The first peak of these signatures represents the initial pile deformation traveling down the pile; its amplitude decreases and arrival time increases with depth along the pile.

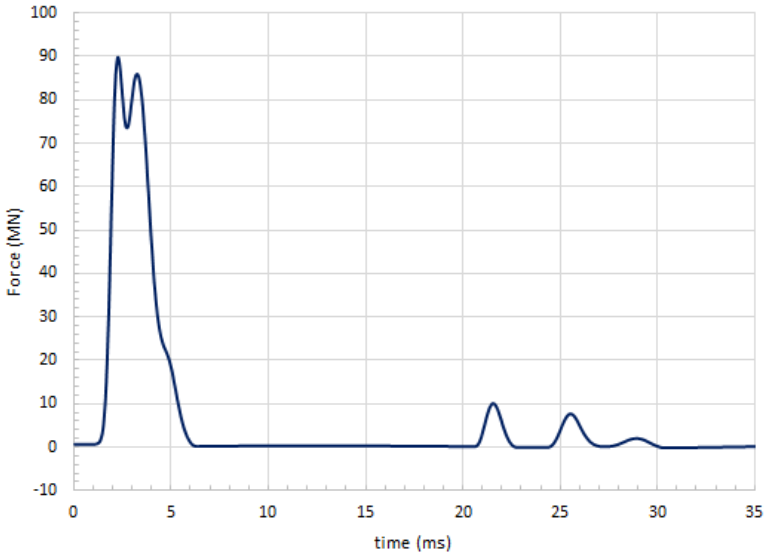


Figure 17. Force at the top of a pile during impact driving of a 25-m long, 5-m wide cylindrical steel pile with the MENCK 500T (underwater) hammer.

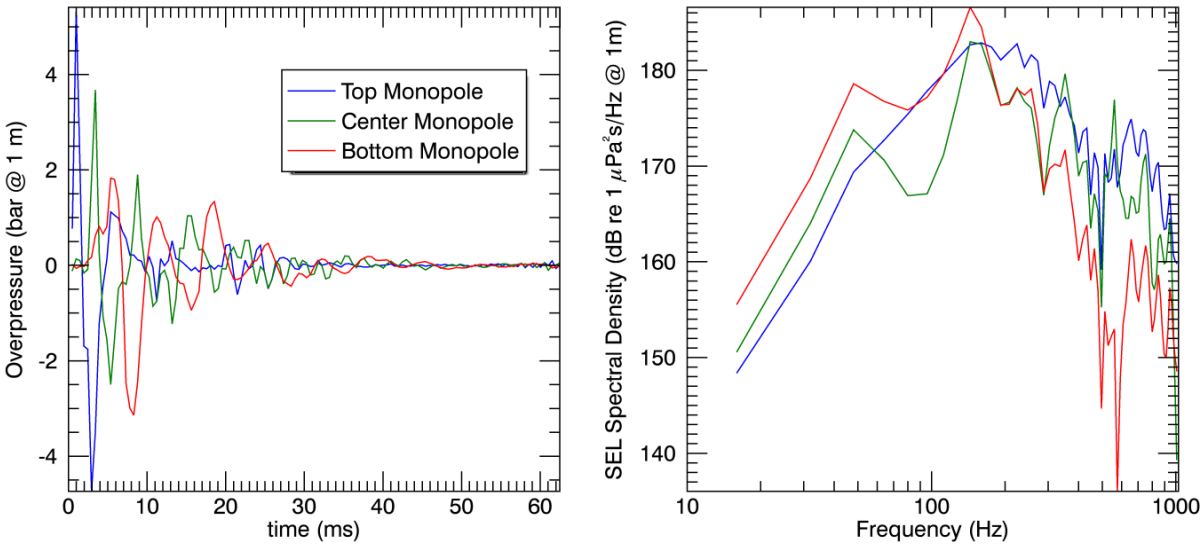


Figure 18. Predicted overpressure signature of three monopoles along the modeled pile: top (in water), center (in water), and bottom (in substrate).

5.2. Sound Fields

5.2.1. Vessels

This section includes the distances to marine mammal injury thresholds resulting from the presence of vessels (Table 7). For the purpose of estimating M-weighted SEL_{24h} in this study, all vessels were assumed stationary, operating over 90% of a 24 hour period. Peak pressure level thresholds for injury criteria were not reached; distances to peak pressure levels are not presented below.

The tabulated values represent the maximum R_{max} and $R_{95\%}$ from any vessels present in a scenario.

Table 7. Scenarios 1–3: Distances (m) to marine mammal injury for non-impulsive sources.

Hearing group	Southall et al. (2007)			Finneran (2015)		
	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)
Scenario 1						
Low-frequency cetaceans	215	6	6	207	< 5	< 5
Mid-frequency cetaceans	215	< 5	< 5	199	< 5	< 5
Scenario 2						
Low-frequency cetaceans	215	< 5	< 5	207	< 5	< 5
Mid-frequency cetaceans	215	-	-	199	-	-
Scenario 3						
Low-frequency cetaceans	215	9	9	207	6	6
Mid-frequency cetaceans	215	< 5	< 5	199	-	-

5.2.2. Vertical Seismic Profile Source

This section presents the distances to marine mammal injury thresholds for the VSP source in Scenario 4. To estimate distances to marine mammal injury thresholds in M-weighted SEL_{24h}, one operational period was modeled (i.e., it was assumed that the VSP source produces 40 pulses in 24 hours). Distances to peak pressure level thresholds are either not reached or less than distances to M-weighted SEL_{24h} thresholds for injury criteria (Table 8); distances to peak pressure levels are not presented below. In Figure 19, area ensonified at or above injury thresholds are compared; the range to the Mid-frequency cetacean injury threshold based on Finneran (2015) was below the minimum resolvable range.

Table 8. Scenario 4: Distances (m) to marine mammal injury thresholds for the VSP source.

Hearing group	Southall et al. (2007)			Finneran (2015)		
	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)	$R_{95\%}$ (m)
Low-frequency cetaceans	198	73	68	192	39	36
Mid-frequency cetaceans	198	35	32	187	-	-

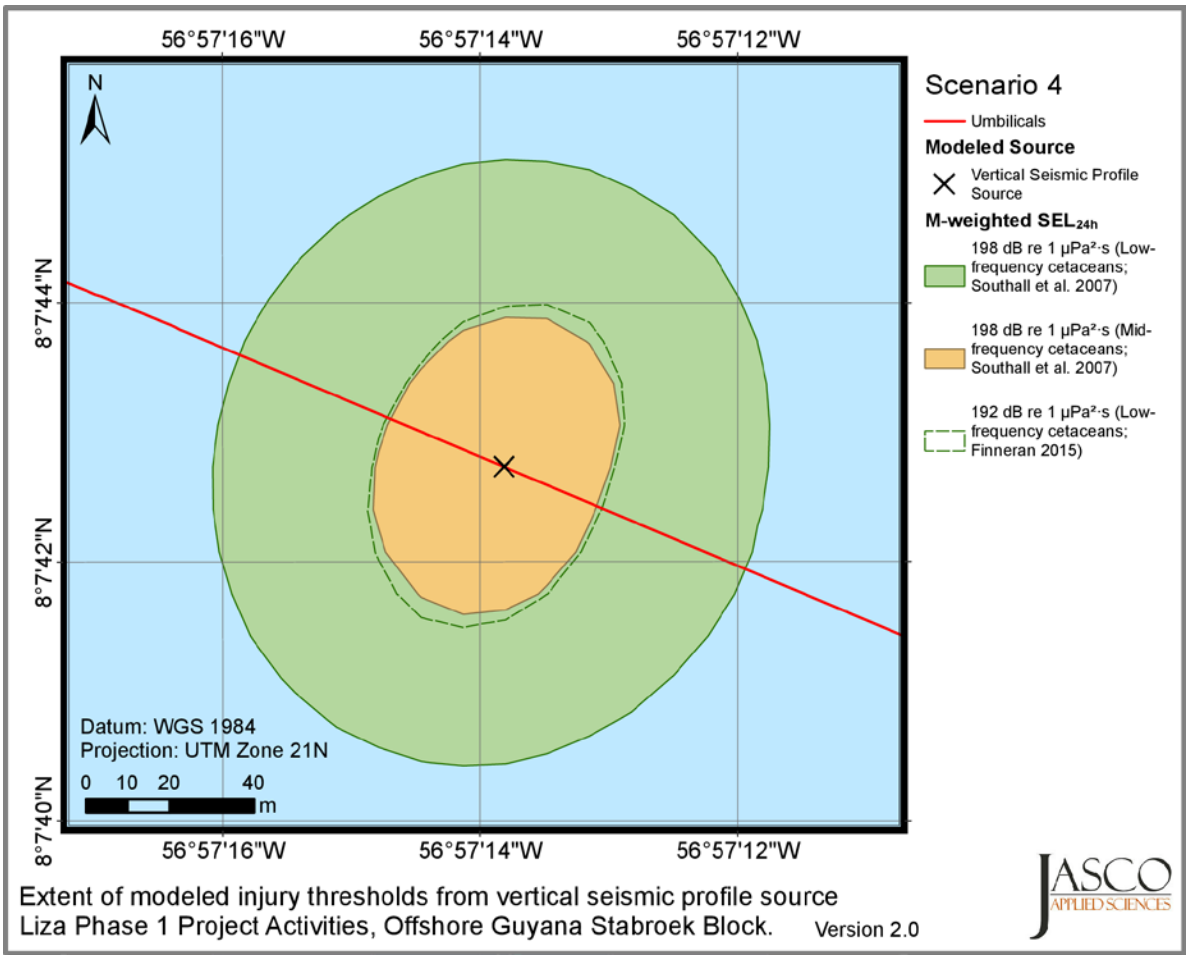


Figure 19. Scenario 4: Sound level contour map showing the extend of the maximum-over-depth M-weighted SEL_{24h} from the VSP source for marine mammal injury thresholds based on Southall et al. (2007) and Finneran (2015).

5.2.3. Impact Pile Driving

This section presents the distances to marine mammal injury thresholds for the underwater pile driving operations in Scenarios 5 and 6. To estimate distances to marine mammal injury thresholds in M-weighted SEL_{24h}, we assumed that one pile was driven for 5 hours, at a rate of 38 strikes per minute, every 24 hours. Distances to peak pressure level thresholds were either not reached or were less than distances to M-weighted SEL_{24h} thresholds for injury criteria; distances to peak pressure levels are not presented.

Tables 9–10, and Figures 20–23, present the distances to marine mammal injury thresholds at Drill Center 2-P and the FPSO, respectively. Figures 21–22 and 24–25 present vertical slices of the corresponding M-weighted SEL_{24h} fields, east of the piles. The parabolic equation (PE) approximation used in FWRAM (Section 3.2) is estimated to be valid for sound propagating up to 45° from the horizontal plane at the source depth. This angle is indicated by the black dash line in each slice.

Table 9. Scenario 5: Distances (m) to marine mammal injury thresholds for the underwater pile driving operations at Drill Center 2-P.

Hearing group	Southall et al. (2007)		Finneran (2015)	
	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)
Low-frequency cetaceans	198	1,300	192	1,025
Mid-frequency cetaceans	198	762	187	136

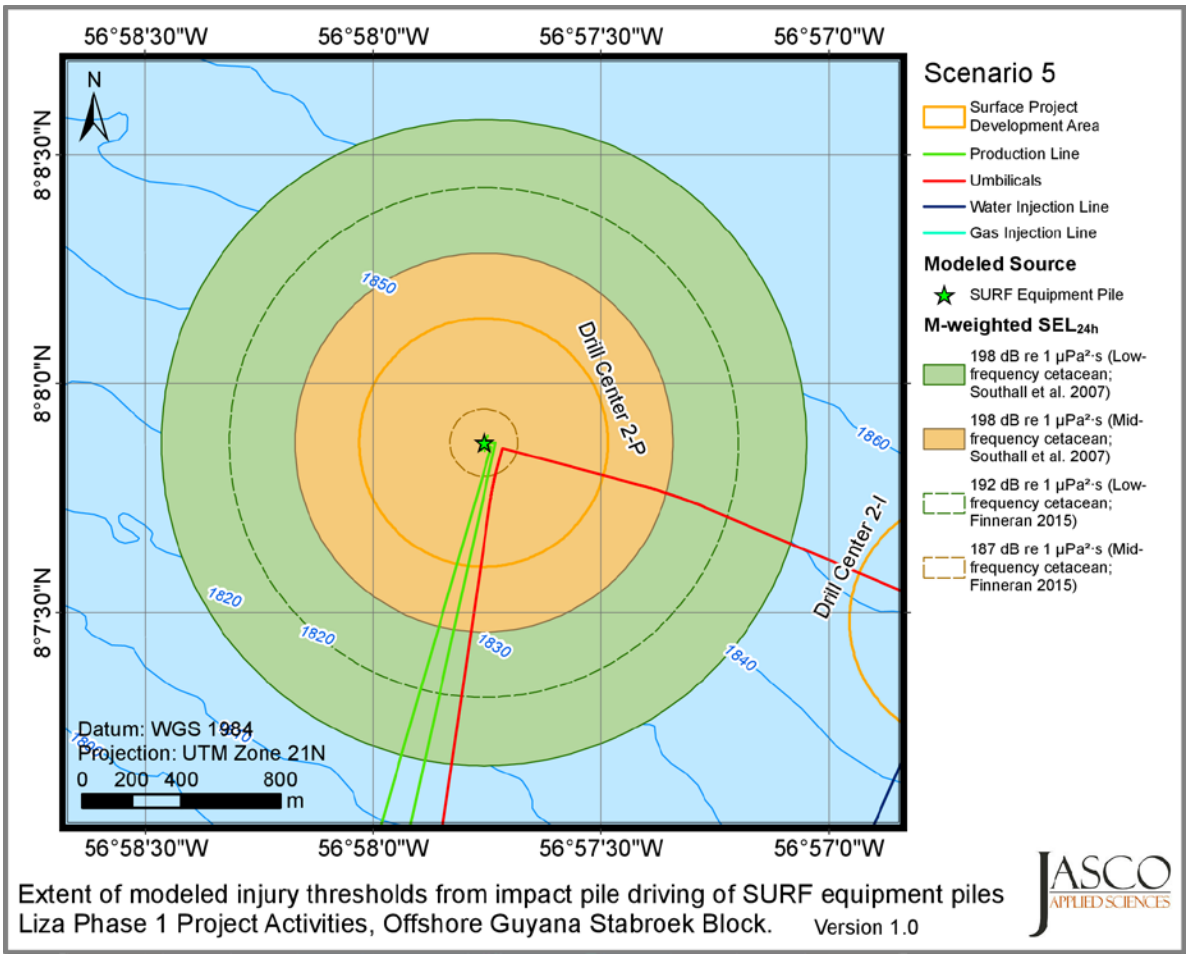


Figure 20. Scenario 5: Sound level contour map showing the extend of the maximum-over-depth M-weighted SEL_{24h} from impact pile driving for marine mammal injury thresholds based on Southall et al. (2007) and Finneran (2015).

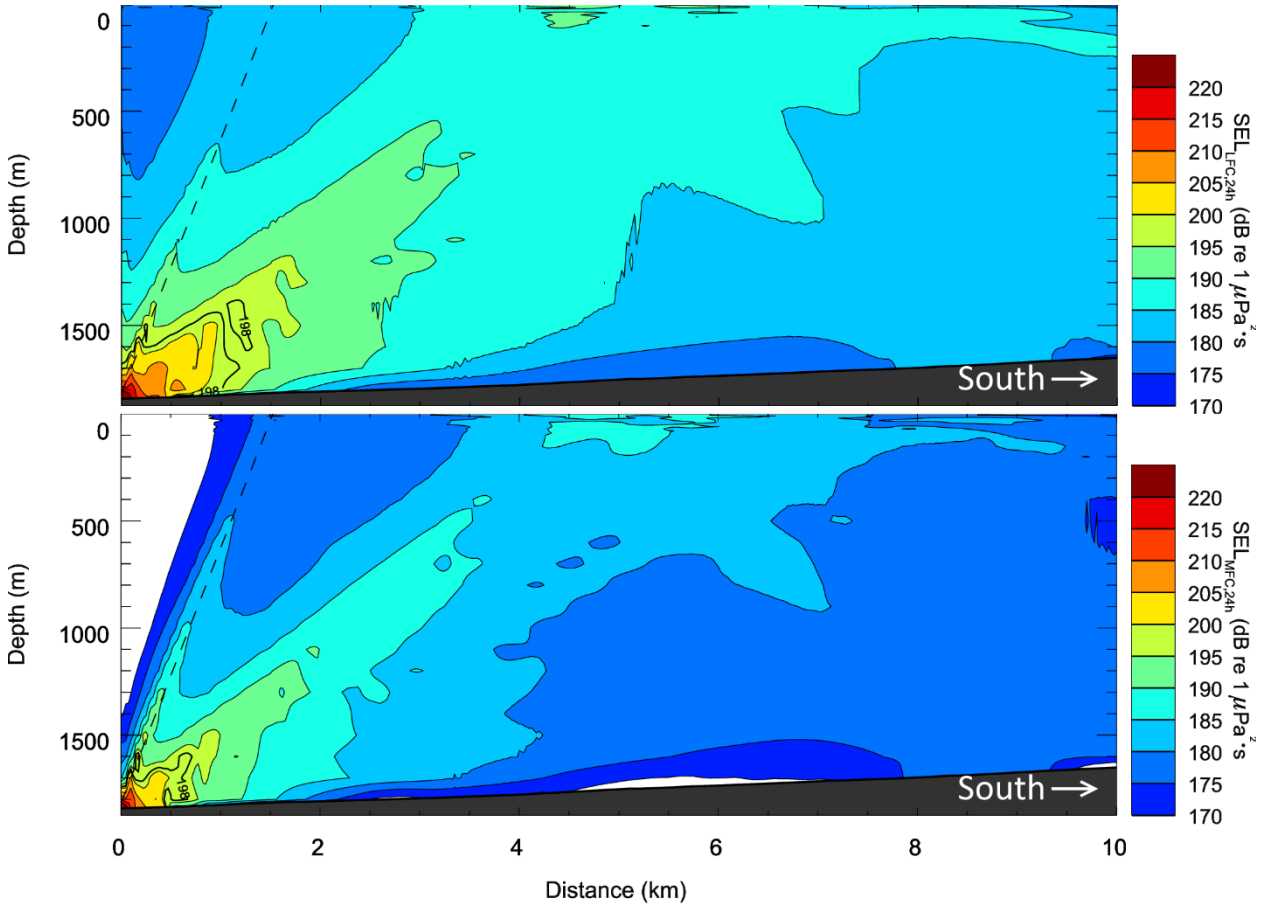


Figure 21. Scenario 5: Estimated M-weighted SEL_{24h} based on Southall et al. (2007), propagating south of the pile at Drill Center 2-P. The thicker black lines indicate sound level isopleths corresponding to the injury thresholds for (top) low- and (bottom) mid-frequency cetaceans. The dash line indicates the limiting angle below which the model is valid; received levels above the source (left of the dash line) are expected to be underestimated. The dark area at the bottom of the plot shows decreasing water depth.

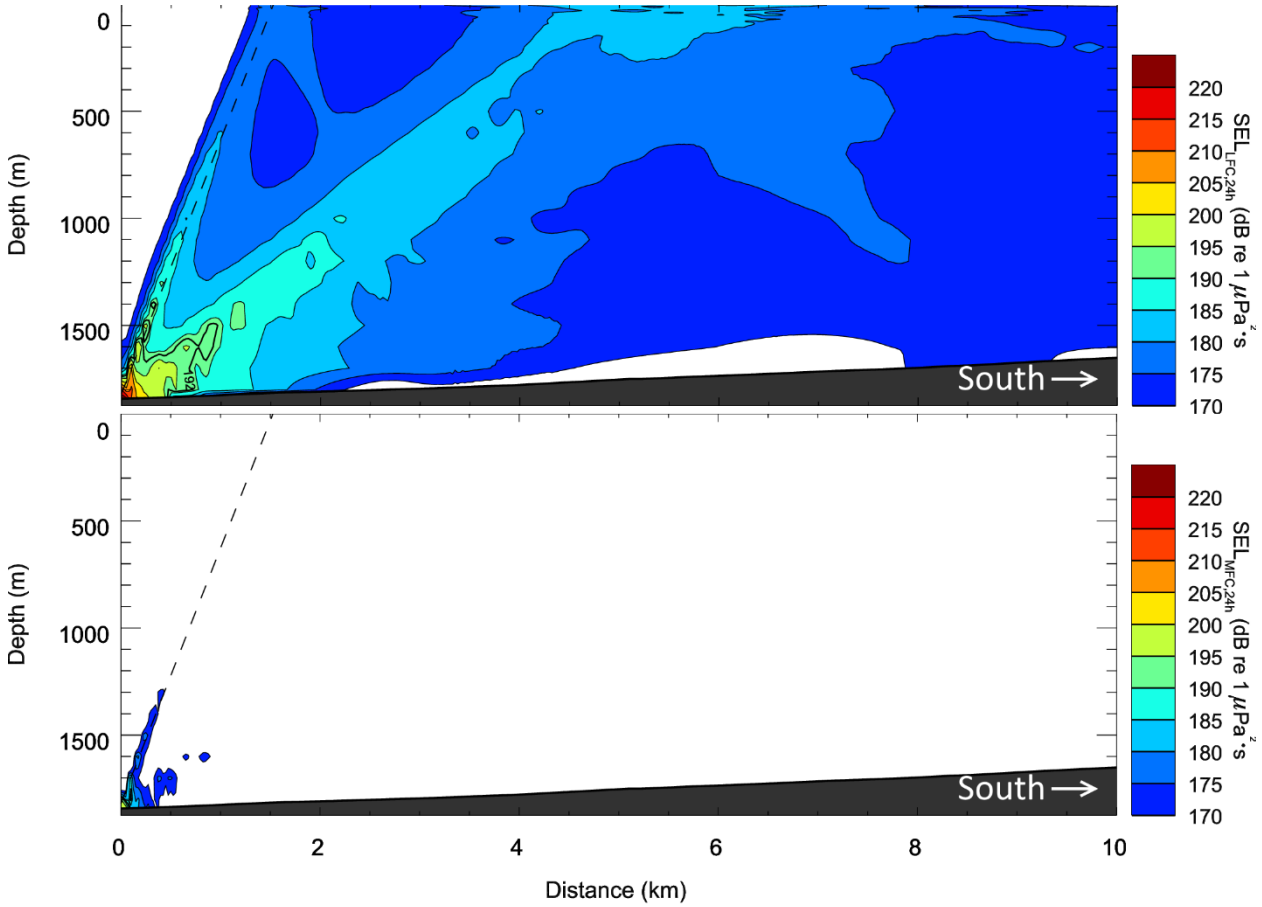


Figure 22. Scenario 5: Estimated M-weighted SEL_{24h} based on Finneran (2015), propagating south of the pile at Drill Center 2-P. The thicker black lines indicate sound level isopleths corresponding to the injury thresholds for (top) low- and (bottom) mid-frequency cetaceans. The dash line indicates the limiting angle below which the model is valid; received levels above the source (left of the dash line) are expected to be underestimated. The dark area at the bottom of the plot shows decreasing water depth.

Table 10. Scenario 6: Distances (m) to marine mammal injury thresholds for the underwater pile driving operations at the FPSO location.

Hearing group	Southall et al. (2007)		Finneran (2015)	
	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)	Threshold (M-weighted SEL_{24h}; dB re 1 µPa²·s)	R_{max} (m)
Low-frequency cetaceans	198	1,375	192	1,075
Mid-frequency cetaceans	198	725	187	100

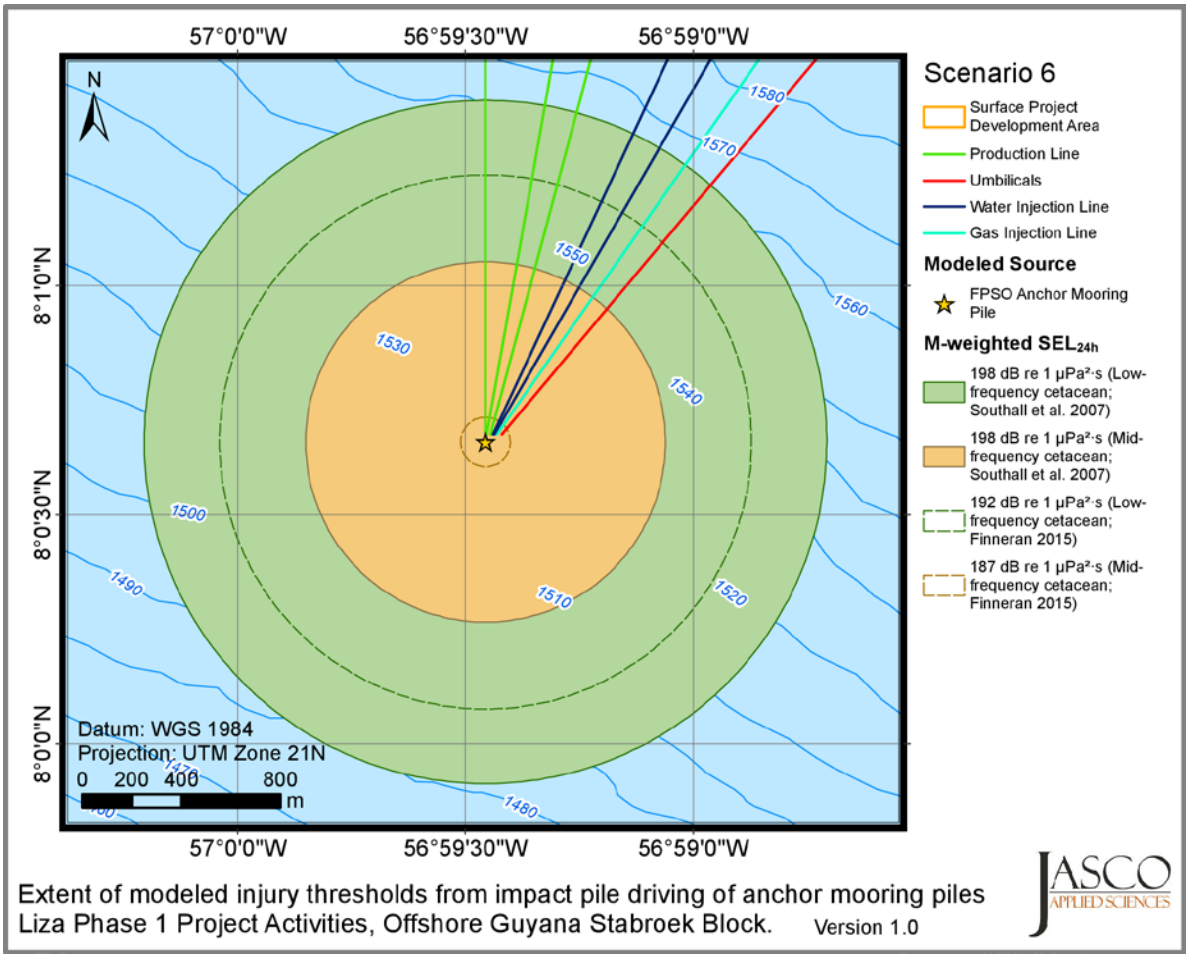


Figure 23. Scenario 6: Sound level contour map showing the extend of the maximum-over-depth M-weighted SEL_{24h} from impact pile driving for marine mammal injury thresholds based on Southall et al. (2007) and Finneran (2015).

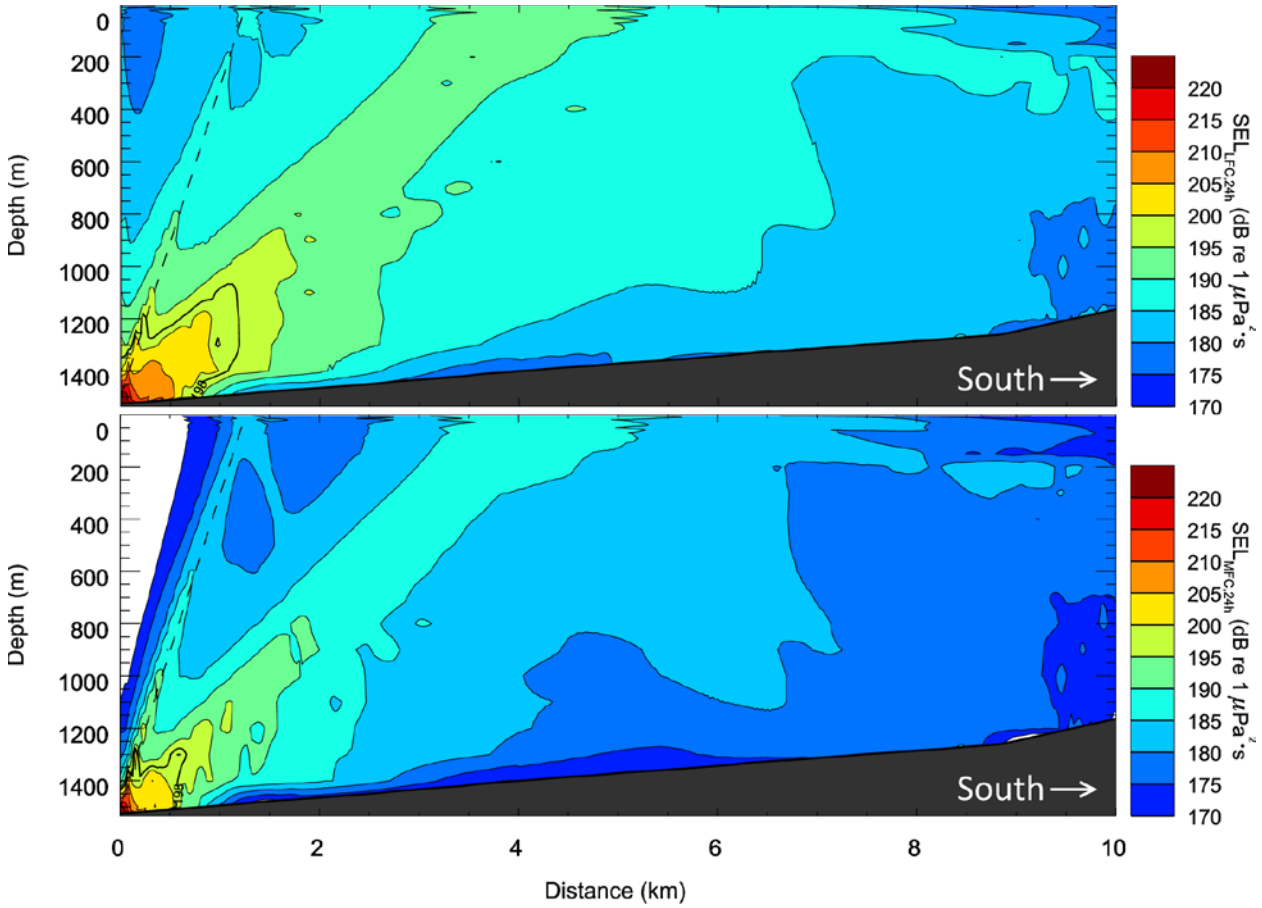


Figure 24. Scenario 6: Estimated M-weighted SEL_{24h} based on Southall et al. (2007), propagating south of the FPSO anchor mooring piles. The thicker black lines indicate sound level isopleths corresponding to the injury thresholds for (top) low- and (bottom) mid-frequency cetaceans. The dash line indicates the limiting angle below which the model is valid; received levels above the source (left of the dash line) are expected to be underestimated. The dark area at the bottom of the plot shows decreasing water depth.

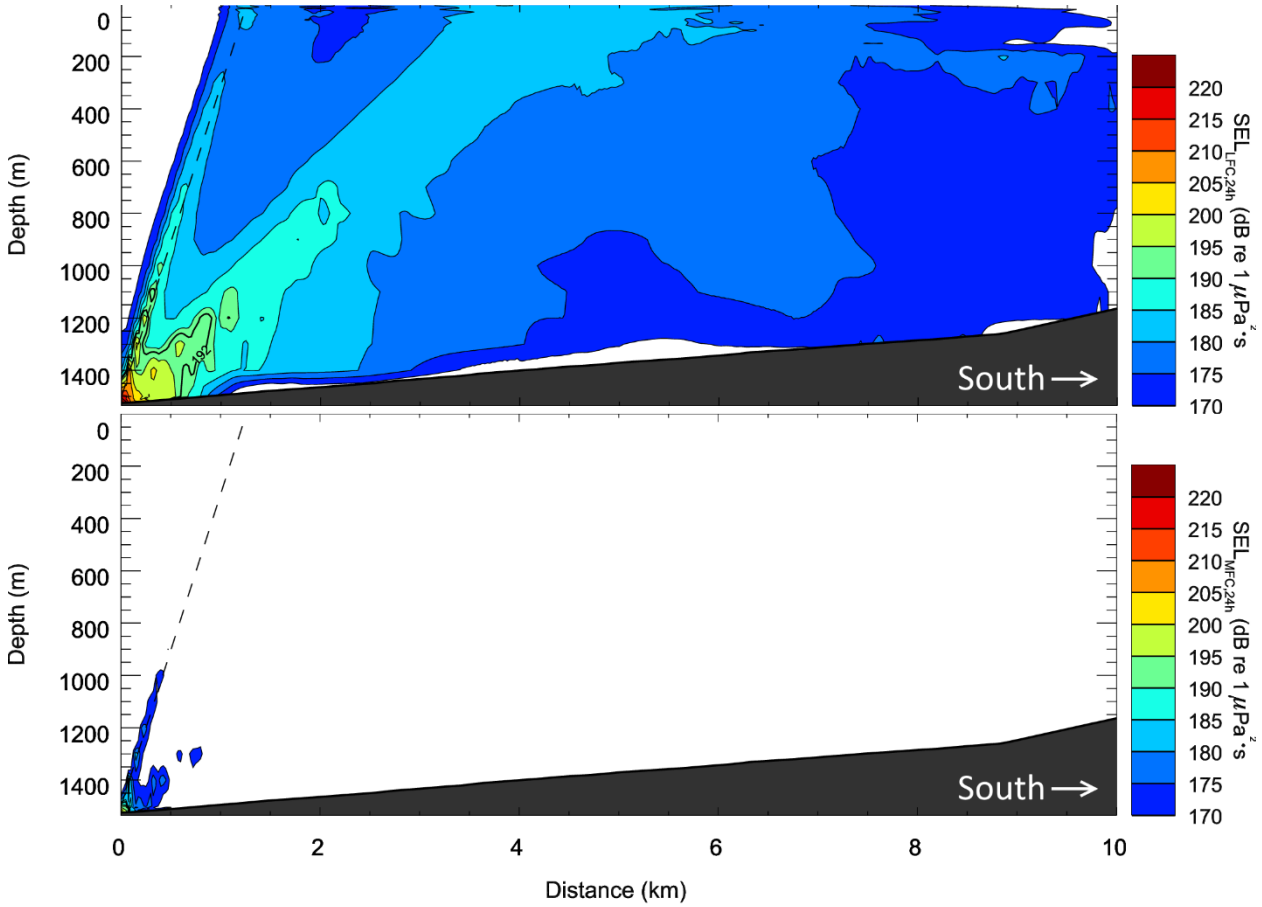


Figure 25. Scenario 6: Estimated M-weighted SEL_{24h} based on Finneran (2015), propagating south of the FPSO anchor mooring piles. The thicker black lines indicate sound level isopleths corresponding to the injury thresholds for (top) low- and (bottom) mid-frequency cetaceans. The dash line indicates the limiting angle below which the model is valid; received levels above the source (left of the dash line) are expected to be underestimated. The dark area at the bottom of the plot shows decreasing water depth.

6. Discussion

The estimated broadband source levels of vessels varied from 173.4 dB re 1 µPa at 1 m for the light construction and field intervention vessels, to 196.1 dB re 1 µPa at 1m for the large tug. Although source levels may vary substantially during operations, the modeled source level spectra of the vessels represent conservative averages over a 24 hour period.

For scenarios 1 through 3, the distances to injury thresholds from vessels were small: <10 m for all species, thus essentially insignificant relative to the size of the vessels. The distances to injury thresholds were similar for Southall et al. (2007) and Finneran (2015) criteria (Table 7). These results assume that the vessels were stationary for 24 hours and the animal was present within the stated distance for the entire accumulation period (24 hours).

The broadband (10–25,000 Hz) per-pulse SEL source level of the VSP source was 219–220 dB re 1 µPa^2·s @ 1 m in all directions (Table 6). Distances (R_{max}) to injury thresholds for mid-frequency cetaceans were 35 m based on Southall et al. (2007) and below the minimum resolvable range based on Finneran (2015); for low-frequency cetaceans they were 73 and 39 m, respectively (Table 8). For this source, the injury thresholds based on Finneran (2015) were generally lower than for Southall et al. (2007) due to the steeper roll-off at low frequencies of the weighting functions for the former. Because most of the energy from the VSP source lies below 600 Hz (Figure 15), Finneran's weighting yields a greater discount than Southall et al. (2007) (see Appendix A.4).

Distances to injury thresholds were longer for impact pile driving than for other operations. Across both modelled sites, for mid-frequency cetaceans the maximum ranges were 762 m based on Southall et al. (2007) and 136 m based on Finneran (2015); for low-frequency cetaceans they were 1,375 m and 1,075 m, respectively (Tables 9–10). The differences in ranges between the two sites were minor. The sound levels at or above injury thresholds were found close to the ocean bottom, at depths >1,000 m. Low-frequency cetacean species present in the area are not expected to dive to those depths and, therefore, should never be exposed to injurious sound levels from pile driving activities. A few species within the mid-frequency hearing group, such as some dolphins, may feed at depths greater than 1,000 m and could therefore be affected by pile driving sound. The amount of time these animals spend below 1,000 m is, however, limited due to their need to resurface to breathe, which reduces the probability of injury.

Glossary

1/3-octave-band
Non-overlapping passbands that are one-third of an octave wide (where an octave is a doubling of frequency). Three adjacent 1/3-octave-bands make up one octave. One-third-octave-bands become wider with increasing frequency. See also octave.

90%-energy time window
The time interval over which the cumulative energy rises from 5% to 95% of the total pulse energy. This interval contains 90% of the total pulse energy. Symbol: T_{90}.

90% root-mean-square sound pressure level (90% SPL)
The root-mean-square sound pressure levels calculated over the 90%-energy time window of a pulse. Used only for pulsed sounds.

Air gun
A device that has a chamber of compressed air, which is "fired" (quickly released) to produce a pulse of acoustic energy.

A-weighting
Frequency-selective weighting for human hearing in air that is derived from the inverse of the idealized 40-phon equal loudness hearing function across frequencies.

absorption
The conversion of acoustic energy into heat, which is captured by insulation.

ambient noise
All-encompassing sound at a given place, usually a composite of sound from many sources near and far (ANSI S1.1-1994 R2004), e.g., shipping vessels, seismic activity, precipitation, sea ice movement, wave action, and biological activity.

attenuation
The gradual loss of acoustic energy from absorption and scattering as sound propagates through a medium.

auditory weighting function (frequency-weighting function)
Auditory weighting functions account for marine mammal hearing sensitivity. They are applied to sound measurements to emphasize frequencies that an animal hears well and de-emphasize frequencies they hear less well or not at all (Southall et al. 2007, Finneran and Jenkins 2012, NOAA 2013).

azimuth
A horizontal angle relative to a reference direction, which is often magnetic north or the direction of travel. In navigation it is also called bearing.

background noise
Total of all sources of interference in a system used for the production, detection, measurement, or recording of a signal, independent of the presence of the signal (ANSI S1.1-1994 R2004). Ambient noise detected, measured, or recorded with a signal is part of the background noise.

bandwidth
The range of frequencies over which a sound occurs. Broadband refers to a source that produces sound over a broad range of frequencies (e.g., seismic sources, vessels) whereas narrowband sources produce sounds over a narrow frequency range (e.g., sonar) (ANSI/ASA S1.13-2005 R2010).

bar
Unit of pressure equal to 100 kPa, which is approximately equal to the atmospheric pressure on Earth at sea level. 1 bar is equal to 10^6 Pa or 10^{11} µPa.

broadband sound level
The total sound pressure level measured over a specified frequency range. If the frequency range is unspecified, it refers to the entire measured frequency range.

broadside direction
Perpendicular to the travel direction of a source. Compare with endfire direction.

cavitation
A rapid formation and collapse of vapor cavities (i.e., bubbles or voids) in water, most often caused by a rapid change in pressure. Fast-spinning vessel propellers typically cause cavitation, which creates a lot of sound.

cetacean
Any animal in the order Cetacea. These are aquatic, mostly marine mammals and include whales, dolphins, and porpoises.

compressional wave
A mechanical vibration wave in which the direction of particle motion is parallel to the direction of propagation. Also called primary wave or P-wave.

continuous sound
A sound whose sound pressure level remains above ambient sound during the observation period (ANSI/ASA S1.13-2005 R2010). A sound that gradually varies in intensity with time, for example, sound from a marine vessel.

decibel (dB)
One-tenth of a bel. Unit of level when the base of the logarithm is the tenth root of ten, and the quantities concerned are proportional to power (ANSI S1.1-1994 R2004).

endfire direction
Parallel to the travel direction of a source. See also broadside direction.

ensonified
Exposed to sound.

equal-loudness contour
A curve or curves that show, as a function of frequency, the sound pressure level required to cause a given loudness for a listener having normal hearing, listening to a specified kind of sound in a specified manner (ANSI S1.1-1994 R2004).

far-field
The zone where, to an observer, sound originating from an array of sources (or a spatially-distributed source) appears to radiate from a single point. The distance to the acoustic far-field increases with frequency.

fast-average sound pressure level
The time-averaged sound pressure levels calculated over the duration of a pulse (e.g., 90%-energy time window), using the leaky time integrator from Plomp and Bouman (1959) and a time constant of 125 ms. Used only for pulsed sounds.

fast Fourier transform (FFT)
A computationally efficiently algorithm for computing the discrete Fourier transform.

frequency
The rate of oscillation of a periodic function measured in cycles-per-unit-time. The reciprocal of the period. Unit: hertz (Hz). Symbol: *f*. 1 Hz is equal to 1 cycle per second.

geoacoustic
Relating to the acoustic properties of the seabed.

hearing group
Grouping of marine mammal species with similar hearing ranges. Commonly defined hearing groups include low-, mid-, and high-frequency cetaceans, pinnipeds in water, and pinnipeds in air.

hearing threshold
The sound pressure level that is barely audible for a given individual in the absence of significant background noise during a specific percentage of experimental trials.

hertz (Hz)
A unit of frequency defined as one cycle per second.

high-frequency cetacean
The functional hearing group that represents odontocetes specialized for using high frequencies.

intermittent sound
A level of sound that abruptly drops to the background noise level several times during the observation period.

impulsive sound
Sound that is typically brief and intermittent with rapid (within a few seconds) rise time and decay back to ambient levels (NOAA 2013, ANSI S12.7-1986 R2006). For example, seismic sources and impact pile driving.

low-frequency cetacean
The functional hearing group that represents mysticetes (baleen whales).

mid-frequency cetacean
The functional hearing group that represents some odontocetes (dolphins, toothed whales, beaked whales, and bottlenose whales).

M-weighting
The process of band-pass filtering loud sounds to reduce the importance of inaudible or less-audible frequencies for broad classes of marine mammals. “Generalized frequency weightings for various functional hearing groups of marine mammals, allowing for their functional bandwidths and appropriate in characterizing auditory effects of strong sounds” (Southall et al. 2007).

mysticete
Mysticeti, a suborder of cetaceans, use their baleen plates, rather than teeth, to filter food from water. They are not known to echolocate, but use sound for communication. Members of this group include rorquals (Balaenopteridae), right whales (Balaenidae), and the gray whale (*Eschrichtius robustus*).

non-impulsive sound
Sound that is broadband, narrowband or tonal, brief or prolonged, continuous or intermittent, and typically does not have a high peak pressure with rapid rise time (typically only small fluctuations in decibel level)

that impulsive signals have (ANSI/ASA S3.20-1995 R2008). For example, marine vessels, aircraft, machinery, construction, and vibratory pile driving (NIOSH 1998, NOAA 2015).

octave
The interval between a sound and another sound with double or half the frequency. For example, one octave above 200 Hz is 400 Hz, and one octave below 200 Hz is 100 Hz.

odontocete
The presence of teeth, rather than baleen, characterizes these whales. Members of the Odontoceti are a suborder of cetaceans, a group comprised of whales, dolphins, and porpoises. The toothed whales' skulls are mostly asymmetric, an adaptation for their echolocation. This group includes sperm whales, killer whales, belugas, narwhals, dolphins, and porpoises.

otariid
A common term used to describe members of the Otariidae, eared seals, commonly called sea lions and fur seals. Otariids are adapted to a semi-aquatic life; they use their large fore flippers for propulsion. Their ears distinguish them from phocids. Otariids are one of the three main groups in the superfamily Pinnipedia; the other two groups are phocids and walrus.

parabolic equation method
A computationally-efficient solution to the acoustic wave equation that is used to model transmission loss. The parabolic equation approximation omits effects of back-scattered sound, simplifying the computation of transmission loss. The effect of back-scattered sound is negligible for most ocean-acoustic propagation problems.

peak sound pressure level (peak SPL)
The maximum instantaneous sound pressure level, in a stated frequency band, within a stated period. Also called zero-to-peak sound pressure level. Unit: decibel (dB).

percentile level, exceedance
The sound level exceeded *n* % of the time during a measurement.

permanent threshold shift (PTS)
A permanent loss of hearing sensitivity caused by excessive acoustic exposure. PTS is considered auditory injury.

phocid
A common term used to describe all members of the family Phocidae. These true/earless seals are more adapted to in-water life than are otariids, which have more terrestrial adaptations. Phocids use their hind flippers to propel themselves. Phocids are one of the three main groups in the superfamily Pinnipedia; the other two groups are otariids and walrus.

pinniped
A common term used to describe all three groups that form the superfamily Pinnipedia: phocids (true seals or earless seals), otariids (eared seals or fur seals and sea lions), and walrus.

point source
A source that radiates sound as if from a single point (ANSI S1.1-1994 R2004).

power spectrum density
The acoustic signal power per unit frequency as measured at a single frequency. Unit: $\mu Pa^2/Hz$, or $\mu Pa^2 \cdot s$.

power spectral density level
The decibel level ($10\log_{10}$) of the power spectrum density, usually presented in 1 Hz bins. Unit: dB re 1 µPa^2/Hz.

pressure, acoustic
The deviation from the ambient hydrostatic pressure caused by a sound wave. Also called overpressure. Unit: pascal (Pa). Symbol: *p*.

pressure, hydrostatic
The pressure at any given depth in a static liquid that is the result of the weight of the liquid acting on a unit area at that depth, plus any pressure acting on the surface of the liquid. Unit: pascal (Pa).

received level
The sound level measured at a receiver.

Root-mean-square sound pressure level (SPL)
See sound pressure level.

shear wave
A mechanical vibration wave in which the direction of particle motion is perpendicular to the direction of propagation. Also called secondary wave or S-wave. Shear waves propagate only in solid media, such as sediments or rock. Shear waves in the seabed can be converted to compressional waves in water at the water-seabed interface.

signature
Pressure signal generated by a source.

sound
A time-varying pressure disturbance generated by mechanical vibration waves travelling through a fluid medium such as air or water.

sound exposure
Time integral of squared, instantaneous frequency-weighted sound pressure over a stated time interval or event. Unit: pascal-squared second (Pa^2·s) (ANSI S1.1-1994 R2004).

sound exposure level (SEL)
A cumulative measure related to the sound energy in one or more pulses. Unit: dB re 1 µPa^2·s. SEL is expressed over the summation period (e.g., per-pulse SEL [for seismic sources], single-strike SEL [for pile drivers], 24-hour SEL).

sound field
Region containing sound waves (ANSI S1.1-1994 R2004).

sound pressure level (SPL)
The decibel ratio of the time-mean-square sound pressure, in a stated frequency band, to the square of the reference sound pressure (ANSI S1.1-1994 R2004).

For sound in water, the reference sound pressure is one micropascal (p_0 = 1 µPa) and the unit for SPL is dB re 1 µPa:

$$\mathrm{SPL} = 10\log_{10}\left(p^2 / p_0^2\right) = 20\log_{10}\left(p / p_0\right)$$

Unless otherwise stated, SPL refers to the root-mean-square sound pressure level. See also 90% sound pressure level and fast-average sound pressure level.

sound speed profile
The speed of sound in the water column as a function of depth below the water surface.

source level (SL)
The sound pressure level measured 1 meter from a theoretical point source that radiates the same total sound power as the actual source. Unit: dB re 1 µPa @ 1 m.

spectrum
An acoustic signal represented in terms of its power (or energy) distribution compared with frequency.

temporary threshold shift (TTS)
Temporary loss of hearing sensitivity caused by excessive acoustic exposure.

transmission loss (TL)
The decibel reduction in sound level between two stated points that results from sound spreading away from an acoustic source subject to the influence of the surrounding environment. Also called propagation loss.

wavelength
Distance over which a wave completes one oscillation cycle. Unit: meter (m). Symbol: λ.

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Appendix A. Underwater Acoustics

A.1. Acoustic Metrics

Underwater sound pressure amplitude is measured in decibels (dB) relative to a fixed reference pressure of p_0 = 1 µPa. Because the perceived loudness of sound, especially impulsive sound such as from seismic sources, pile driving, and sonar, is not generally proportional to the instantaneous acoustic pressure, several sound level metrics are commonly used to evaluate sound and its effects on marine life. We provide specific definitions of relevant metrics used in the accompanying report. Where possible we follow the ANSI and ISO standard definitions and symbols for sound metrics, but these standards are not always consistent.

The zero-to-peak sound pressure level, or peak sound pressure level (PK; dB re 1 µPa), is the maximum instantaneous sound pressure level in a stated frequency band attained by an acoustic pressure signal, $p(t)$:

$$L_{p,pk} = 20\log_{10}\left[\frac{\max\left(\left|p(t)\right|\right)}{p_0}\right]. \quad \text{(A-1)}$$

$L_{p,pk}$ is often included as a criterion for assessing whether a sound is potentially injurious; however, because it does not account for the duration of a sound event, it is generally a poor indicator of perceived loudness.

The root-mean-square (rms) sound pressure level (SPL; dB re 1 µPa) is the rms pressure level in a stated frequency band over a specified time window (T, s) containing the acoustic event of interest. It is important to note that SPL always refers to an rms pressure level and therefore not instantaneous pressure

$$L_p = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt \Big/ p_0^2\right). \quad \text{(A-2)}$$

The SPL represents a nominal effective continuous sound over the duration of an acoustic event, such as the emission of one acoustic pulse, a marine mammal vocalization, the passage of a vessel, or over a fixed duration. Because the window length, T, is the divisor, events with similar sound exposure level (SEL) but more spread out in time have a lower SPL.

The sound exposure level (SEL, dB re 1 µPa^2·s) is a measure related to the acoustic energy contained in one or more acoustic events (N). The SEL for a single event is computed from the time-integral of the squared pressure over the full event duration (T):

$$L_E = 10\log_{10}\left(\int_T p^2(t)dt \Big/ T_0 p_0^2\right) \quad \text{(A-3)}$$

where T_0 is a reference time interval of 1 s. The SEL continues to increase with time when non-zero pressure signals are present. It therefore can be construed as a dose-type measurement, so the integration time used must be carefully considered in terms of relevance for impact to the exposed recipients.

SEL can be calculated over periods with multiple acoustic events or over a fixed duration. For a fixed duration, the square pressure is integrated over the duration of interest. For multiple events, the SEL can be computed by summing (in linear units) the SEL of the N individual events:

$$L_{E,N} = 10\log_{10}\left(\sum_{i=1}^{N} 10^{\frac{L_{E,i}}{10}}\right). \quad \text{(A-4)}$$

If applied, the frequency weighting of an acoustic event should be specified, as in the case of M-weighted SEL (e.g., $L_{E,LFC,24h}$; Appendix A.3). The use of fast, slow, or impulse exponential-time-averaging or other time-related characteristics should else be specified.

A.1.1. 1/3-Octave Band Analysis

The distribution of a sound's power with frequency is described by the sound's spectrum. The sound spectrum can be split into a series of adjacent frequency bands. Splitting a spectrum into 1 Hz wide bands, called passbands, yields the power spectral density of the sound. This splitting of the spectrum into passbands of a constant width of 1 Hz, however, does not represent how animals perceive sound.

Because animals perceive exponential increases in frequency rather than linear increases, analyzing a sound spectrum with passbands that increase exponentially in size better approximates real-world scenarios. In underwater acoustics, a spectrum is commonly split into 1/3-octave-bands, which are one-third of an octave wide; each octave represents a doubling in sound frequency. The center frequency of the ith 1/3-octave-band, $f_c(i)$, is defined as:

$$f_c(i) = 10^{i/10} , \tag{A-5}$$

and the low (f_{lo}) and high (f_{hi}) frequency limits of the ith 1/3-octave-band are defined as:

$$f_{lo} = 10^{-1/20} f_c(i) \quad \text{and} \quad f_{hi} = 10^{1/20} f_c(i) . \tag{A-6}$$

The 1/3-octave-bands become wider with increasing frequency, and on a logarithmic scale the bands appear equally spaced (Figure A-1). The acoustic modeling spans from band 10 ($f_c(10)$ = 10 Hz) to band 45 ($f_c(45)$ = 32 kHz).

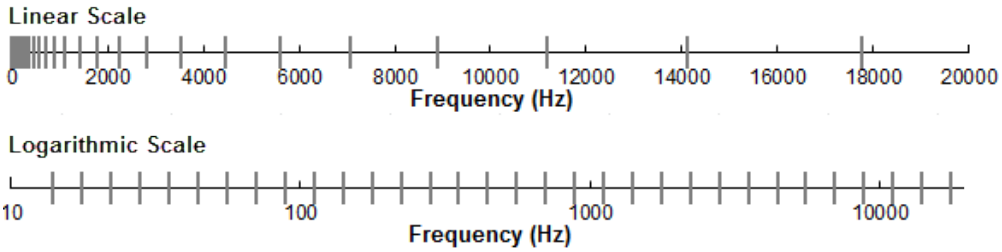


Figure A-1. One-third-octave-bands shown on a linear frequency scale and on a logarithmic scale.

The sound pressure level in the ith 1/3-octave-band $(L_b^{(i)})$ is computed from the power spectrum $S(f)$ between f_{lo} and f_{hi}:

$$L_b^{(i)} = 10 \log_{10} \left(\int_{f_{lo}}^{f_{hi}} S(f) df \right) . \tag{A-7}$$

Summing the sound pressure level of all the 1/3-octave-bands yields the broadband sound pressure level:

$$\text{Broadband SPL} = 10 \log_{10} \sum_i 10^{L_b^{(i)}/10} . \tag{A-8}$$

Figure A-2 shows an example of how the 1/3-octave-band sound pressure levels compare to the power spectrum of an ambient noise signal. Because the 1/3-octave-bands are wider with increasing frequency, the 1/3-octave-band SPL is higher than the power spectrum, especially at higher frequencies. Acoustic

modeling of 1/3-octave-bands require less computation time than 1 Hz bands and still resolves the frequency-dependence of the sound source and the propagation environment.

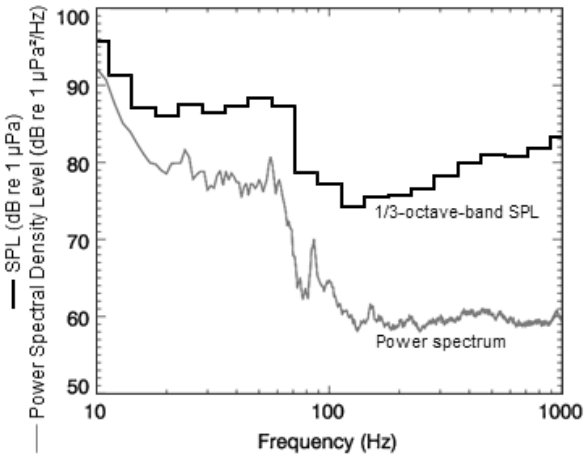


Figure A-2. A power spectrum and the corresponding 1/3-octave-band sound pressure levels of example ambient noise shown on a logarithmic frequency scale.

A.2. Sound Sources

A.2.1. Types of Sound

Numerous scientific reviews and workshops over the past 40 years have focused on how anthropogenic sounds can affect marine life (Payne and Webb 1971, Fletcher and Busnel 1978, Richardson et al. 1995, MMC 2007, Nowacek et al. 2007, Southall et al. 2007, Weilgart 2007, Tyack 2008). When assessing potential impacts of anthropogenic sound on marine life, sound sources and their resulting sounds are commonly divided into two main categories: impulsive, which includes single and multiple pulses, and non-impulsive. Impulsive sounds are typically brief and intermittent with a rapid rise time and decay (NOAA 2015). Examples of impulsive sound sources include impact pile driving, seismic sources, and some types of sonar. Non-impulsive sounds can be brief or prolonged, continuous or intermittent, and do not generally have the high peak pressure and rapid rise time that impulsive sounds do (NOAA 2015). Examples of non-impulsive sound sources include vibratory pile driving, vessel propulsion systems, and some types of sonar.

Numerous definitions and mathematical distinctions (e.g., Burdic 1984, Harris 1998) differentiate impulsive and non-impulsive sounds from one another. In practice, however, the distinction between these two sound types is not always apparent. Certain signals, such as those emitted by acoustic deterrents and harassment devices, share properties with both impulsive and non-impulsive sounds. Similarly, while vibratory pile drivers are commonly classified as continuous, it is possible to distinguish the rapid rise times associated with individual strikes of the driver very near the pile (within a few meters). Propagation effects also play a role in the classification of sounds; a sound that is deemed impulsive near the source might be categorized as non-impulsive farther from the source, due to spreading (e.g., Greene and Richardson 1988).

A.2.2. Vessel Sounds

Underwater sound that radiates from vessels is produced mainly by propeller and thruster cavitation, with a smaller fraction of sound produced by sound transmitted through the hull, such as by engines, gearing, and other mechanical systems. Sound levels tend to be the highest when thrusters are used to position the vessel and when the vessel is transiting at high speeds. A vessel's sound signature depends on the vessel's size, power output, propulsion system (e.g., conventional propellers vs. Voith Schneider propulsion), and the design characteristics of the given system (e.g., blade shape and size). A vessel produces broadband acoustic energy with most of the energy emitted below a few kilohertz. Sound from onboard machinery, particularly sound below 200 Hz, dominates the sound spectrum before cavitation begins—normally around 8–12 knots on many commercial vessels (Spence et al. 2007). Sound from vessels typically raises the background sound level by tenfold or more (Arveson and Vendittis 2000).

A.2.3. Vertical Seismic Profile Sources

Seismic air guns generate pulsed acoustic energy by releasing a highly compressed air bubble into the water that expands and then collapses. These sources produce frequencies from several hertz to a few kilohertz, with larger element volumes producing lower frequencies and higher sound levels.

During a vertical seismic profiling, a stationary source array is deployed from either a drill ship or a closely stationed auxiliary vessel. A single element produces an approximately omnidirectional sound field, emitting acoustic energy equally in all directions. For all seismic surveys, source array layouts and firing delays are configured to achieve higher sound energy emission levels in the vertical direction where the pulses from all elements add in-phase. Lower levels of sound energy are emitted in other directions. Source arrays might show significant directionality in the horizontal direction due to the phase delay between pulses because the elements are horizontally separated.

A.2.4. Impact Pile Driving

Impact pile driving consists of infixing piles of various shapes and materials into the ground by striking the top end of the pile with a ram. In its simplest form, pile driving is achieved by a free-falling ram directly striking the pile. After the strike, the ram is raised and the action repeated until a sufficient portion of the pile penetrates the ground. Additional equipment can be used for higher efficiency or to accomplish activities such as driving fully submerged piles. For example, free-falling pile drivers have generally been replaced by more sophisticated mechanisms that control downward and upward movement of the ram. Cushion materials can be installed between the ram and the drive head. Aside from redistributing some of the energy from the hammer impact and protecting the contact surfaces from damage, the cushion also allows some control on the maximum amplitude and duration of the force applied to the pile.

After each strike, the initial radial deformation at the top of the pile wall caused by impact compression rapidly travels downward along the pile, generating in the process a pressure wave in the water column. Because of the properties of the material, the deformation travels down the pile faster than the speed of sound in water, resulting in a radiating pressure wave that resemble a Mach cone with a cone angle of ~17° (Reinhall and Dahl 2011).

A.3. Acoustic Effect Criteria

A.3.1. Marine Mammals

It has been long recognized that marine mammals can be adversely affected by underwater anthropogenic sound. For example, Payne and Webb (1971) suggested that communication distances of fin whales are reduced by shipping sounds. Subsequently, similar concerns arose regarding effects of other underwater sound sources and the possibility that impulsive sources could cause auditory injury. This led to a series of workshops held in the late 1990s, conducted to address acoustic mitigation requirements for seismic surveys and other underwater sound sources (NMFS 1998, ONR 1998, HESS 1998, Nedwell and Turnpenny 1998, Ellison and Stein 1999).

The U.S. National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) considered recommendations from these workshops and adopted a set of interim thresholds for assessing injury and disturbance due to both impulsive and non-impulsive, or continuous sound, types of acoustic sources (e.g., NOAA 1998). We refer to these thresholds as the NMFS SPL criteria. Regulatory agencies in many countries have applied these criteria since the early 2000s, but recent advances in assessment approaches are starting to replace them.

The NMFS SPL criteria for acoustic exposure injury to marine mammals were set according to recommendations for cautionary estimates of sound levels leading to onset of permanent hearing threshold shift (PTS). These criteria prescribe injury thresholds of 190 dB re 1 µPa SPL for pinnipeds and 180 dB re 1 µPa SPL for cetaceans (NMFS 2013). A corresponding injury threshold was not defined for non-impulsive sounds at that time. NMFS indicates that the SPL criteria should be used for all sources including sonars and explosives (NMFS 2013). These injury thresholds are applied to individual acoustic pulses and do not consider the overall duration of the sound or its acoustic frequency distribution.

Criteria that do not take into account exposure duration or acoustic spectra are generally insufficient for assessing hearing injury. Human workplace noise assessments consider the SPL as well as the duration of exposure and sound spectral characteristics. For example, the International Institute of Noise Control Engineering (I-INCE) and the Occupational Safety and Health Administration (OSHA) suggests thresholds in C-weighted peak pressure level and A-weighted time-average sound level (dB(A)[1] L_{eq}). They also suggest exchange rates that increase the allowable thresholds for each halving or doubling of exposure time. This approach assumes that hearing damage depends on the relative loudness perceived by the human ear. It also assumes that the ear might partially recover from past exposures, particularly if there are periods of quiet nested within the overall exposure.

In recognition of shortcomings of the SPL-only based injury criteria, in 2005 NMFS sponsored the Noise Criteria Group to review literature on marine mammal hearing to propose new acoustic exposure criteria (NMFS 2013). Some members of this expert group published a landmark paper (Southall et al. 2007) that suggested assessment methods similar to those applied for humans. The resulting recommendations introduced dual acoustic injury criteria for impulsive sounds that included peak pressure level thresholds and cumulative SEL_{24h} thresholds, where the subscripted *24h* refers to the 24 hour accumulation period for calculating SEL. The peak pressure level criterion is not frequency weighted whereas the SEL_{24h} is frequency weighted according to one of four marine mammal species hearing groups: Low-, Mid- and High-Frequency Cetaceans (LFC, MFC, and HFC respectively) and Pinnipeds in Water (PINN). These weighting functions are referred to as M-weighting filters (analogous to the A-weighting filter for human; Appendix A.4.1). The SEL_{24h} thresholds were obtained by extrapolating measurements of onset levels of Temporary Threshold Shift (TTS) in belugas by the amount of TTS required to produce Permanent Threshold Shift (PTS) in chinchillas. The Southall et al. (2007) recommendations do not specify an exchange rate, which suggests that the thresholds are the same regardless of the duration of exposure (i.e., it infers a 3 dB exchange rate).

[1] The "A" refers to a specific frequency-dependent filter shaped according to a human equal loudness contour.

In 2012, the US Navy recommended a different set of criteria for assessing Navy operations (Finneran and Jenkins 2012). Their analysis incorporated new dolphin equal-loudness contours[2] to update weighting functions and injury thresholds for LFC, MFC, and HFC. They recommended separating the pinniped group into otariids (eared seals) and phocids (earless seals) and assigning adjusted frequency thresholds to the former based on several sensitivity studies (Schusterman et al. 1972, Moore and Schusterman 1987, Babushina et al. 1991, Kastak and Schusterman 1998, Kastelein et al. 2005, Mulsow and Reichmuth 2007, Mulsow et al. 2011a, Mulsow et al. 2011b).

In 2015, the US Navy updated the set of recommended thresholds and frequency-weighting functions based on newly available data Finneran (2015). In general, thresholds at low frequencies were increased from the 2012 recommendations, and thresholds for the low-frequency cetaceans were increased at all frequencies.

As of 2016, an optimal approach is not apparent. There is consensus in the research community that an SEL-based method is preferable either separately or in addition to an SPL-based approach to assess the potential for injuries. In August 2016, after substantial public and expert input into three draft versions and based largely on the above-mentioned literature (NOAA and US Dept of Commerce 2013, 2015, 2016), NMFS finalized technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing (NMFS 2016). The guidance describes injury criteria with new thresholds and frequency weighting functions for five hearing groups described by Finneran and Jenkins (2012).

A.4. Marine Mammals Frequency Weighting

The potential for sound to affect animals depends on how well the animals can hear it. Sounds are less likely to disturb or injure the auditory system of an animal if they are at frequencies that the animal cannot hear well. An exception occurs when the sound pressure is so high that it can physically injure an animal by non-auditory means (i.e., barotrauma). For sound levels below such extremes, the importance of sound components at particular frequencies can be scaled by frequency weighting relevant to an animal's sensitivity to those frequencies (Nedwell and Turnpenny 1998, Nedwell et al. 2007).

A.4.1. Southall et al. 2007

Auditory weighting functions for marine mammals—called *M-weighting* functions—were proposed by Southall et al. (2007). Functions were defined for five hearing groups of marine mammals:

- Low-frequency cetaceans (LFCs)—mysticetes (baleen whales)
- Mid-frequency cetaceans (MFCs)—some odontocetes (toothed whales)
- High-frequency cetaceans (HFCs)—odontocetes specialized for using high-frequencies
- Pinnipeds in water—seals, sea lions, and walrus
- Pinnipeds in air

The M-weighting functions have unity gain (0 dB) through the passband and their high and low frequency roll-offs are approximately –12 dB per octave. The amplitude response in the frequency domain of each M-weighting function is defined by:

$$G(f) = -20\log_{10}\left[\left(1+\frac{a^2}{f^2}\right)\left(1+\frac{f^2}{b^2}\right)\right] \quad \text{(A-9)}$$

where G(f) is the weighting function amplitude (in dB) at the frequency f (in Hz), and a and b are the estimated lower and upper hearing limits, respectively, which control the roll-off and passband of the

[2] An equal-loudness contour is the measured sound pressure level (dB re 1 µPa for underwater sounds) over frequency, for which a listener perceives a constant loudness when exposed to pure tones.

weighting function. The parameters *a* and *b* are defined uniquely for each hearing group (Table A-1). The auditory weighting functions recommended by Southall et al. (2007) are shown in Figure A-3.

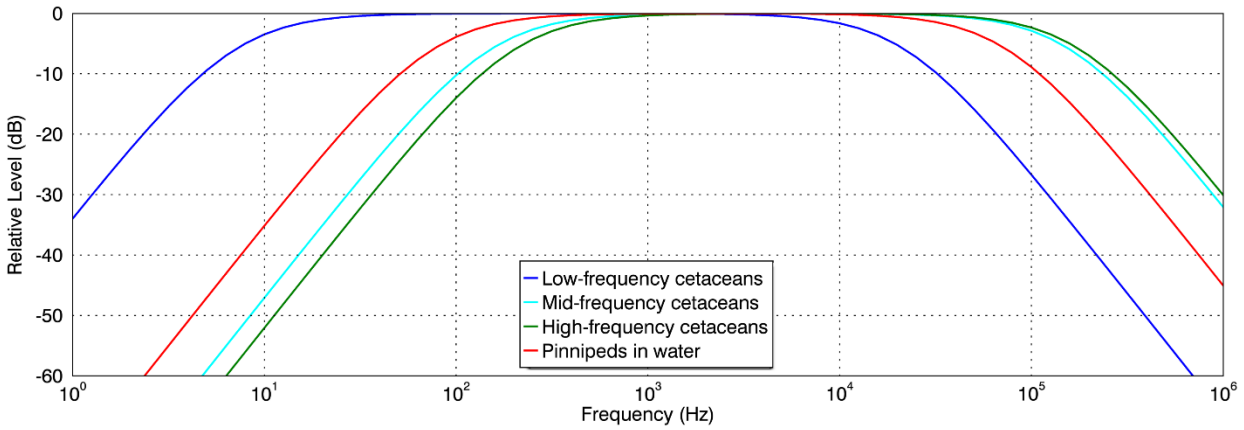


Figure A-3. Auditory weighting functions for functional marine mammal hearing groups as recommended by Southall et al. (2007).

Table A-1. Parameters for the auditory weighting functions recommended by Southall et al. (2007).

Hearing group	Southall et al. (2007)	
	a (Hz)	*b* (Hz)
Low-frequency cetaceans (LFC)	7	22,000
Mid-frequency cetaceans (MFC)	150	160,000
High-frequency cetaceans (HFC)	200	180,000
Pinnipeds in water (Pw)	75	75,000

A.4.2. Finneran 2015

In 2015, a U.S. Navy Technical Report by Finneran (2015) recommended new auditory weighting functions. The overall shape of the auditory weighting functions is similar to human A-weighting functions, which follows the sensitivity of the human ear at low sound levels. The new frequency-weighting function is:

$$G(f) = K + 10\log_{10}\left[\left(\frac{(f/f_{lo})^{2a}}{\left[1+(f/f_{lo})^{2}\right]^{a}\left[1+(f/f_{hi})^{2}\right]^{b}}\right)\right], \quad \text{(A-10)}$$

Although the inclusion of some species changed (e.g., the addition of hourglass (*Lagenorhynchus cruciger*) and Peale's (*Lagenorhynchus australis*) dolphins to the high-frequency functional hearing group), the five recommended functional hearing groups remained those presented in the Finneran and Jenkins (2012). Table A-2 lists the frequency-weighting parameters for each hearing group; Figure A-4 shows the resulting frequency-weighting curves.

Table A-2. Parameters for the auditory weighting functions recommended by Finneran (2015).

Hearing group	*a*	*b*	f_{lo} (Hz)	f_{hi} (kHz)	*K* (dB)
Low-frequency cetaceans	1.5	2	380	13,000	0.43
Mid-frequency cetaceans	1.6	2	7,400	110,000	1.02
High-frequency cetaceans	1.7	2	16,000	150,000	1.63
Phocid pinnipeds in water	2.0	2	770	27,000	0.49
Otariid pinnipeds in water	0.8	2	1,300	37,000	0.38

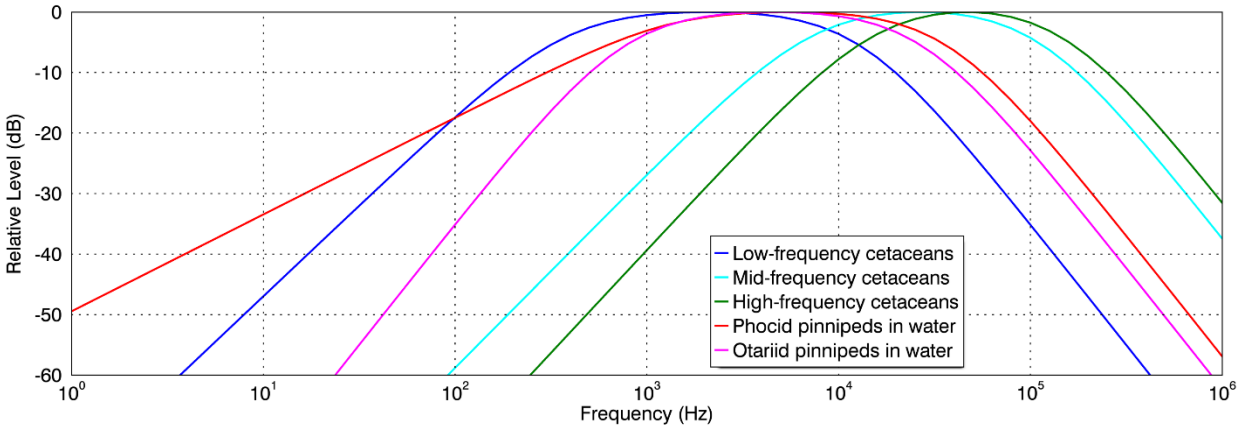


Figure A-4. Auditory weighting functions for functional marine mammal hearing groups as recommended by Finneran (2015).

A.5. Sound Propagation Models

A.5.1. Transmission Loss

The propagation of sound through the environment was modeled by predicting the acoustic transmission loss—a measure, in decibels, of the decrease in sound level between a source and a receiver some distance away. Geometric spreading of acoustic waves is the predominant way by which transmission loss occurs. Transmission loss also happens when the sound is absorbed and scattered by the seawater, and absorbed scattered, and reflected at the water surface and within the seabed. Transmission loss depends on the acoustic properties of the ocean and seabed; its value changes with frequency.

If the acoustic source level (SL), expressed in dB re 1 µPa @ 1 m, and transmission loss (TL), in units of dB, at a given frequency are known, then the received level (RL) at a receiver location can be calculated in dB re 1 µPa @ 1 m by:

$$\mathrm{RL} = \mathrm{SL} - \mathrm{TL} \, . \qquad \text{(A-11)}$$

A.5.2. Acoustic Propagation with MONM

Underwater sound propagation (i.e., transmission loss) at frequencies of 10 Hz to 2 kHz was predicted with JASCO's Marine Operations Noise Model (MONM). MONM computes received per-pulse SEL for directional impulsive sources, and SEL over 1 s for non-impulsive sources, at a specified source depth.

MONM computes acoustic propagation via a wide-angle parabolic equation solution to the acoustic wave equation (Collins 1993) based on a version of the U.S. Naval Research Laboratory's Range-dependent

Acoustic Model (RAM), which has been modified to account for a solid seabed (Zhang and Tindle 1995). The parabolic equation method has been extensively benchmarked and is widely employed in the underwater acoustics community (Collins et al. 1996). MONM accounts for the additional reflection loss at the seabed, which results from partial conversion of incident compressional waves to shear waves at the seabed and sub-bottom interfaces, and it includes wave attenuations in all layers. MONM incorporates the following site-specific environmental properties: a bathymetric grid of the modeled area, underwater sound speed as a function of depth, and a geoacoustic profile based on the overall stratified composition of the seafloor.

MONM computes acoustic fields in three dimensions by modeling transmission loss within two-dimensional (2-D) vertical planes aligned along radials covering a 360° swath from the source, an approach commonly referred to as N×2-D. These vertical radial planes are separated by an angular step size of $\Delta\theta$, yielding N = 360°/$\Delta\theta$ number of planes (Figure A-5).

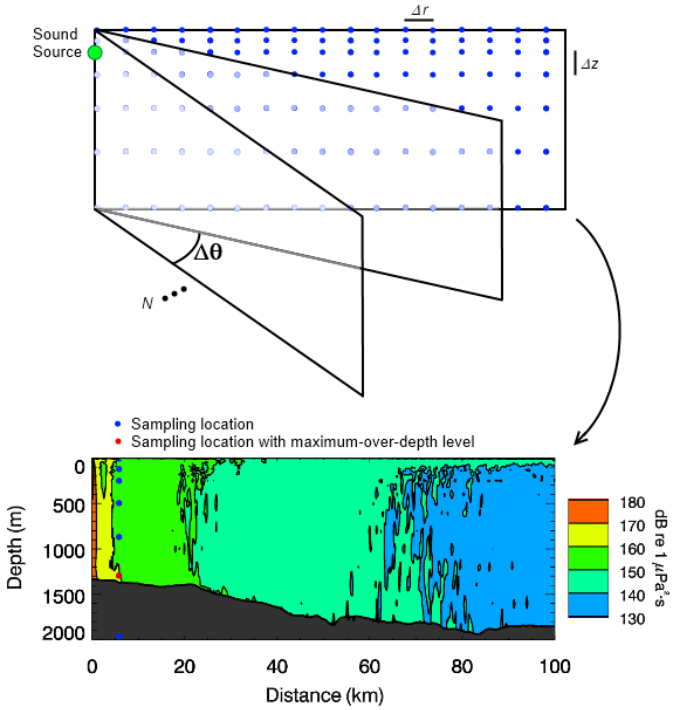


Figure A-5. The N×2-D and maximum-over-depth modeling approach used by MONM.

MONM treats frequency dependence by computing acoustic transmission loss at the center frequencies of 1/3-octave-bands. Sufficiently many 1/3-octave-bands, starting at 10 Hz, are modeled to include the majority of acoustic energy emitted by the source. At each center frequency, the transmission loss is modeled within each of the N vertical planes as a function of depth and range from the source. The 1/3-octave-band received per-pulse SEL are computed by subtracting the band transmission loss values from the directional source level in that frequency band. Composite broadband received SEL are then computed by summing the received 1/3-octave-band levels.

The frequency-dependent transmission loss computed by MONM may be corrected to account for the attenuation of acoustic energy by molecular absorption in seawater. The volumetric sound absorption is quantified by an attenuation coefficient, expressed in units of decibels per kilometer (dB/km). The absorption coefficient depends on the temperature, salinity, and pressure of the water as well as the sound frequency. In general, the absorption coefficient increases with the square of frequency. The absorption of acoustic wave energy has a noticeable effect (>0.05 dB/km) at frequencies above 1 kHz. For example, at 10 kHz the absorption loss over 10 km distance can exceed 10 dB. This coefficient for seawater can be computed according to the formulae of François and Garrison (1982b, b), which

consider the contributions of pure seawater, magnesium sulfate, and boric acid. The formula applies to all oceanic conditions and frequencies from 200 Hz to 1 MHz. For this project, absorption coefficients were computed and applied for all modeled frequencies. Because of the computational expense associated with parabolic equation modeling at frequencies at or above several kHz and the relative importance of absorption at such frequencies, the transmission loss in each frequency band between 6 and 32 kHz was approximated from the transmission loss computed at 5 kHz by applying the correct frequency-dependent absorption coefficient in each band.

The received per-pulse SEL sound field within each vertical radial plane is sampled at various ranges from the source, generally with a fixed radial step size. At each sampling range along the surface, the sound field is sampled at various depths, with the step size between samples increasing with depth below the surface. The step sizes are chosen to provide increased coverage near the depth of the source and at depths of interest in terms of the sound speed profile. For areas with deep water, sampling is not performed at depths beyond those reachable by marine mammals. The received per-pulse SEL at a surface sampling location is taken as the maximum value that occurs over all samples within the water column, i.e., the maximum-over-depth received per-pulse SEL. These maximum-over-depth per-pulse SEL are presented as color contours around the source.

MONM's predictions have been validated against experimental data from several underwater acoustic measurement programs conducted by JASCO (Hannay and Racca 2005, Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010, Racca et al. 2012a, Racca et al. 2012b, Martin et al. 2015).

An inherent variability in measured sound levels is caused by temporal variability in the environment and the variability in the signature of repeated acoustic impulses (sample sound source verification results is presented in Figure A-6). While MONM's predictions correspond to the averaged received levels, cautionary estimates of the threshold radii are obtained by shifting the best fit line (solid line, Figure A-6) upward so that the trend line encompasses 90% of all the data (dashed line, Figure A-6).

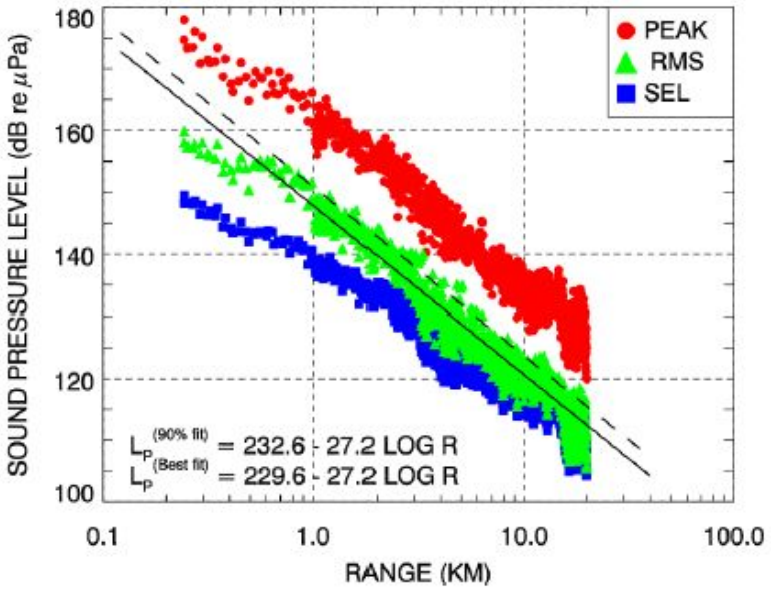


Figure A-6. Peak and SPL and per-pulse SEL versus range from a 20 in^3 air gun array. Solid line is the least squares best fit to SPL. Dashed line is the best fit line increased by 3.0 dB to exceed 90% of all SPL values (90th percentile fit) (Ireland et al. 2009, Figure 10).

Sound source verification results show that this 90th percentile best-fit is, on average, 3 dB higher than the original best fit line for sources in water depths greater than 20 m (Aerts et al. 2008, Funk et al. 2008, Ireland et al. 2009, O'Neill et al. 2010, Warner et al. 2010). Consequently, a safety factor of 3 dB is

customarily added to the predicted received levels to provide cautionary results reflecting the inherent variability of sound levels in the modeled area.

The transmission loss computed by MONM can be further corrected to account for the attenuation of acoustic energy by molecular absorption in seawater. The volumetric sound absorption is quantified by an attenuation coefficient, expressed in units of decibels per kilometer (dB/km). The absorption coefficient depends on the temperature, salinity, and pressure of the water as well as the sound frequency. In general, the absorption coefficient increases with the square of frequency. The absorption of acoustic wave energy has a noticeable effect (>0.05 dB/km) at frequencies above 1 kHz. At 10 kHz, the absorption loss over a 10 km distance can exceed 10 dB. This coefficient for seawater can be computed according to the formulae of François and Garrison (1982b, 1982a), which consider the contribution of pure seawater, magnesium sulfate, and boric acid. The formulae apply to all oceanic conditions and frequencies from 200 Hz to 1 MHz.

A.5.3. Acoustic Propagation with FWRAM

For impulsive sounds, time-domain representations of the pressure waves generated in the water are required to calculate peak pressure level or to accuratly model sound propagating away from a vertical source array. For this study, synthetic pressure waveforms were computed using FWRAM, which is a time-domain acoustic model based on the same wide-angle parabolic equation (PE) algorithm as MONM. FWRAM computes synthetic pressure waveforms versus range and depth for range-varying marine acoustic environments, and it takes the same environmental inputs as MONM (bathymetry, water sound speed profile, and seabed geoacoustic profile). Unlike MONM, FWRAM computes pressure waveforms via Fourier synthesis of the modeled acoustic transfer function in closely spaced frequency bands. FWRAM employs the array starter method to accurately model sound propagation from a spatially distributed source (MacGillivray and Chapman 2012).

Synthetic pressure waveforms were modeled over the frequency range 10–2048 Hz, inside a 1 s window. The synthetic pressure waveforms were post-processed, after applying a travel time correction, to calculate PK and SEL metrics versus range and depth from the sources.



Environmental and Socioeconomic Management Plan

Liza Phase 1 Development Project

Esso Exploration and Production Guyana, Limited

February 2017

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EEPGL Country Manager _____ _____
Date

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TAB LE OF CONTENTS

1.0 INTRODUCTION AND SCOPE 1

2.0 ENVIRONMENTAL AND SOCIOECONOMIC MANAGEMENT FRAMEWORK 3

2.1 OBJECTIVES OF THE ESMP 3
2.2 ENVIRONMENTAL POLICY AND LEGAL FRAMEWORK 3
2.2.1 National Constitution of Guyana 3
2.2.2 The Environmental Protection Act 3
2.2.3 The Guyana Geology and Mines Commission Act 4
2.3 RESOURCE-SPECIFIC LEGAL REQUIREMENTS FOR THE PROJECT 4
2.3.1 National Laws and Regulations 4
2.3.2 National Policy Framework 7
2.3.3 International Conventions and Protocols 7
2.4 EEPGL'S MANAGEMENT POLICIES AND COMMITMENTS 8
2.5 ORGANIZATIONAL STRUCTURE 9
2.6 COMPETENCY, TRAINING, AND AWARENESS 10
2.6.1 Training Programs and Delivery 11

3.0 PROJECT SPECIFIC MANAGEMENT PLANS 13

3.1 ENVIRONMENTAL MANAGEMENT PLAN 15
3.1.1 Introduction and Scope 15
3.1.2 Management Measures 15
3.2 SOCIOECONOMIC MANAGEMENT PLAN 20
3.2.1 Introduction and Scope 20
3.2.2 Management Measures 20
3.3 OIL SPILL RESPONSE PLAN 34
3.4 PRELIMINARY END OF OPERATIONS DECOMMISSIONING PLAN 34
3.5 ENVIRONMENTAL AND SOCIOECONOMIC MONITORING PLAN 34
3.6 DOCUMENTATION, REPORTING, AND RECORD KEEPING 38

List of Figures

Figure 1-1. Location of the Liza Project Development Area within the Stabroek Block 2

Figure 2-1. The OIMS Framework 9

Figure 3-1. ESMP Structure 14

Figure 3-2. EEPGL's Five-Step Grievance Management Procedure 23

Figure 3-4. Chance Find Procedure Flow Chart 33

List of Tables

Table 2-1. Resource-Specific Environmental and Social Laws....4
Table 2-5. Training Roles and Responsibilities....11
Table 3-1. Air Quality Management Measures....15
Table 3-2. Water Quality Management Measures....17
Table 3-3. Marine Ecosystem Management Measures....19
Table 3-4. Socioeconomic Management Measures....25
Table 3-5. Transportation Management Measures....26
Table 3-6. Road Safety Management Measures....28
Table 3-8: Two-tiered Chance Find Hierarchy....32
Table 3-7. Environmental and Socioeconomic Monitoring Measures....35
Table 2-3. Summary of Reporting....38

APPENDICES

Appendix 1: Waste Management Plan
Appendix 2: Stakeholder Engagement Plan
Appendix 3: Preliminary End of Operations and Decommissioning Plan

LIST OF ACRONYMS

AUV ..... Automated Underwater Vehicle
BFROC ..... base fluid retained on cuttings
BOD ..... Biological Oxygen Demand
BOEM ..... U.S. Bureau of Ocean Energy Management
CHS ..... Cultural Heritage Specialist
CITES ..... Convention on International Trade in Endangered Species of Wild Fauna and Flora
CO ..... carbon monoxide
COD ..... Chemical Oxygen Demand
COLREG ..... Convention on the International Regulations for Preventing Collisions at Sea
CSC ..... International Convention for Safe Containers
EEPGL ..... Esso Exploration and Production Guyana Limited
EIA ..... Environmental Impact Assessment
EPA ..... Guyanese Environmental Protection Agency
EPI ..... Environmental Performance Indicator
ESMP ..... Environmental and Socioeconomic Management Plan
FAO ..... Food and Agriculture Organization
FPSO ..... Floating Production, Storage, and Offloading
GGMC ..... Guyana Geology and Mines Commission
GPS ..... Global Positioning System
GRA ..... Guyana Revenue Authority
JNCC ..... Joint Nature Conservation Committee
MARAD ..... Maritime Administration
MARPOL 73/78 ..... International Convention for the Prevention of Pollution by Ships, 1973, as modified by the Protocol of 1978
MPN ..... most probable number
NABF ..... non-aqueous base fluid
NADF ..... non-aqueous drilling fluid
NEAP ..... National Environmental Action Plan
OAS ..... Organization of American States
OGP ..... Oil and Gas Producers
OI ..... Operations Integrity
OIMS ..... Operations Integrity Management System
PDA ..... Project Development Area
ROV ..... remotely operated vehicle
SEP ..... Stakeholder Engagement Plan
SSLT ..... Site Safety Leadership Team
TSS ..... total suspended solids
VSP ..... Vertical Seismic Profile
WBDF ..... Water Based Drilling Fluids

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1.0 INTRODUCTION AND SCOPE

Esso Exploration and Production Guyana, Limited (EEPGL) is the Operator of the Stabroek Petroleum Prospecting Licence Area (referred to hereafter as the Stabroek Block), the largest petroleum prospecting license area offshore Guyana. In 2015, oil was discovered in the Liza field within the eastern half of the Stabroek Block approximately 190 km (~120 mi) offshore from Georgetown in waters approximately 1,500 to 1,900 meters (m) deep. Subsequent surveys and exploratory drilling have identified a reservoir of oil in a sandstone formation approximately 3,600 m below the seabed (approximately 5,400 m below sea level). EEPGL, together with Hess Guyana Exploration Limited and CNOOC Nexen Petroleum Guyana Limited, are parties to a Petroleum Agreement with the Government of Guyana. Under this agreement, and in light of the Liza field discovery, EEPGL has applied for a Petroleum Production Licence and submitted a Project Development Plan to the Minister responsible for Petroleum. This agreement is conditioned on EEPGL obtaining all required permits for EEPGL to develop the Liza field and recover the oil.

The scope of this Environmental and Socioeconomic Management Plan (ESMP) is intended to cover Phase 1 of the Liza development (the Project), which will include drilling approximately 17 subsea development wells and using a Floating Production Storage and Offloading (FPSO) vessel to process, store, and offload the recovered oil. The Project drilling and production operations activities will collectively occur in what is referred to as the Project Development Area (PDA), which is an approximately 50 km^2 (~20 mi^2) area located approximately 190 km (~120 mi) offshore. Figure 1-1 illustrates the location of the PDA. The Project will also involve shorebase facilities and marine/aviation services to support development drilling, FPSO and subsea equipment installation, and production operations.

EEPGL prepared a separate Environmental Impact Assessment (EIA) which:

- described the local and regional environmental context of the Project;
- described all components of the Project activities;
- identified the environmental issues/risks associated with the Project activities; and
- explained why the Project activities should be considered environmentally acceptable.

This ESMP covers regulatory compliance as well as environmental and socioeconomic management requirements for the Project-related activities described in the EIA. It provides the basis of EEPGL's environmental and socioeconomic management program, which is the mechanism through which the company will ensure that the environmental impacts resulting from the Project activities, including cumulative impacts, will be acceptably managed. Where appropriate, it contains environmental objectives and targets which EEPGL seeks to accomplish in order to avoid, reduce, or remedy negative impacts.

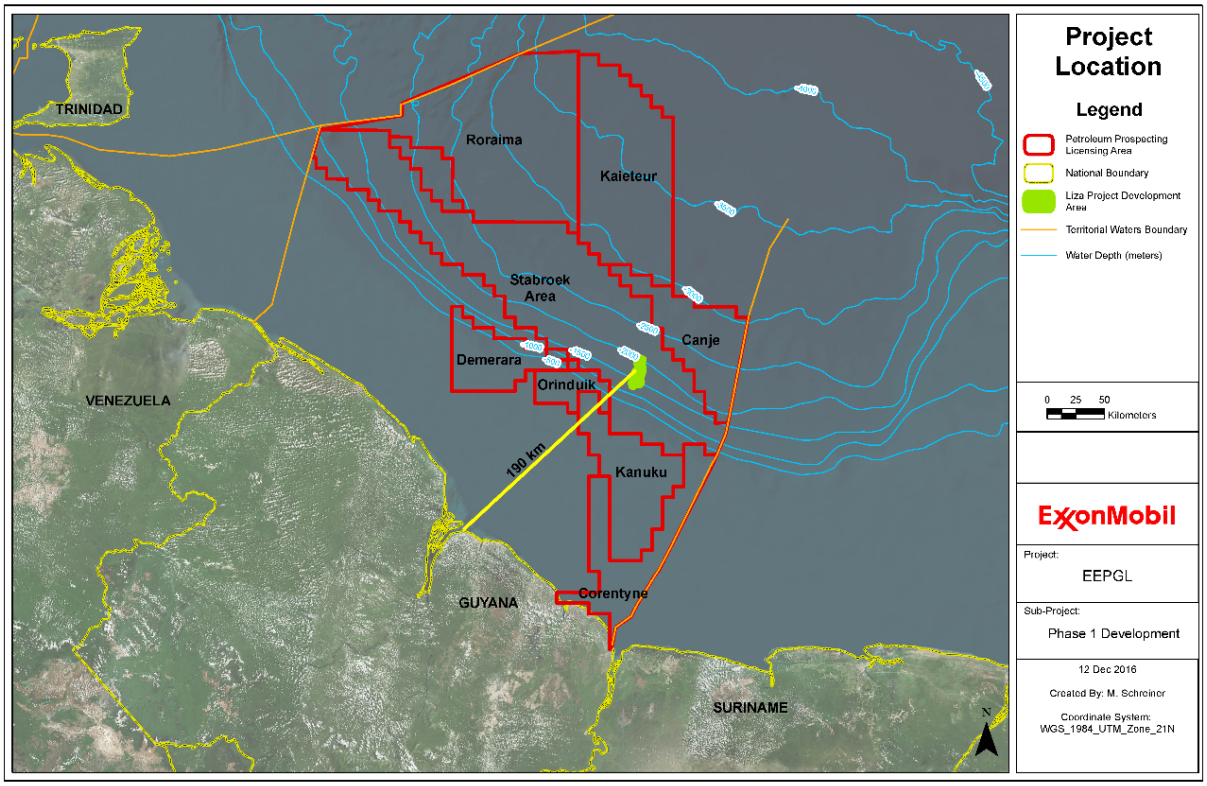
The following are not considered within the scope of this ESMP:

- Regulatory compliance associated with employment visas and taxes associated with the Project;

- Employment, commercial, and financial laws and regulations;
- Environmental and socioeconomic management and regulatory compliance activities for exploration-related activities in the Stabroek block or other nearby blocks where no interfaces are required to be maintained with the Phase 1 Project; and
- Provisions for local content, which are addressed in the Project Development Plan and the associated Local Content Plan as covered in the Project's Petroleum Production Licence.

It is important to note that the ESMP will be used throughout the Project life cycle. However, the document will be regularly updated in an effort to remain aligned with the Project as it progresses from installation to production operations and to decommissioning. As production activities progress, it is envisioned that this plan will be periodically revised as appropriate during the twenty year production operations stage.

Figure 1-1. Location of the Liza Project Development Area within the Stabroek Block



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

2.0 ENVIRONMENTAL AND SOCIOECONOMIC MANAGEMENT FRAMEWORK

2.1 Objectives of the ESMP

The objectives of this ESMP are to:

- Demonstrate commitment to compliance with applicable laws, regulations, and executed Project agreements through documented plans and procedures;
- Describe the process the Project will use to identify, evaluate, communicate, and comply with applicable regulatory requirements and obligations and EEPGL policies and procedures, and to maintain a current list of Project-applicable requirements and obligations;
- Establish clear roles and responsibilities and describe how the Project will interface in relation to environmental, socioeconomic and regulatory matters;
- Utilize regulatory compliance management systems, processes, and procedures;
- List the types of reports that will be used to communicate environmental, socioeconomic and regulatory compliance and overall status updates; and
- Identify training and awareness requirements for the Project and contractors.

2.2 Environmental Policy and Legal Framework

The legal framework for this ESMP consists of the key general environmental laws and resource-specific environmental laws that have either a direct or indirect relevance to the Project. Statutes described in this section impose specific legal obligations on EEPGL under Guyana law and include:

- The National Constitution of Guyana
- The Environmental Protection Act
- The Guyana Geology and Mines Commission Act

2.2.1 National Constitution of Guyana

Guyana is governed according to the Constitution of the Co-operative Republic of Guyana, as amended. The constitution took effect in 1980 and expressly provides for protection of the environment. Article 25 establishes "improvement of the environment" as a general duty of the citizenry.

2.2.2 The Environmental Protection Act

In 1996, the Environmental Protection Act (hereinafter referred to as the Act) was enacted to implement the environmental provisions of the Constitution. The Act is Guyana's single most significant piece of environmental legislation because it articulates national policy on important environmental topics such as pollution control, the requirements for environmental review of projects that could potentially impact the environment, and the penalties for environmental infractions. It also provides for the establishment of an environmental trust fund. Most importantly, the Act authorized the formation of the Environmental Protection Agency (EPA),

and establishes the EPA as the lead agency on environmental matters in Guyana (FAO, 2013). The Act further mandates the EPA to oversee the effective management, conservation, protection and improvement of the environment (EPA, 2012). It also requires the EPA to take the necessary measures to ensure the prevention and control of pollution, assessment of the impacts of economic development on the environment, and the sustainable use of natural resources.

2.2.3 The Guyana Geology and Mines Commission Act

The Guyana Geology and Mines Commission Act was enacted in 1979, and authorized the government to establish the Guyana Geology and Mines Commission (GGMC). The GGMC promotes and regulates the exploration and development of the country's mineral resources. The GGMC has a dedicated petroleum division, but petroleum related activities also occur in other divisions, such as the Geological Services division and the Environment Division. The GGMC's most important role with respect to the Project is related to EEPGL's Petroleum Agreement, under which production would be conducted.

2.3 Resource-specific legal requirements for the Project

2.3.1 National Laws and Regulations

In additional to the legal framework described in Section 2.2, several Guyanese environmental laws with more narrowly defined scopes pertain to specific biological or physical natural resources. Other laws which primarily have a public health-related focus are also indirectly related to the environment.

Guyana has several national laws that regulate impacts on physical environmental media, biological resources including wildlife and fisheries, and socioeconomic aspects with potential to be affected by the Project. In addition to these laws, Guyana also has national laws governing waste management and noise. These laws and regulations are described in greater detail in Table 2-1.

Table 2-1. Resource-Specific Environmental and Social Laws

Title	Objective	Relevance to the Project
Biological Resources		
Fisheries Act, 2002	Regulates fishing and related activities in Guyana territorial waters.	Section 33(1) of the Fisheries Act authorizes the prohibition and/or regulation of deposition or discharge of substances harmful to fish. Would primarily affect the contents of routine discharges from Project vessels and the FPSO.

Title	Objective	Relevance to the Project
Wild Birds Protection Act, 1987	Protects listed wild birds in Guyana.	Sections 3 and 6 prohibit knowingly wounding or killing wild birds listed in the First and Second Schedule of the Act and establishes penalties.
Species Protection Regulations, 1999	Provides for the establishment of a Management Authority and a Scientific Authority in compliance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).	Provides for wildlife protection, conservation, and management.
Wildlife Management and Conservation Regulations, 2013 (recently supplemented by passing of Wildlife Conservation and Management Bill, 2016)	Provides for the establishment of a Management Authority and the management of the country's flora and fauna.	Provides a supportive mechanism cognizant of the national goals for wildlife protection, conservation, management and sustainable use.
Physical Resources		
Environmental Protection Water Quality Regulations, 2000	Focused on setting effluent standards, reporting requirements and penalties for violations of standards, and permitting requirements for discharges.	Regulates discharges of listed substances, which could include substances used during the Project. Would affect the concentrations of certain constituents (primarily metals, but including others such as nitrogenous compounds, fluoride, and sulfate) that could be discharged in the routine discharges from the Project.
Environmental Protection Air Quality Regulations, 2000	Sets ambient air quality standards, reporting requirements, penalties for violations of standards, and permitting requirements for stationary and mobile sources.	Regulates discharges that could be emitted during the Project, including smoke, particulates, and carbon monoxide (CO).
Environmental Protection Hazardous Waste Regulations, 2000	Establishes requirements for generating, handling, and disposing of hazardous waste as well as penalties for violations of these requirements.	Identifies wastes subject to regulation, including several types of waste that could be produced by the Project.
Toxic Chemicals Control Act No. 13 of 2000, as amended in 2007	Provides for the formation of a Pesticides and Toxic Chemicals Control Board. Establishes requirements for registration, licensure, and trade in pesticides and toxic chemicals. Amended in 2007 to provide rules for the exportation of pesticides and toxic chemicals.	Establishes regulations pertaining to the use of toxic chemicals and pesticides. Pesticides will not be required for this Project, but small amounts of chemicals may be used. The Act would regulate the importation, registration, and use of these chemicals.

Title	Objective	Relevance to the Project
Environmental Protection Noise Management Regulations, 2000	Establishes general provisions for noise avoidance and restrictions from multiple commercial and industrial sources including sound making devices, night clubs, equipment, tools, and construction activities.	Tools and equipment includes pile drivers, steam shovels, pneumatic hammers, pumps, vent or valve devices and any other similar equipment. A regulated facility includes any offshore installation and any other installation, whether floating or resting on the seabed.
Draft Guyana Standard, Requirements for Industrial Effluent Discharge into the Environment, 2015	Compulsory standard used for monitoring of effluents into freshwater, estuarine, and marine water resources.	Sets limits for key parameters in discharges of industrial effluent. Would affect the concentrations of many of the same constituents in routine discharges that would be regulated under the Environmental Protection Water Quality Regulations 2000. Would also dictate the general water chemistry parameters (e.g., temperature, biological oxygen demand, pH) of these discharges.
Public Health		
Occupational Safety and Health Act, 1997	Legally defines the responsibilities of workers and management with respect to keeping workplaces safe.	Would generally apply to workers and Project-related activities on the Project sites.
Food & Drug Regulations (Food and Drug Act)	Regulates the sale, advertisement, preparation, and handling of food products. Regulates the manufacture, advertisement, trade, and administration of pharmaceuticals. Provides the Ministry of Health authority to inspect facilities to establish compliance with sanitation standards.	Governs the preparation of food and provision of medications at Project facilities.
Social / Cultural Resources		

Title	Objective	Relevance to the Project
National Trust Act	Stewardship of historic resources and places of cultural significance.	Governs the management of any building, structure, object, or other man-made or natural feature that is of historic or national cultural significance that could be impacted by the Project. Includes shipwrecks and other marine features. Would only apply to the Project in the event of a chance find, in which case the Act would require EEPGL to work cooperatively with the National Trust to manage any resources discovered.

Most recently, the Minister of Natural Resources, who functions as the sponsoring Minister for the Oil and Gas industry, announced plans in September 2015 to upgrade the country's upstream oil and gas policy, which was originally crafted in 2012 and finalized in 2014, indicating an evolving policy and regulatory framework surrounding the oil and gas industry in Guyana.

To date, there are 16 laws concerning oil and gas in Guyana. The majority of these laws are housed with the EPA, National Advisory Council on Occupational Safety and Health, Guyana Revenue Authority (GRA), GGMC, or Guyana National Bureau of Standards.

2.3.2 National Policy Framework

Guyana's National Development Strategy (NDS), National Environmental Action Plan (NEAP), and Integrated Coastal Zone Management (ICZM) Action Plan relate to environmental protection and natural resource management goals. The NDS identifies several distinct natural "features" of Guyana's that could be affected by the Project including the coastal zone and fisheries. Guyana's NEAP articulates the national government's approach to managing the environment, with particular emphasis on environmental management and pollution control. The ICZM Action Plan articulates the government's strategy for managing coastal environmental resources, several of which could be impacted by the Project. These same documents are also relevant to the Project from a socioeconomic perspective because they outline priorities for the country's economic and social development in the context of environmental protection and natural resource management goals.

2.3.3 International Conventions and Protocols

Guyana is signatory to a number of international and regional conventions and protocols that are relevant to environmental management aspects including air quality/climate change, pollution prevention, and conservation of biodiversity and wildlife habitat. These agreements include several prominent conventions concerning pollution control and waste management such as the International Convention for the Prevention of Pollution from Ships (MARPOL

73/78), the Basel Convention on the Transboundary Movement of Hazardous Wastes and Their Disposal, and the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, and reflect a particular focus on control of pollution and environmental contamination.

Guyana is also a signatory to several international and regional conventions and protocols that are relevant to environmental and socioeconomic aspects, although not all of these agreements have been translated into national legislation. Examples include climate change agreements such as the Kyoto Protocol and the UNFCCC, the UNESCO Convention on the Protection of Underwater Cultural Heritage, and maritime safety conventions such as the International Convention for the Safety of Life at Sea. These international conventions and protocols are described in greater detail in the EIA, Chapter 3: Administrative Framework.

2.4 EEPGL's Management Policies and Commitments

The Company and its affiliates (including EEPGL) are committed to conducting business in a manner that is compatible with the environmental and socioeconomic needs of the communities in which it operates, and that protects the safety, security, and health of its employees, those involved with its operations, its customers, and the public. These commitments are documented in its Safety, Security, Health, Environmental, and Product Safety policies. These policies are put into practice through a disciplined management framework called the Operations Integrity Management System (OIMS).

EEPGL's OIMS Framework[1] establishes common expectations used by Company affiliates worldwide for addressing risks inherent in its business. The term Operations Integrity (OI) is used to address all aspects of its business that can impact personnel and process safety, security, health, and environmental performance.

Application of the framework is required across all Company affiliates, with particular emphasis on design, construction and operations. Management is responsible for ensuring that management systems satisfying the OIMS Framework are in place. Implementation will be consistent with the risks associated with the business activities being planned and performed. Figure 2-1 provides a high level description of the OIMS Framework and its 11 essential elements.

[1] http://corporate.exxonmobil.com/company/about-us/safety-and-health/operations-integrity-management-system

Figure 2-1. The OIMS Framework



2.5 Organizational Structure

EEPGL will have an organization which is responsible for managing the Project activities over the life cycle of the Project. A dedicated in-country organization will be in place throughout each Project stage. The organizational size and makeup will evolve over time to accommodate the business needs associated with drilling development wells, installation of FPSO and SURF components, production operations, logistical support, and ultimately decommissioning.

The in-country organization will be led by a Lead Country Manager, and supported by various discipline managers such as Operations, Engineering, Human Resources, Public & Government Affairs, Business Services (e.g. Procurement, Controllers, Information Technology), Law, and SSH&E. The in-country organization will also be supported by a number of technical, business, and administrative specialists located inside and outside of Guyana. The in-country organization is responsible for all in-country Project activities, and will be the organization which interfaces with government and stakeholders.

The in-country organization will also be supported by several teams which are responsible for managing certain types of Project activities. Examples of such teams include a Drill Team which manages the drilling and completion of the development wells; a Logistics Team which manages logistical support (e.g. shorebase, aviation, marine vessels); and a Project Team which manages the engineering, procurement, construction, and installation of the FPSO and SURF components. Each of these teams has a suite of discipline managers to support the planning and execution of the Project Activities that they are responsible for, including SSH&E. These teams interface with the EEPGL in-country organization in a seamless manner to deliver their scopes of work for the Project. EEPGL will ultimately manage production operations.

The EEPGL management team will be supported by a SSH&E team which provides technical expertise, training, and administrative support for OIMS implementation, which addresses disciplines such as safety, security, health, environmental, regulatory, and socioeconomics.

Organization charts and organizational roles and responsibilities will be further defined in future revisions of this document once the Project achieves a Final Investment Decision (FID).

The management team of EEPGL is accountable for managing the Project activities in alignment with OIMS and EEPGL's established SSH&E policies, in compliance with the laws and regulations of Guyana, and in line with the commitments and obligations associated with the EIA and ESMP.

EEPGL defines SSH&E roles and responsibilities for its organizations and individuals to ensure they understand expectations.

2.6 Competency, Training, and Awareness

EEPGL will assign suitably competent personnel to manage and support the Project activities in alignment with OIMS, which provides guidelines for personnel selection, placement, and competency verification. EEPGL will provide/validate that its personnel have been provided the appropriate SSH&E training, in alignment with OIMS.

EEPGL will verify that its contractors have competency, training, and awareness programs in place which are consistent with EEPGL's programs, in alignment with OIMS.

EEPGL and its contractors will provide SSH&E training and awareness programs which include:

- Country/site specific inductions for new personnel and visitors;
- General training covering broad SSH&E roles and responsibilities for all personnel;
- Management training direct at management and supervisory level personnel; and
- Project and job specific training specific to those with direct duties and roles in SSH&E, commensurate with their level of responsibility.

EEPGL will include ESMP related training and awareness in the above programs as appropriate to ensure that personnel with ESMP roles and responsibilities understand expectations related to commitments and obligations, mitigation measures, monitoring programs, and reporting. Table 2-5 provides a conceptual overview of roles and responsibilities for EEPGL's competency, training, and awareness program.

Table 2-5. Training Roles and Responsibilities

Position	Responsibilities
Management	• Approve overall training processes and procedures • Verify competent and trained personnel are available to support Project activities
Site Supervision	• Ensure their personnel have the required knowledge and skills to perform job tasks • Review and approve training plans for their personnel • Provide time/resources required for their personnel to complete/maintain training • Review training progress for their personnel on an annual basis • Consult with management on actions to take when a person does not meet the requisite knowledge/skills after training has occurred
Personnel	• Complete training requirements • Provide feedback on training received
SSH&E Personnel	• Provide SSH&E training programs with support from training resources
Training Resources	• Provide SSH&E training programs with support from SSH&E personnel • Assist with delivery of training (where appropriate) and evaluate training results

2.6.1 Training Programs and Delivery

EEPGL will develop competency, training, and awareness program appropriate to the Project's needs. Training may be provided through a variety of means, which may include but is not limited to: briefings, toolbox talks, coaching/mentoring, on-the-job training in specific elements or tasks, self-study, instructor-led training, seminars, workshops, computer-based training, or the provision of specific skills as necessary. These and other means (such as posters, signs, site newsletters, etc.) may be used to promote environmental, socioeconomic, and regulatory compliance awareness. Training programs may be delivered by both EEPGL, contractor, and third party training resources.

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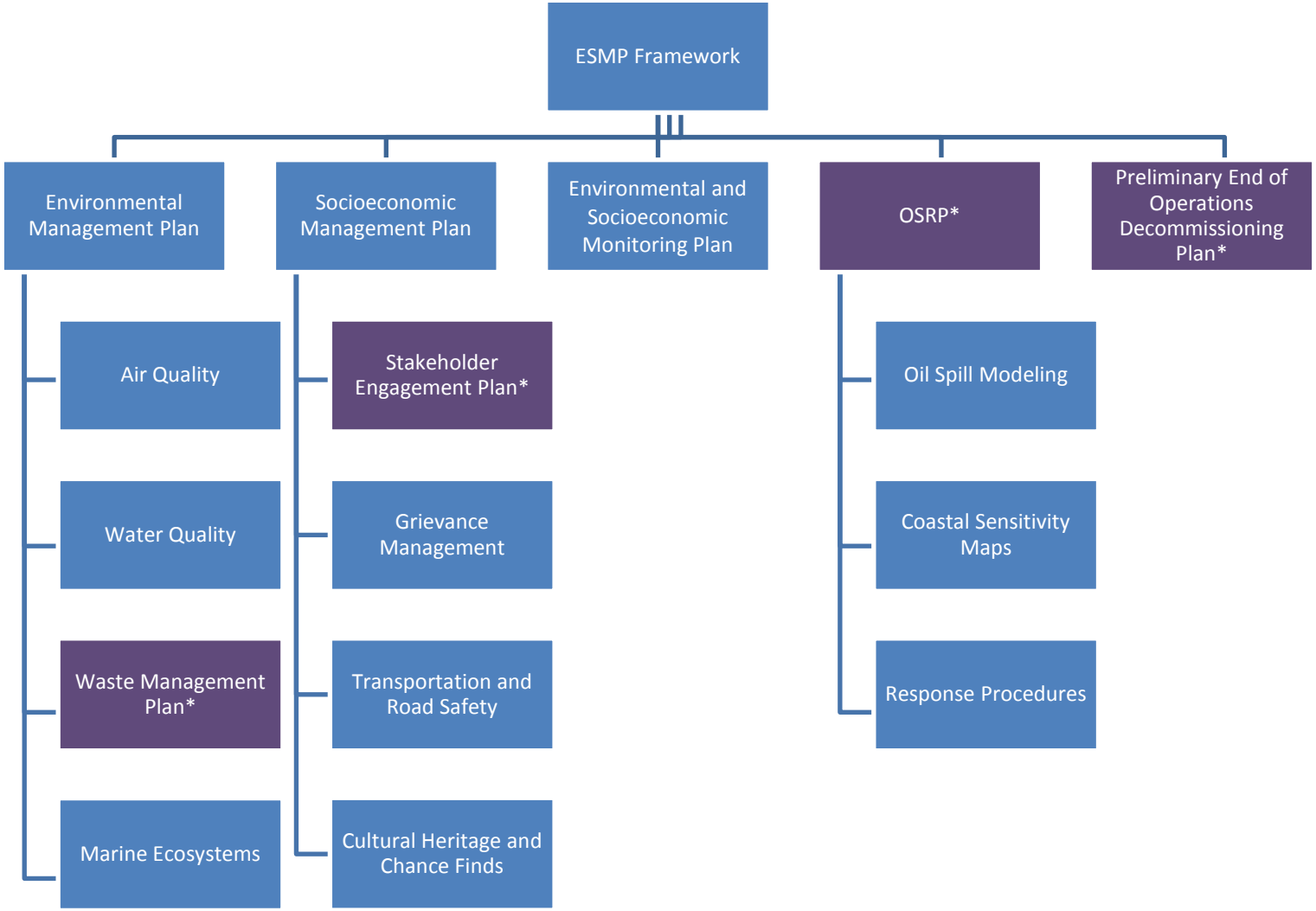
3.0 PROJECT SPECIFIC MANAGEMENT PLANS

In accordance with the structure of the ESMP as described in Section 9.3 of the Liza Phase 1 EIA, the ESMP includes several specific management plans that are organized into five categories:

- Environmental Management;
- Socioeconomic Management;
- Environmental and Socioeconomic (E&S) Monitoring;
- Oil Spill Response; and
- Preliminary End of Operations Decommissioning

Each of the above categories includes one or more specific management plans, which are included within the body of this document unless otherwise noted, as shown in Figure 3-1.

Figure 3-1. ESMP Structure



* *Due to the size and/or complexity of these documents, these are standalone plans, and are provided either as an Appendix to this ESMP or as a separate volume to the regulatory submittal for the Liza Phase 1 Project (i.e., OSRP).*

3.1 Environmental Management Plan

3.1.1 Introduction and Scope

The purpose of the Environmental Management Plan (EMP) is to identify specific measures that EEPGL or its contractors would implement to avoid or minimize potential adverse environmental impacts of the Project, and enhance positive benefits. The scope of this plan includes environmental impacts that result directly or indirectly from the Project, and over which EEPGL exercises control.

3.1.2 Management Measures

This section summarizes the impacts of the Project that require management actions as identified in the EIA. The following sub-sections identify the source of impact, receptor, the management measure, and the involved facility for air quality, water quality management, waste management, and marine ecosystems.

3.1.2.1 Air Quality Management

EEPGL will implement measures to manage impacts on air quality as listed in Table 3-1.

Table 3-1. Air Quality Management Measures

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Emissions to Atmosphere	Air Quality	Re-inject produced gas which is not utilized as fuel gas on the FPSO to avoid routine flaring.	FPSO
Emissions to Atmosphere	Air Quality	Maintain equipment and marine vessels in good working order and operate in accordance with manufacturer's specifications.	Drill Ship, FPSO, Installation / Decommission-ing Vessels, Other Marine Vessels, Shorebase
Emissions to Atmosphere	Air Quality	Shut down (or throttle down) sources of combustion equipment in intermittent use where reasonably practicable in order to reduce air emissions (e.g., vehicles, portable equipment).	Drill Ship, FPSO, Installation / Decommission-ing Vessels, Other Marine Vessels, Shorebase
Emissions to	Air Quality,	Submit an annual emissions inventory including	Drill Ship, FPSO,

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Atmosphere	Climate	greenhouse gas emissions.	Installation / Decommission-ing Vessels, Other Marine Vessels
Emissions to Atmosphere	Air Quality	Utilize low sulphur fuels for major vessels, where available and commercially viable.	Drill Ship, Installation / Decommission-ing Vessels, Other Marine Vessels
Emissions to Atmosphere	Air Quality	Utilize dust suppression measures to reduce impacts to air quality.	Shorebase
Emissions to Atmosphere	Air Quality	Notify regulator when process upset events or unplanned maintenance occur, resulting in a flaring event averaging at least 10 MMSCFD and lasting 10 days or longer.	FPSO
Emissions to Atmosphere	Air Quality	Avoid routine venting (excludes tank flashing emissions, standing/working/breathing losses) except during safety and emergency conditions.	FPSO
Emissions to Atmosphere	Air Quality	Avoid use of chlorofluorocarbons (CFCs) and polychlorinated biphenyls (PCBs).	FPSO
Emissions to Atmosphere	Air Quality	Implement inspection, maintenance and surveillance programs to identify and prevent leaks.	FPSO
Emissions to Atmosphere	Air Quality	Operate incinerator in accordance with Waste Management Plan and avoid incineration of restricted materials.	FPSO, Drill Ship

3.1.2.2 Water Quality Management Measures

EEPGL will implement measures to manage impacts on marine water quality as listed in Table 3-2.

Table 3-2. Water Quality Management Measures

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Operational Discharges	Marine Water Quality	Produced water discharge will be treated to comply with an oil in water content of 29 mg/L (monthly average) and 42 mg/L (daily maximum).	FPSO
Operational Discharges	Marine Water Quality	Cooling water discharge designed to avoid increases in ambient water temperature of more than 3°C at 100 m (~328 ft).	FPSO
Wastewater Discharge to Sea	Marine Water Quality	Bilge water will be treated and tested per MARPOL requirements to ensure compliance with an oil in water content of <15 ppm.	Drill Ship, FPSO, Installation / Decommission -ing Vessels, Other Marine Vessels
Wastewater Discharge to Sea	Marine Water Quality	Sewage and food waste will be treated in accordance with MARPOL (e.g., food comminuted to 25 mm diameter particle size or less, sewage goes through a marine sanitation device).	Drill Ship, FPSO, Installation / Decommission ing Vessels, Other Marine Vessels
Discharge of Cuttings to Sea	Marine Water Quality	Use of low-toxicity International Oil and Gas Producers (IOGP) Group 3 Non-Aqueous Base Fluid (NABF) as well as utilization of solids control and cuttings dryer systems to treat cuttings, such that end of well maximum weighted mass ratio averaged over all well sections drilled using non-aqueous fluids shall not exceed 6.9 percent wet weight base fluid retained on cuttings.	Drill Ship
Discharge of Cuttings to Sea	Marine Water Quality	There shall be no discharge of free oil as a result of the discharge of NADF cuttings.	Drill Ship
Commission-ing Discharges	Marine Water Quality	There shall be no visible oil sheen on receiving water as a result of any discharges.	All Marine Vessels, SURF

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Drilling and Operational Discharges	Marine Water Quality	All vessel wastewater discharges (e.g. storage displacement water, ballast water, bilge water, deck drainage) must comply with MARPOL.	Drill Ship, FPSO, Installation / Decommission -ing Vessels, Other Marine Vessels
Hydrocarbon Spills	Marine Water Quality	Utilize leak detection controls during FPSO offloading (e.g., for breach of floating hose, instrumentation / procedures to perform volumetric checks).	FPSO
Hydrocarbon Spills	Marine Water Quality	Utilize leak detection controls during installation and operation of SURF equipment (e.g., pigging and pressure testing of lines, periodic ROV surveys of subsea trees, manifolds, flowlines and risers).	FPSO, SURF
Hydrocarbon Spills	Marine Water Quality	Implement and maintain OSRP (see Appendix 3).	Drill Ship, FPSO, Installation / Decommission -ing Vessels, Other Marine Vessels, Shorebase

3.1.2.3 Waste Management

The Project will evaluate waste generation volumes associated with Project activities. Locations and capacities of acceptable waste handling, treatment, storage, and disposal facilities will be further assessed in relation to Project waste generation. The Project's Waste Management Plan is attached in Appendix 1.

3.1.2.4 Marine Ecosystems

EEPGL will implement measures to manage impacts on marine ecosystems as listed in Table 3-3.

Table 3-3. Marine Ecosystem Management Measures

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Collision Between Vessels and Marine Species	Marine Mammals, Marine Turtles, Seabirds	• Provide awareness training to Project dedicated marine personnel to recognize signs of marine mammals at the sea surface. • Issue standing instruction to Project dedicated vessel masters to avoid marine mammals and marine turtles while underway and reduce speed or deviate from course, when possible, to reduce probability of collisions. • Provide standing instruction to Project dedicated vessel masters to avoid any identified rafting seabirds, when possible, when transiting to and from PDA.	Drill Ship, FPSO, Installation / Decommission-ing Vessels, Other Marine Vessels
Auditory Impacts on Marine Species	Marine Mammals, Marine Fish	• Gradually increase intensity of seismic impulses and hammer energy (during pile driving) to allow sensitive species to vacate area before injury occurs (i.e., soft starts); • Utilize MMOs during VSP (although use of MMOs is more effective for identification of marine mammals, these individuals can also detect marine turtles depending on weather conditions, and they will be tasked with observing for marine turtles as well) and implementation of other measures recommended by the Joint Nature Conservation Committee (JNCC, 2010), as applicable; and • Maintain equipment (including marine vessels) in good working order and operate them in accordance with manufacturers' specifications so as to limit sound levels to the extent reasonably practicable.	Installation Vessels Drill Ship Drill Ship, FPSO, Installation / Decommission-ing Vessels, Other Marine Vessels
Entrainment or Impingement of Marine Fish	Marine Fish	Provide screening for cooling water and ballast water intakes on FPSO and Drill Ship to minimize the entrainment of finfish.	FPSO, Drill Ship
Visual Disturbance of Marine Species	Marine Turtles, Seabirds	Where practicable, direct lighting on FPSO and major vessels to required operational areas rather than at the sea surface or skyward.	FPSO, Drill Ship

In addition to the measures listed in Table 3-3, most if not all of the water quality management measures listed in Table 3-2 and several of the waste management measures listed in the Waste Management Plan will also contribute to management of Project-related impacts on marine ecosystems.

3.2 Socioeconomic Management Plan

Under planned operations, the Project is expected to have few adverse socioeconomic impacts, and likely an overall positive impact due to increased revenues to the Guyanese government, as well as increased local business activity as a result of Project procurement and employment. Nevertheless, EEPGL is committed to minimizing any anticipated adverse socioeconomic impacts, as well as enhancing positive benefits associated with the Project through the implementation of a Project-specific Socioeconomic Management Plan (SMP).

3.2.1 Introduction and Scope

The purpose of the Socioeconomic Management Plan (SMP) is to identify discrete and specific actions that EEPGL or its contractors would implement to avoid, minimize, or mitigate potential adverse socioeconomic impacts from the Project, or to enhance benefits of the Project.

The scope of this plan includes socioeconomic impacts that result directly or indirectly from the Project, and over which EEPGL exercises control. In addition, specific actions and goals related to local workforce development are addressed separately under a Project-specific local content plan, which is outside the scope of the EIA and ESMP.

3.2.2 Management Measures

3.2.2.1 Stakeholder Engagement

EEPGL has developed a Stakeholder Engagement Plan (SEP) aimed at fostering ongoing communication with stakeholders, toward the objectives of 1) identifying, understanding, and addressing community/stakeholder priorities and concerns, and 2) improving Project decision-making and transparency. The SEP is considered a key component of the SMP and is an evergreen document subject to update throughout the Project as EEPGL conducts more engagement activities and gains further insight and understanding about different stakeholders and their concerns. The full SEP is included as Appendix 2 to this document.

3.2.2.2 Grievance Management

EEPGL has developed a mechanism by which stakeholders (including employees) can provide feedback in the form of issues or concerns, comments, concerns or grievances, and which will allow the Project to respond to or address such feedback in a consistent, transparent, and timely manner. The implementation of such a mechanism complements proactive or preventative management policies or procedures already in place, ensuring that when administrative

controls do not adequately address an issue, there is recourse for resolution. EEPGL has a Community Grievance Mechanism (CGM), which allows EEPGL and its contractors to receive and respond to stakeholders regarding a range of potential Project activities and impacts. The CGM will apply to all aspects of the Project and will be open to any affected stakeholder. As such, it will play a role in monitoring the effectiveness of other socioeconomic management measures (see Section 3.5 Monitoring Program). EEPGL has the responsibility for day-to-day functioning of the CGM.

Objectives of the CGM are to:

- Provide stakeholders with a mechanism to communicate feedback, issues, or concerns requests and/or complaints to EEPGL in a timely manner so that they can be addressed quickly and proactively;
- Process grievances so they are acknowledged, tracked, and addressed by EEPGL in a timely and confidential manner;
- Continuously improve Project performance in key areas as a result of stakeholder feedback provided through the CGM; and
- Demonstrate EEPGL's commitment to meaningful stakeholder engagement and respect for local opinions and concerns.

Guiding Principles of the CGM

The CGM has been developed in line with the following core principles:

- Ensure communities face no barriers to accessing and using the mechanism;
- Establish the mechanism early on;
- Base the mechanism on a transparent, predictable process and ensure it is well publicized and understood;
- Build trust in the legitimacy and fairness of the mechanism; and
- Create an organizational structure and mind-set that support the mechanism.

Definition of Grievances

Inquiries received by EEPGL will fall into one of five categories defined as follows:

1. Complaint – An expression of discontent, regret, pain, censure, resentment, or grief. A direct, tangible incident along with its alleged damage, impact or dissatisfaction that occurred as a result of company or contractor actions, perceived or actual. Complaints are typically accompanied by a request for resolution and rectification.
2. Concern – A matter that engages a person's attention, interest, or care, or that affects a person's welfare or happiness. Related to questions or requests for information or general perceptions unrelated to a specific impact or incident and/or recorded in an individual grievance. Concerns are good indicators of where stakeholders lack or misunderstand information.

3. Issue – A point in question or a matter that is in dispute, as between contending parties in an action at law. A pre-existing complaint or concern between two non-Project entities, one of which may attempt to use the company's activities as the leverage to achieve resolution. Issues should be transmitted to the entities directly involved along with an explanation as to how they can affect the company. Issues may evolve into loss of the project's social license to operate if not handled properly.
4. Request – The act of asking for something to be given or done, especially as a favor or courtesy; a solicitation or petition. A communication from a stakeholder asking for something – donation, community project, job, contract, or some other benefit for a group or individual. Requests may evolve into loss of the company's social license to operate if not handled properly.
5. Guidance - An advice or information aimed at resolving a problem or difficulty, especially as given by someone in authority.

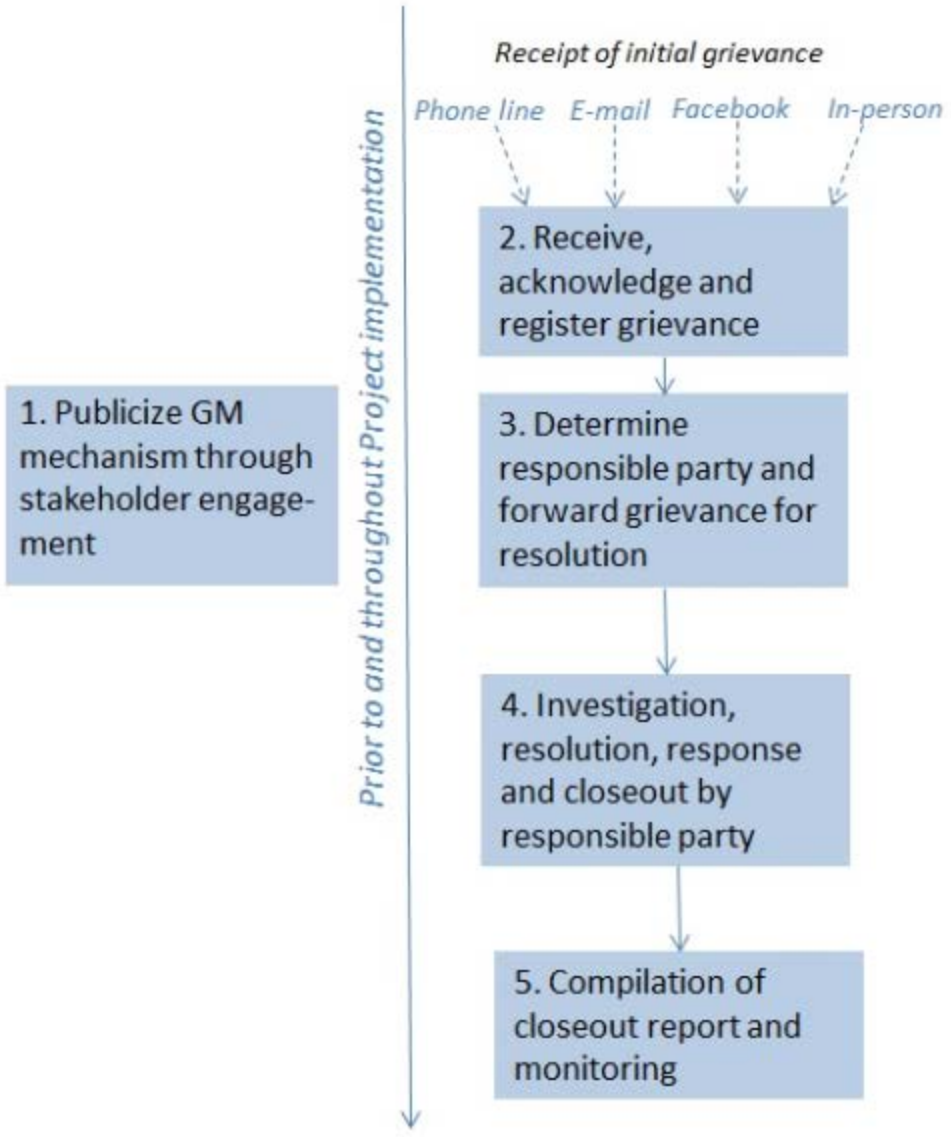
Implementation of the CGM

Contractors and EEPGL should coordinate in the process of addressing issues on a regular basis. It is the responsibility of the Contractors to report all grievances received, along with the required information for entry into the CGM, and it is the responsibility of EEPGL to investigate each grievance and ensure the grievance is addressed in a timely manner. Contractors will be provided a Project-specific CGM log (consistent with EEPGL's log) to ensure the consistent collection of grievance information, which will be completed and submitted to EEPGL on a periodic basis. This will include:

- Type of grievance - issue, concern, compliant (e.g., property damage, work conditions, noise, traffic);
- Brief description of grievance;
- Status of grievance (registered, assessed, under investigation, in resolution, closed);
- Date grievance was received;
- Date the incident occurred, if applicable.

The CGM procedure is depicted in Figure 3-2.

Figure 3-2. EEPGL's Five-Step Grievance Management Procedure



As shown in Figure 3-2, stakeholder feedback can be received by EEPGL or its contractors in the following three ways:

1. In person, either to an EEPGL employee or representative;
2. Via telephone - (592) 231 2866, extension 12400
3. Via email –Guyanastaff@exxonmobil.com

Responsible parties must be identified to manage receipt of the grievances at each feedback avenue, and these individuals must be trained in proper documentation of information and timely input of the data into the database. Upon receipt, EEPGL will register the grievance in a

CGM database, determine the appropriate responsible party, and forward the grievance to that party for resolution. As is required by the type of grievance, the responsible party will then undergo investigation activities as appropriate for resolution and appropriate response to the grievant. Once resolved, a summary of the grievance resolution will be entered into the CGM database to allow for tracking and reporting. This consolidated database will also allow for the monitoring of Project-wide trends and for identification of potential recurring issues associated with specific contractors or Project activities.

Receipt, registration, prioritization, and resolution of grievances using the CGM should adhere to the following guidelines:

a. Established forms to be filled in with all necessary information – clarify that if a grievance is submitted verbally, it must be transcribed as soon as possible after.
b. Details should be compiled – electronically if possible, and registers of chain of custody and communication must be established.
c. When a grievance is received with a name attached, the grievant must be notified within a specific timeline that their grievance has been registered, as well as providing a timeline for future activities, including the timeline by when the Project should have a proposed resolution.
d. When a grievance is received without a name attached, the grievance must be addressed and documented within a pre-specified timeframe. If relevant and practicable (for example in the case of worker grievances), information on the grievance and how it has been addressed should be disseminated publicly. This should in no way infringe on the confidentiality of any grievant.
e. Where necessary/relevant an interview with the grievant could be helpful to obtain further details.
f. Specified timeframes should be established for confirming receipt of the grievance, completing the investigation, and providing a resolution.
g. Options for resolution should include: unilateral response; bilateral response (the aggrieved party and EEPGL developing a solution together); third party response (though a mediator); or through a judicial process as appropriate, outside of the CGM. Given that the purpose of the mechanism is to proactively address concerns before they escalate, it is important to maximize the opportunities for bilateral response wherever possible.

CGM Mechanism Monitoring

In addition to monitoring the effectiveness of the CGM itself, data from the CGM can be a useful tool in monitoring the effectiveness of management measures for a range of Affiliate and Project aspects, in combination with other resource-specific monitoring indicators. CGM indicators that should be monitored include:

- Number of grievances registered within the reporting period (e.g., monthly, quarterly, or annually);
- Number of grievances closed during the reporting period;
- Topic of grievance;

- Distribution of aged grievances (i.e., under 30 days, 30 to 60 days, 60 to 90 days, more than 90 days).

Monitoring of these indicators will allow EEPGL to identify trends across the Project phases, activities and facilities, allowing for adjustment of the CGM or other management plans and procedures.

It should be understood that receipt of a large number of grievances does not necessarily indicate poor Project performance; a large number could in fact be indicative of high quality engagement and dialogue between the Project and the community. The goal of the CGM mechanism process should therefore not be to reduce the number of grievances received, but rather should be to develop and maintain trust and confidence on the part of the community that when valid grievances arise, EEPGL will respond appropriately. Ensuring that the same types of grievances are not raised repeatedly, and maintaining a reasonable average time to achieve closure of grievances, are key indicators of good performance.

3.2.2.3 Socioeconomic Management Measures

EEPGL will implement measures to manage socioeconomic impacts as listed in Table 3-4.

Table 3-4. Socioeconomic Management Measures

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Project Employment	Guyanese Population	Utilize Guyanese nationals where reasonably practical. Partner with select local institutions and agencies to support workforce development programs.	N/A
Project Procurement	Guyanese Population	Procure Project goods and services locally when available, and when they meet minimum standards and when commercially competitive. Engage with local area agricultural development co-ops to identify potential supply contract opportunities.	N/A
Project Workforce	Guyanese Population	Develop a Worker Code of Conduct that includes requirements for interaction with local communities while on shore-leave. Ensure that contract agreements require strict adherence to the Code of Conduct.	N/A
Various	Guyanese Population	Implement a transparent, accessible, and consistent CGM mechanism early on, prior to onset of Project activities. Ensure CGM mechanism is well publicized and understood by the public.	N/A
Various	Guyanese Population	Develop and implement a Stakeholder Engagement Plan.	N/A

Various	Guyanese Population	Monitor grievances received and resolved by the CGM mechanism; adjust CGM mechanism, and other management measures, as required (see Section 3.5: Monitoring Program).	N/A

3.2.2.4 Transportation

EEPGL will implement measures to manage impacts on transportation and road and marine safety as listed in Table 3-5.

Table 3-5. Transportation Management Measures

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Increased Vehicular Traffic	Road Users (e.g. Drivers, Cyclists, and Pedestrians)	• Development of an onshore logistics/journey management plan to reduce potential conflicts with local road traffic when transporting goods to/from onshore support facilities. • Implement a Stakeholder Engagement Plan that includes a CGM mechanism process for stakeholders.	Shorebase, Waste Management Facility, Other Onshore Support Infrastructure
Increased Aviation Traffic	Other Aircraft and Users of Ogle Airport	• Coordinate with relevant aviation authorities and stakeholders to understand peak Project-related utilization rates. • Implement a Stakeholder Engagement Plan that includes a CGM mechanism process for stakeholders.	FPSO, Drill Ship

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Increased Vessel Traffic; Increased Risk of Marine Casualty Event (Collision, Grounding); Reduced Ocean Surface Area for Non-Project Activities	Commercial Cargo and Fishing Vessels; Subsistence Fishing Vessels	• Observation of standard local navigation procedures in and around the Georgetown Harbour and Demerara River, as well as best ship-keeping and navigation practices while at sea, shall be implemented. This includes Notice to Mariners, Trawlers Association, and Co-ops. • Relevant authorities will be informed of the Project activities. • Notices to Mariners will be issued through MARAD to alert mariners of the installation/drilling activities. • EEPGL will conduct an augmented stakeholder engagement process (along with relevant authorities) to identify and communicate with maritime users who might not ordinarily receive Notices to Mariners. • Vessels will have radar systems and communication mechanisms to communicate with third party mariners. • Marine safety exclusion zones will be maintained around the Drill Ship, FPSO, and major installation vessels. • Implement a Stakeholder Engagement Plan that includes a CGM mechanism process for stakeholders, including local fishing interests. • Monitor engagement with fishing communities to record locations of fisheries activities and to check for adherence to communications protocol and grievances follow up.	Shorebase, FPSO, Drill Ship, Installation / Decommission-ing Vessels, Other Support Vessels

3.2.2.5 Road Safety

EEPGL will implement measures to manage impacts on road safety as listed in Table 3-6.

Table 3-6. Road Safety Management Measures

SOURCE OF IMPACT	RECEPTOR	MANAGEMENT MEASURE	INVOLVED FACILITY
Increased Vehicular Traffic	Road Users (e.g., Drivers, Cyclists, Pedestrians)	Development of an onshore logistics/journey management plan to reduce potential conflicts with local road traffic when transporting goods to/from onshore support facilities.	Shorebase and Onshore Support Infrastructure
Increased Vehicular Traffic	Road Users (e.g., Drivers, Cyclists, Pedestrians)	Definition of typical, primary travel routes.	Shorebase and Onshore Support Infrastructure
Vehicular Incidents	Road Users (e.g., Drivers, Cyclists, Pedestrians)	Definition of required driver training for Project dedicated drivers, including (but not limited to) defensive driving, loading/unloading procedures, and safe transport of passengers, if applicable.	Shorebase and Onshore Support Infrastructure
Vehicular Accidents	Road Users (e.g., Drivers, Cyclists, Pedestrians)	Designation and enforcement of speed limits, through speed governors, GPS, or other monitoring systems for Project dedicated vehicles.	Shorebase and Onshore Support Infrastructure
Increased Vehicular Traffic	Road Users (e.g., Drivers, Cyclists, Pedestrians)	Avoidance of deliveries during typical peak traffic hours or scheduled openings of the Demerara Harbour Bridge, to the extent reasonably practicable.	Shorebase and Onshore Support Infrastructure
Vehicular Breakdowns; Traffic Congestion	Road Users (e.g., Drivers, Cyclists, Pedestrians); Project Drivers	Definition of vehicle inspection and maintenance protocols that include all applicable safety equipment for Project dedicated vehicles.	Shorebase and Onshore Support Infrastructure
Vehicular Incidents	Local Communities	Community safety program for impacted schools and neighborhoods to improve traffic safety.	Shorebase and Onshore Support Infrastructure

3.2.2.6 *Cultural Heritage Management and Chance Finds*

Cultural Heritage Management Plan

EEPGL will implement this Cultural Heritage Management Plan (CHMP) aligned with international best practice to protect cultural heritage that is inadvertently discovered during drilling and installation activities. The CHMP includes a Cultural Heritage Monitoring Plan, Chance Find Procedure, and Cultural Heritage Training Program, as described below.

Cultural Heritage Monitoring Program

In consultation with the Guyana National Trust (GNT) and other relevant cultural heritage stakeholders, EEPGL will implement a Cultural Heritage Monitoring Program for all activities that disturb the seafloor. The purpose of this monitoring is to identify, record, and protect cultural heritage that was not identified during existing condition studies and other pre-drilling or pre-installation cultural heritage investigations.

Monitoring will be conducted by Project staff supported by a remote professional cultural heritage specialist (CHS) who will be on call to assess any potential chance finds that are identified. Cultural heritage monitoring will be conducted by any EEPGL and contractor staff with the potential to discover underwater cultural heritage, which would generally be limited to AUV/ROV operators. These staff will be responsible for reporting any potential chance finds to Project management, who would then notify the CHS.

Chance Find Procedure

The following types of underwater cultural heritage, while not likely based on existing conditions studies, could potentially be encountered during the drilling or installation stages:

- Shipwrecks or parts thereof; and
- Artifacts from debris fields associated with shipwrecks.

The Chance Find Procedure will use a two-tiered approach for identifying, assessing, and resolving potential chance finds. The purpose of this approach is to utilize an on-call CHS to resolve minor chance finds without necessitating consultations with the GNT, and to minimize Project delays by allowing for the quick resolution of non-significant finds. The defining characteristics of each chance find tier and the processes for assessing them and determining if consultation is required will be developed in consultation with the GNT and other cultural heritage stakeholders prior to the drilling and installation programs, as appropriate.

All potential chance finds identified will be reported as soon as practicable (i.e., within approximately 24 hours) to EEPGL and the designated CHS, using the Chance Find Reporting Form in Figure 3-3. The CHS will determine if the potential chance find is cultural heritage and, if so, assign it to a chance finds tier. Figure 3-4 provides a detailed flow diagram of the Chance

Find Procedure. All chance finds will follow the two-tiered hierarchy that is presented in Table 3-8.

Since little to no material from the seafloor is expected to be brought to the surface, the collection of artifacts is not anticipated. In the unlikely event that underwater chance finds are accidentally brought to the surface, they should be immediately placed in a container filled with sea water from the area of the find and maintained indefinitely, as exposure to the air can cause artifacts that have been underwater to decompose or oxidize very rapidly. Documentation of the find, including photographs of the artifact(s) with a scale included in the frame, should be made immediately. Artifacts and associated documentation and photographs taken by Project personnel should be given to the designated CHS.

Although recovery of underwater artifacts to the surface is not anticipated, any recovered artifacts would belong to the Guyanese government, and EEPGL would be responsible for providing them to the GNT. For underwater chance finds not brought to the surface, such as shipwrecks or associated debris fields, avoidance is the preferred approach, as excavation of underwater archaeological sites is costly and time consuming. Specific management guidance will be provided by the Project for each cultural heritage site identified and documented.

The Project will maintain records on chance finds and the implementation of treatment plans. These may include:

- Reports that describe chance finds identified, the results of chance find assessments, internal and external communications and instructions, and supporting documentation (or other reference materials as appropriate); and
- Any additional reports prepared to fulfill specific requirements of the GNT.

Cultural Heritage Training Program

Project and Contractor personnel with the potential to identify underwater chance finds (e.g., AUV/ROV operators) will receive awareness training in the identification of chance finds and the Chance Find Procedure as described above. The Project will develop training materials, such as a quick reference hand-out, which will be provided to applicable Project personnel. The Project will maintain records of all chance find training provided to Project personnel.

EEPGL and its contractors will establish the communication and engagement protocols for the on-call CHS. The Contractor will designate its personnel that require cultural heritage awareness training. The training will provide the necessary information on how to identify and respond to chance finds.

All Project personnel who may have contact with cultural heritage objects will be made aware that it is illegal and forbidden to disturb or remove cultural heritage objects offsite for personal gain.

Chance Find Reporting Form

Date of find:

Location of find (description and GPS):

Project person making the find:

Project person notified of the find:

Date notified:

Time notified:

Cultural Heritage Specialist notified of the find:

Date notified:

Time notified:

Description of the find:

Description of the initial response to the find:

Prescribed treatment methodology for the find and any needed modifications to Project execution:

Date of handover of the artifact(s), if recovered to surface:

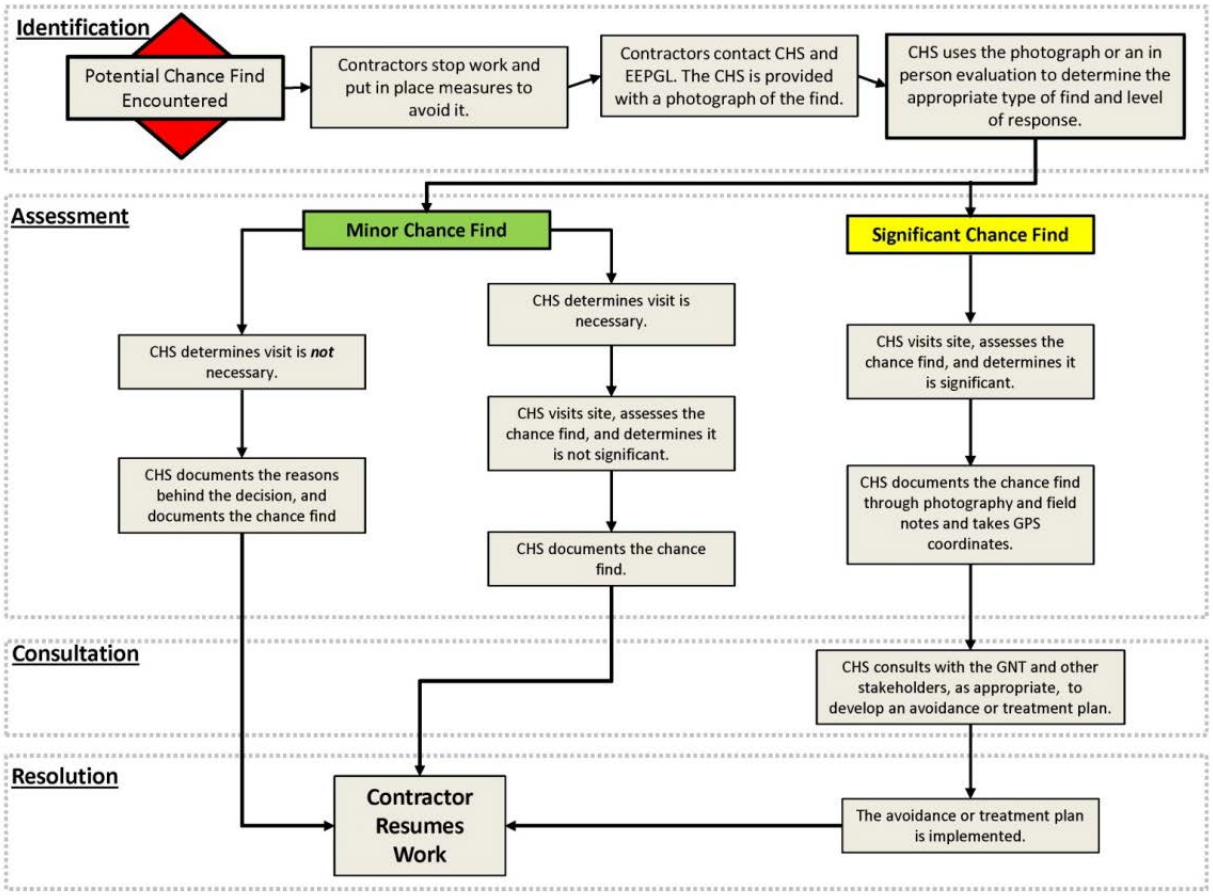
Recipient of the artifact(s), if recovered to surface:

Date of closure of the chance find:

Table 3-8: Two-tiered Chance Find Hierarchy

Chance Find Type	Characteristics	Evaluation Process
Minor Chance Finds	Modern features or objects that do not meet the criteria for cultural heritage under Guyana laws and regulations.	Drilling and installation activities will stop in the area of the find as soon as safely possible, where appropriate and where practical. The potential chance find will be reported to EEPGL (if found by a contractor) and the CHS within approximately 24 hours. In the unlikely event that an artifact is brought to the surface, the CHS will determine if a site visit is necessary to examine the artifact. If the potential chance find is discovered in situ, the CHS will examine images collected from the ROV. If the CHS determines that it is a minor chance find, drilling and installation activities will resume in the area. Drilling and installation activities will not be stopped if there is no reasonable expectation that the potential chance find would not be disturbed/damaged.
Significant Chance Finds	Significant historic features (e.g., shipwrecks), objects (i.e., artifacts), or human remains that meet the criteria for cultural heritage under Guyana laws and regulations.	Drilling and installation activities will stop in the area of the find as soon as safely possible, where appropriate and where practical. The potential chance find will be reported to EEPGL (if found by a contractor) and a CHS within approximately 24 hours. In the unlikely event that an artifact is brought to the surface, the CHS will determine if a site visit is necessary to examine the artifact. If the potential chance find is discovered in situ, the CHS will examine images collected from the ROV. If the CHS determines that it is a significant chance find, the CHS will develop an avoidance or treatment plan in consultation with the GNT. Installation activities will resume in the area upon acceptance of the avoidance plan or completion of the treatment plan. Drilling and installation activities will not be stopped if there is no reasonable expectation that the potential chance find would not be disturbed/damaged.

Figure 3-4. Chance Find Procedure Flow Chart



3.3 Oil Spill Response Plan

The Project's Oil Spill Response Plan can be found in Appendix 3.

3.4 Preliminary End of Operations Decommissioning Plan

The Preliminary End of Operations and Decommissioning Plan can be found in Appendix 4.

3.5 Environmental and Socioeconomic Monitoring Plan

EEPGL will implement an Environmental and Socioeconomic Monitoring Plan to assess the accuracy of the residual impact predictions in the EIA and to assess the effectiveness of the management measures described in this ESMP and other supporting plans. This section provides a monitoring framework that describes the specific monitoring activities that EEPGL will undertake, once the facility has achieved steady-state operations, to validate the findings of the EIA, ensure the effective implementation of the management measures described in Section 3.1 through 3.4, track environmental and socioeconomic performance, and adjust Project operations or mitigations, if necessary, through the life of the Project.

Monitoring activities for environmental and socioeconomic resources in Table 3-7 are organized by the resources / receptors discussed in Section 3.1 (e.g., air quality), and then by Project stage (i.e., Drilling, Installation, Production Operations, and Decommissioning). The table also identifies the specific Project component or "aspect" that each monitoring activity is intended to monitor and the specific environmental or socioeconomic receptor. The specific monitoring activities included in Table 3-7 were selected based on the findings of the EIA; level of stakeholder interest in specific impacts and receptors, as assessed through the stakeholder engagement process; and the EPA's prior monitoring requirements for exploration activities in the Stabroek Block. For monitoring activities that are similar to those that have been undertaken previously during exploration activities, details including the location and frequency of monitoring activities, data to be collected, and reporting frequency is provided. For other activities, ERM and EPA will work collaboratively to develop these details.

At the time this ESMP was prepared, the contracts for key components of the Project had not been finalized so it was not possible to assign responsibility for implementing specific components of the monitoring program. EEPGL will ultimately be responsible for all monitoring, but may delegate some responsibility to contractors. The ESMP is intended to be a "living" document and will be updated to assign these responsibilities as contracts are finalized and responsible parties can be identified. The ESMP will also be updated as necessary throughout the operational stage of the Project to maximize the value of the data collected, capture lessons learned, achieve continuous improvement, and ensure cost-effective tracking of the Project's environmental and socioeconomic performance over time.

Table 3-7. Environmental and Socioeconomic Monitoring Measures

SOURCE OF POTENTIAL IMPACT	ASPECT	RECEPTOR	ACTIVITY	INVOLVED FACILITY
AIR QUALITY				
Production Operations				
Combustion Emissions	Emissions from Flaring	Offshore Air Quality	Keep records of non-routine flaring of produced gas.	FPSO
FPSO Emissions	Fuel Consumption; Emissions from Flaring	Offshore Air Quality	An air emissions inventory report will be prepared annually.	FPSO
FPSO Emissions	Emissions from flaring	Offshore Air Quality	Monitor flare performance to maximize efficiency of flaring operation.	FPSO
All Project Phases				
GHG Emissions	Fuel Consumption; emissions from Flaring	Climate	Quantify direct Project GHG emissions from the Project facilities and equipment utilized within the Project AOI.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels, Shorebase
Combustion Emissions	Fuel Consumption	Offshore Air Quality	Monitor on an ongoing basis the volume of fuel used by all combustions sources and equipment on FPSO and other marine vessels.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels
Combustion Emissions	Fuel Consumption	Offshore Air Quality	Monitor volume of fuel used for helicopter operation.	HELICOPTERS
WATER QUALITY				
Drilling and Installation Phase				
Drilling Discharges	WBDF/ WBDF & NADF Cuttings, Wellwork Fluids, and Cements	Benthic Organisms, Marine Water Quality	Prior to and post-drilling, an ROV will take pictures of the area immediately surrounding the well location to monitor for marine water quality impacts.	Drill Ship
Drilling Discharges	WBDF/ WBDF & NADF Cuttings, Wellwork Fluids, and Cements	Benthic Organisms, Marine Water Quality	Estimate and record volume and type of drilling fluids and cuttings discharged into the sea.	Drill Ship
Drilling Discharges	WBDF/NABF/ NADF, Cuttings and Cements	Marine Water Quality	Monitor daily during drilling to ensure that end of well maximum weighted mass ratio averaged over all well sections drilled using non-aqueous fluids shall not exceed of 6.9 percent wet weight base	Drill Ship

SOURCE OF POTENTIAL IMPACT	ASPECT	RECEPTOR	ACTIVITY	INVOLVED FACILITY
			fluid retained on cuttings.	
Production Operations				
Operational Discharges	Produced Water	Marine Water Quality	Monitor daily discharge volume.	FPSO
Operational Discharges	Produced Water	Marine Water Quality	Measure oil and grease content (grab sample once per day).	FPSO
Operational Discharges	Cooling Water	Marine Water Quality	Perform daily inspections to verify no visible sheen from discharge.	FPSO
Operational Discharges	Cooling Water	Marine Water Quality	Monitor discharge temperature to avoid increases in ambient water temperature of more than 3°C at 100 m (~328 ft).	FPSO
Offloading Operations	Offloading Operations	Marine Water Quality	Utilize load monitoring system in the FPSO control room to support FPSO offloading.	FPSO
Production of Hydrocarbons	Offloading Operations	Marine Water Quality	Monitor pressure and temperature of subsea wells and manifolds by a control system on the FPSO to detect and prevent leaks.	FPSO
All Project Phases				
Operational Discharges	Black Water	Marine Water Quality	Monitor chlorine concentration of treated sewage discharges.	FPSO, FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels,
Operational Discharges	Black Water, Gray Water, and Food Wastes	Marine Water Quality	Perform daily visual inspection of discharge points to ensure absence of floating solids and discoloration of the water.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels
Operational Discharges	Black Water, Gray Water, and Food Wastes	Marine Water Quality	Record estimated quantities of grey water, black water, and comminuted food waste discharged (based on POB and water consumption) in Garbage Record Book.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels
Operational Discharges	Bilge Water	Marine Water Quality	Perform continuous oil in water content (automatic) monitoring to ensure compliance with 15 ppm MARPOL limit and record in Oil Record Book; observe surface of the sea in the discharge area to ensure no formation of oil sheen.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels
Operational Discharges	Ballast Water	Marine Water Quality	Record estimated volume of ballast water discharged and location (per ballasting operation).	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels

SOURCE OF POTENTIAL IMPACT	ASPECT	RECEPTOR	ACTIVITY	INVOLVED FACILITY
Hydrocarbon Spill	Drilling or offloading	Marine Water Quality	Refer to OSRP Section 6.1 Surveillance and Monitoring.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels, Shorebase
WASTE MANAGEMENT				
REFER TO WASTE MANAGEMENT PLAN				
MARINE ECOSYSTEMS				
All Project Phases				
Injury/Mortality of Marine Mammals and Marine Turtles	Vessel Traffic	Marine Mammals and Marine Turtles	Monitor on an ongoing basis visual detections of Marine Mammals and Marine Turtles made from Project vessels.	FPSO, Drill Ship, Installation/Decommissioning Vessels and Support Vessels
SOCIOECONOMIC RESOURCES				
All Project Phases				
Project Employment	Economy	Guyanese Population	Monitor percentage of Project workforce made up of Guyanese nationals.	N/A
Project Procurement	Economy	Guyanese Population	Monitor percentage of Project goods and services expenditures procured locally on a calendar year basis.	N/A
Various	Community	Guyanese Population	Track number and types of complaints received via the Project Community Grievance Mechanism (CGM).	N/A
Various	Community	Guyanese Population	Monitor average time for processing and resolution of grievances.	N/A
Various	Community	Guyanese Population	Track percentage of grievances resolved.	N/A
Hearing Impairment	Occupational Safety	Project Workforce	Monitor Project workers' occupational exposure to sound.	All Project Facilities
TRANSPORTATION AND ROAD SAFETY				
All Project Phases				
Vehicular Traffic	Road Safety	Community	Monitor vehicular speed through speed governors, GPS, or other monitoring systems for Project dedicated vehicles.	All Onshore Travel Routes
Vehicular Traffic	Road Safety	Community	Monitor driver fatigue (e.g., supervision, administrative constraints for work and rest periods, etc.) for Project dedicated	All Onshore Travel Routes

SOURCE OF POTENTIAL IMPACT	ASPECT	RECEPTOR	ACTIVITY	INVOLVED FACILITY
			drivers.	
Vessel Traffic	Marine Safety	Community	Record instances of marine vessels entering marine safety exclusion zones.	FPSO, Drill Ship, Major Installation/Decommissioning Vessels

3.6 Documentation, Reporting, and Record Keeping

The requirement for monitoring stems from the need to verify Project Activities are being conducted in accordance with commitments made and to provide performance information to regulators and other relevant stakeholders. As such, the results of monitoring will be reported internally and externally.

Reporting requirements include those stipulated in the following:

1. Applicable regulations required by Guyana and related to the Petroleum Production Licence; and
2. Project commitments, regulatory filings, and Project agreements.

Reporting is summarized in Table 2-3

Table 2-3. Summary of Reporting

Reporting Requirement	Description
Project SSH&E Status Report	EEPGL will provide a high level Project SSH&E Status Report on a semi-annual basis that includes a summary of the Project activities completed during the period, key SSH&E-related performance metrics, and highlights of SSH&E accomplishments, improvement initiatives, and lessons learned. The content and structure of the Project SSH&E Status Report will be developed in collaboration with the EPA.
Statutory SSH&E metrics	EEPGL will periodically provide reports summarizing statutory SSH&E metrics, in line with applicable regulations and in collaboration with EPA. These reports may include, but are not limited to: • Air emissions (including GHGs);

	• Waste types/volumes, disposal methods/locations; • Discharges types/volumes (e.g., wastewater, drill cuttings/fluids, etc.); • Fuel consumption; and • Spills (e.g., hydrocarbons, chemicals).
Emergency/incident notification and reporting	All environmental incidents and excursions will be appropriately documented and reported to the relevant authorities, in line with regulations.

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Appendix 1 – Waste Management Plan

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Liza Phase 1 Floating Production Storage and Offloading (FPSO) Development Project

Esso Exploration and Production Guyana Limited (EEPGL)

Preliminary Waste Management Plan (WMP) for Stabroek Block Offshore Guyana



February 2017

Review and Approval

Reviewed by:

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Contents

Contents 3

Tables 4

Figures 4

1 INTRODUCTION **5**

2 PROJECT DESCRIPTION **5**

3 SCOPE AND OBJECTIVES **6**

4 EEPGL ROLES AND RESPONSIBILITIES **7**

4.1 EEPGL Specific Responsibilities: **8**

4.2 Marine Vessel Owner/Operator Specific Responsibilities (Supply, Support, Installation, Drill Ships and FPSO): **8**

4.3 Waste Service Provider Specific Responsibilities **9**

5 REGULATORY REQUIREMENTS AND GUIDELINES **10**

5.1 Local Regulatory Requirements and Waste Definitions **11**

5.2 National Environmental Legislation **12**

5.3 Guyana Permits and Licenses **13**

5.4 International Conventions **13**

5.4.1 MARPOL 73/78 13

5.4.2 Basel Convention 14

6 WASTE MANAGEMENT STRATEGY **15**

6.1 Waste Categories **16**

6.2 Waste Management Practices **17**

6.3 Waste Classification **18**

6.4 Handling of Wastes **18**

6.6 Handling of Hazardous Materials **19**

6.7 Waste Segregation and Storage **20**

6.8 Waste Tracking Process **22**

6.9 Waste Transfer to Shore **22**

7 WASTE MANAGEMENT METHODS **23**

7.1 Incineration/Thermal Treatment 23
7.2 Neutralization 24
7.3 Stabilization/Solidification 24
7.4 Bioremediation 24
7.5 Liquid Waste Treatment 24
7.6 Burial Disposal (Landfill) 25
7.7 Beneficial Reuse 25
8 SPILL AND EMERGENCY RESPONSE 25
8.1 Oil Spill Cleanup – Waste Management 25
9 WASTE MONITORING AND REPORTING GUIDELINES 26
9.1 Waste Monitoring 26
9.2 Waste Recordkeeping and Reporting 27
10 WASTE TRAINING 27
10.1 Offshore Waste Management Training 28
10.2 Onshore Waste Management Training 28
Attachment 1: PROJECT WASTES, MANAGEMENT METHODS AND ESTIMATED ANNUAL QUANTITIES 29
Attachment 2: GUYANA HAZARDOUS WASTE RECORDING AND REPORTING FORM 32
Attachment 3: SAMPLE WASTE/GARBAGE RECORD BOOK 36
Attachment 4: SAMPLE OIL RECORD BOOK 37
Attachment 5: SAMPLE CHAIN OF CUSTODY FORM FOR LAB SAMPLES 38
Attachment 6: SAMPLE MARINE TRANSPORT MANIFEST 39
Attachment 7: SAMPLE WASTE MANIFEST 40
Attachment 8: HAZARD CLASS SYMBOLS FOR HAZARDOUS WASTE AND MATERIALS 41

Tables

Table 1: Summary Roles and Responsibilities Chart 10
Table 2: MARPOL Annexes 13
Table 3: Recoverable Materials, Waste Types and Categories 16
Table 4: Waste Management Practices 17
Table 5: Basic Label Form 21
Table 6: Waste Monitoring Guidelines 26

Figures

Figure 1: Waste Management Hierarchy 15

1 INTRODUCTION

The objective of this document is to govern waste management associated with Esso Exploration & Production Guyana, Limited's (EEPGL) Liza Phase 1 Floating Production Storage and Offloading (FPSO) Development Project, which includes: drilling, installation, commissioning, production, and decommissioning activities within the Stabroek Block located in offshore Guyana waters in a manner that meets all regulatory requirements and minimizes impacts on the surrounding environment. This plan has been prepared in conjunction with EEPGL's Environmental Management Plan (EMP; section 3.1 of the Liza Phase 1 Environmental and Socioeconomic Management Plan) for the project and will be executed through the proper handling, storage, and disposal of hazardous and non-hazardous wastes. It is an evergreen document and will be updated as needed.

This document:

- Defines and categorizes the different types of waste that may be generated by offshore development and production activities;
- Specifies and documents the management and disposal practices that apply to each category of waste; and
- Specifies and documents the monitoring and reporting guidelines that apply to each category of waste.

This Waste Management Plan is applicable to the management of those wastes generated by the Liza Phase 1 FPSO Development Project during all phases including: drilling, installation, commissioning, production operations and decommissioning. The scope of this document covers waste management procedures and practices from the points of generation both offshore and onshore, through storage, treatment, transportation recycling, reuse and disposal. Planned discharges (e.g. produced water, cooling water) are managed under the Liza Phase 1 EMP and under individual vessel Garbage Management Plans and are therefore outside the scope of this document. Wastes that cannot be managed at the point of generation offshore will be transported to the shorebase and then to the onshore waste management facilities operated by a qualified permitted third party waste management service provider for further segregation, consolidation, treatment, transportation and/or disposal or directly (for non-hazardous wastes) to the final approved recycling, reuse or disposal facilities.

2 PROJECT DESCRIPTION

The Project proposes to develop the offshore resource by drilling approximately 17 subsea development wells and using a FPSO vessel to process, store, and offload recovered oil. The FPSO will be connected to the wells via associated equipment, collectively referred to as subsea umbilicals, risers, and flowlines (SURF), to transmit produced fluids (i.e., oil, gas, produced water) from production wells to the FPSO, as well as treated gas and water from the FPSO to the injection wells.

The Project consists of five primary stages: drilling, installation, hook-up and commissioning, production operations and decommissioning. The Project will generate a variety of recoverable materials as well as solid, semi-solid, and liquid wastes that are both hazardous and non-hazardous, which will vary over time by Project stage. Estimated recoverable materials and waste types and volumes to be generated during each stage of the project has been provided in Attachment 1.

As per the current project schedule, waste could be generated as early as 2018. Waste volumes generated will increase early in the project as concurrent drilling and SURF installation activities occur from 2018 - 2020, which are then followed by the hookup and commissioning of the FPSO. Waste volumes will then begin to decrease as drilling activities conclude in 2020-2021 and significantly decrease thereafter during the stage of production operations alone in 2022 to approximately 2040. When production operations cease, some waste will be generated during the decommissioning stage.[1]

3 SCOPE AND OBJECTIVES

The scope of the WMP includes the following:

- Identifying the sources and processes that generate recoverable materials and wastes;
- Identifying opportunities to avoid waste generation and minimize both the quantities and associated hazards of waste generated;
- Identifying those recoverable materials eligible for recycling, reclaiming, and reuse;
- Identifying the hazards associated with each waste type;
- Estimating the annual quantities for each recoverable material and expected waste type over the various project stages;
- Selecting approved containers and ensuring proper segregation of materials and wastes;
- Identifying preferred management, storage, treatment, and disposal methods for all wastes;
- Identifying and assessing acceptable waste management facilities;
- Identifying and assessing acceptable waste management service provider for transporting recoverable materials received at the shorebases from the FPSO, Drill Ship, Installation, and Supply and Support Vessels that cannot be managed offshore to the final recyclers, reclaimers, handling, storage, treatment and disposal facilities approved by EEPGL by the contracted waste management service providers;
- Providing the process knowledge and Safety Data Sheets (SDS) to ensure safe handling of all materials and wastes to reduce the risk of worker exposure or a release to the environment, including personal protective equipment (PPE).

[1] *Any dates specified in this document are based on the current project schedule which is subject to change. They are provided to help conceptualize anticipated duration of each Project stage.*

- Ensuring the proper reporting and recordkeeping is performed through the utilization of multiple log books and records to document the generation, storage, transportation, and final disposition of all recoverable materials and wastes including an annual waste summary report and incorporation of waste summary information in the end of activity reports (i.e. End of Well, End of Survey, or End of Stage Reports).

The objectives of this plan are as follows:

- Verify EEPGL manages the recoverable materials and wastes generated by the Project in accordance with internationally accepted standards and applicable local (i.e., Guyana) regulations;
- Verify contractors, including Drill Ship, FPSO and installation, supply and support vessel contractors manage their recoverable materials and waste in accordance with their individual vessel waste/garbage management plans, internationally accepted standards and applicable Guyanese Laws and waste regulations.
- Provide practical methods for handling, storing, transporting, recycling, and disposing of wastes generated during all stages of the Project.

4 EEPGL ROLES AND RESPONSIBILITIES

EEPGL is the Owner of this plan and is responsible for its implementation, maintenance, and periodic update as necessary.

EEPGL's obligations include:

- Verify Project drilling, installation, hook-up & commissioning, production operations, and decommissioning conform to the requirements of this plan;
- Ensure all recoverable materials and wastes are properly characterized and profiled based on process knowledge and the sampling and analysis of hazardous wastes as required per the WMP;
- Perform routine inspections and periodic self-assessments to verify compliance;
- Identify qualified third party waste service providers capability of the storage, transportation, treatment, recycling, reuse, and disposal of those wastes generated by the Project;
- Perform periodic audits/assessments of third party waste service providers utilized by EEPGL to verify they are properly permitted and have similar processes and procedures in place in their own individual WMPs or Vessel Garbage Management Plans;
- Verify that vessel owners and operators properly track and manage waste from the point of generation offshore through storage, treatment, reuse and, if needed, transportation to shore for further handling.
- Confirm chain of custody and manifest records are kept documenting the subsequent transfer of recoverable materials and wastes at the shorebase to the third party waste service providers who will perform the final transport, storage, segregation, consolidation, recycle, reuse, treatment, and disposal of materials and wastes in accordance with their WMPs; and

- Ensure that all recoverable materials and waste records are kept and required annual reports prepared, reviewed, and submitted to the Guyana Environmental Protection Agency (EPA) as required and copies are retained by EEPGL for our records.

4.1 EEPGL Specific Responsibilities:

- Will ensure that there are sufficient resources (e.g. people, time, expertise and finances) to manage and monitor the Project waste issues;
- Will ensure that the WMP is implemented, maintained, and periodically reviewed and updated as needed;
- Will identify the permits required and ensure timely application to the appropriate authority;
- Will ensure all permits/licenses are in place prior to carrying out the work;
- Will ensure that all relevant third parties are kept informed as the Project progresses;
- Will ensure that the Venture Office Manager is fully informed on any waste management issue;
- Will, in conjunction with the EMDC Environmental Advisor in Houston, write procedures for area specific issues;
- Will ensure that the Drill Ship, FPSO Vessel, installation, supply and support vessels, onshore logistics, and waste service provider are aligned and are implementing or over seeing their WMP specific waste duties;
- Will review the WMP procedures developed by the contractor and subcontractors;
- Will undertake and carry out internal audits on waste management in line with the program of audits agreed upon by EEGPL and ensure remedial actions are closed out;
- Will ensure that contractors maintain all necessary permits associated with the waste management activities;
- Will ensure all waste management contractors maintain proper documentation in accordance with the Guyana requirements for generation, transportation, and disposal of waste;
- Will ensure all waste management contractors maintain proper documentation in accordance with the Guyana requirements for generation, transportation and disposal of waste;
- Will provide waste related input to the WMP procedures;
- Will control hierarchical waste management approach integral to the EEPGL waste management strategy; and
- Will ensure that the waste records are maintained at the Venture Office for review.

4.2 Marine Vessel Owner/Operator Specific Responsibilities (Supply, Support, Installation, Drill Ships and FPSO):

- Will ensure that the correct equipment and containers are on site when required;
- Will ensure that all equipment and recoverable material/waste storage areas are well maintained and inspected;

- Will be responsible for the completion and maintenance of the waste manifests as they are progressed through the chain of custody process;
- Will carry out surveys as necessary to ensure any waste issues are identified and managed accordingly. This includes ensuring all wastes are correctly segregated;
- Will carry out or supervise all waste monitoring ensuring that all waste records are fully completed and correctly stored and filed. This includes ensuring waste is manifested separate from cargo with all details as to type of waste, volume of waste, quality of waste, and final destination.
- Will ensure that all required labels and placards are in use and are correct. This will need to be coordinated with the waste contractor;
- Will have designated personnel to coordinate with shorebase operators
- Will maintain an up-to-date recoverable material/waste inventory;
- Will maintain and inspect recoverable material/waste storage areas;
- Will ensure that all remedial actions identified by monitoring and inspections offshore and at the shorebase are closed out;
- Will keep copies of all necessary permits associated with waste management activities; and
- Notify EEPGL Logistics Representative of recoverable materials/wastes to be transported to shore.

4.3 Waste Service Provider Specific Responsibilities

- Will spot-check and inspect loads (i.e. bags, containers, skips, totes, and tanks) to verify they conform to the paperwork, bill of ladings, and trip tickets prepared by the generator of the recoverable materials and wastes for transport to the shorebase;
- Will ensure loads are properly labeled from the generator and identify the hazards of such materials and wastes;
- Will oversee the safe offloading and transfer of recoverable materials and waste to trucks for final transport, storage, recycling, recovery, treatment, or disposal;
- Will ensure that any transfers times are recorded and met;
- Will manage the completion of all manifests and other documents to record the final disposition of all materials and wastes with copies to EEPGL and regulatory authorities and maintain the original records as required;
- Will perform periodic self-assessments
- Will provide guidance and training/local capacity building on waste management issues as requested by EEPGL;
- Will ensure that all waste transport trucks are thoroughly inspected and placarded before they leave the shorebase for the disposal facilities;
- Will supervise all waste transfer operations to ensure they are correctly implemented;
- Will provide a point of contact to the EEPGL Logistics Supervisor; and
- Will ensure proper inspection, maintenance, and use of its equipment.

Table 1 summarizes these roles and responsibilities.

Table 1: Summary Roles and Responsibilities Chart

Task	Shorebase Operators & Waste Contractor	Drill Ships, FPSO, Installation Vessels, Supply and Support Vessels	EEPGL
Implement WMP	R	R	A
Designate waste storage areas	R/A	R/A	C
Minimize waste	R/A	R/A	C
Properly utilize all required waste transfer and disposal forms	R	R	A
Keep up to date with waste laws and requirements	R/A	I	R/A
Maintain waste inventory	R	I	A
Document date waste is removed from site	R	A	I
Coordinate contractor procedures	I	R	R/A
Provide periodic waste training	R	R	A
Responsible (R), Accountable (A), Consulted (C), Informed (I)			

5 REGULATORY REQUIREMENTS AND GUIDELINES

This document supports the EIA prepared and submitted for the Liza Phase 1 FPSO Development Project and is Appendix 1 of the Environmental and Socioeconomic Management Plan (ESMP) for the Project. The WMP has been developed to comply with the requirements of the Laws of Guyana, applicable international conventions and supportive of local guidelines including:

- Environmental Protection Act of 1996;
- Regulations made under the Environmental Protection Act 1996 (No. 11 of 1996) of 2000;
- Environmental Guidelines for the Transportation, Storage and Occupational Handling of Chemical/Industrial Hazardous Waste of 2011 (as appropriate);
- Environmental Guidelines for Removal, Treatment & Disposal of Oily Sludge of 2011 (as applicable) (as appropriate);
- Environmental Guidelines for the Storage, Transportation & Occupational Handling of Biomedical Waste of 2011 (as appropriate and as applicable to medical waste that may be generated);
- MARPOL 73/78 - International Convention for the Prevention of Pollution from Ships, Revised Annex V, Ship Garbage Management Plans and Record Books;
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (if applicable, no such shipments are currently planned); and

- Further details on these laws and conventions are contained in the following sections.

5.1 Local Regulatory Requirements and Waste Definitions

This plan deals with recoverable materials and wastes that will be generated from the drilling, installation, hook-up & commissioning, production and decommissioning of the Liza Phase 1 FPSO Project activities located in the Stabroek Block, offshore Guyana. Limited recoverable materials and wastes will also be generated by support operations conducted at the shorebase, offices, and warehouses utilized to support offshore operations.

The definition of a hazardous waste per the Guyana Hazardous Waste Regulation, 2000 Part I, 2(e) is "A hazardous waste means a waste or combination of wastes which, because of its quantity, concentration or physical, chemical or infectious characteristics, may pose a substantial hazard to human health and belong to any category contained in Schedule I unless they do not contain any of characteristics contained in Schedule II and include:

(i) Hazardous industrial waste;
(ii) Acute hazardous waste chemical;
(iii) Hazardous waste chemical;
(iv) Severely toxic waste;
(v) Flammable waste;
(vi) Corrosive waste;
(vii) Reactive waste;
(viii) Radioactive waste;
(ix) Clinical waste; or
(x) Leachate toxic waste or polychlorinated biphenyl waste,

as well as a mixture of acute hazardous waste chemical, hazardous waste chemical, pathological waste, radioactive waste, or severely toxic waste and any other waste or hazardous material." Further descriptions of such wastes including hazardous waste chemicals … etc. can be found in Schedule I.

- A "liquid industrial waste" means a waste that is both liquid and industrial waste but does not include:
  (i) Hauled sewage;
  (ii) Waste from the operation of sewage works;
  (iii) Waste from the operation of water works;
  (iv) Waste that is produced in any month in an amount less than twenty-five litres or otherwise accumulated in an amount less than twenty-five litres;
  (v) Waste directly discharged by a generator from a waste generation facility into a sewage works or sewage system;
  (vi) Waste that results directly from food processing and preparation operations, including food packaging, food preserving and restaurants;

(vii) Drilling fluids and produced waters associated with the exploration or production of crude oil or natural gas;

(viii) Processed organic waste; or

(ix) Asbestos waste.

- A “clinical waste” means:

  (i) Any part of the human body including tissues and bodily fluids, but excluding fluids, extracted teeth, hair, nail clippings, and the like that are not infectious;

  (ii) Any part of the carcass of an animal infected with a communicable disease;

  (iii) Non-anatomical waste infected with communicable disease; or

  (iv) Any waste that is generated in the diagnostic, treatment, or immunization of human beings or animals and related activities that include research or autopsies;

- A “flammable waste” means a waste that is either solid, liquid, an oxidizing substance, or an ignitable compressed gas, which, under certain conditions may be readily combustible or may cause or contribute to fire through friction, absorption of moisture or spontaneous chemical changes and when ignited, burns so vigorously and persistently that it creates a danger; and
- An “incinerator waste” means the residue from incineration, other than incinerator ash and fly-ash.

Additional regulations and guidelines govern specific wastes including chemical, industrial, and biomedical wastes. EEPGL and its contractors may generate as a result of offshore clinic operations and associated medical treatment small quantities of sharps or other biological material or biomedical waste also referred to “Red Bag Waste” due to the color of the containers used and special labeling to denote such a potential biohazard. Such wastes could be incinerated offshore or brought to shore for proper treatment and disposal per the Guyana biomedical waste guidelines.

As noted above sewage and other planned discharges are excluded from these chemical/industrial hazardous waste guidelines. All planned discharges from EEPGL offshore operations have been described in and will be managed under the EMP and Monitoring Plan found under sections 3.1 and 3.5, respectively, of the ESMP for the Liza Phase 1 FPSO Development Project and under individual vessel Garbage Management Plans.

5.2 National Environmental Legislation

In 1996 the Environmental Protection Act (hereinafter referred to as the Act) was enacted to implement the environmental provisions of the Guyana Constitution. The Act authorized the formation of the Environmental Protection Agency (EPA), as the lead agency on environmental matters in Guyana (FAO, 2013).

The environmental compliance element of the Project will be regulated under several statutes. These statutes contain measures that must be implemented to ensure compliance with applicable policies, guidelines, and legislation in Guyana. They include the Maritime zone act of 2010 No 18: 2010 and the EPA protection act of 1996.

5.3 Guyana Permits and Licenses

The Liza Phase 1 FPSO Development Project and EEPGL will be governed under the provisions of the Petroleum Sharing Contract (PSC), Joint Operating Agreement (JOA), and Liza Production License for the Stabroek Block that will be issued upon review and approval of the Liza Project Development Plan, and Environmental Authorisation that will be issued upon review and approval of the EIA and supporting plans, including this WMP, by the Guyana EPA. All of these documents may contain general and specific waste management commitments, obligations, and conditions. The WMP will be updated upon issuance of the Liza Production License and Environmental Authorisation to reflect any additional requirements contained in those documents.

5.4 International Conventions

5.4.1 MARPOL 73/78

EEPGL will operate under the provisions of MARPOL 73/78.

MARPOL 73/78 standards place restraints on the contamination of the sea, land, and air by ships. The Convention includes two protocols dealing respectively with reports on incidents involving harmful substances and arbitration, and six annexes which contain regulations for the prevention of various forms of pollution. Table 2 provides short descriptions of each annex.

Table 2: MARPOL Annexes[2]

MARPOL Annex	Description
Annex I: Regulations for the Prevention of Pollution by Oil	Prevention of pollution by oil from operational measures as well as from accidental releases.
Annex II: Control of Pollution by Noxious Substances	Details the criteria and measures for the control of pollution by noxious liquid substances carried in bulk.
Annex III: Prevention of Pollution by harmful Substances Carried by Sea in Packaged Form	Contains general requirements for the issuing of detailed standards on packing, marking, labelling, documentation, stowage, quantity limitation, exception, and notifications.
Annex IV: Prevention of Pollution by Sewage from Ships	Requirements to control pollution of the sea by sewage and grey water.
Annex V: Prevention of Pollution by Garbage from Ships	Deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of.
Annex VI: Prevention of Air Pollution from Ships	Sets limits on certain air pollutants and prohibits deliberate emissions of ozone depleting substances.

[2] *International Maritime Organization (IMO). (2015). International Convention for the Prevention of Pollution of Ships (MARPOL). Accessed 9 December 2015 at http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx.*

All Solid combustible waste (except for food waste) as listed in Table 4 suitable for incineration will be managed on the Drill Ship and FPSO Vessel as the first preference; the remainder will be stored on board and sent back to shore for treatment or disposal in accordance with local regulations. Food waste will be comminuted or ground prior to discharge. Black water / sewage will be treated with chlorine per MARPOL standards and discharged. Management and monitoring measures implemented to ensure treatment standards for these discharges are met are described in the ESMP.

The primary provisions of MARPOL 73/78 relevant to waste management to the Project are those applicable to offshore vessels as follows:

- Waste Management Plan: A formal Waste Management Plan shall be developed and enforced by the Unit owner;
- Waste Record Book: All wastes generated should be recorded in the Waste Record Book;
- Plastic Waste and General Waste (except Food Waste): The disposal to the sea of all plastics, including but not limited to synthetic ropes, synthetic fishing nets, and plastic garbage bags, and all other general waste, including paper products, rags, glass, metal, bottles, crockery, dunnage, lining and packing materials, is prohibited;
- Food Waste: The disposal to the sea of food wastes that have been passed through a comminuter or grinder shall be made not less than 12 nautical miles from the nearest land. Such comminuted or ground food waste shall be capable of passing through a screen with openings no greater than 25 mm; and
- When waste to be disposed of is a mix of waste types having different disposal requirements, the more stringent requirements shall apply.

5.4.2 Basel Convention

The objective of the Basel Convention is to control the transboundary movements of hazardous waste and their disposal and by such protect human health and the environment against the adverse effects of hazardous waste if not managed correctly. Its scope covers a wide range of wastes defined as “hazardous wastes” based on their origin and/or composition and their characteristics, as well as two types of wastes defined as “other wastes” – household waste and incinerator ash.

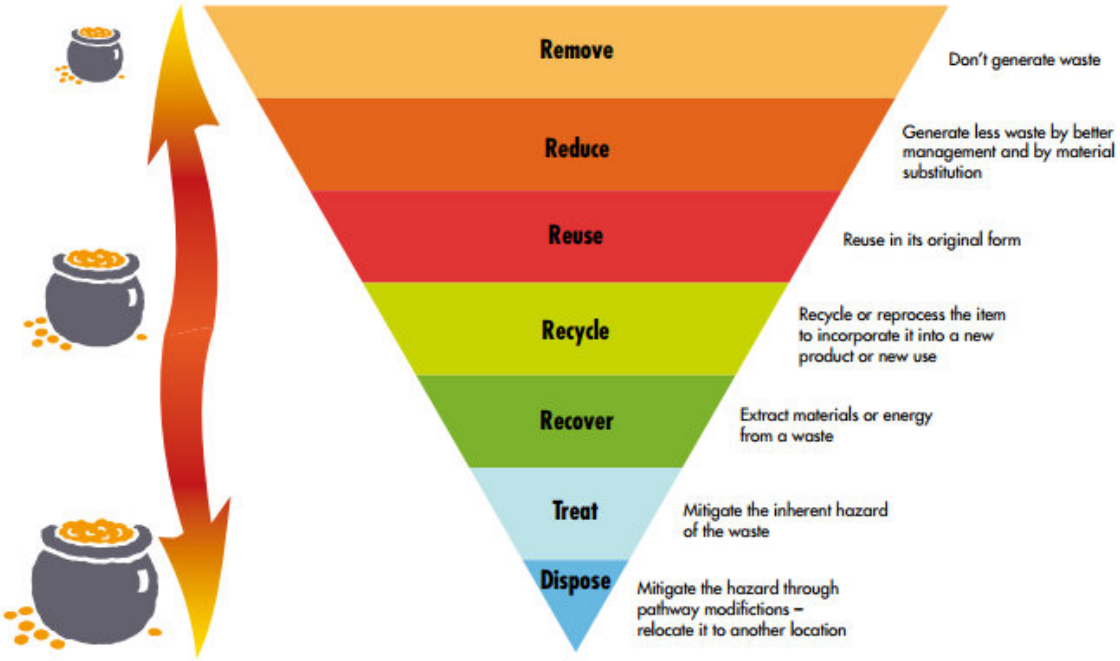
The primary provisions of the Convention center around the following principles:

- The reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal;
- The restriction of transboundary movements of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management; and
- A regulatory system applying to cases where transboundary movements are permissible.

Guyana became a signatory to the Basel Convention on March 7, 2001.

6 WASTE MANAGEMENT STRATEGY

1. Generation of waste should be Avoided, Prevented, or Reduced at the source whenever feasible;
2. Wastes that are not Prevented should be Reused or Recycled in an environmentally safe manner, whenever feasible;
3. Waste that are not Prevented or Recycled should be Treated in an environmentally safe manner, whenever feasible; and
4. Finally, Disposal should be employed as a last option and when employed, should be conducted in an environmental responsible manner.



Source: OGP. (2009). Guidelines for waste management with special focus on areas with limited infrastructure. Accessed 21 November 2015 at http://www.ogp.org.uk/pubs/413.pdf.

Figure 1: Waste Management Hierarchy

EEPGL will encourage its contractors and suppliers (e.g., of equipment, materials, goods and services) to minimize packaging on products wherever possible, or to package products in recyclable materials, to limit waste generation at each stage of the Project. Whenever practicable, surplus and unused materials will be returned to a vendor or recycled as the means of management i.e. reused for the same or a new purpose, converted into a new product, enable the reduction in the consumption of a new product or raw material.

Where possible, measures will be implemented to minimize contractor waste generation. These include:

- Avoiding single use items where reusable items could be used (e.g., use washable plates rather than paper plates);
- Purchasing supplies with minimal or recyclable packaging;
- Using reusable and/or biodegradable materials;
- Order only what is needed;
- Store products properly to prevent spillage or contamination;
- Keep all product containers in good condition, clearly labeled; and
- Maintain good housekeeping and maintenance of facilities.

6.1 Waste Categories

A description of the recoverable materials, common waste types, and categories expected to be generated by the Liza Phase 1 FPSO Development project have been summarized in Table 3.

Table 3: Recoverable Materials, Waste Types and Categories

#	Waste Category	Waste Types
1	Non-hazardous wastes	General & domestic trash, incinerator ash & residue (must be tested), production solids (e.g. scale, sand), dry filters, abrasive blast media, filter media, desiccant/drying agents
2	Recyclable materials	Wood, paper, cardboard, glass, aluminum cans, plastic, scrap metal including metal packaging, clean empty steel drums, empty/punctured aerosol cans
3	Hazardous waste liquids	Used lube/motor oil, contaminated hydrocarbons (crude, diesel, etc.), oily water, contaminated water-based drilling fluid, non-aqueous drilling fluid, drilling slops, well treatment & completion fluids, waste brines, treatment chemicals, liquid paint waste, drum/container rinse, acid & caustic solutions, hydraulic fluid
4	Hazardous waste solids	Production solids & sludges, oily trash/debris, oily/wet filters, drums/containers with chemical residues, dried paint waste, consumables (e.g. non-empty aerosol cans, oil filters, grease tubes, dope brushes)
5	Special hazardous wastes	Medical/biological waste, batteries (including alkaline, lead-acid, nickel-cadmium), fluorescent light bulbs & ballasts, mercury and mercury-containing equipment, radioactive waste including Naturally Occurring Radioactive Material (NORM), electronic waste

6.2 Waste Management Practices

The key waste management practices covered by this WMP include:

- Proper waste classification and identification;
- Proper handling, segregation and storage;
- Proper recycling, reclaiming or recovery; and
- Proper treatment and disposal.

Each of the categories and individual types of wastes listed above has been summarized with the preferred waste management practices to be used in Table 4.

Table 4: Waste Management Practices

Waste Management Practices	Recoverable Materials and Waste Streams
Recycle	Plastic, glass, scrap metal including empty steel drums and empty/punctured aerosol cans
Landfill	General trash, used PPE, dessicant and other drying agents, filter media, abrasive blast media, uncontaminated cement, incinerator ash and other hazardous waste treatment residues that have been tested to ensure safe for land disposal
Recycle into FPSO Process	When possible, the following will be recycled into the FPSO production/separation process: used lube/motor oil, used glycol, oily water, de minimis quantities of off-spec product/materials, by-products, oil slops
Offshore Incineration (non-hazardous wastes)	Wood, paper, cardboard, general trash
Offshore incineration (hazardous wastes)	Used lube/motor oil (when not possible to recycle into FPSO process), contaminated hydrocarbons (crude, diesel, etc.), oil filters and oily debris (rags, gloves, wood, vegetation, sorbent pads, paper, etc.), paint waste, medical waste
Onshore Treatment	Drilling slops (mixture of used drilling muds, water, cement spacer, additives), oil-contaminated cement and completion brines, used drilling muds not discharged w/ cuttings, production sludges and solids, tank bottom sludge, pigging waste, used and unused chemicals/solvents, hazardous drum rinse, oily water, contaminated drums, containers, packaging, non-empty aerosol cans, batteries (lead acid, nickel-cadmium, lithium, mercury cell), electrical/electronic waste, mercury-containing equipment, e.g. thermometers and other instruments (should be very little), radioactive/NORM waste (only in case that it is produced)

6.3 Waste Classification

Proper waste management begins with an accurate classification of each waste, which is critical for safe storage, transportation, and treatment/disposal planning. This will be based on generator processes and process knowledge, review of manufacturer's safety data sheets, product specifications, and select laboratory testing and analysis as required to ensure the hazards are known for each waste including whether they are flammable, corrosive (acid or base), reactive (oxidizer, pyrophoric, reducer), and/or toxic.

Whenever supporting analytical results are necessary to initially profile and characterize a waste stream, the following analytical tests will commonly be baseline of what will be performed:.

- Flashpoint;
- pH;
- Toxicity (TCLP metals, and in some cases volatiles, e.g. BTEX); and
- Reactivity (reactive sulfides, reactive cyanides).

The disposal contractor will be consulted to ensure appropriate analytical methods and tests are performed. EEPGL will audit and approve labs used to analyze EEPGL waste and other materials.

Waste sampling will be performed by properly trained personnel using the appropriate PPE. Samples will be packaged in appropriate containers and properly labeled. A chain of custody form (sample provided in Attachment 5) must accompany all lab samples during transport.

6.4 Handling of Wastes

Personnel involved in the handling of hazardous, scheduled wastes must recognize and understand the associated potential hazards and shall be trained to a level commensurate with their job duties.

Standard personal protective equipment (PPE) for hazardous/scheduled waste-handling activities include the following:

- Gloves: leather or chemically resistant (depending on the type of waste);
- Safety glasses, goggles or face shield;
- Hard hat;
- Steel-toed shoes or boots; and
- Coveralls or other suitable work clothes.

Additional PPE may be required for specific hazardous/scheduled wastes (e.g., latex boot covers and air-purifying respirator). Further information is also contained in the Safety Data Sheet (SDS) documents.

6.6 Handling of Hazardous Materials

All hazardous materials shall be stored in designated areas on the Drill Ship and FPSO Vessel where the potential for damage to containers is minimized (i.e. paint stored in paint locker, acids stored in enclosed areas, etc.). Additionally, hazardous materials must be stored in areas with adequate containment.

Any hazardous materials to be shipped offshore will not be accepted by the Drill Ship, FPSO Vessel, or installation, supply and support vessels unless the following requirements are met:

- Appropriate Safety Data Sheets (SDS) must accompany the material;
- Materials have been accounted for under the Guyana Revenue Authority Investment Development Agreement (IDA);
- Applicable requirements for materials import, customs clearance and use; and
- Materials have been approved under the Guyana Pesticides and Toxic Chemicals Control Act of 2000 (if applicable).

Hazardous materials shall be transported in proper containers affixed with a hazardous waste label and placard(s) indicating the applicable hazard class(es). Placards containing internationally recognized symbols exist for the following hazard classes (see Attachment 8):

1. Explosives
2. Flammable liquids
3. Flammable solids or waste solids other than explosives which may be readily combustible
4. Oxidizing substances
5. Organic peroxides
6. Poisonous substances
7. Infectious substances
8. Corrosives
9. Toxic gases
10. Toxic substances which if inhaled or ingested may cause delayed or chronic effects
11. Ecotoxic substances which if released may present immediate or delayed adverse impacts to the environment by means of bioaccumulation and/or toxic effects upon systems; and
12. Materials capable, after disposal, of yielding another material which possesses any of the characteristics specified in items 1 – 11.

All containers with hazardous materials transferred to and from the Drill Ship, FPSO Vessel, and installation, supply and support vessels must be clearly identified on the cargo manifest, properly placarded per the hazard classes listed above, and accompanied by a SDS if applicable.

6.7 Waste Segregation and Storage

Waste generated on the Drill Ship, FPSO Vessel, and installation, supply and support vessels will be collected in appropriately labeled bin collectors, tanks, bottles, drums, or other designated receptacle. Proper containers will be used for each recoverable material and waste. Secondary containment will be provided for all liquid and hazardous wastes.

Non-hazardous wastes, including recyclables, shall be physically separated from Hazardous Wastes (HW) and segregated by type in order to:

- Maximize the possibilities for waste recycling or reuse;
- Minimize the possibility of contamination of non-hazardous wastes by HW;
- Ensure that waste storage is contained; and
- Ensure the proper management of each specific waste;

Additionally, the following segregation & storages practices will be utilized:

- Wastes shall be stored in containers that are in good condition and compatible with characteristics of the materials in question
- Sealable containers shall be provided for hazardous/scheduled wastes;
- Incompatible wastes are segregated to minimize potential chemical reactions;
- Containers bearing wastes should be labeled in accordance with regulatory requirements; and
- Different types of HW shall be stored separately from each other and from non-hazardous waste.

Containers bearing wastes should be labeled with the following information:

- Classification, i.e. hazardous or non-hazardous;
- Name/description of the waste
- Applicable hazardous waste characteristics (see list in Section 6.5);
- Physical state of the waste (i.e. solid or liquid).

In addition to the requirements stated above, HW containers must be labeled with the following information:

- Name and address of EEPGL;
- Placard(s) corresponding to the applicable hazard class(s) (during transport only); and
- Packaging or start of accumulation date.

Hazardous waste should be labelled in the specified format as follows:

- The size of the label should not be less than 20 centimeters (cm) x 30 cm [7.9 inches (in) x 11.8 in];
- Labels should have a yellow background with black lettering conspicuously marked in paint or another permanent form of marking;
- The material of the label should be scratch proof, resist to tampering and able to withstand open weather exposure;
- The basic label form is provided below in Table 5;
- Generally, the label should be attached to the side of the vessel, container, and tank. In case of repeated use of the vessel, container, and tank, the label should be a plate and hung on the side of it. For containment buildings, all hazardous wastes types contained in the building should be included in the plate;
- The label should identify the hazardous characteristic(s) of the waste (e.g. flammable, corrosive, toxic, etc.)

Labelling procedures should be completed at the location where the waste was generated and should be retained at the destination treatment, storage, and disposal facilities.

Table 5: Basic Label Form

Hazardous Waste		
Waste Information	Waste type / description	Name and/or description of the waste/material
	Waste Classification	Hazardous or non-hazardous
	Hazard Class	Name of the hazard class (see placards in Attachment 8; e.g. Toxic, Corrosive, Flammable, Explosive, Reactive, Infectious)
	Physical Form	Liquid, Solid, or Sludge
	Quantity	Quantity of the hazardous waste contained in the vessel, container or tank
	Packaging date	Date the hazardous waste is packed in the vessel, container or tank
	Shipping date	Date the hazardous waste must be removed from the storage area and transported off site if applicable
	Waste transport record number	Manifest number if transported off site
Container Information	Capacity	Maximum capacity or volume of the container
	Material	Material that a vessel, container or tank is made of
Generator Information	Name	Name of the waste generator (company name)
	Address	Address of the waste generator
	Telephone #	Telephone number of the waste generator

6.8 Waste Tracking Process

A Marine Transport Manifest (see Attachment 6) will be used for all vessel shipments of hazardous and non-hazardous wastes and must contain the types and quantities of hazardous and non-hazardous wastes being transported.

Additionally, a waste manifest (sample included in Attachment 7) shall be completed and must accompany all shipments of hazardous and non-hazardous wastes. This includes over-water shipments as well as land shipments. The purpose of this manifest is to track each shipment of waste from the point of generation to the point of final treatment, recycling or disposal. EEPGL is responsible for completing waste manifests prior to shipment.

In compliance with MARPOL 73/78, marine vessels including the supply, support, installation vessels as well as the Drill Ship, and FPSO Vessel will maintain a Garbage Record Book and record of used oil generated (See Attachments 3 and 4). The Garbage Record Book can be modified to allow tracking of Project-related wastes outside the scope of the categories specified in the MARPOL regulations; therefore, it will be referred to as a Waste/Garbage Record Book in the remainder of this document.

Vessels must retain copies of all Marine Transport Manifests and waste manifests with the Waste/Garbage Record Book for a minimum of two years.

6.9 Waste Transfer to Shore

Marine vessels used to transport waste shall have necessary licenses and approval from the Guyana authorities. Crews on vessels that transport hazardous waste must have training in basic emergency response, and knowledge of labeling and placarding requirements.

Vessels transporting waste must carry both a completed Marine Transport Manifest (see Attachment 6) and a completed waste manifest (see example in Attachment 7). These documents must contain the name, description and quantity of all wastes being transported..

All waste containers must be labeled per the requirements described in Section 6.6. Hazardous waste containers must be affixed with the appropriate placard(s) corresponding to the hazard class(es) of the waste being transported. .

EEPGL will confirm vessel waste shipments meet the requirements above and that vessel crews have completed and documented compliance with the minimum training requirements.

7 WASTE MANAGEMENT METHODS

The following treatment and disposal methods may be employed to manage Project waste:

- **Offshore:**
  - Incineration;
  - Discharge (macerated food);
  - Other methods allowed by Environmental Permit.
- **Onshore:**
  - Incineration;
  - Other thermal treatment (e.g. thermal desorption);
  - Neutralization;
  - Stabilization (e.g. solidification);
  - Bioremediation;
  - Liquid waste treatment;
  - Burial disposal (landfill);
  - Beneficial reuse.

EEPGL's contracted waste service provider will be expected to furnish all required equipment and facilities for the storage, handling, transportation, treatment, and disposal of hazardous and non-hazardous waste brought onshore. In some cases (i.e. special hazardous wastes), waste may need to be shipped to other approved facilities owned and/or operated by a different service provider.

7.1 Incineration/Thermal Treatment

Thermal treatment, including incineration, is a preferred technology for the management of combustible solid wastes and liquid wastes. It can be performed utilizing a variety of incinerators (single and dual chamber), thermal desorption units, or other thermal treatment technologies. The Drill Ship and FPSO Vessel will be equipped with incinerators designed to handle the types and quantities of combustible wastes specified in Attachment 1 and capable of destroying hazardous constituents in those waste streams. EEPGL's contracted waste service provider may also utilize incineration or other forms of thermal treatment for hazardous and non-hazardous wastes that cannot be managed by the offshore incinerators. Incinerator ash and residue will be analyzed as described in Section 6.3 of this plan to ensure suitability for land disposal prior to shipment to the landfill. There can be an expected 75% - 85% reduction by volume of incinerated solid wastes, and a significantly higher percent reduction for incinerated liquid wastes.

7.2 Neutralization

Neutralization is an effective treatment method for certain waste acids and caustics in which chemicals are mixed to raise or lower the pH to a neutral level. Appropriate health and safety considerations must be taken and specific controls put in place when performing neutralization. It is important to verify that waste liquids can be safely neutralized prior to mixing of any chemicals, which can often result in an exothermic reaction. Commonly used chemicals for neutralization are a 98% sulfuric acid (to neutralize a base) and 50% sodium hydroxide or calcium hydroxide (lime) (to neutralize an acid).

7.3 Stabilization

Stabilization can be any process used to alter the physical or chemical properties of a waste to render it suitable for land disposal or further treatment. One form of stabilization is solidification, in which waste is physically or chemically bound or encapsulated it in a stabilizing material to form a hardened block that will prevent the potential constituents of concern (e.g. metals) from being released or leached into the environment. Common binding agents or stabilizing materials are cement, clay, fly ash or asphalt. Stabilization/solidification is sometimes used as a secondary treatment following incineration for wastes that may have residual leachable constituents after all volatiles and hydrocarbons have been removed through thermal treatment.

7.4 Bioremediation

Bioremediation can be an effective form of treatment for organic wastes, such as hydrocarbon or hydrocarbon-contaminated wastes (e.g. hydrocarbon-impacted soil). Bioremediation is often performed in open pits or other open spaces where natural or added organisms and surrounding oxygen are used to break down the organic material in the waste until hazardous constituents are reduced to a level suitable for land disposal. It is important to utilize a barrier to protect groundwater sources beneath the bioremediation area and design facilities to prevent runoff or contamination outside of the designated bioremediation area. EEPGL has strict criteria for which wastes are eligible for bioremediation (generally only exploration and production (E&P) wastes in which hydrocarbons are demonstrated through analytical testing to be the only hazardous constituent present. Once the hydrocarbon content of bioremediated waste is reduced to 5% or less, it can become eligible for beneficial reuse.

7.5 Liquid Waste Treatment

There are a variety of forms of industrial liquid waste treatment that can be used to remove hazardous constituents from liquid wastes, making them suitable for land disposal (i.e. discharge). A properly designed treatment plant is the preferred management method for large volume liquid wastes, such as slops, oily water, or washwater from vessel tank cleanouts.

7.6 Burial Disposal (Landfill)

Non-hazardous solid wastes that are not recycled, reclaimed or reused will be transported and disposed of at an approved and permitted landfill. Wastes must be demonstrated to meet standards for land disposal through generator knowledge or analytical testing prior to landfilling. In Guyana, the Haags Bosch Landfill has been permitted by the Guyana EPA and is managed by the Ministry of Communities. Should additional engineered landfills become available in Guyana, those will be assessed and reviewed for use.

7.7 Beneficial Reuse

It may be possible to use exploration and production (E&P) wastes for beneficial purposes. EEPGL has strict standards for when a waste is eligible for beneficial reuse. Untreated wastes that are demonstrated through analytical testing to meet certain criteria (i.e. hydrocarbon content less than 5%, all other constituents of concern below levels that could cause harm to the environment) can be eligible for beneficial reuse. Wastes that do not initially meet these criteria may be treated to meet the standard. Such reuse can offer important environmental benefits such as waste minimization (avoids unnecessarily using up landfill space), dust suppression, and improved road maintenance.

8 SPILL AND EMERGENCY RESPONSE

EEPGL, marine vessels, waste transporters, and the waste service provider will all have Emergency Response (ER) Plans to address possible emergency contingencies such as spills, fires, and explosions. These plans include specific and actionable steps for multiple risk scenarios. The action steps and the resources applied increase as the seriousness of the emergency or release increases. In the case of scenarios outside the local capability (Tier I), EEPGL will activate its Regional Response Team (RRT) (Tier II-III). The RRT is a large group of responders that have been trained for response actions around the world. The ER Plans also include all required internal and external incident communications processes and contact numbers.

8.1 Oil Spill Cleanup – Waste Management

All waste generated as a result spill cleanup activities will be managed in accordance with this plan, EEPGL's Oil Spill Response Plan (OSRP), as well as Guyana law and local regulations. The typical waste streams associated with a cleanup are, but not limited to, recovered product not able to be reintroduced into the system, oily water, absorbent materials, decontamination materials, contaminated trash and debris, general trash and debris, vegetation/foliage, etc. Should a significant spill occur, an incident specific waste management plan will be developed as part of the response.

Additional waste management provisions can be found in Section 6.9 of the EEPGL OSRP, which is found in Appendix 3 of the ESMP. Procedures for the disposition of deceased wildlife are included in the Wildlife Response Plan (Appendix E of the OSRP).

9 WASTE MONITORING AND REPORTING GUIDELINES

Monitoring and reporting of those recoverable materials and wastes generated and their final management are critical components to the successful implementation of this WMP for EEPGL and its contractors.

9.1 Waste Monitoring

The monitoring program will be facilitated by regular inspections conducted by EEPGL. A summary of monitoring guidelines is provided in Table 7.

Table 6: Waste Monitoring Guidelines

Monitoring Activity	Frequency	Originator	Documentation
Record type and quantity of each individual waste stream onboard	Any time new waste is generated	Dedicated personnel on all vessels	Waste/Garbage Record Book; Oil Record Book; Incinerator Log
Inspect waste storage area and containers; log inspections	Daily	Dedicated personnel on all vessels, at shore base, and Waste Management Service Provider's facility	Daily inspection log
Document marine waste transfer	Each instance waste is transported	Dedicated personnel on all vessels and at shorebase	Marine Transport Manifest and Waste Manifest
Sample and perform analytical testing	As needed to properly classify waste	EEPGL / Waste Management Service Provider	Chain of Custody; Laboratory analysis results
Complete Recoverable Material and Waste Summaries	Monthly; Annual	Waste Management Service Provider / EEPGL	Monthly Waste Inventory and Annual Waste Summary Report
Complete and submit reports required per the Environmental Permit	Dependent on final permit conditions	EEPGL	End of Survey, End of Well, End of Stage Reports, EPA Recording and Reporting Form, any other reports required by Environmental Permit
Waste facility audits & inspections	Periodic	EEPGL	Inspection logs & reports

9.2 Waste Recordkeeping and Reporting

Waste management performance will be measured against agreed upon reporting and recordkeeping requirements including:

- Types and volumes of wastes (hazardous and non-hazardous) generated;
- Maintenance of required vessel Waste/Garbage Record Book and Oil Record Books;
- Maintenance of required incinerator logs;
- Maintenance of Marine Transport Manifests and waste manifests to document custody transfer and the final means of disposition for each recyclable material and waste;
- Preparation of waste reports required per the Environmental Permit, such as the Guyana EPA Recording and Reporting Form shown in Attachment 2;
- Maintenance of monthly waste inventories;
- Preparation of annual waste management summary reports;
- Routine inspections and periodic assessments of Waste Management Service Provider's facilities; and
- Maintenance of hazardous substances / chemical inventory register and transboundary shipment forms, if required. These forms should be kept by EEPGL personnel at either the shore base or venture office.

Any issue of non-compliance will be tracked and documented in the monthly report.

10 WASTE TRAINING

General training will be conducted prior to the project with all EEPGL personnel, contractors, and any others that will be involved with recoverable material and waste generation and management during the life of the Liza Phase 1 FPSO Development Project. This training will cover:

- EEPGL Waste Management Practices;
- Environmental Permit requirements;
- Typical waste streams;
- Identification, classification, and labelling of hazardous and non-hazardous waste;
- Handling, segregation, storage, and treatment/disposal options;
- Personal Protective Equipment (PPE) requirements; and
- Waste management during normal operating conditions as well as emergencies.

In addition to the general waste management training, additional offshore and onshore-specific waste training will be provided to the appropriate personnel.

10.1 Offshore Waste Management Training

EEPGL personnel and contractors working offshore will attend a training focused on waste management in the offshore environment. This training will support compliance to both Guyana regulations as well as EEPGL responsible waste management practices. Topics to be covered in these trainings will include, but not be limited to:

- Opportunities to minimize waste generation;
- Waste generation offshore and potential impacts on marine life;
- Specific types of hazardous and non-hazardous waste that can be generated offshore and associated risks;
- Handling, storing, and transporting wastes, with particular focus on hazardous waste to ensure safety of personnel and environment; and
- Waste tracking, monitoring, and auditing standards and practices.

10.2 Onshore Waste Management Training

Onshore waste management training will be conducted for EEPGL personnel and contractors as appropriate. The waste management service provider will also provide training for all its waste personnel and verify training has been performed for waste transporters. This training will cover more specific topics, including:

- Application of Guyana laws and guidelines;
- Opportunities to minimize onshore waste generation;
- Waste generation onshore and potential risks to health, safety, and the environment;
- Specific types of hazardous and non-hazardous wastes that can be generated offshore and sent to shore for treatment/disposal, as well as potential waste generated from onshore activities;
- Handling, storing, and transporting wastes onshore, with particular focus on hazardous waste to ensure safety of personnel and the environment; and
- Waste tracking, monitoring, and auditing standards and practices.

Attachment 1: PROJECT WASTES, MANAGEMENT METHODS AND ESTIMATED ANNUAL QUANTITIES

Hazardous Wastes

Waste Information: Hazardous Wastes				Volume By Year / Metric Tonnes					
Waste Stream	Waste Source	Primary Disposal Method	Alternate Disposal Methods	2018	2019	2020	2021	2022–2039	2040
Used lube oil / motor oil	Equipment and vehicle maintenance and repair (of internal-combustion engines, pumps, and compressors)	When practicable, recycle into FPSO process	Offshore or Onshore Incineration, Onshore Recycling	76	175	236	94	9	4
Contaminated hydrocarbons (contaminated crude, diesel, etc.)	General maintenance activities and spill response	Offshore incineration	Onshore treatment	4	13	18	10	5	8
Oily Debris (rags, gloves, wood, vegetation, sorbent pads, paper, etc.)	Routine operations & maintenance, rags and oil spill clean-up activities	Offshore incineration	Onshore treatment	6	21	26	12	5	12
Oily Filters and Oil Filter Sludge	Vehicle and equipment engines during all project phases	Offshore incineration	Onshore treatment	6	21	30	17	10	15
Paint waste	Equipment and facilities activities and maintenance during all phases	Onshore Treatment		2	7	8	3	1	3
Medical waste	First aid and routine clinical procedures	Offshore incineration	Onshore treatment	1	3	4	2	1	1
Drum rinse	Drum and container rinsing	Onshore treatment		2	7	7	2	0	5
Pigging waste	General maintenance activities	Onshore treatment		0	4	6	5	5	3
Slops containing used drilling muds (NAF), cement spacer, chemical additives, washwater	Drilling operations	Onshore treatment		1210	2720	3626	1360	0	0
Oil contaminated completion brines	Well completion activities	Onshore treatment	Offshore incineration	18	40	54	20	0	0
Oily water	Tank and operating equipment cleaning	When practicable, recycle into FPSO process	Onshore treatment	24	58	81	37	10	5
Unused or contaminated solvents/chemicals	Operations, wastewater or water treatment systems, laboratories	Onshore treatment		4	13	56	61	57	57
Glycol	Operations and vessel equipment maintenance	When practicable, recycle into FPSO process	Onshore treatment	2	7	15	12	10	5
Oil sludge/Tank bottom sludge	Operations and vessel equipment maintenance	Onshore treatment		25	80	94	38	10	30
Oil contaminated cement		Onshore treatment		370	830	1110	415	0	0
Fluorescent bulbs	Replacement of light tubes	Stabilize & landfill		0	1	1	0	0	1

Waste Information: Hazardous Wastes				Volume By Year / Metric Tonnes					
Waste Stream	Waste Source	Primary Disposal Method	Alternate Disposal Methods	2018	2019	2020	2021	2022–2039	2040
Non-punctured Aerosol / pressurized spray cans	General maintenance activities	Onshore treatment		2	5	6	3	1	1
Batteries (Lead Acid, Nickel-Cadmium, Lithium, Mercury Cell)	Instruments and small equipment	Onshore treatment / send to approved battery recycler		5	15	46	45	39	22
Electrical/electronic waste	Instruments and computer related equipment	Onshore treatment / send to an approved E-waste recycler		0	2	2	1	1	6
Contaminated drums, containers, packaging (metal or plastic)	Operations and general maintenance	Onshore treatment	Landfill (plastic drums)	8	26	44	31	22	16
Radioactive waste		Send to facility permitted to manage NORM		<1	<1	<1	<1	<1	<1
Mercury-containing equipment		Onshore treatment		<1	<1	<1	<1	<1	<1

Waste Information: Non-Hazardous Wastes

Waste Information: Non-Hazardous Wastes				Volume By Year / Metric Tonnes					
Waste Stream	**Waste Source**	**Primary Disposal Method**	**Alternate Disposal Methods**	**2018**	**2019**	**2020**	**2021**	**2022–2039**	**2040**
Recyclable domestic trash (plastic & glass)	Discarded items from, kitchen, living quarters, bathroom, laundry, warehouse, offices	Recycle	Landfill	39	100	136	62	19	24
Incinerator Ash	Incinerator	Landfill		17	40	55	24	5	7
General/domestic trash: non-recyclable	Discarded items from kitchen, living quarters, bathroom, laundry, warehouse, offices	Incinerate offshore or landfill		96	269	495	335	200	216
Desiccant	Air drying equipment (i.e. instrument air, air filtration systems)	Landfill		0	0	4	5	5	3
Production solids (e.g. sand, scale)	Operational maintenance from wells and producing equipment	Landfill		0	0	<1	<1	<1	15
Abrasive blast media (uncontaminated)	Construction and general maintenance	Landfill		0	0	2	3	3	2
Dry Filters	General Maintenance	Offshore incineration, recycle carcasses with scrap metal when possible	Landfill	4	10	20	15	10	8
Paper, Cardboard & Wood	Wooden pallets, construction, general maintenance	Offshore incineration	Recycle, landfill	154	360	503	218	45	45
Scrap metal	Equipment maintenance, metal packaging	Recycle	Landfill	24	61	110	72	45	25
Empty aerosol / pressurized spray cans	General maintenance	Recycle	Landfill	1	2	3	1	1	1
Empty steel drums	Construction & Operations	Recycle	Landfill	22	53	71	29	4	4

Attachment 2: GUYANA HAZARDOUS WASTE RECORDING AND REPORTING FORM

EPA-EMD2012HWRRF1R1

RECORDING AND REPORTING FORM OF HAZARDOUS WASTES (*for* New and Existing Operations)

General Instructions/Requirements/Information

The Recording and Reporting Form must be completed by the holder of an Environmental Authorization no later than forty-five days after the end of the operating year.

Note: The report should be prepared on activities relating to the previous calendar year.

1. This Form must be completed in BLOCK LETTERS (preferably completed electronically) and a hard copy along with any additional information requested submitted to:

   The Executive Director
   Environmental Protection Agency
   Ganges Street
   Sophia, Georgetown, Guyana
   Telephone: (592) 225-2062 / 1218 / 0506 / 6917
   Fax: (592) 225-5481
   Email: epa@epaguyana.org Website: www.epaguyana.org

2. The information provided in this form must be kept by the holder of the authorization for a period of not less than three years or for such other extended time as the Agency may determine.

Specific Instructions for Completing Form

3. **Block A:** Provide the Permit Reference number, the name of the Company, Project address, mailing address (if different). In this section also provide the name, designation, telephone number, email/fax of a contact person.

4. **Block B:** Provide a description of the operation process. Identify all hazardous materials/chemicals used within the operation process. Also provide the number of years the project has been operational.

5. **Block C:** Provide information on **hazardous materials/chemicals used** in the life cycle of the project. Provide the type of hazardous material/chemicals used (see attached list), its hazardous, physical and chemical characteristics (see attached list), the quantity and the type of storage e.g. containers, bags etc.

6. **Block D**: Provides information on the **hazardous wastes generated.** Provide the type of hazardous material/chemicals used (see attached list), its hazardous, physical and chemical characteristics (see attached list), the quantity and the type of storage e.g. containers, bags etc.

7. **Block E**: Once authorized all spills must be reported. Provide information on the date of incident, type and amount of waste spilled, measures taken to mitigate incident.

EPA-EMD2012HWRRF1R1

A. IDENTIFICATION INFORMATION			
Generator's Permit Reference Number:			
Company Name:			
Project Address:		Region	
Mailing Address (if Different):		Region	
Contact Personnel			
Name :			
Designation:			
Telephone number:			
FAX:			
Email:			

B. OPERATION DETAIL

Brief description of operating process and raw materials (specifically hazardous materials and quantity) used:

No. of Years of Operation: 1-4 years ☐ 5-19 years ☐ over 20 years ☐

C. HAZARDOUS MATERIALS/ CHEMICALS (All Parts of This Section Must Be Completed)

Types of Hazardous Materials/ Chemical	Hazardous Characteristics	Quantity of Hazardous Materials/Chemical		Physical Characteristics	Chemical Characteristics	Type of Storage
		Mass (kg/gallons)	Volume (m^3)			

EPA-EMD2012HWRRF1R1

D. HAZARDOUS WASTES (All Parts of this Section Must Be Completed)						
Type of Hazardous Wastes generated	**Hazardous Characteristics**	**Quantity of Hazardous Waste Generated**		**Physical Characteristics**	**Chemical Characteristics**	**Type of Storage**
		Mass (kg/gallons)	**Volume (m^3)**			

E. SPILLS/CHEMICALS RELEASE		
Date/s of Incident	**Type and Approximate Amount of Waste Lost (kg/gallons)**	**Measures Taken to Resolve the Incident**

OTHER	
Data for off-site Shipment of Waste (transporter and receiver details, location of the off-site facility, etc.)	
Treatment Standard for Waste (if applicable)	
Waste Minimization Efforts (different ways used by the company to reduce the waste generated)	
Details on any Pollution Prevention Plan by the company	



EPA-EMD2012HWRRF1R1

Other Information (e.g. Emergency Response Plan, Occupational Handling Measures)	

Attachment 3: SAMPLE WASTE/GARBAGE RECORD BOOK

Ship's Name:

Official No:

IMO No:

Garbage Categories:

- Category 1: Plastics
- Category 2: Floating dunnage, lining, or packing material
- Category 3: Ground-down paper products, rags, glass, metal, bottles, crockery, etc.
- Category 4: Cargo residues, paper products, rags, glass, metal, bottles, crockery, etc.
- Category 5: Food waste
- Category 6: Incinerator ash except from plastic products which may contain toxic or heavy metal residues
- Other Releases - Treated sanitary wastewater, grey water, ballast

NOTE: The discharge of any garbage other than food waste is prohibited in special areas. . Garbage other than Category 1 transferred to reception facilities need only be listed as a total estimated amount.

Waste Type	Date/ Time	Position of the Ship	Estimated Amount of Waste Generated Solid (m3); Liquid (L)	Category 1-6	Estimated Amount of Food Waste Comminuted and Discharged (m3)	Estimated Amount Transferred to Reception Facilities or to Other Ship Solid (m3); Liquid (L)	Estimated Amount Incinerated Solid (m3); Liquid (L)	Certification / Signature
Food Waste	1/1/17; 13:00		2 m3	5	2 m3	NA	NA	
Paper Products	1/15/17; 07:30		15 m3	3	NA	NA	15 m3	
Used Oil	2/20/17; 15:20		50 L	4	NA	50 L		

Master's Signature:

Date:

Attachment 4: SAMPLE OIL RECORD BOOK

Ship's Name: _____

Distinctive Number or Letters: _____

Gross Tonnage: _____

Period From: _____ To: _____

Machinery Space Operations (All Ships) or Cargo / Ballast Operations (Oil Tankers)

(*Delete that operation above which does not apply*)

Date	Code Letter	Item Number	Record of Operations / Signature of Officer in Charge

Master's Signature:

Date:

Attachment 5: SAMPLE CHAIN OF CUSTODY FORM FOR LAB SAMPLES

CHAIN-OF-CUSTODY RECORD

1. Facility Information:

   Facility Name_____

2. Sample Information:

   Time Sample Collected _____:_____ [ ] AM or [ ] PM (Check One)

   Date Sample Collected _____/____/_____ (Month/Day/Year)

   Name of Sampler (Print) _____

   Signature of Sampler _____

   Sampler's Company Name _____

   Analysis Information: _____

3. Chain-of-Custody: (To be completed by each person relinquishing sample)

Name (Please Print)	Signature	Facility	Relinquished To (Name / Facility)	Date mm/dd/yr	Time

4. Laboratory Shipping Information:

   Laboratory Name: _____

   Laboratory Address: _____

   _____

   Date Shipped: ____/____/____ (Month/Day/Year)

   Estimated Arrival Date: ____/____/____ (Month/Day/Year)

   Estimated Arrival Time: Collected _____:_____ [ ] AM or [ ] PM (Check One)

Attachment 6: SAMPLE MARINE TRANSPORT MANIFEST

Generator:		From	MANIFEST Nr: GUY-18-XXX
Prepared Date:	Day- Month - Year	Well Nr/Ref:	OPERATOR REF: Vessel Owner-Operator
Shipped Date:	Day- Month - Year	VESSEL:	OTHER REF:
Lease Holder:	EEPGL		DESTINATION: Georgetown Supply Base

ITEM	QTY	WASTE CAT	DG REF	UN CODE	PACKING	S/N ID/REF	OTHER REF	DESCRIPTION	OWNER
1	1	n/a	n/a	n/a	n/a	13220		Containers o/w:	
	8	8	n/a	n/a	Bags			Old Grout Bag, Non Hazardous, Non Recyclable	
	6	8	n/a	n/a	Big Bags			Sack Room Waste, Non Hazardous, Non Rec	
2	1	n/a	n/a	n/a	n/a	13190		Containers o/w:	
	6	1	n/a	n/a	Big Bags			General - Non Hazardous - Non Recyclable	
3	1	n/a	n/a	n/a	n/a	13258		Containers o/w:	
	1	3	n/a	n/a	Skip			Wood - Non Hazardous - Non Recyclable	
4	1	n/a	n/a	n/a	n/a	13262		Containers o/w:	
	1	3	n/a	n/a	Skip			Wood - Non Hazardous - Non Recyclable	
5	1	n/a	n/a	n/a	n/a	13195		Containers o/w:	
	6	8	n/a	n/a	Big Bags			Sack Room Waste, Non Hazardous, Non Rec	
								Sub Totals	

1st Transporter	2nd Transporter	Final Destination	Totals
DATE:	VEHICLE REG/ID:	DATE	VEHICLE REG/ID:
NAME:		NAME	
SIGN:		SIGN	

Grand Totals

Final destination receiver to return a completed signed copy to originator.

Waste Categories

Glass
d - Aluminium
8 Chemical Waste
9 Hospital Waste
Oily Effluents
Hydraulic / Lube Oil / Fuel
14 Mud
15 Waste Water Mud
Tetra Pack
Vegetable Oil
Others

Declaration: I hereby declare that the information contained herein, is true and correct, to the best of my knowledge:

Vessel Name: _____

Signature: _____

Name: (Print) _____

Attachment 7: SAMPLE WASTE MANIFEST

WASTE GENERATOR INFORMATION

Generator: _____
Address: _____
Contact Information: Office _____ Mobile _____email_____
Contact Person: _____ Position_____
Manifest Number:_____

WASTE INFORMATION (To be completed by waste generator)

Waste Description: ☐ Hazardous ☐ Non Hazardous

(Provide a brief description)_____
Process Generating Waste: _____
_____
Physical State ☐ Solid ☐ Liquid ☐ Sludge ☐ Other _____
Physical Properties Colour _____
Odour _____
MSDS ☐ Yes ☐ No
Special Handling Requirements ☐ Yes ☐ No
Waste Volume ☐ _____Barrels (42 Gal.) ☐_____ Drum (55 Gal.) ☐_____ Gallons
☐ _____ Cubic Meters ☐_____Pounds

DISPOSAL INFORMATION (To be completed by TTTU)

Disposal Option ☐ Recycling ☐ Thermal Desorption
☐ Incineration ☐ Landfill
Disposal Facility ☐ Tiger Tanks ☐ Haag Bosch
☐ Other (Recycling) _____
Haulage /Storage ☐ Truck ☐ HWS Skip ☐ Cuttings Box ☐ Other

WASTE RECEIPT AT GENERATORS FACILITY

Physical State ☐ Solid ☐ Liquid ☐ Sludge ☐ Other _____
Physical Properties Colour _____
Odour _____
MSDS ☐ Yes ☐ No
Waste Volume ☐ _____Barrels (42 Gal.) ☐_____ Drum (55 Gal.) ☐_____ Gallons
☐ _____ Cubic Meters ☐_____Pounds

Dispatched By: _____ Signature_____ Date _____
Received By:_____ Signature_____ __ Date_____

Attachment 8: HAZARD CLASS SYMBOLS FOR HAZARDOUS WASTE AND MATERIALS



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Appendix 2 – Stakeholder Engagement Plan

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Esso Exploration and Production Guyana Limited

Stakeholder Engagement Plan

Liza Phase 1 Development

Stabroek License Area
Offshore Guyana

[For Public Disclosure]

February 2017

Contents

1 INTRODUCTION 1
1.1 Objectives 1
2 ADMINISTRATIVE FRAMEWORK 2
2.1 The Environmental Protection Act 2
3 STAKEHOLDER ENGAGEMENT STRATEGY 3
3.1 Overview 3
3.2 Stakeholder Identification Methodology 3
3.3 Stakeholders 4
3.4 Roles and Responsibilities 8
3.5 Conclusion 9
Appendix A: LIZA PHASE 1 EIA – SUMMARY OF STAKEHOLDER ENGAGEMENT ACTIVITIES 10
A.1 Overview of Engagement Activities to Date 10
A.2 Overview of Planned Activities 10

Figures

Figure 1: Example Liza 1 Development Workshop Stakeholder Map 5
Figure 2: Example Stakeholder Engagement Strategy for EIA Development 6

Glossary

Terms	Description
Stakeholder	Any individual or group who is affected by a project or may have an interest in, or influence over it
Consultation	The process of sharing information, ideas and concerns in a two-way dialogue between project proponents and stakeholders, allowing stakeholders to express their views and for these to be considered in the decisions about project planning and implementation
Disclosure	The process of publishing and making available information in various ways (such as on the internet, in paper form or in press announcements)
Engagement	General term for activity including disclosure and consultation
Environmental Impact Assessment (EIA)	A systematic process for identifying and managing the potential environmental, social and health aspects, impacts and related risks associated with major projects
Environmental Management Plan (EMP)	A project-specific plan developed to identify and implement measures to protect the environment and comply with environmental legislation
Environmental and Social Management Plan (ESMP)	A system to manage the environmental and social risks and impacts of a project's activities
Esso Exploration and Production Guyana Limited (EEPGL)	A subsidiary of ExxonMobil in Guyana
Feedback	Formally issued inquiry, comment, concern or complaint about the Project or associated activities by individuals or organizations
Feedback Mechanism	Process by which inquiries, comments, concerns or grievances are formally submitted by interested parties, and tracked and addressed by the Project proponent
Strategic Environmental Assessment (SEA)	A systematic decision support process to consider environmental and possibly other sustainability aspects during the planning phases of a project
Terms of Reference (TOR)	Document that describes the purpose, scope, limitations and structure of a project or process

1 INTRODUCTION

The Esso Exploration and Production Guyana Limited (EEPGL) Stakeholder Engagement Plan (SEP) is designed for an ongoing exchange of information that allows the Company to 1) identify, understand and address community/stakeholders priorities and concerns, and 2) improve decision-making and transparency. This is an evergreen document that will evolve according to EEPGL activities. For example, Appendix 1 is the Liza Phase 1 EIA – Summary of Stakeholder Engagement Activities.

Environmental Resources Management (ERM) has been contracted by EEPGL to support the Liza Phase 1 environmental permitting process, including completion of the Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA) and associated stakeholder engagement activities. All efforts occur on behalf of EEPGL.

1.1 Objectives

This SEP has been developed to meet the expectations of the company, regulators and the communities. The SEP describes the stakeholder identification process and outlines an engagement program to promote meaningful, timely and effective engagement with stakeholders. It builds on previous engagement efforts, including those documented in the SEA and those underway for Liza Phase 1 EIA.

Engaging stakeholders is an important aspect of managing ongoing social and environmental performance and non-technical risks.

The objectives of stakeholder engagement are to:

- Promote the development of respectful and open relationships between stakeholders and EEPGL;
- Identify stakeholders and understand their interests, concerns and influence in relation to ongoing activities;
- Provide stakeholders with timely information about Company activities, in ways that are appropriate to their interests and needs;
- Support alignment with the Government of Guyana requirements and corporate standards and guidelines for stakeholder engagement;
- Record feedback and resolve any grievances that may arise through a formal feedback mechanism.

2 ADMINISTRATIVE FRAMEWORK

Socioeconomic and stakeholder components are considered in a number of laws, including the Environmental Protection Act. Additionally, Guyana is a signatory to a number of international and regional conventions and protocols aimed at addressing socioeconomic and stakeholder concerns. EEPGL proposes to conduct stakeholder engagement to comply with the spirit and intent of these laws, Guyana National Plans, and international agreements, including those outlined in the Liza Phase 1 EIA Terms of Reference (TOR).[1]

2.1 The Environmental Protection Act

In 1996, the Environmental Protection Act (hereinafter referred to as the Act) was enacted to implement the environmental protection provisions of the Constitution. The Act is Guyana's single most significant environmental legislation because it articulates national policy on important environmental topics such as pollution control, the requirements for environmental review of projects that could potentially impact the environment, and the penalties for environmental infractions. Most importantly, the Act authorized the formation of the Environmental Protection Agency (EPA), and establishes the EPA as the lead agency on environmental matters in Guyana (FAO, 2013). The Act further mandates the EPA to oversee the effective management, conservation, protection and improvement of the environment (EPA, 2012). It also requires the EPA to take the necessary measures for the prevention and control of pollution, assessment of the impact of economic development on the environment, and the sustainable use of natural resources.

The Act outlines the process for conducting an EIA with timeframes for some step. It specifically regulates stakeholder involvement. The stakeholder engagement process describes how a project proponent should undertake consultation to provide stakeholders with opportunities to express their views on project risks, impacts and mitigation measures, and to allow the project to consider and respond to them. There is a 28-day public consultation period for the scoping phase in which a Project Summary is submitted and the 60-day public consultation period after the entire Draft EIA is submitted.

Outside of and in addition to these EIA public consultation periods, EEPGL is committed to promoting and providing means for adequate engagement with stakeholders throughout the project lifecycle on issues that could potentially affect them and so that relevant environmental and social information is disclosed and disseminated. EEPGL's ongoing and planned engagement activities are complementary to EIA-regulated disclosure periods.

[1] *Terms of Reference (TOR) define the scope and intention of the Liza 1 Project EIA*

3 STAKEHOLDER ENGAGEMENT STRATEGY

3.1 Overview

The stakeholder engagement strategy is one component of managing project risk by familiarizing stakeholders with EEPGL's activities and efforts to protect safety, health and the environment, incorporate stakeholder input into business decisions, and build a positive relationship between EEPGL and the community.

EEPGL's engagement strategy:

- Proactively identifies and engages stakeholders to provide an overview and understanding of activities;
- Collects stakeholder input for the identification of potential impacts and associated management plans;
- Facilitates the consideration of stakeholder input when making business decisions;
- Outlines a mechanism to address concerns/grievances in a timely manner;
- Monitors and reports trends.

The stakeholder engagement strategy integrates the following elements:

- Identification and assessment of stakeholders;
- Mechanisms, methods, and tools for engagement;
- Engagement activities that have been undertaken to date;
- Planned engagement activities;
- A formal stakeholder feedback mechanism;
- Monitoring and reporting of engagement activities.

3.2 Stakeholder Identification Methodology

One of the first steps in stakeholder engagement planning is the identification of stakeholders. Stakeholders typically include government officials, regulators, co-venturers, members of the community and public at large, non-governmental organizations (NGOs) and civic leaders, media, employees and contractors, and industry associations. Stakeholders can be individuals working on a project, groups of people or organizations, or even segments of a population. A stakeholder may be actively involved in a project's work, affected by the project's outcome, or in a position to affect the project's success.

To develop an effective SEP, it is necessary to identify stakeholders and to understand their needs and expectations for engagement, and their priorities and objectives in relation to the Project.

As part of this process it is particularly important to identify individuals and groups who may find it more difficult to participate and those who may be differentially or disproportionately affected

by the project because of their marginalized or vulnerable status. It is also important to understand how stakeholders may be affected – or perceive they may be affected – so that ongoing engagement can be tailored to inform them in an appropriate manner and address their views and concerns.

One way to characterize stakeholders is by their relationship to the effort in question, for example:

- *Primary stakeholders* are the people or groups that stand to be directly affected, either positively or negatively, by an effort or the actions of an agency, institution, or organization;
- *Secondary stakeholders* are people or groups that are indirectly affected, either positively or negatively, by an effort or the actions of an agency, institution, or organization;
- *Key stakeholders*, who might belong to either or neither of the first two groups, are those who can have a positive or negative effect on an effort, or who are important within or to an organization, agency, or institution engaged in an effort.

While an interest in an effort or organization could be just that – intellectually, academically, philosophically, or politically motivated attention – stakeholders are generally said to have an interest in an effort or organization based on whether they can affect or be affected by it. The more they stand to benefit or lose by it, the stronger their interest is likely to be; and the more heavily involved they are in the effort or organization, the stronger their interest is as well.

Stakeholders' interests can be many and varied. A few of the more common include:

- Economics;
- Social Change;
- Labor;
- Environment;
- Safety and Security.

3.3 Stakeholders

Stakeholders are identified at the beginning of new activities. Once identified, stakeholders are assessed based on their anticipated degree and topics of interest, as well as their role in processes which may affect activities. (Figure 1) The information is input into a stakeholder log. The SEP is an evergreen document, so additional stakeholders will be added to the stakeholder log as they are identified. Potential stakeholders, including those identified through the EIA baseline data collection process, are listed in Annex A. This table is not exhaustive.

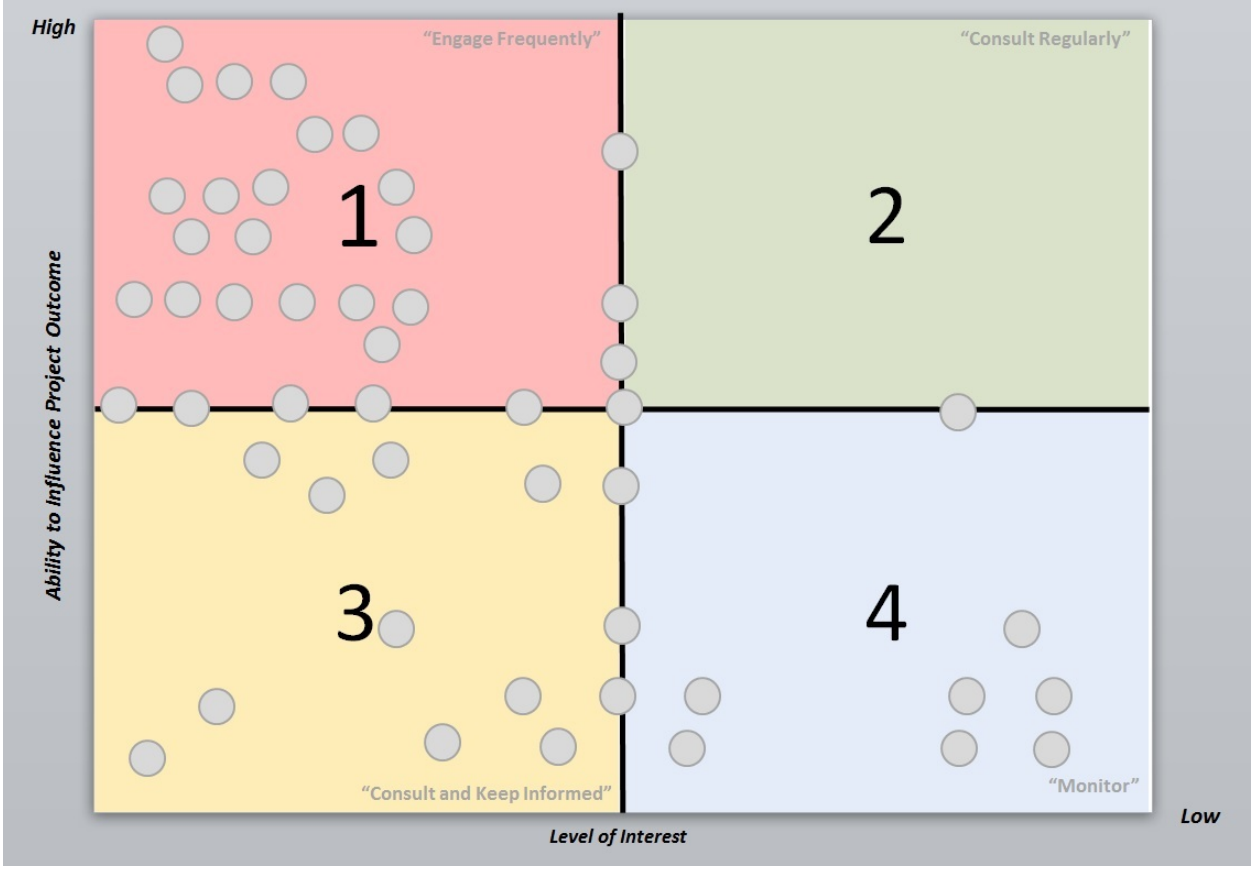


Figure 1: Example Liza 1 Development Workshop Stakeholder Map

Methods and Tools

EEPGL's stakeholder engagement strategy includes methods and tools to facilitate stakeholder communication and dissemination of public information. As shown in Figure 2, the different types of methods employed interact to allow informed engagement. The first method is information provision, which offers stakeholders information to support their understanding of the proposed activities. The other methods are consultation, which supports dialogue and active receipt of stakeholder feedback/input based on the information provided, and incorporation of input. These methods capture opinions, concerns and knowledge on how activities may interact with a stakeholder's natural and social environment, allowing EEPGL to gather information concerning topics that are important to its stakeholders. These activities provide stakeholders an opportunity to ensure their comments and opinions are heard and concerns addressed.

The tools and mechanisms listed in italics in Figure 2 describe how EEPGL intends to provide information to stakeholders, consult with and solicit information from stakeholders, and report back on how stakeholder input has been incorporated into key documents such as project plans.

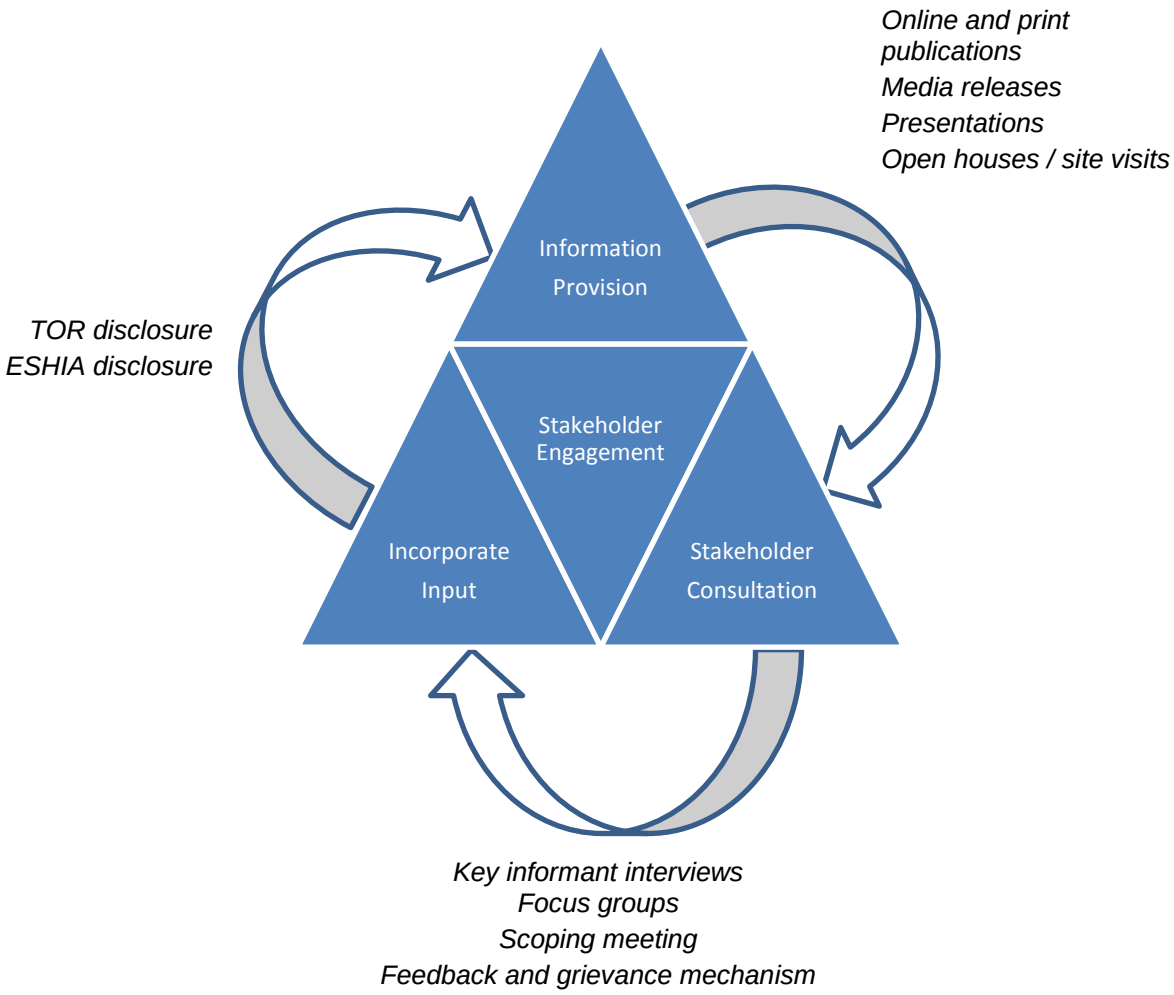


Figure 2: Example Stakeholder Engagement Strategy for EIA Development

Information Provision activities provide information to a broad audience or group of stakeholders as efficiently as possible. Activities include dissemination of online material and print publications, media releases, presentations and open houses.

Stakeholder Consultation activities involve a two-way flow or exchange of information between stakeholders and the Project. Activities include one-on-one and small group meetings, public meetings including a question and answer session, town hall meetings, feedback mechanism such as a webpage, email address or dedicated phone line.

Incorporate Input activities include TOR disclosure and ESHIA disclosure, which includes making the documents available for review and comment.

Stakeholder Grievance Mechanism

EEPGL has a community grievance mechanism (CGM) for stakeholders to provide feedback related to any issues or concerns, guidance, requests and/or complaints (considered grievances) associated with activities. The Project will address these in good faith through a transparent and impartial process.

Objectives of the CGM are:

- Provide stakeholders with a mechanism to communicate feedback, issues or concerns requests and/or complaints to EEPGL in a timely manner so that they can be addressed quickly and proactively
- Process so they are acknowledged, tracked and addressed by EEPGL in a timely and confidential manner
- Continuously improve Project performance in all areas
- Demonstrate EEPGL's commitment to meaningful stakeholder engagement and respect for local opinions and concerns

For a full description of the CVM please refer to the Environmental and Socioeconomic Management Plan (ESMP).

EEPGL will consider any feedback that it receives as a critical component of the broader stakeholder engagement activities, including monitoring and reporting.

Stakeholders can contact EEPGL to submit feedback in three ways:

1. In person, either to an EEPGL employee or representative;
2. Via telephone – (592) 231 2866, extension 12400; or
3. Via email –Guyanastaff@exxonmobil.com

NOTE: The EPA prescribes that stakeholder feedback and comments related to SEA/EIA should be addressed to:

The Environmental Protection Agency

c/o Director – Environmental Management Permitting Division

Ganges Street, Sophia, Georgetown

Phone: 225-0506 / 225-5467-8 / 225-5471-2

Fax: 225-5481

E-mail epa@epaguyana.org

Website: www.epaguyana.org

Monitoring and Reporting

Monitoring is an important part of determining the effectiveness of the activities undertaken, and revising them, as required, to ensure effective engagement. A tool is used to log all engagements with stakeholders, and capture feedback received from stakeholders. This tool allows for an analysis of trends in stakeholder interest and concern, which will help EEPGL design further engagement programs and activities.

As part of EEPGL's management systems, performance indicators are assigned to the monitoring process and will be tracked for completion. A number of key performance indicators will be monitored by EEPGL on a regular basis in relation to stakeholder engagement measures. These may involve the following parameters:

- Number of consultation meetings and other public discussions /forums conducted within a period (e.g. monthly, quarterly, or annually)
- Number of grievances received within a period (e.g. monthly, quarterly, or annually)
- Number of those closed within the prescribed timeline and the reason for aged grievances within the prescribed timeline and trends
- Type of public grievances received and trends

3.4 Roles and Responsibilities

In order for a SEP to be implemented successfully, adequate resources and responsibilities need to be designated. Please note that this does not include roles assigned to the Government of Guyana and the EPA.

Role	Responsibilities
EEPGL	
Lead Country Manager	• Review and approve SEP • Assist in implementation of the SEP
Public and Government Affairs Manager	• Review and approve SEP to ensure alignment with current affiliate stakeholder engagement information, philosophies, activities, and relationships • Own and steward the affiliate's feedback mechanism, including the management of grievances • Assist in the development and implementation of the SEP • Assist in documentation of engagements conducted • Help maintain a comprehensive archive on captured data
SSH&E Manager	• Review and approve the SEP • Review and authorise any financial provisions for stakeholder engagement (tied to SEA/EIA Stakeholder engagement)
ER&S Lead	• Review, approve and steward the SEP to ensure it meets permitting requirements • Assist in the definition, development and implementation of the SEP, ensuring correct application of the EEPGL internal requirements • Periodically review progress in the development and implementation of stakeholder engagement activities • Periodically review SEP, monitoring outcomes, and elaborate where necessary

Role	Responsibilities
Service Department and Business Leads/Advisors and Contractors	• Conduct engagements as directed by the affiliate and/or ER&S Lead • Complete all reporting including outcomes and stakeholder input for all engagements
Houston based ExxonMobil Management	
Project Leadership	• Provide adequate resources to implement the SEP • Ensure that the SEP is designed, developed and implemented as per legal requirements and ExxonMobil requirements for all operations
ERM	
Environmental and Social Consultant	• Engage with stakeholder to explain EIA process and collect information required to complete a robust EIA • Document all engagements conducted • Maintain a comprehensive archive on all items captured / generated during / related to the conduct of the EIA (lists of concerns / issues / comments, newspaper articles, handouts / posters developed, fact sheets, etc.).

3.5 Conclusion

This SEP will be periodically revised and updated as necessary according to EEPGL ongoing activities. This will help to maintain the validity and adequacy of the information presented, and that the identified methods of engagement remain appropriate in relation to the legislative requirements and specific phases of the Project development. Any major changes to the Project activities and to its schedule will be duly reflected in the SEP.

APPENDIX A: LIZA PHASE 1 EIA – SUMMARY OF STAKEHOLDER ENGAGEMENT ACTIVITIES

Ongoing positive stakeholder relationships throughout the entire lifecycle of a project are critical to its success. Stakeholder engagements are in progress, and will continue specifically through the environmental authorization application and the corresponding EIA processes.

A.1 Overview of Engagement Activities to Date

EEPGL began pro-active communication regarding the company's activities in 2013 to lay the groundwork for establishing and maintaining stakeholder relations. Informational meetings and exchanges of information were conducted between the Project team members and key external audiences, including government officials, stakeholders within the general public, and representative non-governmental organizations. In addition to being a good business practice, these early engagements helped to inform the Strategic Environmental Assessment that was submitted to the EPA in March 2014.

Stakeholder engagements have been ongoing since then and included meetings with individual stakeholders, public forums and training for local agencies and officials in the form of workshops on topics such as oil spill response. Newspaper notifications were printed in July 2016 to increase public awareness.

A schedule of the larger and more structured stakeholder engagement activities is presented in Annex A. Not all stakeholder engagement activities are included, for example, face-to-face meetings which are part of the normal course of business for EEPGL.

A.2 Overview of Planned Activities

The intention of EEPGL is to undertake a sufficient level of engagement to keep the public and interested parties aware of its progress and milestones and to facilitate stakeholder feedback.

A.2.1 Regular government engagement

Continuous engagements with government and agencies that have oversight of the Project, such as the Ministry of Natural Resources, Guyana Geology and Mines Commission and Environmental Protection Agency, will take place throughout the lifecycle of the project.

A.2.2 Environmental Application and Public Comment Period

Stakeholders had the opportunity through a 28-day public review period to provide input on EPA's determination on whether an EIA was required. The EPA determined an EIA is required.

A.2.3 TOR and Public Comment Period

EEPGL held face-to-face meetings with select members of civil society to provide specific Project information prior to the TOR submittal. Stakeholders had the opportunity through a series of six sector and public scoping meetings to provide input into the issues and concerns

they wish to be considered within the EIA. Once the TOR was submitted, EEPGL held regular meetings with the EPA and Guyana Geology and Mines Commission to discuss the submittal.

A.2.4 EIA Baseline Data Collection

On behalf of EEPGL and as part of the EIA preparation, ERM held key informant interviews with the following stakeholders in an effort to collect relevant baseline data:

- Ministry of Agriculture, including the Department of Fisheries;
- Ministry of Communities;
- Ministry of Public Health;
- Department of Tourism;
- Ministry of Social Protection;
- Ministry of Indigenous Peoples Affairs;
- Ministry of Public Infrastructure ;
- Maritime Administration Department;
- Guyana Land and Surveys Commission;
- Bureau of Statistics;
- National Trust of Guyana;
- Private Sector Commission;
- Protected Areas Commission;
- University of Guyana Centre for the Study of Biological Diversity;
- Guyana Marine Conservation Society;
- Conservation International;
- World Wildlife Fund;
- Association of Trawler Owners and Seafood Processors;
- National Aquaculture Association of Guyana;
- Guyana Rice Producers' Association;
- Supenaam-Parika Speedboat Owners' Association;
- Mainstay Amerindian Village;
- Vilvordeen-Fairfield Women's Association;
- Pomeroon Women's Agro-Processors Association;
- West End Agricultural Development Society;
- Big Bird & Sons Fishing Complex (Charity);
- Lima Fishermen's Development Co-op;
- Georgetown Fishermen's Co-op Society Ltd.;
- Parika Fishermen's Development Co-op;
- Ogle International Airport;

- African Culture Development Association;
- Guyana Hindu Dharmic Sabha;
- Region 2 Development Council.

A.2.5 EIA Preparation

Through 2016, the EEPGL team has planned for additional targeted one-on-one meetings with the EPA, Guyana Geology and Mines Commission and civil society in addition to larger and more structured engagements such as:

- October 2016: Scoping meeting with key agencies and informants to define potential impacts and scope of study; and
- October/November/December 2016: Public Scoping Meetings for all interested stakeholders to provide Project information, solicit questions and input from the public
  - Region 1 public consultation was held on November 11, 2016;
  - Region 2 public consultation was held on October 26, 2016;
  - Region 3 public consultation was held on October 24, 2016;
  - Region 4 public consultation was held on December 3, 2016;
  - Region 5 public consultation was held on December 2, 2016;
  - Region 6 public consultation was held on November 8, 2016.

A.2.6 Draft EIA Submittal and Public Comment Period

Once EEPGL submits the Draft EIA, a 60-day public comment period will begin. Per the Environmental Protection Act, during the course of the environmental impact assessment, the developer and the person carrying out the environmental impact assessment shall consult members of the public and interested bodies and organizations.

It is anticipated that in addition to public consultation meetings led by ERM, EEPGL will also conduct round-table meetings with groups of stakeholders (NGOs; members of interest groups, etc.) to discuss the preliminary EIA impacts and proposed mitigating measures, to seek feedback on progress and to help identify gaps/issues which may need to be addressed in more detail or new concerns/issues that need to be further investigated.

A.2.7 Other Engagements

The Project is committed to provide stakeholders with regular access to information about the activities as well as access to a feedback mechanism through which stakeholders may provide input and receive response to feedback.

Annex A: Sample of Identified Potential Stakeholders

Stakeholder Category	Interest in Project	Potential Stakeholders
Regulatory /Government	National authorities have an interest in the EIA and permitting procedures and Guyanese resources. Local and regional authorities have a general interest in potential impacts and benefits to their respective communities, and may facilitate engagement with local communities. Provides permits for Project activities and business licenses for onshore and offshore facilities.	President of Guyana; Ministry of Natural Resources; Sectoral Committee on Natural Resources; Members of Cabinet; Opposition Government leaders, Guyana Geology and Mines Commission; Environmental Protection Agency; Protected Areas Commission; Government Information Agency; Civil Defense Commission; Guyana Maritime Administration Department; leadership of Regions 1-10; Attorney General; Civil Aviation Authority; Guyana Defence Force; Transportation and Harbors Department; Pesticides and Toxic Chemicals Board; Hydrometeorological Service; Guyana Forestry Commission; Guyana Tourism Authority; Bureau of Statistics; National Trust of Guyana; Toashao's council
Community	Communities who may potentially be impacted positively or negatively by Project activities, or are concerned that they may be impacted.	Georgetown residents; coastal beach users/residents; indigenous people; commercial fishermen
Civil Society, Interest Groups, NGOs	Non-governmental or other organizations and entities that may be interested in a diverse set of issues including environmental protection, socioeconomic development and human rights.	NGOs focused on indigenous peoples' issues; Conservation International; World Wildlife Fund; Religious organizations; Guyana Marine Conservation Society; Mangrove Restoration Project; ECO1
Private Sector	Businesses of any scale that could be affected positively or negatively by the Project.	Fuel and Waste; SURF, Drilling, FPSO Shorebase Contractors
Media	News media outlets that may range from local to international in distribution.	Stabroek News, Kaieteur News, Guyana Chronicle, Guyana Times, www.demerarawaves.com, www.inewsguyana.com, www.newsroom.gy, www.newsourcegy.com, www.newsnow.gy, www.citizensreportgy.com, www.gnnonline.com, National Communications Network TV
Academic Institutions	Academic institutions or foundations that provide research on specific topics of interest.	National Agricultural Research and Extension Institute; Caribbean Agricultural Research and Development Institute; Universities and technical institutes
Professional, Business and Workers' Associations	General or industry-specific associations with interest in how Project activities may represent opportunities for the members or impacts to them.	Private Sector Commission; Guyana Oil & Gas Association, Guyana Manufacturing and Services Association; Guyana Association of Trawler Owners and Seafood Processors; Shipping Association of Guyana; Chambers of Commerce; Rotary Clubs; National Aquaculture Association of Guyana; Tourism and Hospitality Association of Guyana

Annex B : Synopsis of Stakeholder Engagement Activities

SYNOPSIS OF PREVIOUS STAKEHOLDER ENGAGEMENT ACTIVITIES			
Project Activity	**Objective / Desired Outcome**	**Stakeholders / Audience**	**Potential Concerns, Issues & Sensitivities**
Liza-1 Well Drilling Program [August 2011 to November 2013]	Liza-1 well SEA and Environmental Permit	Ministry of Natural Resources	Available skilled/unskilled labor in oil and gas operations
		GGMC	Meeting or exceeding GOM standards Education and communication on Project and Deepwater OSRP
		EPA	• First Deepwater well in Guyana • Resource-or constituency – related concerns
		Natural Resource Management Division of EPA	Potential impact on fisheries resources and supporting coastal ecosystems
		Environmental Assessment Board	First Deepwater well in Guyana
		Ministry of Labor, Human Services and Social Security, and Special Department of Occupational, Safety and Health Department	Local employment
		• Ministry of Labor, Human Services and Social Security • Special Department of Occupational, Safety and Health Department	Occupational, Health and Safety requirements
		Ministry of Local Government and Regional Development	Potential effect on communities
		Guyana Defense Forces and Guyana Police Forces	• Port Security issues • Road Safety through Town
		Ministry of Local Government – Solid Waste Management Department	Capacity and stability of waste management facility
		Ministry of Public Works, and Maritime Administration Department (MARAD)	• Maritime issues, maritime traffic • Security issues, incidents
		Transportation and Harbors Division, and Harbour Master	Wharf/Port access and development
		National Trust Department	• Cultural heritage issues • Archaeological finds
		Mangrove Restoration Project – National Agriculture Research and Extension Institute (NARI)	• Risk and impact to Mangrove ecosystem • Impacts on coastal livelihood artisan fishing, beekeeping and sea defense protection
		Guyana Marine Turtle Conservation Society (GMTCS) and Volunteer Youth Corp (Math and Science Initiative)	• Potential disturbance to sea coastline and transboundary movement • Community and social benefits from Project • Impacts of sound and noise from exploration on sea turtles and other

SYNOPSIS OF PREVIOUS STAKEHOLDER ENGAGEMENT ACTIVITIES			
Project Activity	**Objective / Desired Outcome**	**Stakeholders / Audience**	**Potential Concerns, Issues & Sensitivities**
			sensitive biodiversity • Blowout Prevention and emergency response
Six-Well Drilling Program (Liza-2 and Liza-3 wells) [mid-December 2015 to February 2016]	Six-well Drilling Program EMP and Environmental Permit(s) and present out comes of Multi-well EMPA Process	EPA, GGMC, CI, WWF and other external stakeholders	• Marine sound • Waste management • Effluent discharge standards • Oil spill preparedness and response
	Ongoing dialogues with agencies	EPA/GGMC	Ongoing clarity of EMP and permit status. Discussing document comments and revisions
Liza Phase 1 Development EIA [July 2016 to present]	• Presidential briefing • Continue to build public support for the Project and confidence EEPGL capability. • Identify potential roadblocks/issues before they cause project risk.	President of Guyana	• Legislative requirements, policy requirements, general compliance and project support. • Economic development and local workforce and supplier participation in the project
	• General briefing • Ensure timelines and process is well understood. • Identify potential roadblocks/ issues before they cause project risk.	EPA/GGMC	• Legislative requirements, policy requirements, general compliance and project support. • Capacity concerns due to increasing activities in sector • Evolving regulations and legislation that can affect the agency • Pressure to evolve regulations to meet international standards
	EIA information sharing and baseline data collection interviews	Ministry of Agriculture, Department of Fisheries	• Potential overlap of Project activity with new deep-sea tuna fishery • Potential security concerns related to illegal fishing vessels entering FPSO exclusion zone
		Ministry of Communities	No Project-specific concerns/issues identified
		Ministry of Public Health	• Potential for added burden on Guyanese health system • Potential for social investment in the health sector
		Department of Tourism	• Possible changes to Guyana's image as a "green" nation
		Ministry of Social Protection	• Proper fulfilment of OHS requirements for contractors; ensure contracts are clear on who is responsible • Proper payment and documentation for worker insurance coverage • Potential for informal communities to arise, with potential for prostitution or other exploitation
		Ministry of Indigenous Peoples Affairs	Need for consultation with indigenous communities in Region 1
		Ministry of Public Infrastructure	Possible traffic disruption if offsite storage facilities are used
		Maritime Administration Department	Maintenance of maritime safety and security in Project area
		Guyana Land and Surveys Commission	• Current land speculation in relation to the Project

SYNOPSIS OF PREVIOUS STAKEHOLDER ENGAGEMENT ACTIVITIES			
Project Activity	**Objective / Desired Outcome**	**Stakeholders / Audience**	**Potential Concerns, Issues & Sensitivities**
			• GLSC vetting of any new data produced
		Bureau of Statistics	Project information required to develop economic indicators for the country's new petroleum sector
		National Trust of Guyana	• No Project-specific concerns or issues identified • Interest in CSR support
		Private Sector Commission	• Ensure appropriate local content targets • Accountability and involvement in proper management and investment of the country's revenues from the Project • EPA capacity • Retention of institutional knowledge and experience from this Project
		Protected Areas Commission	Potential impacts of an oil spill on Shell Beach; recommendation for consultation with the 18 communities living on or adjacent to Shell Beach
		University of Guyana Centre for the Study of Biological Diversity	Lack of data regarding pelagic species beyond the continental fish
		Guyana Marine Conservation Society	• EPA/EEPGL transparency; availability of data and studies conducted to date for the Project • Recommendation for consultation with indigenous communities
		Conservation International	• Short timeline of the EIA and lack of EPA capacity • Appropriate use of mitigation hierarchy • Participation of ExxonMobil in the sustainable development of the country
		World Wildlife Fund	No Project-specific issues or concerns identified
		Association of Trawler Owners and Seafood Processors	No Project-specific concerns identified; the Project will be well seaward of trawling activity
		National Aquaculture Association of Guyana	No Project-specific concerns or issues identified; fish farms are segregated from seawater intrusion using the same irrigation and drainage systems as rice fields.
		Guyana Rice Producers' Association	• Main concern for rice industry is improved access to lower cost fuel, which is a significant industry input. • No other concerns or issues identified; rice fields are protected from potential seawater intrusion (and thus oil spills) by elaborate drainage and irrigation systems whereby fields are always upgradient of tidally influenced drainage canals
		Supenaam-Parika Speedboat Owners' Association	No Project-specific issues or concerns identified
		Mainstay Amerindian Village	Reliance of Amerindian communities on natural resources

SYNOPSIS OF PREVIOUS STAKEHOLDER ENGAGEMENT ACTIVITIES			
Project Activity	**Objective / Desired Outcome**	**Stakeholders / Audience**	**Potential Concerns, Issues & Sensitivities**
		Vilvordeen-Fairfield Women's Association	No Project-specific issues or concerns identified
		Pomeroon Women's Agro-Processors Association	• Interested in whether fuel costs will go down • Potential for damage to livelihoods in event of a spill for those residing near the mouth of the Pomeroon River
		West End Agricultural Development Society	No Project-specific issues or concerns identified
		Big Bird and Sons Fishing Complex	No Project-specific issues or concerns identified
		Lima Fishermen's Development Co-op	No Project-specific issues or concerns identified
		Georgetown Fishermen's Co-op Society Ltd.	• Potential for oil spills and their impact on those directly and indirectly employed by fishing • Expected communication from EEPGL sooner, given that exploration has been ongoing
		Parika Fishermen's Development Co-op	No Project-specific issues or concerns identified
		Ogle International Airport	No Project-specific issues or concerns identified
		African Culture Development Association	• Use of Kingston seawall area for festivals and religious ceremonies • Local employment, including skills and technology transfer
		Guyana Hindu Dharmic Sabha	• Use of seashore for religious ceremonies, including funerals • Community investment
		Region 2 Development Council	• Importance of face to face consultation with Region 1 and 2 local stakeholders • Potential for spills • EPA capacity • Community investment
	Two (2) Agency EIA scoping meetings led by EPA	Multiple public and private agencies and NGOS including EPA, GGMC, Ministry of Public Health, Ministry of the Presidency, PAC, GMCS, WWF, CI, others.	• Oil spill response procedures and capabilities • Timing and process for updating TOR to reflect scoping comments • EIA methodology including existing conditions data collection, types of surveys and studies, limitations, predictive analysis and consideration for mitigation • Area of Influence (AOI) determinations • Subcontractor management and monitoring, logistical support rrequirements, and shorebases • Decommissioning • Type of anchor mooring on offshore vessels, types of SURF and FPSO equipment and methods • Strategic Environmental Assessment (SEA) details, current and previous stakeholder engagement

SYNOPSIS OF PREVIOUS STAKEHOLDER ENGAGEMENT ACTIVITIES			
Project Activity	**Objective / Desired Outcome**	**Stakeholders / Audience**	**Potential Concerns, Issues & Sensitivities**
			• Other potential uses of produced gas • Government revenues from Project • Local employment
	Six (6) Public EIA scoping meetings (Regions 1-6) led by EPA	Various national, regional and local agency representatives as well as private citizens.	• National and local benefits, proper management/oversight of revenues • Local employment • Oil spill response procedures and capability • Impacts to air quality • Impacts to marine species • Impacts to fishing • Impacts to coastal resources • Impacts to indigenous people, lands, and resources • Oil spill potential impacts and locations • Potential for social changes such as trafficking, prostitution, and drugs • Role of MMO and MMO data availability • Waste management and discharge • Use and disposal of hazardous substances • Management and use of producted gas • Creditials and experience of the company developing the EIA • Impact of potential natural disaster on Project infrastructure and development area • Recommendations to increase public participation at scoping meetings • Other potential uses for produced gas

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Appendix 3 – Preliminary End of Operations Decommissioning Plan

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Esso Exploration and Production Guyana Limited

Preliminary
End of Operations Decommissioning Plan

February 2017

Contents

1 INTRODUCTION 1
1.1 Purpose and Objectives 1
1.2 Project Overview 1
1.3 Scope 2
2 LEGAL FRAMEWORK 3
3 MAJOR DECOMMISSIONING COMPONENTS AND ACTIVITIES 3
3.1 Prior to Decommissioning 3
3.2 Development Wells 4
3.3 Subsea Equipment 4
3.4 FPSO 4
3.5 Decommissioning Waste 4
4 MITIGATION AND MONITORING 4
4.1 Description of Embedded Controls for Decommissioning 5
4.2 Description of Mitigation Measures for Decommissioning 6
4.3 Description of Monitoring Program 6
5 SCHEDULE 7
6 INFORMATION MANAGEMENT AND REPORTING 7
7 TRAINING AND ENVIRONMENTAL AWARENESS 7

Figures

Figure 1: Preliminary Liza Phase 1 Field Layout 2

1 INTRODUCTION

Esso Exploration and Production Guyana Limited (EEPGL) is the Operator for the development of the Liza prospect in the eastern half of the Stabroek Block (hereafter referred to as the Liza Phase 1 Development Project, or the Project), which is located approximately 190 km (~120 mi) offshore from Georgetown.

1.1 Purpose and Objectives

The purpose of this Preliminary End of Operations Decommissioning Plan (hereafter the Plan) is to provide a preliminary plan for the proposed abandonment and decommissioning of Project wells and facilities at the end of operations, and to describe the anticipated work required to confirm that the abandoned facilities will be left in a condition that avoids harm to the environment.

The objectives of this Plan are to:

- Describe the proposed methods for the safe abandonment, removal, disposal, and/or decommissioning of the Project assets; and
- Describe the plans for managing potential impacts as a result of decommissioning activities through mitigation measures and monitoring.

1.2 Project Overview

The Liza field will be developed during Phase 1 with approximately 17 development wells drilled from two drill centers, each with separate production, gas, and water injection manifolds. Figure 1 illustrates the preliminary field layout of the proposed Liza field development, which includes the development wells, SURF, and a spread-moored FPSO vessel. The facility layout will continue to evolve during the design development process. The various components shown on Figure 1 are further described in the relevant Drilling, SURF, and FPSO sections in Chapter 2 of the Liza Phase 1 Environmental Impact Assessment (EIA).

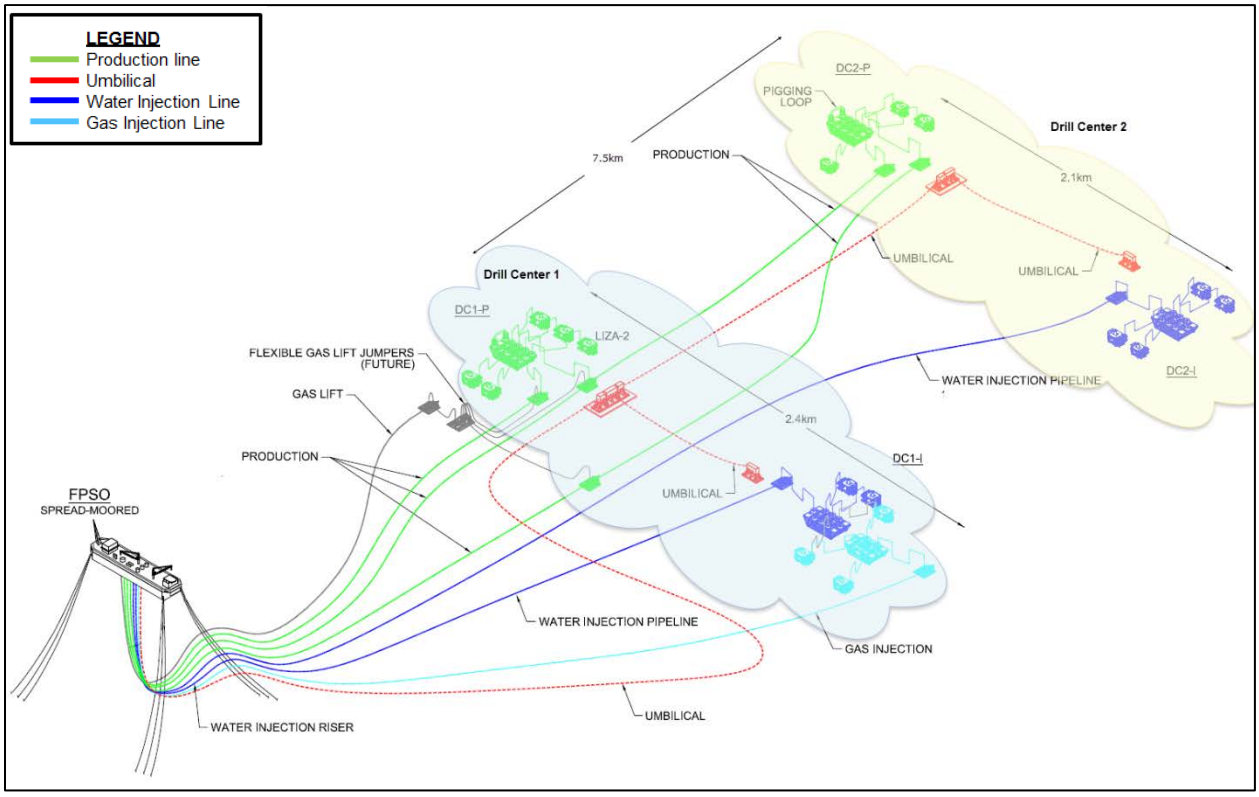


Figure 1: Preliminary Liza Phase 1 Field Layout

1.3 Scope

The scope of this Plan covers the preliminary plans for the plugging and abandonment of the development wells and the decommissioning of Project production facilities. As the Project approaches the end of field life (e.g., several years prior to commencement of decommissioning), it is envisioned that this Plan will be revised to cover the ultimate decommissioning of the facility in compliance with the laws and regulations in effect at that time, while also considering the technology available at that time. This Plan was developed as part of the Environmental and Social Management Plan (ESMP), and as described in the EIA. The current scope of abandonment and decommissioning activities includes:

- Subsurface – approximately 17 development wells;
- Subsea – trees, manifolds, jumpers, flowlines, umbilical, risers, and other subsea equipment;
- FPSO vessel – marine vessel, topsides facilities, and the vessel mooring system; and
- End of operations-related waste.

2 LEGAL FRAMEWORK

The offshore decommissioning process is regulated by a framework of international conventions and guidelines, regional seas conventions, and national legislation. Guyana is currently a party to some of these international conventions and guidelines that pertain to offshore decommissioning, such as:

- United Nations Convention on the Law of the Sea (UNCLOS);
- Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal;
- IMO Guidelines for the Removal of Offshore Installations and Structures (1989).

The decommissioning plan and strategy will be based on a notice of the intent for plugging and abandonment of the development wells and decommissioning the production facilities, which will be provided to the appropriate Guyanese agencies, (e.g. GGMC, EPA) to obtain approval in accordance with the following requirements, or with future applicable legislation:

- Environmental Protection Act (1996);
- Guyana Petroleum (Exploration and Production) Act (1998).

Section 2 of the ESMP further identifies these international conventions, guidelines, and laws; summarizes their relevance to the Project; and articulates the environmental performance criteria they impose.

3 MAJOR DECOMMISSIONING COMPONENTS AND ACTIVITIES

3.1 Prior to Decommissioning

EEPGL will perform inspections, surveys, and testing to assess current conditions that will provide the basis and required information to prepare a plan for decommissioning. All risers, pipelines, umbilicals, subsea equipment, and topside equipment will be safely and properly isolated, de-energized, and cleaned to remove hydrocarbons and other hazardous materials to a suitable level prior to being taken out of service.

Near the time of decommissioning, EEPGL will select, in consultation with the appropriate Guyanese agencies, the final decommissioning strategy based on a comparative assessment, which is designed to evaluate the potential safety, environmental, technical, and economic impacts and associated mitigation measures in order to finalize the decommissioning plan. Consultation with stakeholders would also be conducted by EEPGL during decommissioning planning. A revised Plan will be submitted to the appropriate Guyanese agencies in advance of commencing field work.

3.2 Development Wells

Wells will be permanently plugged and abandoned (P&A) by restoring suitable cap rock to prevent escape of hydrocarbons to the environment. P&A barriers will be installed in the wellbore, of adequate length to contain reservoir fluids, and deep enough to resist being bypassed by fracturing. The number of barriers required will depend on the distribution of hydrocarbon-bearing permeable zones within the wellbore.

3.3 Subsea Equipment

It is expected that the risers, pipelines, umbilicals, subsea equipment, and anchor piles will be disconnected and abandoned in place on the seafloor at the production location, consistent with current standard industry practice, unless an alternative strategy is selected based on the results of the comparative assessment.

3.4 FPSO

The FPSO will be disconnected from its mooring system, removed from the production location, and towed to a new location for re-use or decommissioning. The FPSO anchor piles and mooring lines are expected to be disconnected and abandoned in place on the seafloor at the production location, unless an alternative strategy is seleted based on the results of the comparative assessment, consistent with current standard industry practice.

3.5 Decommissioning Waste

Waste streams associated with decommissioning activities, including hazardous and non-hazardous wastes, will be managed and disposed of in accordance with applicable Guyanese regulations, applicable international conventions and guidelines, and standard industry practice. Methods may include injection downhole into the reservoir for certain types of wastes, separation and incineration offshore for certain types of wastes, or transport to onshore waste management facilities for management and disposal for certain types of wastes. Further details on waste management can be found in the Waste Management Plan.

4 MITIGATION AND MONITORING

There will be areas of disturbance at the sea surface and the seafloor associated with the end of operations activities, as noted in the EIA. The Project Development Area (PDA) will be the site of marine vessel activity for the duration of the decommissioning program as support vessels transfer supplies and personnel to and from the PDA. All disturbances at the sea surface will be temporary in nature.

Disturbances at the seafloor will be associated with the decommissioning of the development wells, FPSO mooring lines, and SURF equipment.

EEPGL will implement measures to manage potential decommissioning-related impacts as listed in Sections 4.1 and 4.2.

4.1 Description of Embedded Controls for Decommissioning

This section of the Plan identifies the embedded controls that EEPGL will implement to reduce environmental and socioeconomic impacts related to decommissioning activities. Additional embedded controls that are specific to the decommissioning stage may be identified during the future comparative assessment performed by EEPGL.

- Maintain marine safety exclusion zones with a 500 m (~1,640 ft) radius around major decommissioning vessels to prevent unauthorized vessels from entering potentially hazardous areas;
- Provide trained medical personnel on board major decommissioning vessels to minimize reliance on medical infrastructure and facilities in Guyana;
- Maintain equipment and marine vessels in good working order and operate in accordance with manufacturer's specifications in order to reduce atmospheric emissions and sound levels to the extent reasonably practicable;
- Shut down (or throttle down) sources of portable combustion equipment in intermittent use where reasonably practicable in order to reduce air emissions;
- Utilize secondary containment for bulk fuel storage and hazardous materials, where practical;
- Regularly check pipes, storage tanks, and other equipment associated with storage or transfer of hydrocarbons/chemicals for leaks;
- Treat sewage to applicable standards under MARPOL;
- For those wastes that cannot be reused, treated, or discharged/disposed on the major decommissioning vessels, they will be manifested and safely transferred to appropriate onshore facilities for management. Onshore waste management contractors will be vetted prior to utilization. If deficiencies in contractors' operations are noted, an action plan to address the identified deficiencies will be established;
- Utilize oil/water separators to limit oil in water content in bilge water to <15 parts per million (ppm; per MARPOL);
- Provide standing instruction to Project dedicated vessel masters to avoid marine mammals and turtles while underway and reduce speed or deviate from course, when possible, to reduce probability of collisions;
- Provide standing instruction to Project dedicated vessel masters to avoid any identified rafting seabirds, when possible, when transiting to and from PDA;
- Observe standard international and local navigation procedures in and around the Georgetown Harbour and Demerara River, as well as best ship-keeping and navigation practices while at sea;
- Project workers will be subject to health screening procedures to minimize risks of communicable diseases;

- Utilize an established Safety, Security, Health, and Environmental (SSHE) program to which all Project workers and contractors will be required to mitigate against risk of injury/illness to workers; and all workers and contractors will receive training on implementation and will be required to adhere to its principles;
- Maintain an Oil Spill Response Plan (OSRP) to ensure an effective response to an oil spill, including maintaining the equipment and other resources specified in the OSRP and conducting periodic training and drills;
- Where practicable, direct lighting on major vessels to required operational areas rather than at the sea surface or skyward.

4.2 Description of Mitigation Measures for Decommissioning

This section of the Plan identifies the mitigation measures that EEPGL will employ to mitigate environmental and socioeconomic impacts related to decommissioning activities. Additional mitigation measures that are specific to the decommissioning stage may be identified during the future comparative assessments performed by EEPGL.

- Report direct GHG emissions from the major vessels owned or controlled by the Project to the EPA on an annual basis in accordance with internationally recognized methodologies and good practice;
- Procure select goods and services locally to the extent reasonably practicable;
- Utilize Guyanese nationals where reasonably practicable;
- Issue Notices to Mariners via MARAD, the Trawler's Association, and fishing co-ops for movements of major marine vessels to aid them in avoiding areas with concentrations of Project vessels and/or where marine safety exclusion zones are active;
- Augment ongoing stakeholder engagement process to identify commercial cargo, commercial fishing, and subsistence fishing vessel operators who might not ordinarily receive Notices to Mariners, and where possible communicate Project activities to those individuals to aid them in avoiding Project vessels;
- Promptly remove damaged vessels (associated with any vessel incidents) to minimize impacts on marine use, transportation, and safety;
- Proactively communicate the Project's limited staffing requirements for decommissioning as a measure to reduce the magnitude of potential population influx to Georgetown from job-seekers;
- Implement the Chance Find Procedure that describes the requirements in the event of a potential chance find of heritage or cultural resources during decommissioning activities;
- Project workers will be required to adhere to a Worker Code of Conduct, which will address shore-leave considerations.

4.3 Description of Monitoring Program

The Project will implement the Environmental and Social Monitoring Plan to ensure that Project activities, including decommissioning, are undertaken in an environmentally responsible

manner, and in a manner that is compliant with applicable laws and regulations, as highlighted in Section 2 of this Plan and in the EIA.

5 SCHEDULE

End of operations / decommissioning activities are expected to begin around 2040. A comparative assessment will be performed in accordance with IMO guidelines in effect at the time, which considers environmental and socioeconomic aspects. A revised Plan will be submitted to the appropriate Guyanese agencies in advance (e.g., several years) of commencing field work. The Plan would be approved prior to the commencement of abandonment and decommissioning activities in the PDA.

6 INFORMATION MANAGEMENT AND REPORTING

Reporting requirements for decommissioning activities include those stipulated in the following:

- Applicable laws and regulations in Guyana; and
- Project commitments contained in regulatory filings and Project agreements.

Decommissioning-related reporting to be provided may include, but is not limited to:

- SSHE reports;
- Emergency/incident reporting;
- Summary of waste volumes/types disposed;
- Air emissions;
- Wastewater discharges;
- Fuel consumption (e.g., supply/support vessesl, helicopters, etc.);
- Close-out reporting at the conclusion of decommissioning activities.

7 TRAINING AND ENVIRONMENTAL AWARENESS

EEPGL will appoint suitably competent staff and develop and implement training programs so that requirements are well understood and systematically applied.

EEPGL personnel will be provided with training appropriate to their level of responsibilities on key environmental, regulatory, and socioeconomic issues and on the required mitigation, monitoring, and reporting measures.

Training may be provided in a variety of means including formal training, as well as informal training such as briefings, toolbox talks, and coaching. Other training may take the form of on-the-job training in specific elements or tasks or the provision of specific skills as necessary. These and other means (such as posters, signs, site newsletter, etc.) may be used to promote SSHE awareness.

EEPGL will verify that its contractors supporting the decommissioning activities have implemented a training program which is consistent with EEPGL competency requirements.



EEPGL Oil Spill Response Plan
ERM Coastal Sensitivity Maps

Liza Phase 1 Development Project

Esso Exploration and Production Guyana, Limited

February 2017

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David W. Blaha

ERM Partner

The business of sustainability

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ESMP VOLUME IV

Esso Exploration and Production Guyana Limited (EEPGL) Oil Spill Response Plan

Liza Phase 1 Floating, Production, Storage and Offloading (FPSO) Development Project

AMENDMENT



February 2017

Review and Approval

Approved by:

EEPGL Country Manager _____ _____
Date

Contents

Contents ii

Tables iv

Figures iv

Amendment Record vii

1 INTRODUCTION 8

2 SCOPE 8

2.1 Project Overview 8

2.2 Geographic Response Area 10

2.3 Incident Management 12

2.4 Response Plan Relationships 14

2.4.1 Esso Exploration and Production Guyana Ltd (EEPGL) Emergency Response Plan (ERP) 14

2.4.2 Country National Plan 14

2.4.3 Legal Framework 15

2.5 OSRP Owner Responsibility 15

3 INITIAL RESPONSE ACTIONS 16

3.1 On-Scene Initial Response Actions 16

3.2 On Scene Incident Commander Initial Actions 18

3.3 Initial Notifications 18

3.4 Initial Source Control Actions 21

3.5 Spill Assessment 22

4 OIL SPILL SCENARIOS 23

5 RESPONSE STRATEGIES 27

5.1 Response Strategy Overview 27

5.2 NEBA 29

5.3 Appropriate Response Strategies 29

5.4 Trans-boundary Impacts 30

6 RESPONSE STRATEGY IMPLEMENTATION 31

6.1 Surveillance and Monitoring 31

6.2 Assisted Natural Dispersion 32

6.3 Operational Spill Cleanup 32

6.4 Onshore/Near Shore Response 33

6.4.1 Harbor Containment and Recovery 33

6.4.2 Shoreline Response 33

6.5 Dispersant Application 34
6.6 Offshore Containment and Recovery 35
6.7 Wildlife Response 36
6.8 In Situ Burning 36
6.9 Waste Management 37
6.10 Subsea Response 38
6.11 Decontamination 39
6.12 Demobilization 40
7 RESPONSE RESOURCES 41
7.1 Tier I Resources 46
7.1.1 Mobilization 46
7.2 Tier II Resources 46
7.3 Tier III Resources 46
7.3.1 ExxonMobil's Regional Response Teams 46
7.3.2 Oil Spill Response Limited (OSRL) 47
7.3.3 Global Dispersant Stockpile (GDS) 49
7.3.4 Subsea Well Response 50
8 EXERCISES AND TRAINING 53
8.1 Oil Spill Training 53
8.2 Incident Command System Training 53
8.3 Oil Spill Exercises 54
Appendix A MODELING RESULTS 56
A.1 Modeling Overview 56
A.2 Model Input Data 59
A.3 Stochastic Model Results (Unmitigated) 59
A.4 Deterministic Model Results (Unmitigated) 71
Appendix B DISPERSANT SPRAYING CONSIDERATIONS 77
Appendix C FORMS 78
C.1 Initial Spill Report Form 78
C.2 Dispersant Use Request Form 79
C.3 Oil Spill Response Notification Form 82
C.4 Oil Spill Response Mobilization Form 84
Appendix D COASTAL SENSITIVITY MAPS 85
Appendix E WILDLIFE RESPONSE PLAN 189

Tables

Table 1: Amendment Record vii
Table 2: Tiered Oil Spill Response Approach 12
Table 3: Incident Commander Initial Checklist 18
Table 4: Notifications Matrix 19
Table 5: Possible Hydrocarbon Release Scenarios by Tier 24
Table 6: Oil Spill Response Resources* 41
Table 7: FPSO Sample List of Common Oil Spill Response Equipment* 44
Table 8: OSRL Service Level Agreement (SLA) Summary 48
Table 9: OSRL GDS Quantities and Locations 49
Table 10: OSR Training Course Information 53
Table 11: ICS Training Course Information 54
Table 12: Oil Spill Exercise Overview and Schedule 54
Table 13: Oil Spill Scenarios Defined for the Oil Spill Modeling 57
Table 14: Oil Thickness (µm) and Equivalent Mass (g/m^2) and Appearance on Water (NRC, 1985) 58
Table 15: Oil Thickness Thresholds for Sea Surface and Shoreline Oiling 58
Table 16: Properties of the Crude Oil Used in the Spill Modeling 59
Table 17: Oil Effects Summary for 95th Percentile 71

Figures

Figure 1: Stabroek Petroleum Production License Area in Green 9
Figure 2: Liza Phase 1 Drilling and Operations Stage Peak Fleet Profile 10
Figure 3: Guyana Geographic Response Area 11
Figure 4: Emergency Management Overview 12
Figure 5: Emergency Response Escalation Model 13
Figure 6: On-Scene Response Actions (Sample) 17
Figure 7: Example Incident Management Team (IMT) with Source Control Branch 21
Figure 8: Emergency Response Generic Actions Flowchart 28
Figure 9: Cone of Response Diagram 30
Figure 10: Surveillance and Monitoring Key Steps 32
Figure 11: Harbor Containment and Recovery Key Steps 33
Figure 12: Shoreline Response Key Steps 34
Figure 13: Dispersant Application Key Steps 35
Figure 14: Containment and Recovery Key Steps 36
Figure 15: In Situ Burning Key Steps 37
Figure 16: Waste Management Key Steps 38
Figure 17: Subsea Response Key Steps 39
Figure 18: Sample Incident Command System Organization 47
Figure 19: GDS Mobilization Responsibilities 49
Figure 20: CSS Mobilization Responsibilities for OSRL and ExxonMobil 51
Figure 21: SIRT Mobilization Responsibilities for OSRL and ExxonMobil 51
Figure 22: SWIS Mobilization 52

Figure 23: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 50 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 60
Figure 24: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 250 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 61
Figure 25: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 50 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 62
Figure 26: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 250 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 63
Figure 27: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 50 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 64
Figure 28: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 2,500 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 65
Figure 29: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 50 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 66
Figure 30: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 2,500 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm 67
Figure 31: Top Panel – Probability of shoreline oiling above a minimum thickness of 1 µm for months December through May for a 2,500 barrel release of Crude oil. Bottom Panel – Minimum time for shoreline oil thickness to exceed 1 µm 68
Figure 32: Top Panel – Probability of shoreline oiling above a minimum thickness of 1 µm for months June through November for a 20,000 barrel a day release of Crude oil for 30 days. Bottom Panel – Minimum time for shoreline oil thickness to exceed 1 µm 69
Figure 33: Top Panel – Probability of shoreline oiling above a minimum thickness of 1 µm for months December through May for a 20,000 barrel a day release of Crude oil for 30 days. Bottom Panel – Minimum time for shoreline oil thickness to exceed 1 µm 70
Figure 34: Area swept results for the 95th percentile surface area oiled 50 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black (none in this scenario), and shoreline oiling is displayed in red (none in this scenario) 72
Figure 35: Area swept results for the 95th percentile surface area oiled 250 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red (none in this scenario) 72
Figure 36: Area swept results for the 95th percentile surface area oiled 50 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black (none in this scenario), and shoreline oiling is displayed in red (none in this scenario) 73
Figure 37: Area swept results for the 95th percentile surface area oiled 250 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red (none in this scenario) 73

Figure 38: Area swept results for the 95th percentile surface area oiled 50 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red (none in this scenario) 74
Figure 39: Area swept results for the 95th percentile surface area oiled 2,500 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red 74
Figure 40: Area swept results for the 95th percentile surface area oiled 50 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red 75
Figure 41: Area swept results for the 95th percentile surface area oiled 2,500 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red 75
Figure 42: Area swept results for the 95th percentile surface area oiled 20,000 bbl per day release for 30 days during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red 76
Figure 43: Area swept results for the 95th percentile surface area oiled 20,000 bbl per day release for 30 days during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red 76

Amendment Record

For each revision of EEPGL's Oil Spill Response Plan (OSRP), EEPGL will insert approval signatures and details in Table 1. Include details on the revision number, description and indication of the revised pages or paragraphs and amendment approval date.

Table 1: Amendment Record

Revision Number	Date	Summary of Amendment	Page Number	Approved by (Signature)
Rev 0	February 8, 2016	EEPGL Oil Spill Reponse Plan (OSRP)		J. Simons
Rev 1	February 27, 2017	EEPGL OSRP Amendment (Amended to reflect further spill scenarios associated with Liza Phase 1 FPSO Development Project and addition of Wildlife Response Plan)	Multiple	J. Simons
2				
3				

1 INTRODUCTION

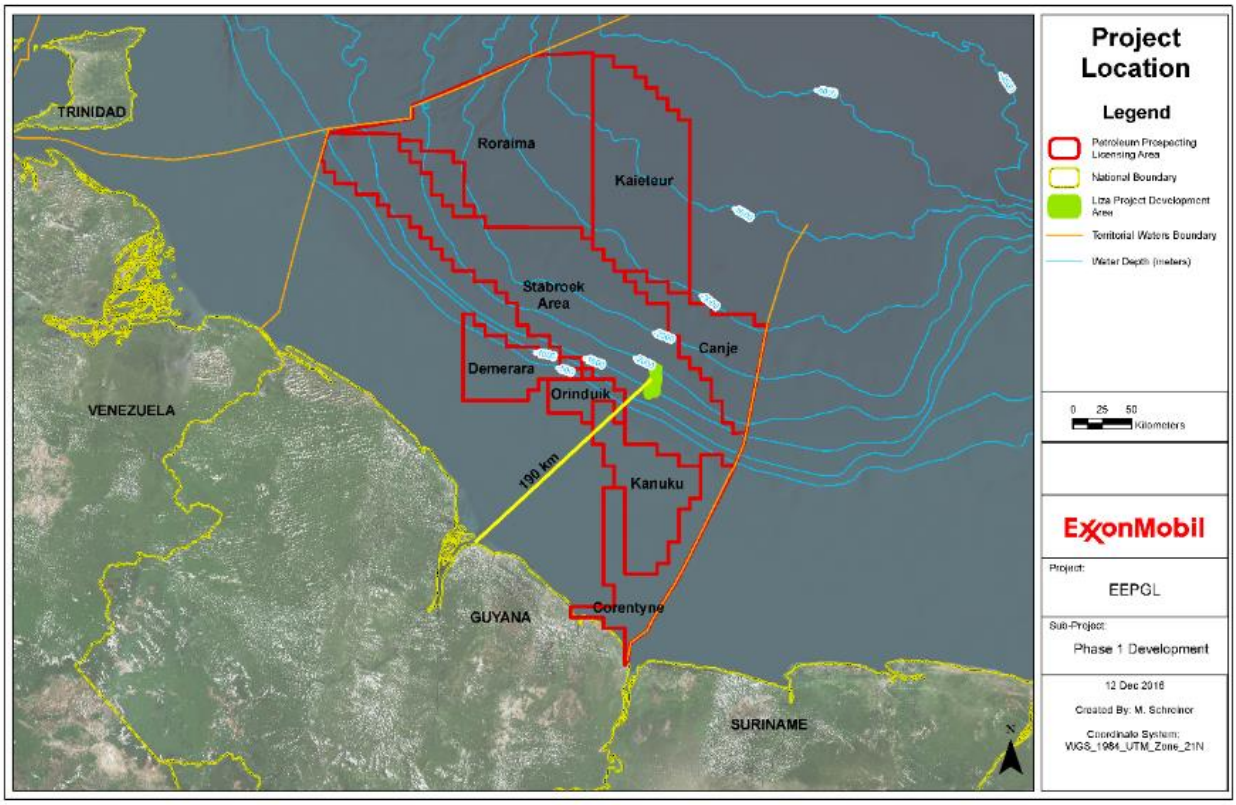
This Oil Spill Response Plan (OSRP) outlines plans and procedures, in the event of an oil spill incident, for engagement between the site operator (Esso Exploration and Production Guyana Limited (EEPGL)), the Guyana Authorities (Environmental Protection Agency (EPA), Civil Defense Commission (CDC), and Guyana Coast Guard (GCG)), ExxonMobil Corporate support teams, and third party support organizations.

This document has been amended to describe EEPGL's on-going exploration, drilling and additional Liza Development (e.g. installation, hook-up, commissioning, drilling and production operations), the equipment and facilities to be used, and how EEPGL will work together with the appropriate Guyana agencies to respond to an oil spill of different severities.

2 SCOPE

2.1 Project Overview

EEPGL submitted a development plan and applied for a Liza production license on December 13, 2016. EEPGL must obtain approval of the Application for Environmental Authorization that was submitted to the Guyana EPA on July 5, 2016 before offshore installation, drilling and production operations maybe initiated. An Environmental Impact Assessment (EIA) in support of such operations was submitted in February 2017 that includes multiple appendices including this OSRP, which sets forth the strategies and plan for how EEPGL will respond to an oil spill and other unplanned events. EEPGL was granted the rights to explore for hydrocarbons in the Stabroek Petroleum Prospecting License Area (referred to hereafter as the Stabroek Block) offshore Guyana (Figure 1).



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

Figure 1: Stabroek Petroleum Production License Area in Green

There will be a variety of marine and aviation support equipment supporting the FPSO, installation vessels, and drill ships, as shown on Figure 2. The support vessels will consist of Platform Supply Vessels (PSVs) conducting re-supply trips to the FPSO and drill ships, Tug Vessels (TVs) supporting tanker offloading activities, and Multi-Purpose Vessels (MPVs) supporting subsea installation and maintenance activities. Based on current drilling activities and past experience with similar developments, it is estimated that during development drilling and FPSO/SURF installation, an average of 12 vessel trips per week may be made to the Project Development Area (PDA).

During FPSO/SURF production operations, it is estimated that this number will be reduced to approximately 7 vessel trips per week. The vessels are planned to be loaded and offloaded at shorebase facilities in Guyana and/or Trinidad. Figure 2 depicts a conceptual diagram and estimated number and types of logistical support equipment that will be utilized to support the Project.

In addition, it is estimated that during development drilling and FPSO/SURF installation a total of as many as 30 to 35 helicopter flights per week will be needed. During FPSO/SURF production operations, an estimated 20 to 25 round-trip helicopter flights per week will be necessary to support FPSO/SURF production operations and development drilling activities.

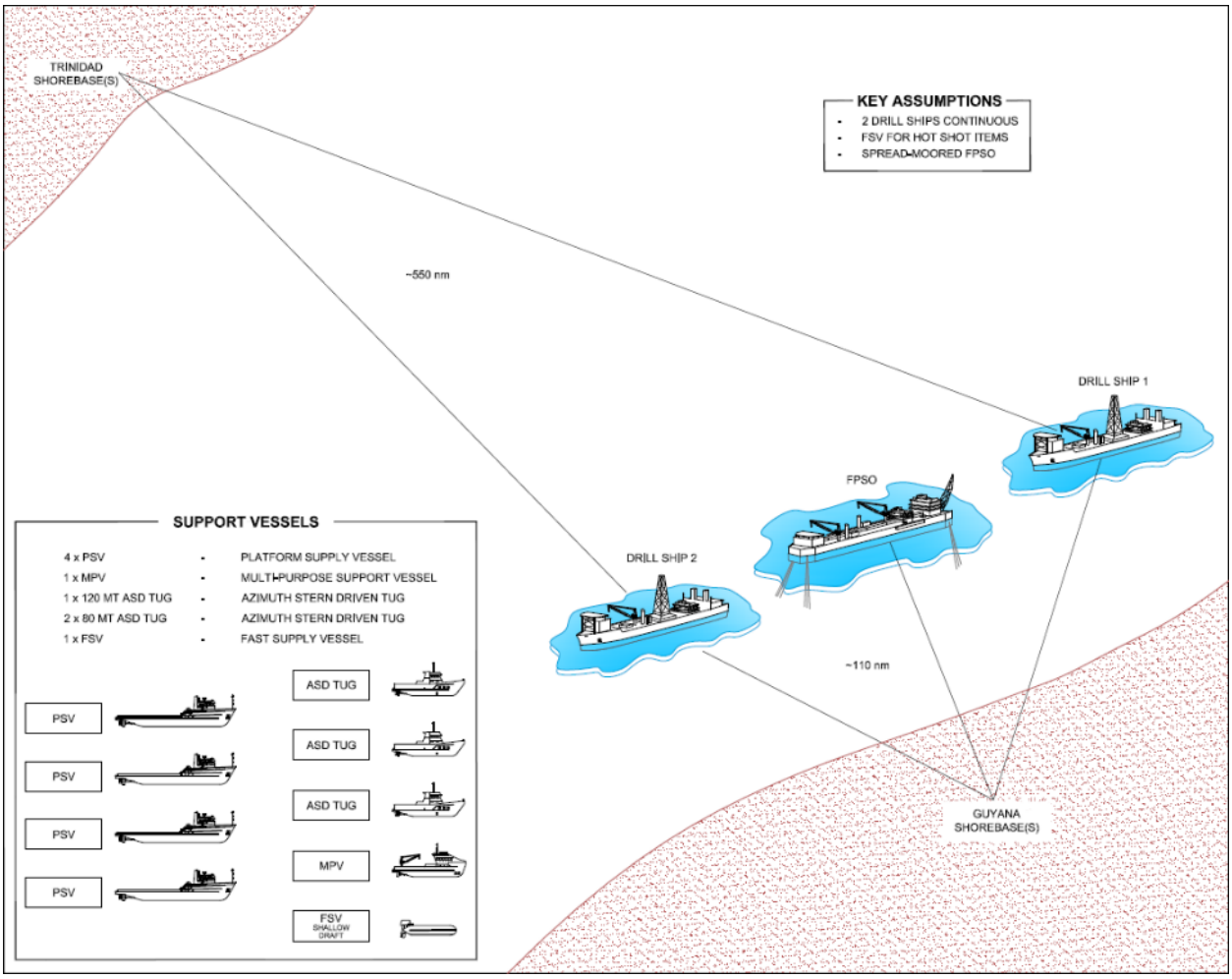
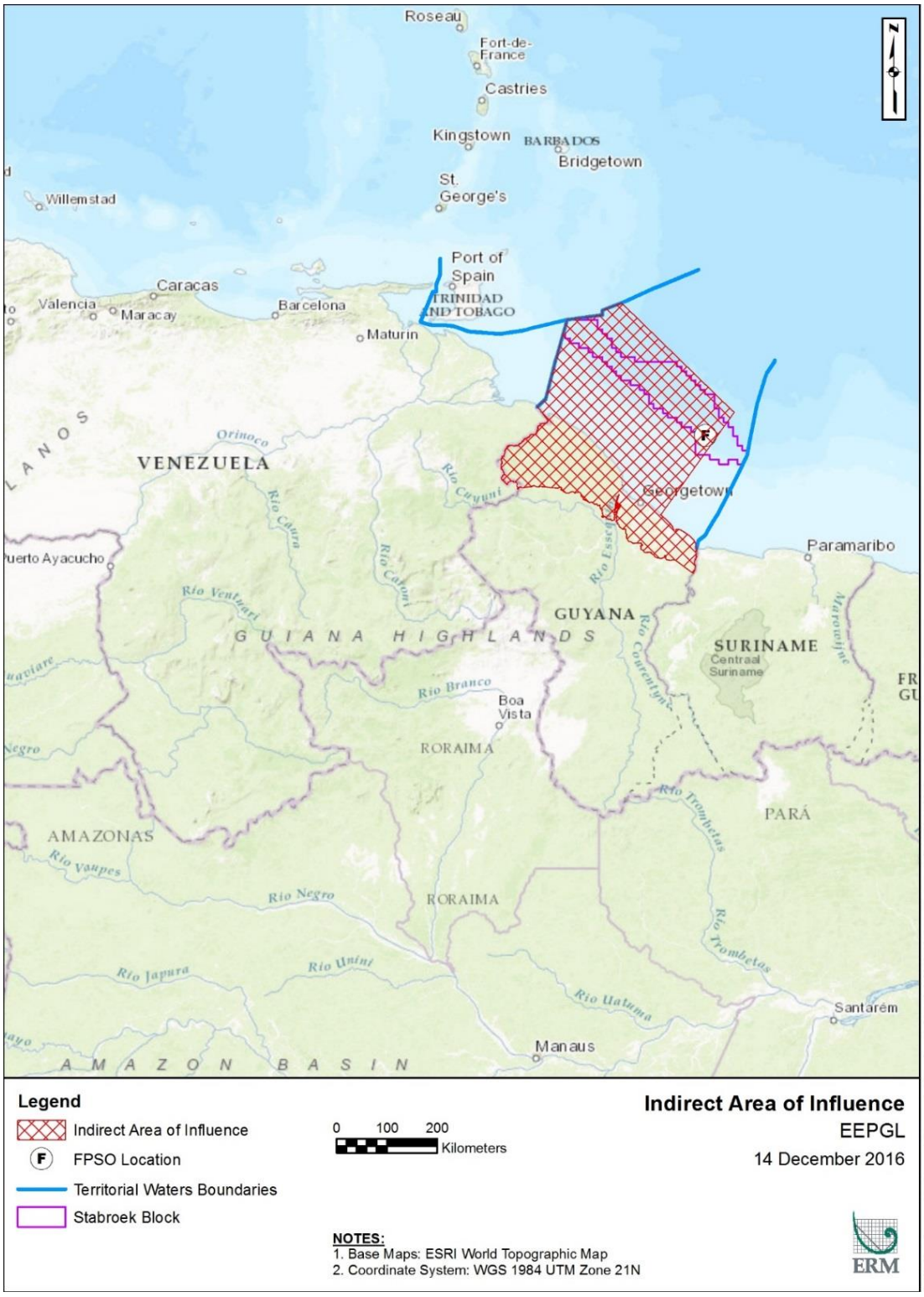


Figure 2: Liza Phase 1 Drilling and Operations Stage Peak Fleet Profile

2.2 Geographic Response Area

Oil spill modeling has determined the potential impact of a loss of well control event (Tier II-III) could include Trinidad and the Southern Caribbean, Lesser Antilles. Figure 2 shows the Guyana Geographical Response Area. EEPGL will manage and coordinate the response from Georgetown, Guyana and utilize in-country logistics for operations in all of the potentially impacted countries, if it is safe to operate there.



**** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.***

Figure 3: Guyana Geographic Response Area

2.3 Incident Management

The response management overview graphic (Figure 4) and supporting information provides guidance for an appropriate field and issues management response. This model depicts the interaction of both the field (tactical) response levels and Headquarters (strategic) support structure.

ExxonMobil tactical response teams include the Emergency Response Team (ERT), Incident Management Team (IMT) and Regional Response Team (RRT). Strategic response teams include the Region Emergency Support Group (ESG) and Business ESG. Additional information is available in the EEPGL Emergency Response Plan (ERP).

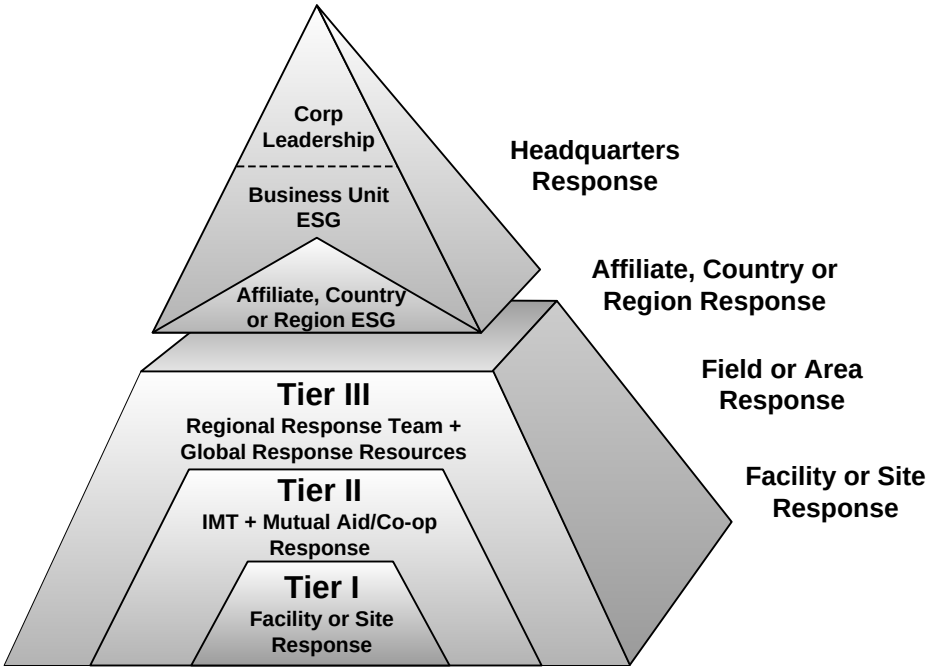


Figure 4: Emergency Management Overview

ExxonMobil has a tiered response approach to oil spill planning globally. Table 2 summarizes the tiered response approach adopted by EEPGL.

Table 2: Tiered Oil Spill Response Approach

Tier	Description
I	Incident is small, under control, and may involve a local company-managed resource response.
II	Incident is large, under control or spill source not immediately under control, and involves mutual aid cooperative response.
III	Incident is large, is not under control, and requires response by the appropriate RRT and specialized resources.

The on-site ERT will manage Tier I incidents in accordance with the site-specific ERP.

Figure 5 depicts the emergency response escalation model. EEPGL will proactively obtain additional support and resources to reduce the impact of a spill in the unlikely event it shows potential to exceed Tier I capabilities.

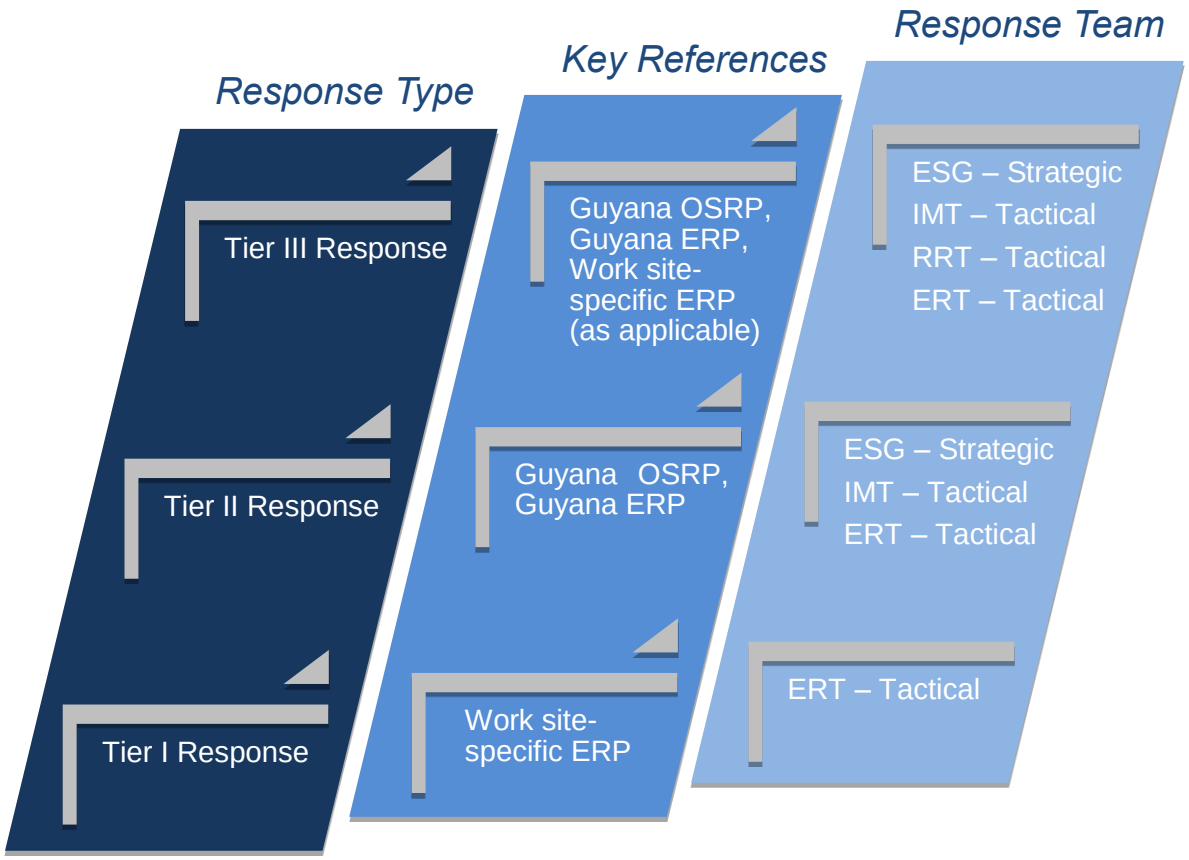


Figure 5: Emergency Response Escalation Model

The ERT will manage Tier I spill responses using the site-specific ERP and resources located on vessels and in port facilities in Guyana and Trinidad. Such resources as well as dispersant application from vessels will also be used for larger Tier II spills until supplemental OSR resources arrive on-scene.

For incidents that may exceed Tier I capabilities, EEPGL would notify Oil Spill Response Ltd (OSRL) in Southampton, UK[1] (Refer to forms in Appendices 0 and C.4), to provide immediate incident management support as well as OSRL's global oil spill technical response teams and equipment.

[1] *Oil Spill Response Ltd or OSRL merged with the Clean Caribbean & Americas (CCA) co-operative in 2013. The hertitage CCA equipment base and personnel located in Ft. Lauderdale, FL are now an integral part of a larger global response co-operative under the name OSRL.*

At all stages of the response operation, EEPGL will work with the appropriate authorities in Guyana and any other affected countries, which will include rapid development of a plan to identify and engage potentially affected stakeholders and communities. EEPGL continues to work cooperatively with the CDC, GGMC and other local agencies and interested stakeholders on a routine basis to ensure open lines of communication are maintained and clear roles and responsibilities are understood and consistent with the agreed emergency response planning for offshore petroleum operations. In recognition of the CDC preparing a national oil spill response plan which is still in the draft stage, when this is finalized, appropriate updates to this OSRP will be incorporated.

Given the limited resources in-country, company will consider setting up a cooperative with a regional OSRO (e.g., Trinidad) to support Tier 2+ oil spill response prior to offshore execution. Whether using a direct agreement or a cooperative, Tier 2+ oil spill response readiness in-country is critical as such spills could potentially have transboundary impacts to neighboring countries.

The EEPGL OSRP is supported by the EEPGL ERP which provides a structured and systematic process for responding to incidents. The ERP outlines plans and procedures for engagement between the incident site, EEPGL and ExxonMobil management and the relevant authorities in Guyana. The ERP covers incidents associated with the shorebases utilized by EEPGL as well as the offshore operations in the Stabroek Block, including the possibility of hydrocarbon and chemical releases, search and rescue, offshore medical evacuation, medical emergency, fatality, fire or explosion at a work site, natural disaster and security or civil disturbance. While the ERP is the primary document for use in all emergencies, it is supplemented by this OSRP in the specific case of an oil spill.

2.4 Response Plan Relationships

2.4.1 Esso Exploration and Production Guyana Ltd (EEPGL) Emergency Response Plan (ERP)

The EEPGL ERP establishes a structured process for responding to events that pose, or could pose, a threat to the people, environment, assets, or reputation impacted by EEPGL activities.

The ERP provides guidelines to assist project, drilling, exploration, and facilities management in effectively responding to an emergency such as an oil spill. This plan is a country-level plan that is mainly focused on emergency response activities conducted at the EEPGL Emergency Response Center(s) (ERC). The EEPGL ERP also references work site-specific Emergency Response Plans such as the Drilling ERP.

2.4.2 Country National Plan

A draft national contingency plan prepared by International Maritime Organization (IMO) identifies the Guyana Coast Guard (GCG) of the Guyana Defense Force as the lead agency for oil spill response operations. However the draft has not yet been formally adopted. Responsibilities in the maritime sector are split between several departments and ministries. The Lands and Surveys Department of the Ministry of Agriculture has jurisdiction in river waters. The Transport and Harbors Department of the Ministry of Public Works, Communications and

Regional Development is responsible for port areas and territorial waters. However, the Coast Guard enforces all maritime regulations and is a key operational organization in any marine incident investigating reports of pollution in navigable waters on behalf of the relevant ministry and department. In addition, the Guyana Defense Force and the Fire Service also assume some operational responsibility for pollution response.

A Draft National Multi-Hazard Preparedness and Response Plan is currently under development by the Guyana Civil Defense Commission (CDC). By developing a national strategy for disaster risk reduction and management the CDC aims to be compliant with global and regional systems such as United Nation International Strategy for Disaster Reduction and the Caribbean Disaster Emergency Response Agency's Comprehensive Disaster Management Framework.

2.4.3 Legal Framework

National laws, regulations and conventions are applicable to EEPGL's activities in the Stabroek Block license area in the case of marine pollution.

Applicable National laws and regulations include:

- National Constitution of Guyana;
- The Environmental Protection Act 1996;
- The Guyana Geology and Mines Commission Act 1979.

Specific regulatory reporting requirements are covered in the EEPGL's ERP.

2.5 OSRP Owner Responsibility

Owner and Administrator: The EEPGL Venture Manager is the Owner of the EEPGL OSRP and the EEPGL OIMS/SSH&E Manager is the Plan Administrator.

Plan Review: The OSRP Administrator and Owner review this plan on an annual basis and/or if there is a significant change to the development drilling and planned production operations.

Site Specific Plans: Other Activity or Site-specific ER Plans for shorebases and those individual vessels owned and operated by others are the responsibility of the site-specific Emergency Response (ER) owners and administrators for those companies. These include the following planned vessel Shipboard Oil Pollution Emergency Plans (SOPEPs).

ONSHORE

- Fuel Storage Terminal Owner/Operator Emergency Response Plan; and
- Shorebase Owner/Operator Emergency Response Plan.

OFFSHORE

- FPSO Owner/Operator SOPEP;
- Conventional Crude Oil Tanker Owners/Operators SOPEP;
- Drill Ship Owners/Operators SOPEPs; and
- Other Installation, Supply, Support Vessel Owners/Operators SOPEPs.

EEPGL's On-Scene Incident Commander will communicate and coordinate with the owners/operators of such assets to ensure they have effectively implemented their ER/SOPEP in the event of a spill or release. Further discussion of such duties and responsibilities are outlined in Section 4. Hard copies of such site specific ER's and SOPEP's will be maintained at the physical asset's location or onboard the vessels with a copy of the FPSO and Drill Ships SOPEP's also maintained at EEPGL's Venture Office.

3 INITIAL RESPONSE ACTIONS

3.1 On-Scene Initial Response Actions

Figure 6 describes the immediate actions of on-scene personnel upon discovery of a spill, including a quick situation analysis and identification of actual or potential health and safety hazards. More detailed site-specific procedures can be found in the appropriate ERP.

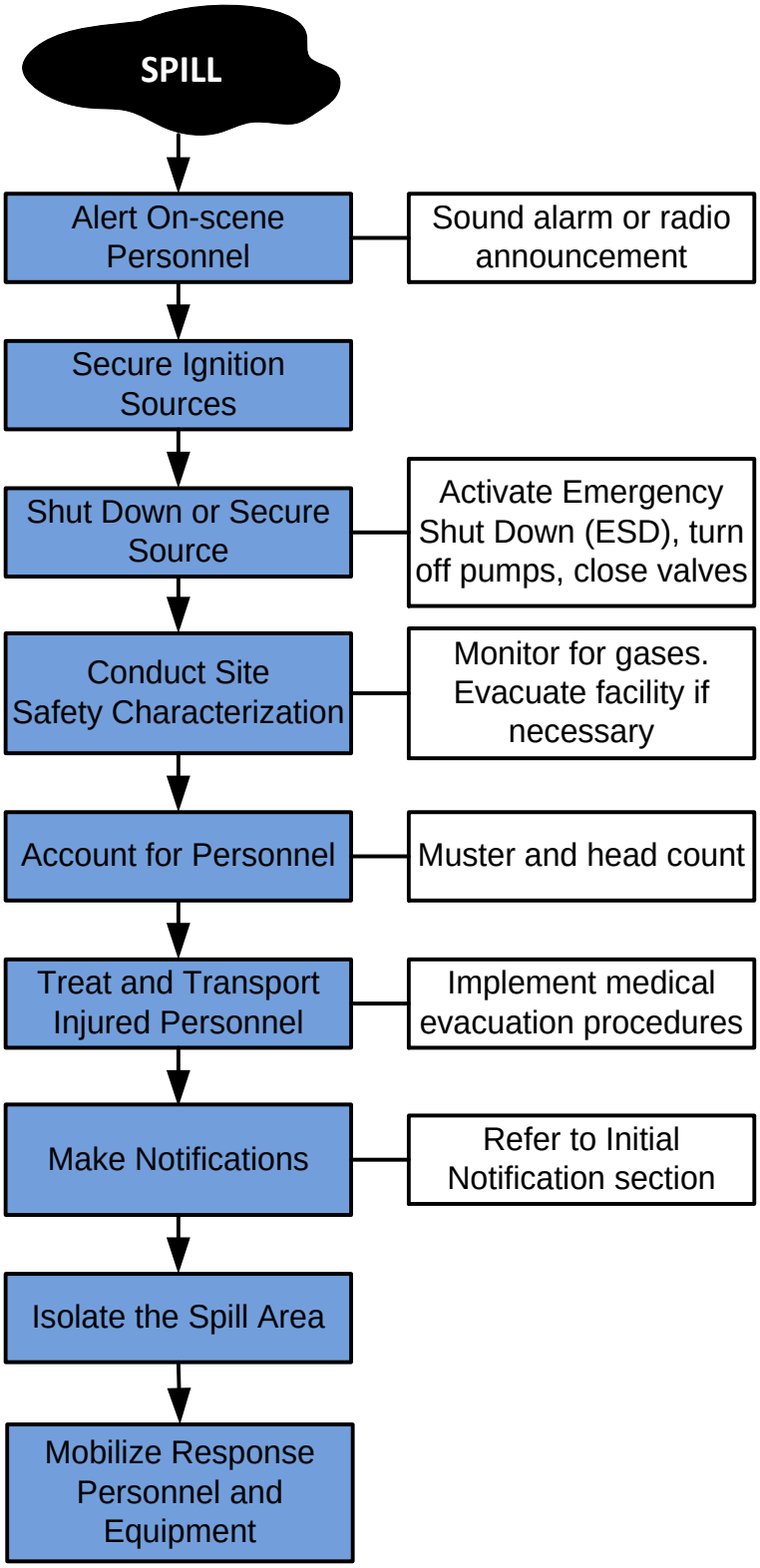


Figure 6: On-Scene Response Actions (Sample)

3.2 On Scene Incident Commander Initial Actions

The On-Scene Incident Commander is responsible for implementing the appropriate initial oil spill response actions including, but not limited to, those in Table 3.

Table 3: Incident Commander Initial Checklist

✓	Action
	Notify EEPGL Duty Manager immediately (use Initial Spill Report Form, Appendix C.1)
	Request resources required to carry out spill response activities.
	Activate personnel and equipment maintained by ExxonMobil.
	Activate required external oil spill response organizations.
	Act as liaison with the lead government organization.
	Authorize notification of applicable external organizations (Table 4).

For site-specific actions refer to the appropriate plans and the ExxonMobil Incident Management Handbook (IMH).

3.3 Initial Notifications

The notifications matrix details which organizations to notify for each incident Tier, once initial on-scene response actions have been addressed (Table 3). The EEPGL ERP provides specific internal and external incident reporting requirements.

Table 4: Notifications Matrix

Organization / Regulatory Body	Spill Criteria	Timing / Responsible Person	Tel number	Form	Email address / Fax number
Guyana Government Agencies					
Coast Guard Guyana Defence Force Ruimveldt Georgetown	All Tier Levels	Within 24 hours / Initial On- scene IC	+592-226-8488 (24 hrs)	N/A	
Harbor Master Transport and Harbors Department Stabroek Georgetown	All Tier Levels	Within 24 hours / Initial On- scene IC	+592-226-7842	N/A	
Guyana EPA Ganges Street, Sophia Georgetown, Guyana	All Tier Levels (subject to permit language)	Within 24 hours / ERT Incident Commander	+592 225-5467 +592 225-5469	N/A	
Maritime Administration Department (MARAD)	Tier II and III	Within 24 hours / ERT Incident Commander	+592 226 3356	N/A	
Guyana Geology and Mines Commission	All Tier Levels	Within 24 hours	+592 225-6691 +592 225-2862	N/A	
ExxonMobil					
EEPGL Duty Manager	All Tier levels	Immediately / Initial On Scene IC	TBD	Internal Notification Form	
NART – RRT	Tier II and III	Immediately / Initial On-scene IC	TBD	Internal Notification Form	
Key 3rd Party Operators					
FPSO Owner/Operator – SBM [Upon arrival at the Liza Direct Area of Influence (AOI)]	All Tier Levels	For all FPSO based incidents Immediately / Source Control / Branch Director	TBD	Internal Notification Form	
Crude Oil Tanker Owner/Operator (While offloading or within the Stabroek Block)	All Tier Levels	For all Tanker based incidents Immediately / Source Control / Branch Director	TBD	Internal Notification Form	

Organization / Regulatory Body	Spill Criteria	Timing / Responsible Person	Tel number	Form	Email address / Fax number
Drill Ship Owner/Contractor (While drilling or within the Stabroek Block)	All Tier Levels	For all Drill Ship based incidents Immediately / Source Control / Branch Director	TBD	Internal Notification Form	
Installation/ PSV/FSV Contractors	All Tier Levels	For all Vessel based incidents Immediately / Source Control / Branch Director	TBD	N/A	
Shorebase(s)	All Tier Levels	Immediately / Initial On Scene IC	TBD	Internal Notification Form	
Fuel Storage Terminal	All Tier Levels	Immediately / Initial On Scene IC	TBD	Internal Notification Form	
Response Contractors					
Oil Spill Response Ltd (Fort Lauderdale)	Tier II and III	Immediately / Initial On-scene IC	+1 954 983 9880	OSRL notification OSRL mobilization	+1 954 987 30001
NRC Trinidad	All Tier Levels	Immediately / Initial On-scene IC	+44 (0) 1908 467 800	N/A	
Wild Well Control	Loss of well control	Immediately if loss of well control / Initial On-scene IC	+1 281 784 4700	N/A	N/A
ROV contractor	Loss of well control	Immediately if loss of well control / Initial On-scene IC	TBD	N/A	TBD
Trendsetter Engineering Inc.	Loss of well control	Immediately if loss of well control / Initial On-scene IC	+1 281 465 8858	N/A	N/A
Relief Well: Halliburton Boots & Coots	Loss of well control	Immediately if loss of well control / Initial On-scene IC	+1 281 931 8884 +234 1271 5020	N/A	N/A

3.4 Initial Source Control Actions

Initial source control actions and resources to control the source of operational spills, including the initial actions to a loss of well control incident, are described in site specific response plans. Sustained source control response operations will be managed and coordinated by the IMT including the Source Control Branch under the Operations Section. See Figure 7 for example IMT with Source Control Branch.

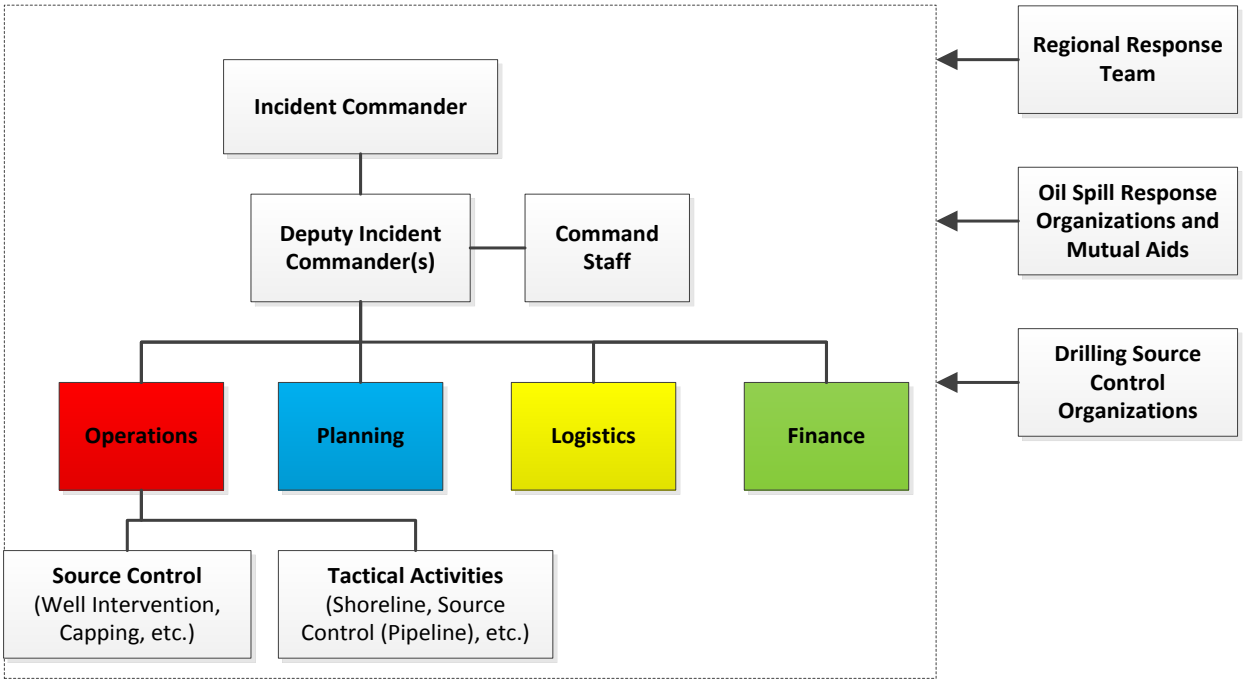


Figure 7: Example Incident Management Team (IMT) with Source Control Branch

3.5 Spill Assessment

An accurate estimation of total spill volume, location and movement is essential to determine the required response Tier, and to plan for and initiate spill cleanup operations. Quick estimation will aid in determining the:

- Equipment and personnel required;
- Potential threat to shorelines and/or sensitive areas, including ecological impact; and
- Waste storage and disposal requirements.

EEPGL will initiate a systematic search with vessels and aircraft (weather permitting) to locate the spill and determine its coordinates.

EEPGL will estimate spill size and movement using coordinates, photographs, drawings, and other information received from vessels, aircraft and satellite imagery. Spotters will photograph the spill from aircraft as often as necessary for operational purposes, and determine its movement based on existing reference points, such as vessels and familiar shoreline features. Modeling of the oil release may be utilized to predict the oil slick's surface movement or trajectory. Modeling will help to identify shorelines that may be at risk from oil stranding, predict the probable timing of that stranding, and provide information regarding how the oil is changing with time.

The Source Control Branch will estimate the volume and rate of a subsea well release.

4 OIL SPILL SCENARIOS

The following tables describe potential hydrocarbon release scenarios in terms of location, hydrocarbon type, volume and potential environmental impact. Appendix D of this OSRP includes coastal sensitivity and shoreline access maps. In addition, Section 3.0 of the Environmental and Socioeconomic Management Plan details the management measures to mitigate risks to resources (e.g., leak detection).

The following locations could experience a hydrocarbon release during the installation, drilling and production operation stages of the Liza Phase 1 FPSO Project offshore Guyana:

- Guyana fuel terminal;
- Guyana shorebase;
- Trinidad shorebase;
- The drilling rig or rigs;
- Offshore from vessels working on behalf of the Installation, Drilling, or Production Operations including the FPSO.

Section 6, RESPONSE STRATEGY IMPLEMENTATION, provides details of potentially appropriate response actions for each identified scenario. Section 7, RESPONSE RESOURCES, details resources available to EEPGL.

Hydrocarbons that could potentially be released during development drilling and production operations include crude oil, marine diesel, fuel oil, aviation fuel, lubricating oil, and non-aqueous drilling fluid. These scenarios are outlined in Table 5. The most appropriate response strategy to a given incident will depend, in part, on the properties of the hydrocarbon spilled. For example, heavy oils tend to persist in the environment longer than lighter hydrocarbons. A significant fraction of spilled diesel fuel, however, may be expected to evaporate and naturally disperse.

The properties of the crude oil are provided in Appendix A, MODELING RESULTS. These modeling results, along with previous spill experience of different oil types, were used to complete the predicted impacts of each spill scenario.

Table 5: Possible Hydrocarbon Release Scenarios by Tier

SCENARIO								Potential Response Strategies
#	Tier	Location	Activity	Possible scenario	Oil Type	Spill Volume	Impact	
-	I	Offshore Drill Ship or FPSO	Bunkering	Operational spill. Release of aviation fuel during refueling of helicopter offshore	Aviation fuel	<10 bbls	Fuel enters the water and will rapidly evaporate	• 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion
-	I	Offshore Helicopter	Aviation	Ditching of an aircraft	Aviation fuel	>10 bbls	Fuel enters the water and will rapidly evaporate	See Above
1	I	Onshore Shorebase, Terminal, Airport Offshore Vessels	Bunkering	Operational spill. Partial loss of storage tank contents or minor spill	• Aviation fuel • Marine diesel • Fuel oil • Lubricating fluids • Oily water • Drilling mud	<10 bbls	Contained onshore or on deck of vessel. No shoreline impact likely	• 6.4 Onshore/Near Shore Response • 6.9 Waste Management • 6.11 Decontamination • 6.12 Demobilization
2	I	Offshore Supply Vessels, Drill Ship or FPSO	Bunkering	Leak or release due to failure of equipment: transfer hose rupture during ship to ship product transfer or release due to human error	• Marine diesel • Fuel oil • Lubricating fluids • Oily water • Crude oil	<50* bbls	Contained on deck of vessel or enters the water, spreads rapidly creating a sheen on the water surface. No shoreline impact likely	• 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion • 6.6 Offshore Containment and Recovery • 6.7 Wildlife Response • 6.9 Waste Management • 6.11 Decontamination • 6.12 Demobilization
3	I	Offshore Supply Vessels, Drill Ship or FPSO	Ballasting	Accidental discharge of untreated bilge water	• Bilge water • Oily water	<50 bbls	Spill enters the water and will spread rapidly creating a sheen on the water surface. No shoreline impact likely	• 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion • 6.6 Offshore Containment and Recovery • 6.7 Wildlife Response • 6.9 Waste Management • 6.11 Decontamination • 6.12 Demobilization
4	II	Onshore Shorebase	Bunkering	Release of larger volume due to rupture of transfer hose in harbor.	Marine diesel	<100* bbls	Oil enters the water and will spread rapidly creating a sheen on the water	• 6.4 Onshore/Near Shore Response • 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion • 6.9 Waste Management

SCENARIO								Potential Response Strategies
#	Tier	Location	Activity	Possible scenario	Oil Type	Spill Volume	Impact	
							surface	• 6.11 Decontamination • 6.12 Demobilization
5	II	Offshore Drillship	Drilling	Disconnect of riser in the event of the loss of Dynamic Positioning (DP)	NADF	<2200 bbls	NADF enters near the seafloor; no shoreline impact likely	• 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion
6	II	Onshore Shorebase Supply Vessels	Bunkering	Release of larger volume due to rupture of transfer hose in harbor.	Marine diesel	500 bbls	Oil enters the water and will spread rapidly creating a sheen on the water surface. Refer to modeling results.	• 6.4 Onshore/Near Shore Response • 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion • 6.9 Waste Management • 6.11 Decontamination • 6.12 Demobilization
7	II	Offshore Drillship/ Well workover	Drilling	Well control incident (e.g. wellbore fluids diverted overboard to protect personnel during well control operations	Wellbore fluids	<250	Spill enters the water. Localized impact. No shoreline impact likely. Refer to modeling results.	• 6.1 Surveillance and Monitoring • 6.2 Assisted Natural Dispersion • 6.6 Offshore Containment and Recovery • 6.5 Dispersant Application • 6.7 Wildlife Response • 6.9 Waste Management • 6.11 Decontamination • 6.12 Demobilization
8	III	Offshore FPSO	Bunkering	Operational spill. Release of crude oil during tanker offloading	Crude oil	2500 bbls*	Potential for localized / area wide impact. Refer to modeling results.	See Above
9	III	Drillship/ Well workover	Drilling	30 day well control incident at seafloor of well.	Wellbore fluids	20000 bbls oil/day Max. 30 days*	Potential for regional / transboundary impact. Refer to modeling results.	See Above

Hydrocarbon releases under Scenarios 1 through 4 would all be small and under control quickly, and would be managed with locally available spill control equipment. A temporary visible sheen on the water surface may occur, water quality would be temporarily impaired in a small area, a very sensitive receptor (e.g., plankton and possibly some shorebirds) may be locally affected, but there is not considered to be potential for any long-term or ecosystem level impacts on ecologically important or protected species.

A hydrocarbon release under Scenario 5 would involve a spill of approximately 2,200 bbl of NADF into the ocean near the seafloor. Under this scenario, the spill would be somewhat controlled because the volume is limited to the capacity of the drilling riser. There is the potential for temporary impacts on several resources/receptors, such as water quality and marine fish and wildlife, but these impacts would be generally short term and limited in area, with rapid resource/receptor recovery expected.

Hydrocarbon release under Scenario 6 would involve a spill of approximately 500 bbl of diesel into the adjacent river or water body where a shorebase is located. Under this scenario, the spill would be quickly controlled and contained because of the relatively small volumes and the ready access to spill control equipment.

Hydrocarbon releases under Scenarios 7 (minor well control release during drilling), 8 (release during offloading from FPSO to tanker), and 9 (major well control incident) would all involve an oil spill requiring the implementation of both our local and regional response resources as well as OSRL's global oil spill technical response teams and equipment, which are further described in Section's 5 -7. Oil spill modeling was performed for scenarios 2, 4, 8 and 9 listed above and during two difference seasons summer and winter each and the results provided in Appendix A.

5 RESPONSE STRATEGIES

5.1 Response Strategy Overview

An oil spill response includes a range of response tools and techniques, response strategies and tactics. It can be constrained by physical conditions, prevailing weather and sea conditions, and safety considerations. EEPGL will evaluate each deployment in terms of feasibility, effectiveness and potential to reduce negative environmental impact (i.e., net environmental benefit). EEPGL will respond with the intent of minimizing the negative impacts of the response and cleanup, as determined by a Net Environmental Benefit Analysis (NEBA, see Section 5.2), which is an evaluation tool that supports decision making. In the event of a release, EEPGL and ExxonMobil technical experts will complete the NEBA for submission to the Guyana EPA as soon as practical.

During EEPGL's operations, the on-site ERT will endeavor to contain any spill at the source, whether it be onshore (shorebase or port) or onboard a vessel (i.e. PSV, FSV, installation, drillship, tug, tanker or FPSO) and minimize any impacts to the environment, using the equipment available at the worksite. In the event of an on-water release, EEPGL will ensure the required notifications are made, initial response actions are implemented and monitor the incident and consider all appropriate response strategies, including containment and recovery as well as dispersants to appropriately respond to the incident.

If released oil is predicted to reach a shoreline, EEPGL will continue to leverage all available resources to stop the release at the source, utilizing provided containment, mechanical recovery, open burning, surface and subsurface dispersant application. EEPGL will also consider and evaluate shoreline protection measures (based on consultation with the appropriate government authorities) and outcomes from the NEBA to identify the combination of key response strategies that would be appropriate, given the specific situation, fate, and trajectory of the oil spill and weather conditions. Local regulatory approval and the ExxonMobil Oil Spill Dispersant Guidelines will govern the application of dispersants.

The following flowchart (Figure 8) provides an overview of actions taken by the EEPGL ERT and IMT in the event of an emergency. A final decision on all necessary actions to be implemented will be determined on a case by case basis tailored to the particular incident and individual circumstances.

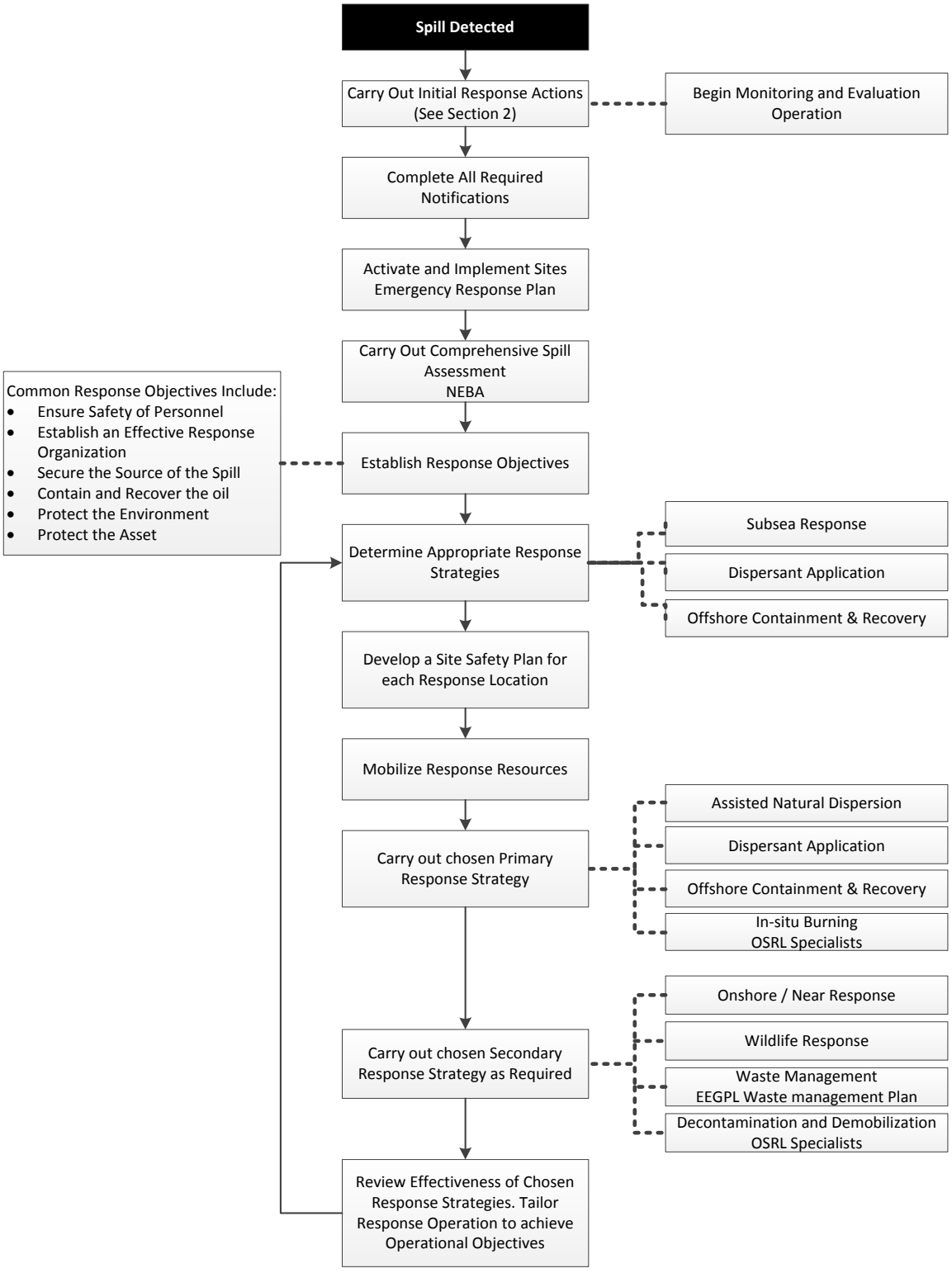


Figure 8: Emergency Response Generic Actions Flowchart

5.2 NEBA

EEPGL will use the Net Environment Benefit Analysis (NEBA) as a key input to the overall Incident Response Planning and in preparation of this OSRP. The Environmental Unit will develop the NEBA in consultation with the appropriate stakeholders and authorities.

NEBA compares the impacts of available response options including, in some cases, leaving the oil to degrade naturally, and selects the option or combination of options that minimizes overall harm to environmental and socioeconomic resources (including cultural sensitivities). The use of NEBA will ensure that EEPGL selects the most appropriate response techniques available to minimize overall environmental impact based on the conditions and sensitivities of an actual incident. In select situations the NEBA may be updated and performed again at the time of a significant spill (Tier III) to further refine and optimize the response strategies to be used given the specific conditions and circumstances existing at the time of the event.

Refer to Section 7 for a list of available resources.

5.3 Appropriate Response Strategies

EEPGL will respond to a release as far offshore as possible, using all appropriate tools and tactics to minimize shoreline impact. In consultation with the Guyana EPA, EEPGL will develop Incident Response Plans that could include the following response strategies for an offshore release:

- Respond with aerially applied dispersants, which can be quickly deployed and treat large surface areas rapidly and efficiently.

The safety of responders also needs to be considered in the evaluation of response strategies. Response tactics depend upon a variety of environmental conditions.

- Implement subsea dispersant application as soon as possible, if warranted, to treat most if not all oil spilled at the source before it encounters surface water resources;
- Deploy in situ burning equipment to burn thick oil near the source;
- Continue to use aerially applied dispersant as a primary response tool for oil further from the source where mechanical recovery/in situ burn operations are less effective;
- Utilize aerial dispersant application during calm seas on emulsified oil;
- Outfit vessels of opportunity (VOO) with dispersant delivery and mechanical containment and recovery systems to provide a fleet of vessels that can be a line of defense against surface oil approaching shorelines.

Shoreline protection and cleanup may be needed for some scenarios, in which case, sensitive shorelines will receive prioritization for protective booming.

Depending on the volume, mechanical recovery at sea is possible due to the anticipated oil thicknesses, but may be difficult due to the active metocean conditions.

There is a health and safety hazard posed by high atmospheric concentrations of hydrocarbons. Air quality should be monitored at all times and personnel should be evacuated immediately if

an exclusion zone is required. Consideration for air quality monitoring is included in the Site Safety Plan.

Figure 9 below shows the cone of response when responding to a loss of well control event using all the available response strategies at once.

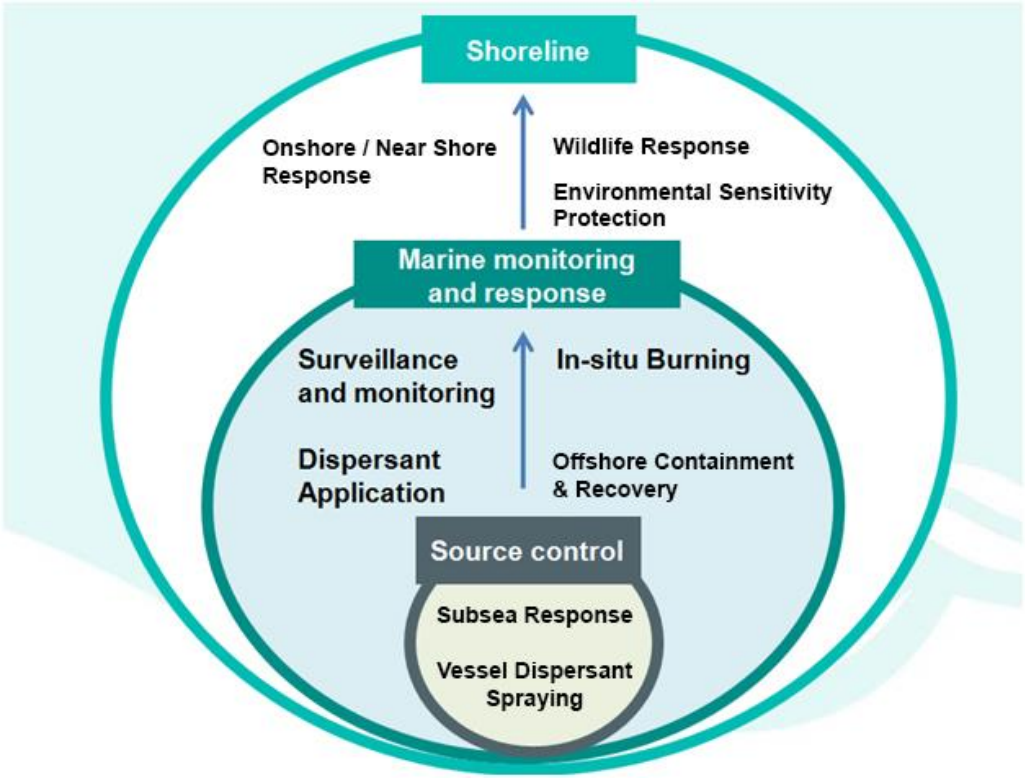


Figure 9: Cone of Response Diagram

5.4 Trans-boundary Impacts

In the event that there is an incident that impacts areas outside the Guyana Exclusive Economic Zone (EEZ), EEPGL will work with representatives for the respective locations to:

- Coordinate operations and communication between different command posts;
- Create a trans-boundary workgroup to manage waste from a product release – including pinpointing waste-handling locations in the impacted region and managing commercial and legal issues;
- Identify places of refuge in the impacted region where vessels in mechanical trouble could go for repairs and assistance;
- Determine how EEPGL and the impacted regional stakeholders can work together to allow equipment and personnel to move to assist in a spill response outside the region while still retaining a core level of response readiness within the two jurisdictions;
- Assigning or accepting financial liability during a response to a trans-boundary event;
- Work with local communities within the impacted area to raise awareness of oil spill planning and preparations.

6 RESPONSE STRATEGY IMPLEMENTATION

The following sections describe the implementation of each response strategy available to EEPGL.

6.1 Surveillance and Monitoring

Surveillance and monitoring is a key strategy relevant to all incidents that enter the marine environment. Surveillance and monitoring teams can fulfill the following response objectives:

- Verify oil spill scale and location;
- Monitor effectiveness of applied response strategies;
- Visually quantify spill volume;
- Direct operations – dispersant application, containment and recovery, shoreline assessment, in situ burning;
- Monitor wildlife.

The resources mobilized will vary depending on the scale of the incident. At a minimum, personnel will take visual observations, and vessel owners/operators will implement their ER/SOPEP's, deploying the Tier I response equipment they have onboard. Depending on the stage of the Liza Phase 1 FPSO Development Project this could include: the FPSO, drillships, tanker, tugs, installation vessels, PSV's, or FSV's, and EEPGL will request updated oil spill modeling from response organizations or support organizations internal to the Corporation. For Tier II or Tier III incidents EEPGL will scale up to a full surveillance plan using helicopters, fixed wing aircraft and satellite imagery.

The IMT will assign an Air Operations Branch as part of the Operations Section for large or complex incidents. The Air Operations Branch will coordinate aerial support according to operational needs and document operational assignments in an ICS-220 Air Operations Summary form, which will be included in the Incident Action Plan (IAP).

The Air Operations Branch Director is responsible for addressing response considerations including flight authorizations and restrictions, air clearances, government support, aerial logistics and operational constraints (e.g. weather, visibility). All air operations must follow the Site Safety Plan and additional emergency procedures specific to the operation.

Figure 10 illustrates the key steps involved in surveillance and monitoring; refer to the ExxonMobil IMH and the OSRL Field Guides for further details. Refer to Section 7, for a list of available resources.



Figure 10: Surveillance and Monitoring Key Steps

6.2 Assisted Natural Dispersion

Assisted natural dispersion is the process of speeding up the natural breakdown of hydrocarbons without the use of chemicals. This strategy is suitable for smaller spills or in combination with other strategies for larger spills.

To assist the natural dispersion process techniques such as prop washing or water hoses can be implemented to introduce energy and agitate the hydrocarbons, thereby assisting with the break up of a surface slick and promoting biodegradation.

6.3 Operational Spill Cleanup

Operational spills are small in volume and easily contained on land, on deck or in very close proximity to a vessel. These spills can originate from shore facilities, vessels or the drill rig. Equipment used for operational spills include sorbent pads, booms, shovels and PPE. This equipment is stored close to the work site for ease of deployment.

- Shore bases in Guyana and Trinidad have site specific ER Plans and are equipped with Tier I spill response kits;
- Vessels maintain a Shipboard Oil Pollution Emergency Plan (SOPEP) and associated equipment onboard the vessel.

For further details on operational spill cleanup, refer to the Incident Management Handbook and Field Response Guide found in Attachment B.

6.4 Onshore/Near Shore Response

6.4.1 Harbor Containment and Recovery

EEPGL will use harbor containment and recovery should a PSV or FSV release hydrocarbons in Port. The harbor response team will employ a strategy that considers tides, currents, wind, vessel traffic, and local infrastructure and stakeholder input. EEPGL will deploy equipment available on site and in the Port (such as or similar to the equipment and trained personnel at the Guyana Fuel Terminals and resources held by NRC for Trinidad) immediately following a release.

Figure 11 illustrates the key steps involved in harbor containment and recovery; refer to the ExxonMobil IMH and OSRL Field Guide for detailed information. Refer to Section 7, for a list of available resources.

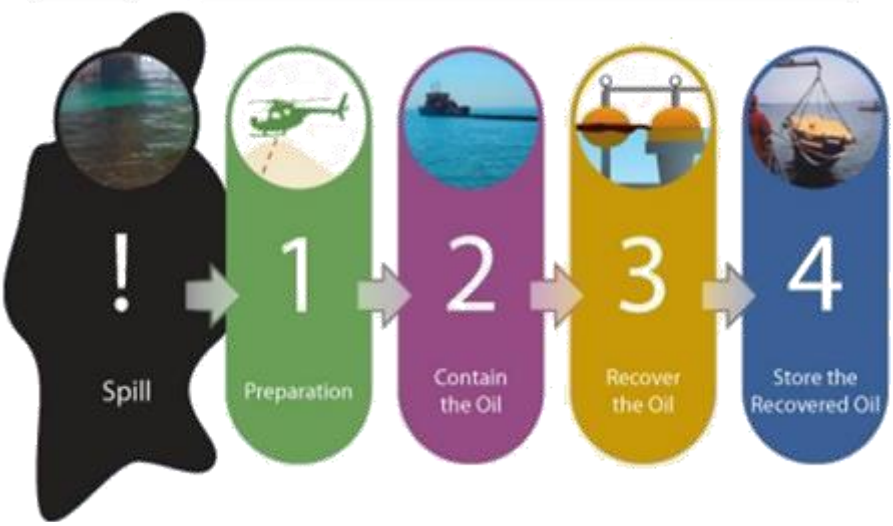


Figure 11: Harbor Containment and Recovery Key Steps

6.4.2 Shoreline Response

EEPGL will implement a shoreline response if released hydrocarbons show the potential to affect a shoreline, prioritizing environmentally or socio-economically sensitive areas (ESAs). These are ranked using an Environmental Sensitivity Index (ESI) and corresponding resource/receptor ratings to identify those projected areas, special status species, fish and other marine life on which these local coastal communities and indigenous peoples depend and live, as assessed in the Environmental Impact Assessment for the Liza Phase 1 FPSO Development Project.

This will consist of using vessel dispersant application to prevent approaching slicks from impacting ESAs and using shoreline booming to protect sensitive areas and provide collection points for hydrocarbon recovery. Initial equipment (e.g., dispersant, mechanical recovery) will come from in country/Region and will be supplemented as necessary via OSRL from Ft. Lauderdale, FL and other bases.

EEPGL has pre identified the environmental and socio-economical sensitive areas that could be impacted by a major oil spill. These coastal sensitivity maps have been provided in Appendix D of this OSRP. In addition, further information can be found in Section 7.4 of the Environmental Impact Assessment and Section 3.0 of the Environmental and Socioeconomic Management Plan for such unplanned events. The IMT will use this information for response planning, including development of protection strategies.

Figure 12 illustrates the key steps involved in a shoreline response; refer to the ExxonMobil IMH and OSRL Field Guide for detailed information. Refer to Section 7 for a list of available resources.



Figure 12: Shoreline Response Key Steps

6.5 Dispersant Application

Dispersants have been used successfully to reduce shoreline and surface impact during many oil spill incidents. When used properly, dispersants can rapidly reduce the volume of oil on the sea surface and accelerate the natural biodegradation process. Dispersants can reduce or eliminate the potential for oil to impact shorelines. EEPGL will only apply dispersants if there is a direct advantage to protecting environmental or socio-economical sensitivities (determined using NEBA, Section 5.2) and they have obtained regulatory approval.

Vessel mounted systems will be used to apply dispersant in small-scale incidents and aircraft will apply dispersant on large oil slicks. Dispersant (and associated vessel spray equipment) will be kept at the shorebase or other easily accessible location where it can be easily loaded on vessels for application. OSRL will conduct aerial dispersant application and will likely base the operation out of the Georgetown airport. In the unlikely event of a well blowout, dispersant is injected subsea at the wellhead location on the seafloor using specialized equipment and Remotely Operated Vehicles (ROVs).

In Guyana, dispersant usage is subject to permission from the Guyana EPA. EEPGL and Guyana EPA both recognize that the key to making the right decision for the best response

strategy is pre-planning. EEPGL is seeking pre-approval from the EPA to use Corexit 9500A type dispersant, supported by a dispersant effectiveness monitoring and evaluation program, as a first strike mitigation method in order to respond quickly in the event of a major offshore release. In accordance with guidance provided by the EPA, EEPGL is using this OSRP as the instrument for pre-approval to use Corexit 9500A type dispersant.

Requesting approval at the time of an incident delays the response, potentially increasing environmental damage. EEPGL will use the Dispersant Spraying Considerations Flowchart (Appendix B) as a guide for whether to use dispersants. Dispersant will be applied according to manufacturers' guidelines and the operating procedures of the spray applicators.

EEPGL will work with the EPA to develop a dispersant application, monitoring and evaluation strategy. The dispersant use application form captures all relevant information to assist in this process (Refer to Appendix C.2).

Figure 13 illustrates the key steps involved in dispersant operations; refer to the ExxonMobil IMH and the OSRL Field Guides for further details. Refer to Section 7, for a list of available resources.

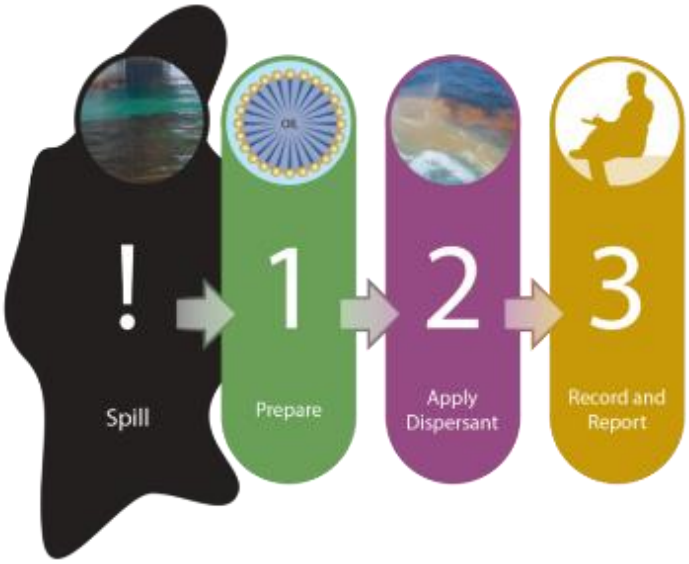


Figure 13: Dispersant Application Key Steps

6.6 Offshore Containment and Recovery

EEPGL is likely to use containment and recovery operations for spills that enter the sea.

OSRL will provide containment and recovery resources for an offshore response. EEPGL will source Vessels of Opportunity (VOOs) to provide platforms for the containment and recovery systems. Barges will store and transport recovered waste in accordance with the Waste Management Plan (Refer to Section 8.1).

Figure 14 illustrates the key steps involved in containment and recovery operations; refer to the ExxonMobil IMH and OSRL Field Guide for detailed information. Refer to Section 7, for a list of available resources.



Figure 14: Containment and Recovery Key Steps

6.7 Wildlife Response

In the event of an oil spill there is potential for wildlife to either become oiled or require protection from the oil. Both require specialist knowledge and regulatory backing.

A Wildlife Response Plan (WRP) specific to Guyana has been developed and provided as Appendix E to allow for a timely, coordinated and effective protection, rescue, and rehabilitation of wildlife to minimize any negative impacts of a spill. The WRP outlines the measures to avoid and mitigate impacts to wildlife, as well as rescue and rehabilitation of affected or injured wildlife should such measures be required.

Details of the wildlife that could be impacted are provided in the Environmental Impact Assessment for the Liza Phase 1 FPSO Development Project.

Should a wildlife response be required, EEPGL will call upon the Sea Alarm Foundation via OSRL to provide specialist advice and assistance with carrying out a response. Opportunities to engage and train further members of the local oil spill response contractor as well as potential members of the potentially affected communities will be evaluated to expand such local resources.

6.8 In Situ Burning

In situ burning is a technique for burning spilled hydrocarbons on the water's surface. EEPGL is only likely to use in situ burning for large-scale Tier III incidents. OSRL will provide the resources required.

Hydrocarbons must be contained within fire retardant boom with sufficient thickness to achieve a successful burn. Other factors that influence burn success include:

- Weather and sea state;

- Volatility of the hydrocarbons;
- Suitable vessel availability; and
- Regulatory approval.

Figure 15 illustrates the key steps involved in burning operations; refer to the ExxonMobil IMH and OSRL Field Guide for detailed information. Refer to Section 7, for a list of available resources.

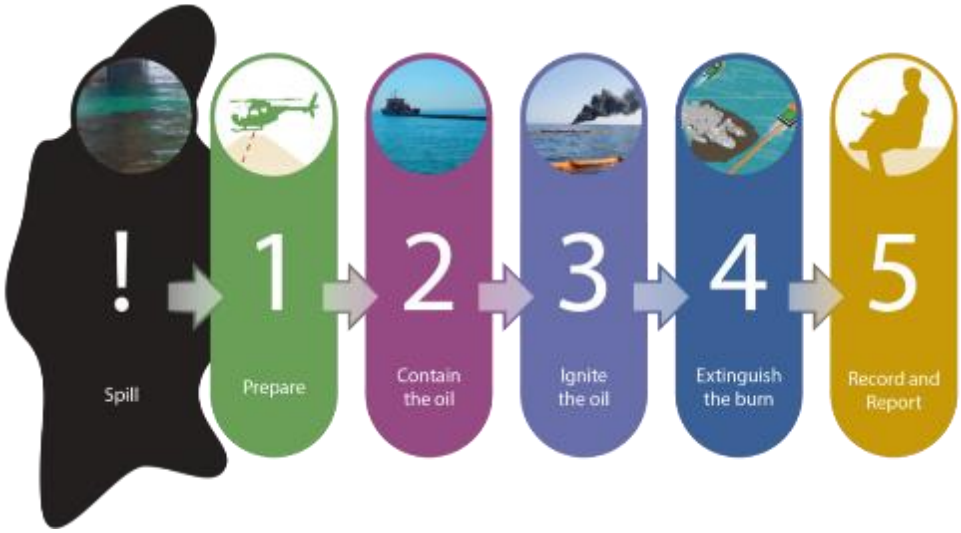


Figure 15: In Situ Burning Key Steps

6.9 Waste Management

EEPGL will manage hazardous waste resulting from clean up activities and ensure appropriate disposal. Large spills can result in significant quantities of waste in various forms:

- Recovered oil;
- Oily water mixed with recovered oil;
- Sorbent materials;
- Oiled containment boom;
- PPE;
- Oiled sediment;
- Oiled vegetation;
- Oiled debris;
- Deceased wildlife.

Effective waste management will minimize secondary contamination, thereby minimizing waste volume. EEPGL have developed a Waste Management Plan (WMP) (refer to Appendix 1 of the Environmental and Socioeconomic Management Plan), which may be adapted as required if a spill is likely to produce more waste than can be handled by their regular waste contractor.

Additional waste management provisions including those associated with the disposition of any deceased wildlife is found in Appendix E, the Wildlife Response Plan.

Figure 16 illustrates the key steps involved in waste management; refer to the ExxonMobil IMH and OSRL Field Guide for detailed information. Refer to Section 7, for a list of available resources.



Figure 16: Waste Management Key Steps

6.10 Subsea Response

The Drilling ERP contains managerial and logistical details on debris clearance, subsea dispersant injection, well capping and relief well drilling. The Tanker Owner/Operator will implement an ERP should any spill occur during tanker offloading and the FPSO ERP will have similar details on the surface and subsea response for a spill from either the FPSO, during tanker offloading or SURF (Subsea umbilical, riser, flowline) equipment during production operations.

If a Tier III well control incident occurs involving the release of wellbore fluids into the sea, EEPGL will be responsible for containing the source. This team is responsible for performing site survey, conducting debris removal operations (as required), evaluating and executing well intervention options, installing subsea dispersant application hardware, and mobilizing and installing a capping device/auxiliary equipment as required. Initially, the team will attempt to operate the existing subsea well control equipment through intervention. If required, the team will mobilize and install a capping device to shut-in the well at the sea floor. Once under control, the forward plan will be designed and executed according to the details of the incident itself. If a relief well is required, it will be drilled to intersect the original well and address specific issues encountered in the original wellbore.

OSRL's Subsea Well Intervention Service (SWIS) provides EEPGL with access to a Subsea Incident Response Toolkit (SIRT), Global Dispersant Stockpile (GDS) and multiple Capping

Stack Systems (CSS). The CSS and SIRT includes equipment that can be mobilized directly to the well site:

- Survey & debris clearance equipment;
- Intervention equipment;
- Dispersant hardware application system*;
- Capping stack systems and auxiliary equipment.

*Dispersant will be mobilized simultaneously through the OSRL GDS service via the EEPGL IMT. For detailed information on the implementation of a subsea response, refer to the Drilling ERP.

The key steps involved with a subsea response are:

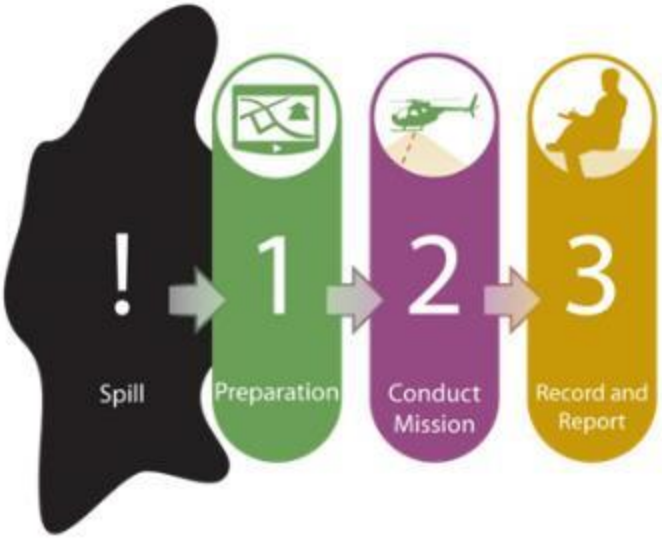


Figure 17: Subsea Response Key Steps

Similar response strategies as those previously described and depicted in Figures 12-16 will be evaluated and utilized for those potential spill scenarios associated with production operations as described in Table 7. Both the tanker and FPSO owner/operators will coordinate their responses to any spill or release that occurs during tanker offloading.

6.11 Decontamination

In the event of a spill, an incident-specific Decontamination Plan will be developed by EEPGL relevant with the nature and extent of the spill to prevent further oiling through secondary contamination. Decontamination is the process of removing or neutralizing contaminants on personnel and any equipment that has come into contact with the oil or oily wastes. To ensure the safety of the responders, the public and prevent further potential impact to the environment a decontamination plan and dedicated area with clearly delinated hot (exclusion), warm (contamination reduction) and cold (clean support) zones will be developed and established. Decontamination procedures are supplemental to the Site Safety Plan. The Planning Section of

the Regional Response Team will support development of the Decontamination Plan with input from Operations and Logistics.

The decontamination procedures will depend on the type and volume of oil that has been spilled, and the type of equipment used during the clean-up operation. Regular decontamination during the response is necessary for the personnel involved with direct clean-up efforts, the vessels involved in the response, and a wide range of spill-related equipment. Any spill response contractor will follow established guidelines for decontamination operations in order to facilitate proper decontamination through the duration of the clean-up effort.

Establishing a field decontamination process is a priority. Regular decontamination will occur in the field, particularly during a large-scale response, so all personnel must be briefed on the decontamination requirements at the beginning of the spill response in order to ensure functioning decontamination operations.

Supervisory personnel are responsible for ensuring that all decontamination activities are occurring according to the guidelines. At the end of the response effort, all the vessels and equipment that have been used at the site will undergo a more thorough cleaning in order to ensure their suitability for future use, including normal operations.

For detailed information on the implementation techniques involved with decontamination, refer to the relevant Field Guide and IMH.

6.12 Demobilization

Once an incident has stabilized and operations are being completed, a decision will be made to commence demobilization of resources (personnel and equipment) as appropriate. An incident-specific Demobilization Plan will be developed incorporating guidance from the Resource Unit Lead, Operations, Logistics and Legal.

The Resource Unit will then coordinate demobilization of resources in accordance with the approved Demobilization Plan.

There are a number of tools available to assist in the determination of cleanup endpoints, including:

- Shoreline Assessment Manual, Third Edition, NOAA, 2000;
- Shoreline Assessment Job Aid, NOAA, 2007;
- Marine Oil Spill Response Options for Minimizing Environmental Impacts, NOAA, API and USCG, 1998;
- Options for Minimizing Environmental Impacts of Freshwater Spill Response, NOAA and API, 1995.

7 RESPONSE RESOURCES

Table 6 lists the resources available to EEPGL for each potential response strategy. Table 7 provides a further summary of the representative oil spill response equipment to be provided on the FPSO.

Table 6: Oil Spill Response Resources*

Response Strategy	Resources Available	Quantity	Location
Surveillance and Monitoring	Heli-port / Shore base	2	Guyana Airport / Shorebase (Examples: Correia International Airport / John Fernandes Port Shorebase or similar, Guyana)
	Helicopters	3	Infield helicopter provider
	Helicopters	As required	National Helicopter Services Limited or similar, Trinidad
	Tracking Buoy	As required	Horizon Marine or similar
	OSRL Trained personnel Fluorometry Satellite Imagery Tracking buoys	Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	
Assisted Natural Dispersion	PSV's / FSV	6	Infield
Operational Spill clean-up	SOPEP material Spill Equipment at shoreside facilites	As required	Onboard all vessel's, at shorebases in Guyana and Trinidad, Fuel Terminals [Examples: SOL Terminal (Guyana), NRC base (Trinidad)]
Onshore/near shore	Onshore/near shore package Fence Boom Skimmers Temporary storage	TBD	Guyana Fuel Terminal (SOL Terminal or similar, Guyana)
			Trinidad Shorebase (NRC base or similar)
	OSRL	Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	

Response Strategy	Resources Available		Quantity	Location
Dispersant Application	Dispersant Spray Package 4000 liters chemical dispersant Afedo Spray nozzles		2	Guyana Shorebase (John Fernandes Port Shorebase or similar), Guyana
	OSRL Vessel mounted spray equipment Aerial spray platform Trained personnel		Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	
	Global Dispersant Stockpile		Refer to: Section 0, Global Dispersant Stockpile	
Offshore containment and recovery	OSRL Offshore boom Offshore skimmers Temporary storage Trained personnel		Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	
Wildlife	OSRL	Wildlife response equipment	Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	
	Sea Alarm Foundation (SAF)	Technical expertise		
	ExxonMobil Biomedical Sciences, Inc. (EMBSI)	Wildlife expertise	Refer: Wildlife Response Plan (Appendix E)	
In Situ Burning	OSRL Fire resistant boom Ignition equipment Trained personnel		Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	
Waste Management	Waste contractor: TBD		N/A	Guyana
	OSRL		Refer: Section 7.3.2, Oil Spill Response Limited (OSRL)	
Subsea Response	OSRL Subsea Well Intervention Services (SWIS)		Refer: Section 0, Global Dispersant Stockpile (GDS)	
	ROV contractor ROVs onboard Technicians 8 (4 man crew per Drill Ship)		4 (2 per Drill Ship)	TBD

Response Strategy	Resources Available		Quantity	Location
	Trendsetter Engineering Inc. Engineers / Technicians to support mobilization and installation of capping equipment		N/A	Houston, TX
	Relief Well: Halliburton Boots & Coots active ranging technology		N/A	Houston, TX
	Additional available equipment: Wild Well Control Well CONTAINED BOP Intervention Subsea Dispersant application kit Debris removal kit Capping Stack system		See WellCONTAINED (TM)	Aberdeen, Scotland
Multi strategy use	Drillship		Up to 2	Infield
	FPSO*		1	Infield (See Table 7 for a list of the common spill response equipment kept onboard)
	Crude Oil Tanker		1	Infield (During scheduled tanker offloading)
	PSV's / FSV	PSV (Similar in class to the Hornbeck Commander, 320 ft class)	4	Infield
		FSV (Similar in class to Chouest Fast Hauler)	1	
	Installation Vessels	MPV (Multi-Purpose Support vessel)	1	
	Tugs	1x 120 MT Azimuth Stern Driven (ASD) Tug 2 x 80 MT ASD Tugs	3	
	Vessel's of Opportunity (VOO's)	Various	N/A	Various

** Note: All equipment and vessels specified are reflective of the peak resources needed during concurrent drilling and production operations.*

Table 7: FPSO Sample List of Common Oil Spill Response Equipment*

FPSO	Detailed List	Quantity
Container # 1	25 m sections of RO Boom 1500 Offshore Boom with ASTM Connectors	2
	Ro Skim Weir Skimmer	1
	15 m Outrigger float arm 3 PARTS with connector BOAT	1
	DOP 250 Dual Screw Pump (Interchangeable with Terminator Skimmer)	1
	Hydraulic Hose Set 40 m	1
	Hose reel for 40 m Hose Set with Hydraulic Winch	1
	Hydraulic Winder for RO Boom Swwep System in 20,ISO Container	1
	Towing set for Ro Sweep System	1
	Repair Kit For Ro Boom 1500 and skimmer	1
	1 Box Plugs BOON and 3 Key	1
	Box PAD Absorbent	1
	Gloves	5
	Disposal coveralls	5
	Ropes	2
	Board	1
Container # 2	Ro Boom 1500with ASTM Conectors	200 m
	Towing set for Ro Boom 1500	1
	Winder Hydraulic for 200m Ro Boom 1500	1
	Powerpack 10kW for Hydraulic Winder with Onboard Boom, inflator, Spark Arrestor & Automatic Shutdown valve	1
	Hose set for 10kW Powerpack	1
	Repair kit for Ro Boom 1500	1
	Spares kit for 10kW Powerpack	1
	Box PAD Absorbent	1
	Gloves	5
	Disposal coveralls	5
	Ropes	2
	Board	1
	Terminator Self Adjusting Weir Skimmer Head with Radio Controlled Thrusters	2

FPSO	Detailed List	Quantity
Container # 3	Desmi Helix Brush Skimmer Adaptor for Terminator skimmer	1
	DOP 250Dual Screw Pump (Interchangeable with Ro Sweep system)	1
	Hose set 40m for Terminator with Thrusters	1
	Hose reel For 40m Hose Set for Terminator with Thrusters & Brush Skimmer Adaptor	1
	Spares kit for Terminator	1
	For use with Ro Sweep Hydraulic Winder, onboard Boom, Inflator for Ro Sweep, Operation of DOP 250 Dual Screw Pump with Ro Sweep & Terminator Skimmer.	1
Container # 4	Spares kit for 50kW Powerpack	1
	Oil Spill Kit Box in Process Area: 5 pack plastic bags 200 L 2 Buckets, 4 pair of hand gloves, 4 packers, 2 disposal coveralls 2 CARTON BOXES OF LUBETECH ROLLS 2 BAGS OF HYDROCARBON ABSORBENT PAD OR ROLL PAD 10 OIL SPILL TAG + 2 rolls BARRIER TAPE	1
Container # 5	AFT Oil Spill Reserve Equipment: 3 Plastic Drums; 2 Boxes (Empty); 1 Box with 8 Chemical Absorbant Pads and Industrial Spillage Absorbent.	1

7.1 Tier I Resources

7.1.1 Mobilization

The EEPGL on site ERT is responsible for mobilizing Tier I resources.

The Tier I equipment held at EEPGL's onshore and offshore operations, including shore bases, fueling terminal, support vessels, drilling rig, tankers and FPSO will be available for rapid deployment in the event of an incident. See site specific ER plans for onshore facilities and individual vessel SOPEPs.

7.2 Tier II Resources

Equipment and trained personnel are available through the terminals and shorebases to initiate an onshore/nearshore response to a Tier II incident.

Vessel dispersant spray operations will be initiated from the PSVs and supported from the shorebases or other accessible locations as needed to supplement other Tier II response actions.

Given the type and quantity of hydrocarbons identified in the EEPGL risk assessment, the distance of the Liza Phase 1 FPSO and drill ships from the coastline, and that oil spill modeling completed for the loss of both a well control, riser or tanker offloading scenario indicated that oil is unlikely to impact a shoreline in less than approximately 5-10 days; it is estimated that regional and international resources can be cascaded into a response in sufficient time to be effective. Therefore, in the event country/Region resources are insufficient, EEPGL would immediately activate additional resources such as ExxonMobil's RRT and OSRL (see Tier III Arrangements Section 5) early in an incident response operation.

In addition, EEPGL could call upon their in-country contracted companies to provide specific technical or logistical assistance (e.g., aircraft, road transportation, and waste management), as well as Vessels of Opportunity located in Guyana and Trinidad, as needed.

7.3 Tier III Resources

7.3.1 ExxonMobil's Regional Response Teams

The ExxonMobil RRT is comprised of two geographically-based units:

- Europe-Africa-Middle East / Asia-Pacific RRT;
- North America RRT.

The first point of contact for EEPGL is the Emergency Preparedness and Response Coordinator for North America RRT, who can initiate activation following instructions from the Venture Manager. Although organized geographically, resources from all RRT units can be mobilized.

The RRT is organized in accordance with the Incident Command System (Figure 18). The organization is led and the incident managed by the Incident Commander and the Command Section, supported by Operations, Planning, Logistics and Finance Sections. The support

sections are further sub-divided into branches and units depending on the scale and type of incident.

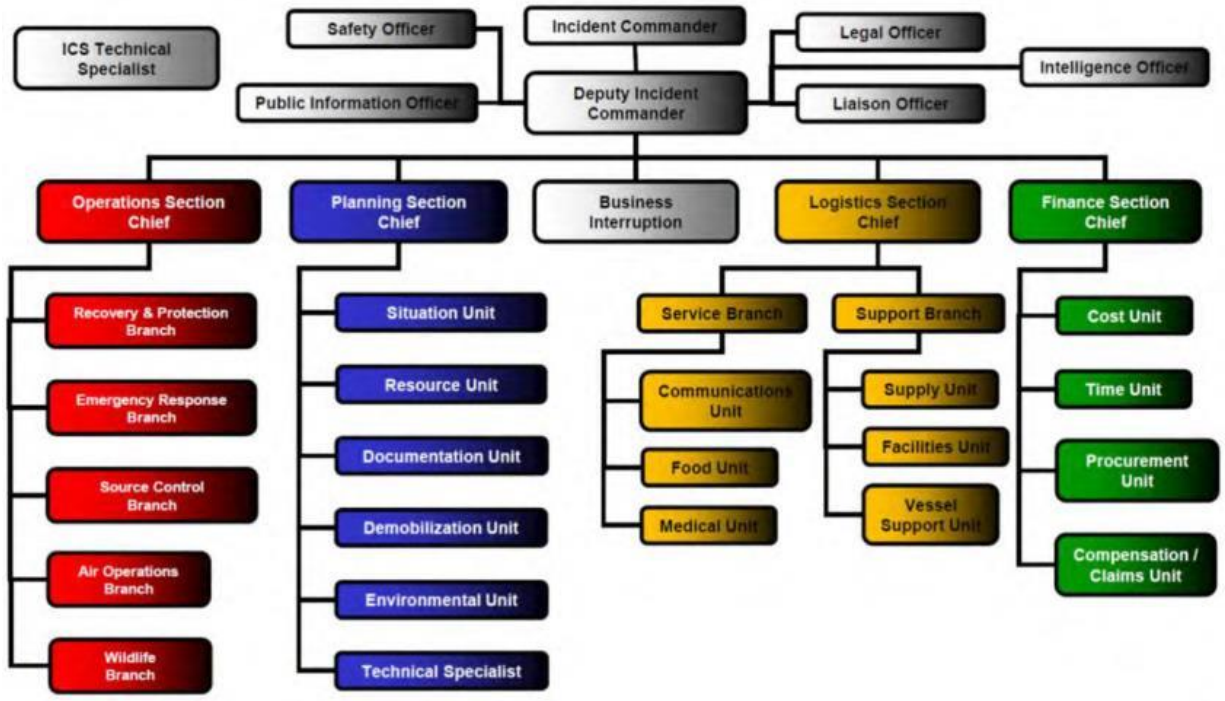


Figure 18: Sample Incident Command System Organization

The RRT includes trained individuals and specialists, with assigned roles and responsibilities, who can be deployed at short notice to address a broad range of emergency situations.

The RRT can be partially or fully activated. Partial activation may be implemented when functional support is required by ERTs at incident sites. Should this occur, RRT members will typically be deployed within the existing on-site ERT structure. For larger incidents, that require an extensive amount of tactical work, an intermediate group called the IMT may be established to provide tactical management support for the ERT. Functional support can be called upon independent of RRT activation, if required

For large emergencies and incidents in remote locations, full activation may be implemented. In Guyana, partial or full activation of the RRT is likely for all Tier II and Tier III incidents, to help manage a major tactical response. In the event that the RRT is activated, an RRT Command Center will be established by the North American RRT.

7.3.2 Oil Spill Response Limited (OSRL)

EEPGL is a Participant member with OSRL, and therefore has immediate access to Tier III technical advice, resources and expertise 365 days a year on a 24 hour basis.

Table 8 summarizes the OSRL service level agreement (SLA) available to EEPGL.

Table 8: OSRL Service Level Agreement (SLA) Summary

Service	Service Standard		EEPGL Membership Type: Participant	
Response notification, mobilization, service and advice	Notification of a spill should be placed to one of the following locations:			
	OSRL BASE	Fort Lauderdale, USA		
	TELEPHONE	+1 954 983 9880		
	FAX	+1 954 987 3001		
	EMAIL	dutymanagers@oilspillresponse.com		
	FORMS	Refer to Appendix 0: OSRL Notification Form		
	The Duty Manager will speak and advise EEPGL immediately, or call EEPGL back within 10 minutes.			
Nominated Contact	OSRL must receive an official mobilization authorization from one of EEPGL's Nominated Call-Out Authorities (anyone can notify OSRL).		EEPGL's Nominated Authority: Greg DeMarco Arthur Powers	
Spill response equipment	SLA response equipment is housed in secure facilities in Southampton, Fort Lauderdale, Bahrain and Singapore. Response equipment is customs cleared response ready. Refer to: OSRL Yearbook for a complete list of equipment available, www.oilspillresponse.com and refer to the equipment stockpile status report http://www.oilspillresponse.com/activate-us/equipment-stockpile-status-report			
	As per the SLA, EEPGL can mobilize up to 50% of the global stockpile. If there is more than one spill EEPGL can mobilize 50% of what remains.			
Dispersant stockpile	If there was an incident, the spiller is entitled to 50% of the ~680m^3 of dispersant located in Southampton, Singapore, Fort Lauderdale and Bahrain. OSRL may be able to obtain further dispersant through the Global Response Network (GRN) and other organizations, if required.			
World-wide transportation of equipment	Aircraft Type	Location	Dispersant Capacity	Range
	C-130 Hercules	Singapore, Seletar	13,000 liters	2000 nm in 8 hours
	Boeing 727	UK, Doncaster	17,500 liters	2,400 nm in 6 hours
	• Aerial dispersant coverage is provided within a six hour notice period. • 24 hour access to global network of cargo and passenger charter services through a dedicated broker.			
Oil spill trajectory and tracking	Trajectory and stochastic services for surface or subsurface oil spills on request, and backtrack services for surface oil spills using commercial modeling software:			
	OILMAP		Oil Spill Contingency and Response Model (OSCAR)	
	Satellite imagery services can be provided on request.			
Response Personnel	OSRL will provide the following response personnel on a first come, first served basis: • 1 x Senior oil spill response manager • 1 x Oil spill response manager • 15 x Spill response specialists / responders • 1 x Logistics Service branch coordinators			
	A Technical Advisor can be dispatched to offer support to EEPGL when they have an oil spill incident or the potential for an incident to occur. This is provided free of charge for the initial assessment period of up to 48 hours. If a full response team is then mobilized, the technical advisor will form part of the available team headcount.			

7.3.3 Global Dispersant Stockpile (GDS)

The GDS is an additional 5,000 m³ of dispersant located across the OSRL bases and in France (Table 9). The dispersant types are those with the largest worldwide approval.

Table 9: OSRL GDS Quantities and Locations

Dispersant	Quantity	Storage Location
Slickgone NS	350 m^3	Singapore
	500 m^3	Southampton, UK
	800 m^3	Saldanha, South Africa
Finasol OSR52	350 m^3	Singapore
	500 m^3	Southampton, UK
	1,500 m^3	Vatry, France
Corexit 9500	500 m^3	Rio de Janeiro, Brazil
	500 m^3	Fort Lauderdale, USA

OSRL and EEPGL mobilization responsibilities depend on the location of the stockpile (Figure 19). For all GDS dispersant located in Southampton, Singapore and Fort Lauderdale, normal SLA logistics and mobilization agreements apply. OSRL will mobilize the GDS alongside all other Tier III equipment.

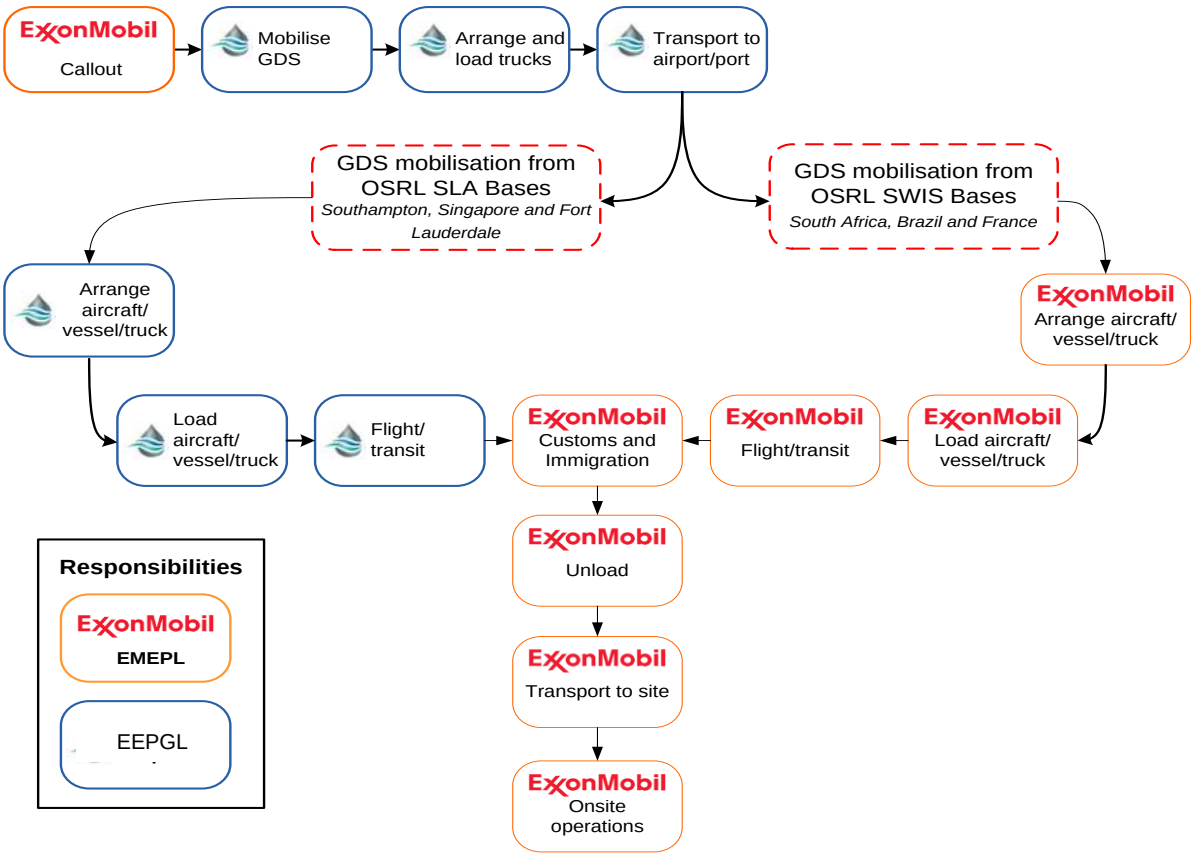


Figure 19: GDS Mobilization Responsibilities

EEPGL would mobilize the GDS through the OSRL Duty Manager. Unlike the SLA, EEPGL can mobilize 100% of the GDS for a single incident; 5,000 m^3 has been estimated to support both a subsea and/or surface response for 30 days, which is consistent with data collected from the 2010 Macondo incident.

Arrival of Tier III equipment and the SLA dispersant is expected in Cheddi Jagan International Airport within 3 days. The re-supply to EEPGL response operations will be arranged between EEPGL and the dispersant's manufacturer.

EEPGL will be responsible for designating the preferred port, arranging the airplane/vessel (in the case of a subsea well response), accepting the dispersant at the port, coordinating customs clearance, in country logistics plus confirming the use of dispersant with local environmental body. The OSRL Duty Manager will advise the operator of the logistical requirements of the GDS.

7.3.4 Subsea Well Response

EEPGL has access to the OSRL Subsea Well Intervention Service (SWIS), Oceaneering, Wild Well Control, Trendsetter Engineering and Halliburton Boots & Coots Services.

The OSRL SWIS provides EEPGL with access to a Subsea Incident Response Toolkit (SIRT) and multiple subsea well Capping Stack Systems (CSS), as required. The CSS and SIRT include equipment that can be mobilized directly to the well site:

- Survey and debris clearance equipment;
- Intervention equipment;
- Dispersant hardware application system*;
- Capping stack systems and auxillary equipment.

*Dispersant must be mobilized simultaneously through the OSRL GDS service via the EEPGL IMT (Section 0).

SWIS holds and maintains four CSSs and two SIRTS globally:

- 15k PSI Subsea Well Capping Stack – Norway and Brazil;
- 10k PSI Subsea Well Capping Stack – South Africa and Singapore;
- Subsea Incident Response Toolkit – Norway and Brazil.

In the event of activation the capping stack providing the fastest response time would be mobilized to the operational area. Further details are outlined in the Drilliing specific ERP.

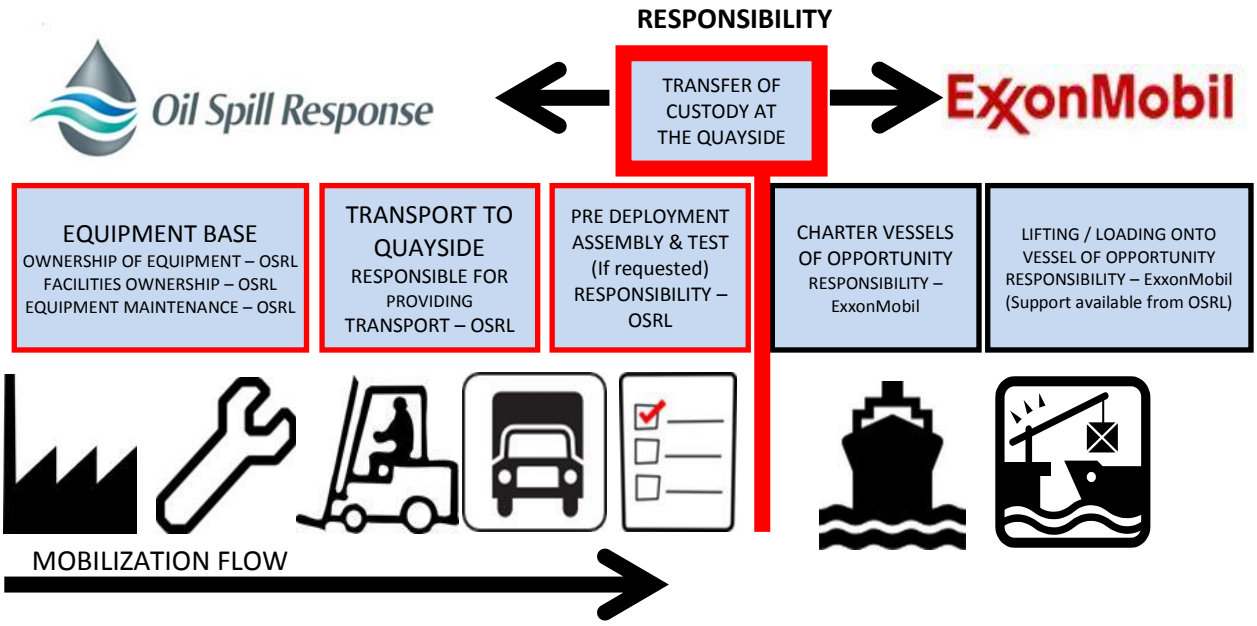


Figure 20: CSS Mobilization Responsibilities for OSRL and ExxonMobil

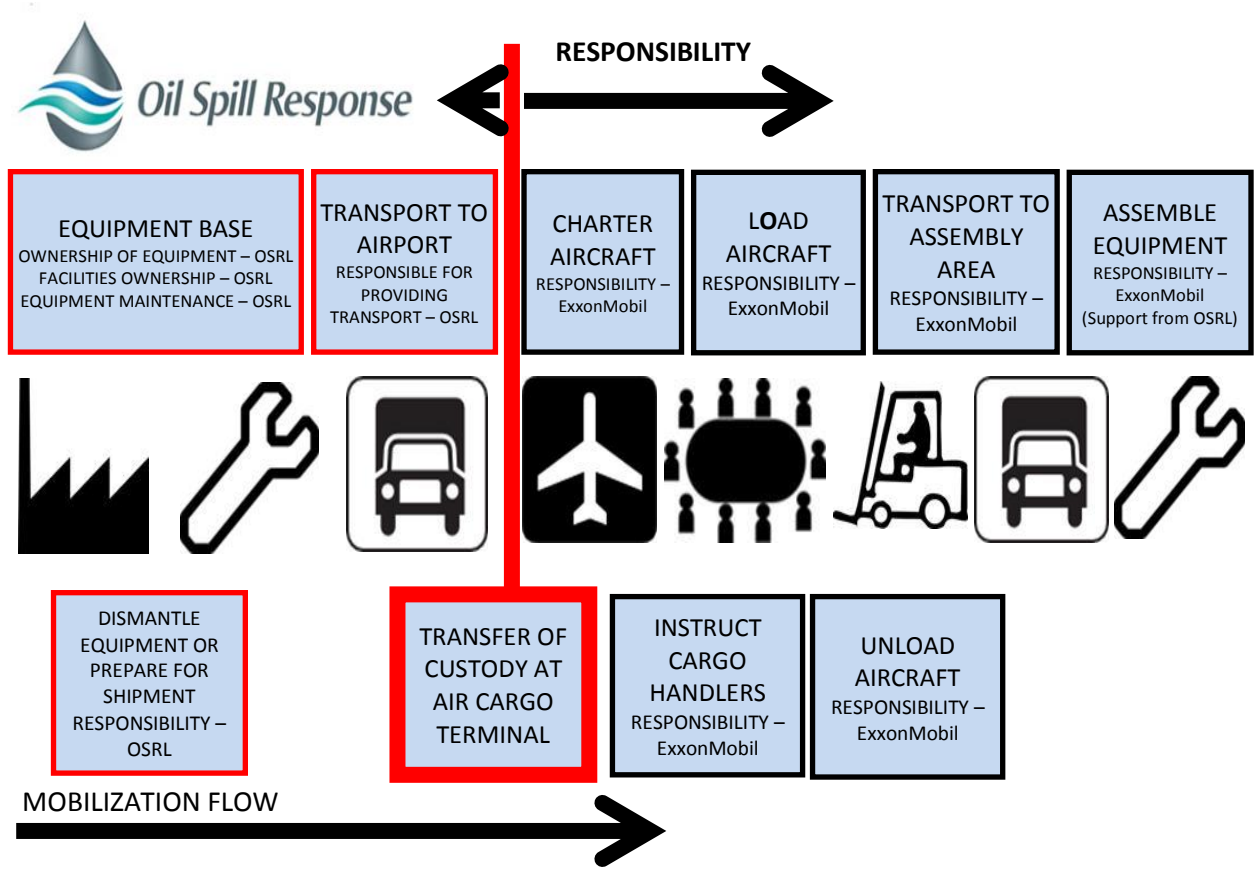


Figure 21: SIRT Mobilization Responsibilities for OSRL and ExxonMobil

In order to mobilize this equipment the following flow chart (Figure 22) should be considered.

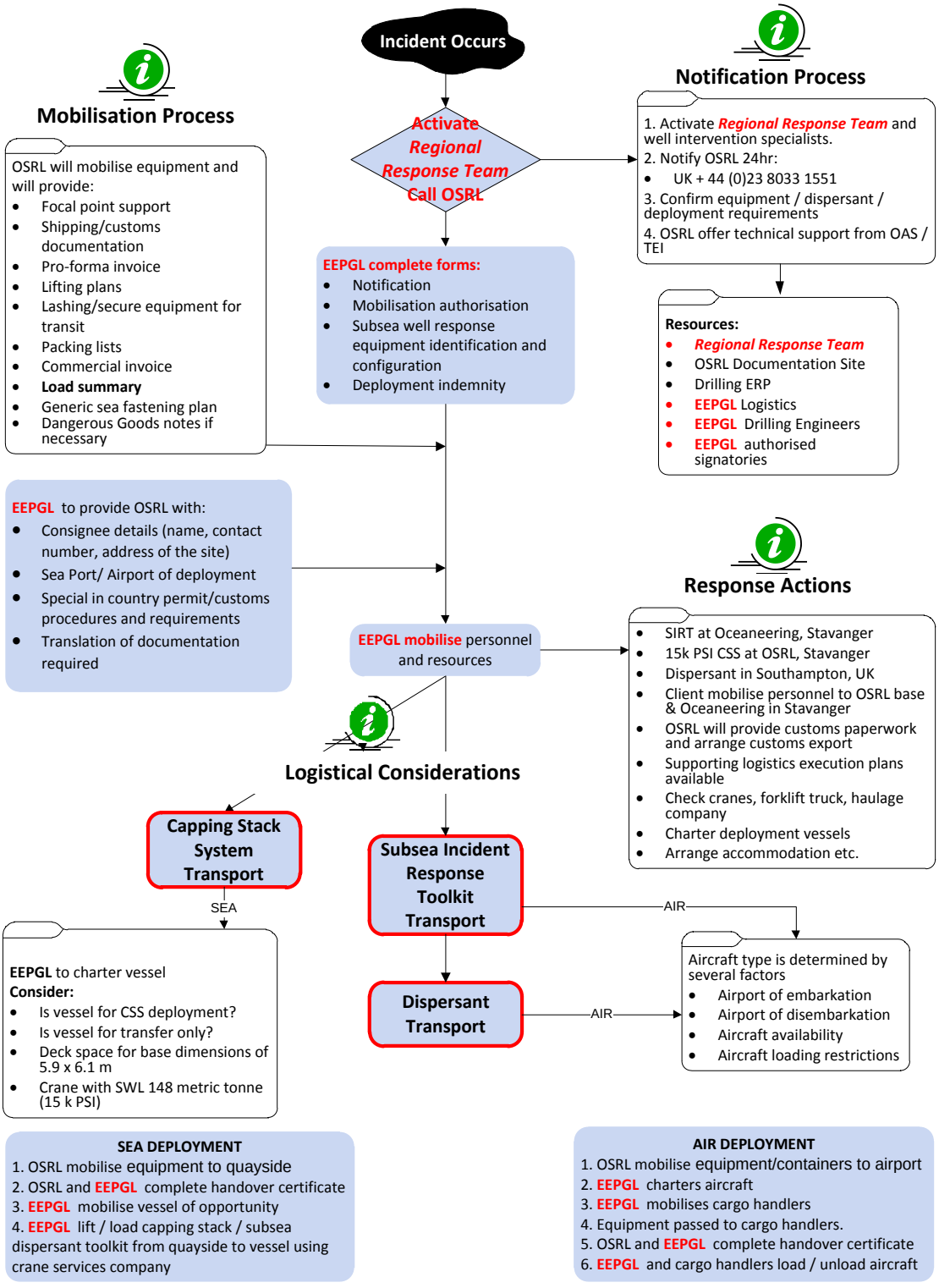


Figure 22: SWIS Mobilization

8 EXERCISES AND TRAINING

EEPGL conducts oil spill training courses and exercises (desktop and in-field) for operations offshore Guyana. The training, drills, and exercises familiarize response personnel with their duties and responsibilities in an oil spill.

8.1 Oil Spill Training

Training requirements depend on an individual's role and experience. There is some overlap between the IMT and the ERT training. This is beneficial since, for example, this provides the IMT with a clear appreciation of the factors likely to affect the performance of a particular technique or piece of equipment and at the same time gives the ERT a better understanding of the overall strategy.

EEPGL ERT and IMT members, which includes the Regional Response Team, will receive oil spill response training listed in Table 10 (or equivalent training such as XOM ICS 100/200 CBT and University of Spill Management) based on their response position.

Table 10: OSR Training Course Information

IMO Course Level	Oil Spill Incident Response Personnel	Course Outline
Level 1	ERT members	Provides training on practical aspects of oil properties, response techniques, health and safety, boom and skimmer deployment, dispersant application, use of sorbents, shoreline cleanup, debris/waste handling and disposal and wildlife casualties.
Level 2	On-Scene Commanders and ERT Leaders	Provides detailed training in oil spill behavior, fate and effects, spill assessment, operations planning, containment, protection and recovery, dispersant use, shoreline cleanup, site safety, storage and disposal of waste, media relations, record keeping, command and control management, communications and information, liability and compensation, response termination and post incident review/briefing.
Level 3	IMT members	Provides an overview of the roles and responsibilities of Senior Personnel in the management of oil spill incidents, cause and effect of oil spills, response policy and strategies, contingency planning, crisis management, public affairs and media relations, administration and finance and liability and compensation.

8.2 Incident Command System Training

ERT and IMT members will receive appropriate ICS Training listed in Table 11**Error! Reference source not found.** based on their roles and responsibilities.

Table 11: ICS Training Course Information

ICS Course Level	Oil Spill Incident Response Personnel	Course Outline
100	Tactical Response Team Members	This course is a web based course aimed at introducing the ICS, basic terminology, common responsibilities, ICS principles and features. A foundation is set that will allow personnel to function appropriately in an ICS. Completing ICS 100 is prerequisite to completing ICS 200.
200		This course is also web based that builds on the foundation information from ICS 100. ICS 200 is required for first level supervisors involved in responding to the incident at the site, Site Response Team. Completing ICS 200 is prerequisite to completing higher level ICS training. Topics covered should include: principles and features, organizational overview, incident facilities, incident resources and common responsibilities.
300	On-Scene Commanders, ERT Leaders and IMT	This course provides description and detail of the ICS organization and operations in supervisory roles on expanding incidents. Topics covered should include: organization and staffing, resource management, Unified Command, transfer of Command, event and incident planning, air operations and establishing incident objectives.
400		This course is designed for more Senior personnel who are expected to perform in a management capacity in the Incident Command Team or IMT. Topics covered should include: General and Command staff, major incident management, multi-agency coordination and ICS for Executives.

8.3 Oil Spill Exercises

Oil spill response exercises test incident response personnel function and responsibilities. They improve oil spill incident response teams skills and awareness, and provide management with an opportunity to assess equipment, measure performance, obtain feedback from participants, update and correct the contingency plans, and give a clear message about the company's commitment to oil spill prevention and response.

An exercise schedule is determined based upon local needs annually by the EEPGL OIMS/SSH&E Manager, which is approved by the EEPGL Country Manger. A suggested guideline including schedule and type of oil spill exercise is outlined in Table 12.

Table 12: Oil Spill Exercise Overview and Schedule

Exercise Type	Description and Purpose	Frequency
OSRP Orientation	A contingency plan orientation exercise is a workshop which focuses on familiarizing the ERT and IMT with their roles, procedures and responsibilities in an oil spill. The aim is to review each section of the plan, encourage discussion, and by using local knowledge and expertise, make useful and practical improvements to the plan where required.	As required or directed
Notification and Callout Exercise	A notification exercise practices the procedures to alert and call out the ERT and IMT. They are normally conducted over the telephone or radio, depending on the source of initial oil spill report. They test communications systems, the availability of personnel, travel options and the ability to transmit information quickly and accurately.	Quarterly

Exercise Type	Description and Purpose	Frequency
	This type of exercise will typically last 1-2 hours and can be held at any time of the day or night.	
Practical Oil Spill Equipment Deployment Exercise	Simple deployment exercises give personnel a chance to become familiar with equipment, or they may be a part of a detailed emergency response scenario, where maps, messages, real-time weather and other factors are included. The exercise is designed to test or evaluate the capability of equipment, personnel, or functional teams within the oil spill response. In deployment exercises, the level of difficulty can be varied by increasing the pace of the simulation or by increasing the complexity of the decision-making and coordination needs. A deployment exercise would typically last from 4-8 hours.	Semi-annually
IMT Tabletop Exercise	A tabletop exercise uses a simulated oil spill to test teamwork, decision-making and procedures. The exercise needs to be properly planned with a realistic scenario, clearly defined objectives for participants, exercise inputs, and a well briefed team in control of the running and debriefing of the exercise. A tabletop exercise will typically last from 2-8 hours.	Annually
Full-scale Incident Management Exercises	Full-scale exercises provide a realistic simulation by combining all of the elements of the tabletop exercise (maps, communications, etc.) and the deployment of related personnel and equipment. This complexity requires the response to be more coordinated than in basic tabletop or deployment exercises. The effort and expense in organizing a realistic full scale exercise means that it is recommended that they be run only once every two years. It may also be cost effective to run full-scale exercises in partnership with other organizations within the region and the ESG. Full-scale exercises can create a very intense learning environment that tests cooperation, communications, decision making, resource allocation and documentation. People involved in full-scale incident management exercises should have attended earlier tabletop exercises. Organizing a realistic full-scale exercise could take many months, requires an experienced planner and a large support team to run the exercise. The full scale exercise will generally last at least one day and often carry on overnight into a second or third day.	Every 3 Years during Production Operations
Joint Exercises (e.g., with other Operators or Regulators)	Joint exercises provide a realistic simulation by combining the full scale oil spill response equipment deployment and tabletop incident management to handle a major spill scenario. The spill scenario involves major consequences to a very wide range of resources, threatening national interests and requiring national and regional cooperation and coordination. Joint exercise involves very wide range of personnel from many different organizations, possibly in various locations, together with a range of equipment deployment opportunity. This exercise is designed to build confidence in EEPGL's preparedness to effectively and efficiently deal with oil spills at all scales. This will also enhance the cooperation among the government and industry at national and regional level in responding to major and/or trans-boundary spills. A joint exercise will generally last at least one day and often carry on overnight into a second or third day.	Every 3 Years during Production Operations

Appendix A MODELING RESULTS

A.1 Modeling Overview

Oil spill modeling was performed for five hypothetical oil spill scenarios, ranging from higher probability small volume operational releases at the water surface to the unlikely large volume spill related to production or drilling operations originating either at the sea surface or from a subsea release at the seabed. These ranged as noted in Table 5 from smaller Tier I incidents of a single release of 50 bbls of marine diesel or crude oil (# 2) to a loss of well control event resulting in 20,000 bbls of wellbore fluids being released for a maximum duration of 30-days (#9). In these five scenarios the oil spill modeling was applied to determine the most likely trajectory for a spill from each scenario and to quantify the oil's fate as it interacts with the environment. The trajectory and fate results were used to predict and determine spill pathways and quantify potential ecological and socioeconomic impacts from such events for both the summer season (June through November), as well as the more conservative winter season (December through May) when current speeds and northerly winds are stronger. All such modeling results are ***Unmitigated*** not taking into account the immediate actions and sustained response and mitigation measures that would be employed in the event of a spill or release. This is done to examine the probability of the shoreline stranding and predict the timing of that stranding.

Fate and Trajecetory

Fate (weathering) and trajectory (movement) models were used to simulate oil transport and predict the changes the oil undergoes as it interacts with water, air, and land (oil fate). The models were used to simulate spill events using the best available characterization of the wind and hydrodynamic (marine currents) forces that drive oil transport. The models quantify the potential consequences from a spill, which can then be used to guide response planning and prioritize response asset deployment. There are typically two modes under which the models can be used: 1) the **stochastic** (statistical) mode that examines *many releases* from the same point utilizing the full range of historical data for wind and currents; and, 2) the **deterministic** mode that examines a *single release* utilizing specific historic wind and hydrodynamic datum from the range of potential data, or utilizing forecast data for an ongoing or future event. The corresponding coastal sensitivity maps that were used to identify and characterize the resources/receptors with the potential to be impacted by a spill based on the modeling results have been provided in Appendix D.

Metocean Conditions

Currents in the upper water column off the Guyana coast are strong and flow towards the northwest along the coast of South America over the entire year. The Guiana Current is part of the regional flow between South America, Africa and the Caribbean Sea, extending from Guyana to the Caribbean.

A.1.1 Oil Spill Model Scenarios

A series of stochastic and deterministic model simulations were run to determine the fate of the oil released for three different products for five different scenarios at the offshore location during two different seasons. Table 13 lists the scenarios that were modeled.

Blowout scenarios consist of 30 days of oil and gas discharge at the wellhead. The blowouts were simulated using the OILMAP DEEP blowout model to determine the discharge plume geometry, define the oil droplet sizes and provide inputs for the SIMAP model simulations. All SIMAP model simulations were run for the 30-day discharge period plus an additional 21 days after oil discharge ceased. An additional model scenario was run at the Ranger area of interest using a small discharge opening in order to investigate the effect it has on the fate of the oil. The smaller opening will result in formation of smaller oil droplets in the blowout plume which will keep a greater fraction of the spilled volume in the water column. No spill response activities were simulated.

Table 13: Oil Spill Scenarios Defined for the Oil Spill Modeling

# Scenario	Release Volume	Released Product	Season
2a	50 bbl	Marine Diesel	Summer
2b	50 bbl	Marine Diesel	Winter
4a	250 bbl	Marine Diesel	Summer
4b	250 bbl	Marine Diesel	Winter
2c	50 bbl	Crude Oil	Summer
2d	50 bbl	Crude Oil	Winter
8a	2,500 bbl	Crude Oil	Summer
8b	2,500 bbl	Crude Oil	Winter
9a	20,000 bbls	Wellbore Fluids	Summer
9b	20,000 bbls	Wellbore Fluids	Winter

A.1.2 Exposure Thresholds

Minimum oil thickness thresholds are used in the SIMAP model in the determination of the probability of oil contamination. The thresholds are specific to the type of impact being considered, either ecological or socio-economic, and they are used in the calculation of oiling probability to determine if oil is present in a quantity sufficient to cause a particular impact.

Floating oil thickness is of interest because it can determine if mechanical recovery is possible and because different surface slick thicknesses will have different effects on waterfowl and other animals at the sea surface. Surface oil is often expressed in units of g/m^2, where 1 g/m^2 corresponds to an oil layer that is approximately 1 micron (µm) thick. Table 14 lists approximate thickness and mass per unit area ranges for surface oil of varying appearance. Dull brown sheens are about 1 µm thick. Rainbow sheen is about 0.2-0.8 g/m^2 (0.2-0.8 µm thick) and silver sheens are 0.05-0.2 g/m^2 (0.05-0.2 µm thick; NRC, 1985). Crude and heavy fuel oil that is greater than 1 mm thick appears as black oil. Light fuels and diesel that are greater than 1 mm thick are not black in appearance, but appear brown or reddish. Floating oil will not always have

these appearances, however, as weathered oil would be in the form of scattered floating tar balls and tar mats where currents converge.

A typical approach to using oil spill models in OSRP is to first apply the stochastic model to determine the probability and timing for the spill scenarios of interest. The stochastic approach captures variability in the trajectories by simulating hundreds of individual spills and generating a map that is a *composite* of all of the trajectories and provides a *probability footprint* showing the most likely path for a given spill scenario. Spill scenarios are typically modeled in stochastic mode to provide composite footprints to estimate probability and timing for each season or wind regimes in the region.

Table 14: Oil Thickness (µm) and Equivalent Mass (g/m^2) and Appearance on Water (NRC, 1985)

Minimum	Maximum	Appearance
0.05	0.2	Colorless and silver sheen
0.2	0.8	Rainbow sheen
1	4	Dull brown sheen
10	100	Dark brown sheen
1,000	10,000	Black oil

The SIMAP model uses specific oil thickness thresholds for calculating the probability or likelihood of the presence of oil on the sea surface or shoreline. Oil thickness thresholds defining the minimum value for expected potential effects to the sea surface and shoreline are listed in Table 15. Socio-economic thresholds were used in all modeling for this project (0.01 µm for surface oiling and 1.0 µm for shoreline oiling). All calculations of the probability of oil shoreline and sea surface contamination are based on these oil thickness thresholds.

Table 15: Oil Thickness Thresholds for Sea Surface and Shoreline Oiling

Threshold Type	Threshold (Mass/Unit Area)	Threshold (Thickness)	Rationale (Socio-economic, Ecological)	Appearance
Oil on Water Surface	0.01 g/m^2	0.01 µm, 0.00001 mm	Socio-economic: A conservative threshold used to determine effects on socio-economic resources (e.g., fishing may be prohibited when sheens are visible on the sea surface).	Fresh oil at this thickness corresponds to a slick being barely visible as a colorless or silvery/grey sheen.
Oil on Shoreline	1.0 g/m^2	1.0 µm, 0.001 mm	Socio-economic This is the threshold for potential effects on socio-economic resource uses, as this amount of oil may conservatively trigger the need for shoreline cleanup on amenity beaches, and impact shoreline recreation and tourism.	May appear as a coat, patches or scattered tar balls.

A.2 Model Input Data

A.2.1 Oil Properties

The physical and chemical properties of the oil are used by the OILMAP DEEP and SIMAP models in calculations of the transport and fate of the spill. The oil used in the models is light crude that can incorporate water when spilled, which can increase both the volume and viscosity. Asessement of this type of oil indicated that while it can take on water, it will not emulsify quickly as some crude oils can.This will serve to keep the oil relatively non-viscous for many hours depending on spill and environmental conditions, which improves the window of opportunity for oil spill response. Table 16 lists some of the properties of the oil used in the model simulations.

Table 16: Properties of the Crude Oil Used in the Spill Modeling

Density (g/cm^3 @25°C)	Viscosity (cP@25°C)	API Gravity	Pour Point (°C)	Maximum Water Content (%)
0.84579	12.797	35.8	12.78	30

A.3 Stochastic Model Results (Unmitigated)

The stochastic modeling results predicted that surface oil would generally travel towards the northwest in all scenarios during both the summer and winter seasons. The probability of any shoreline oiling is generally low, with the smaller volume spills very unlikely to reach the shoreline, and when they do the probability is less than 5%. The oil spill model indicates that even in the unlikely event of a larger volume spill, there is only a 5 to 10 percent chance of shoreline oiling in Guyana. In the case of such a loss of well control, it is predicated that it would take 5 to 15 days for oil to reach shore in the absence of any spill response.

Not all of the individual spill events are predicted to result in oil stranding in excess of the 1 µm thickness threshold with the highest risk to the shoreline of Trinidad and Tobago due to the predominant current flow through the Stabroek Block and into the Caribbean. The probability of oil exposure on the sea surface remains greater than 50% from the discharge site to the coast of Trinidad and Tobago and into the Caribbean Sea. It should be kept in mind that the probabilities are calculated using a minimum oil thickness of 0.01 µm which appears on the sea surface as colorless to silver sheen. The sea surface area oiled for individual spill events ranked as the 95th percentile ranges from 835 to 19,400 km^2. None of the marine diesel spills are predicted to reach the shoreline. Two crude oil and the wellbore fluid scenarios are predicted to reach the Guyana shore, oiling between 25 km and 57 km at a thickness of 1 micron.

A.3.1 Marine Diesel Summer (June through November)

A.3.1.1 Water Surface Results – 50 Barrel Scenario

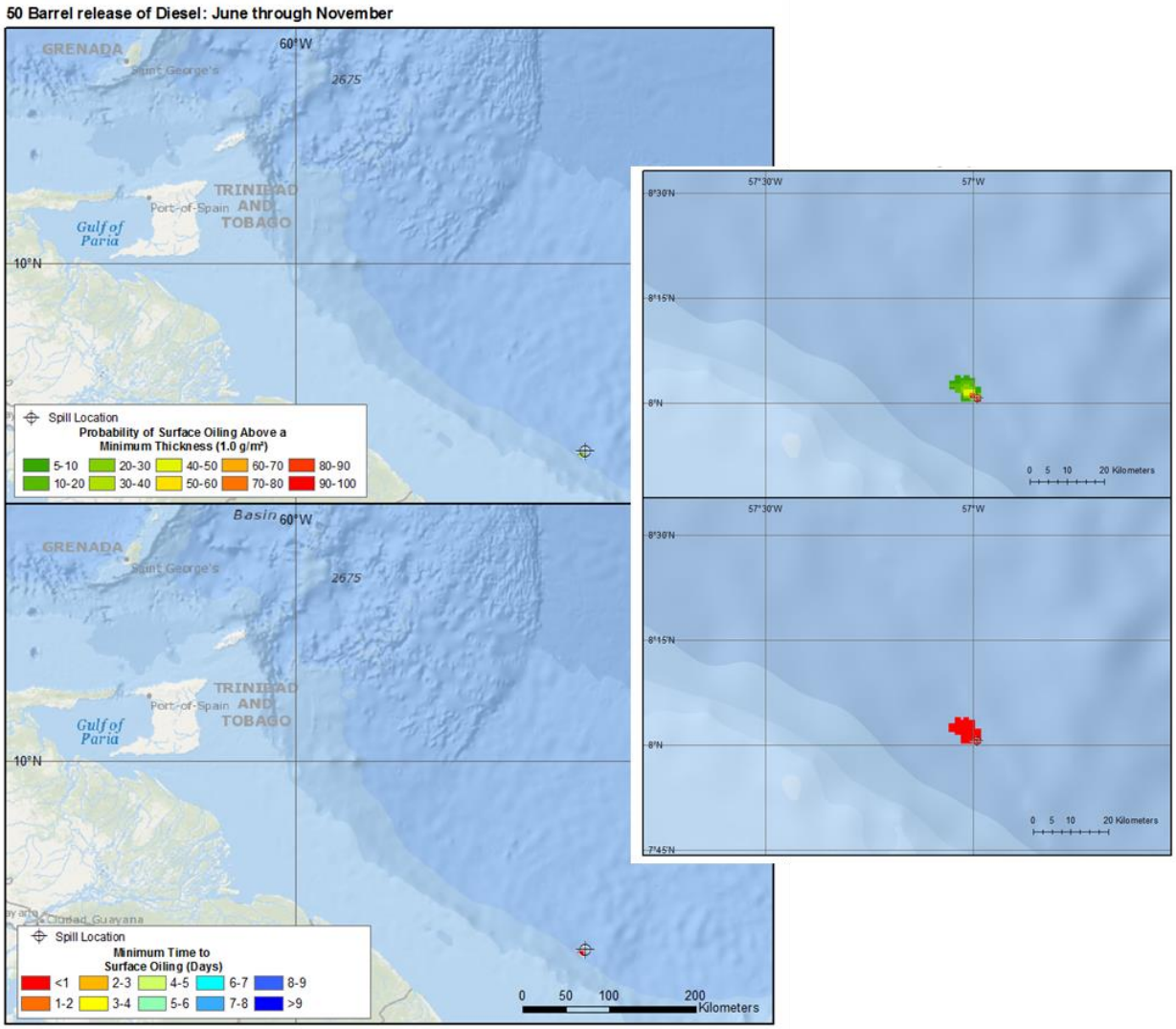


Figure 23: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 50 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.1.2 Water Surface Results – 250 Barrel Scenario

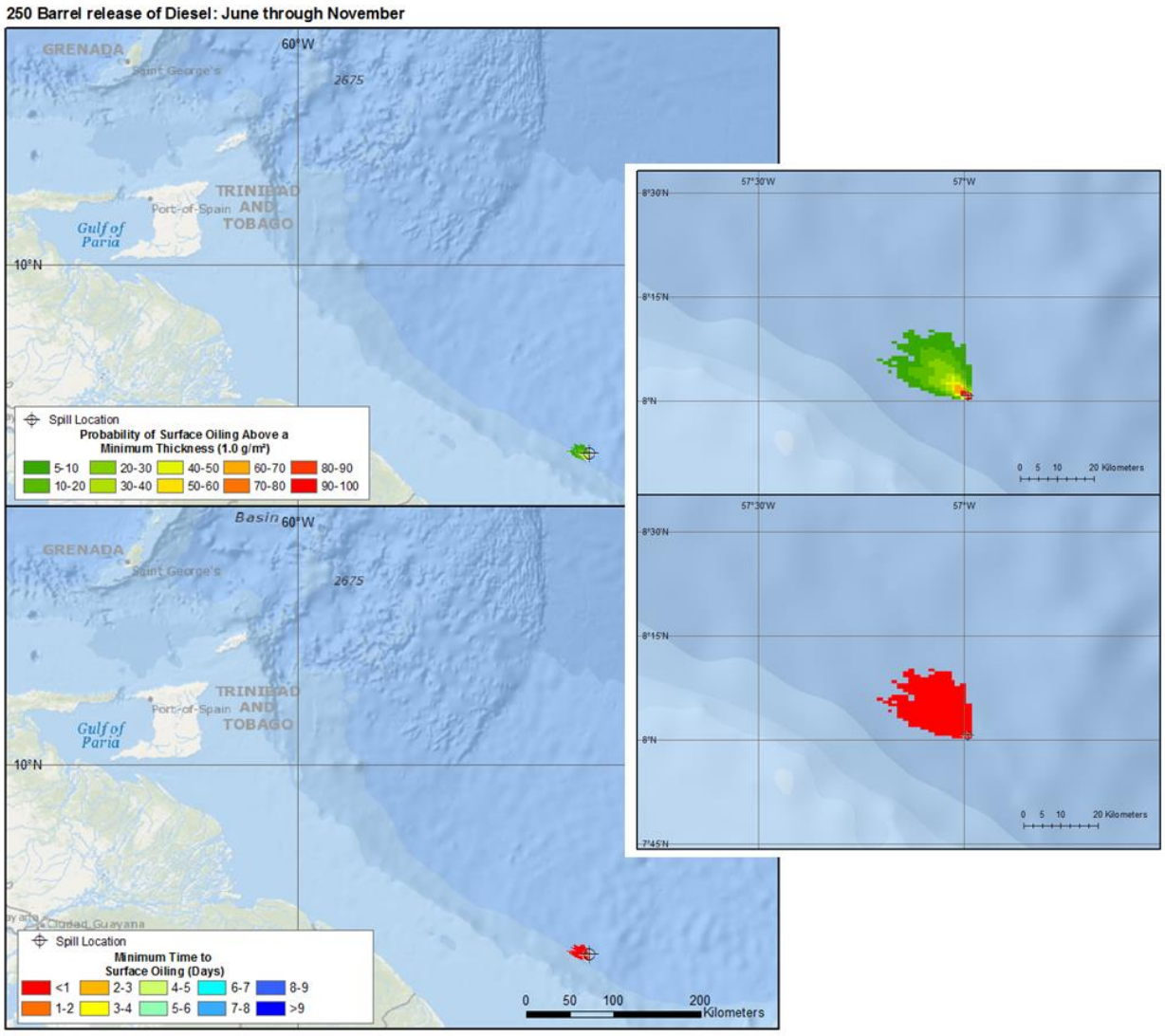


Figure 24: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 250 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.2 Marine Diesel Winter (December through May)

A.3.2.1 Water Surface Results – 50 Barrel Scenario

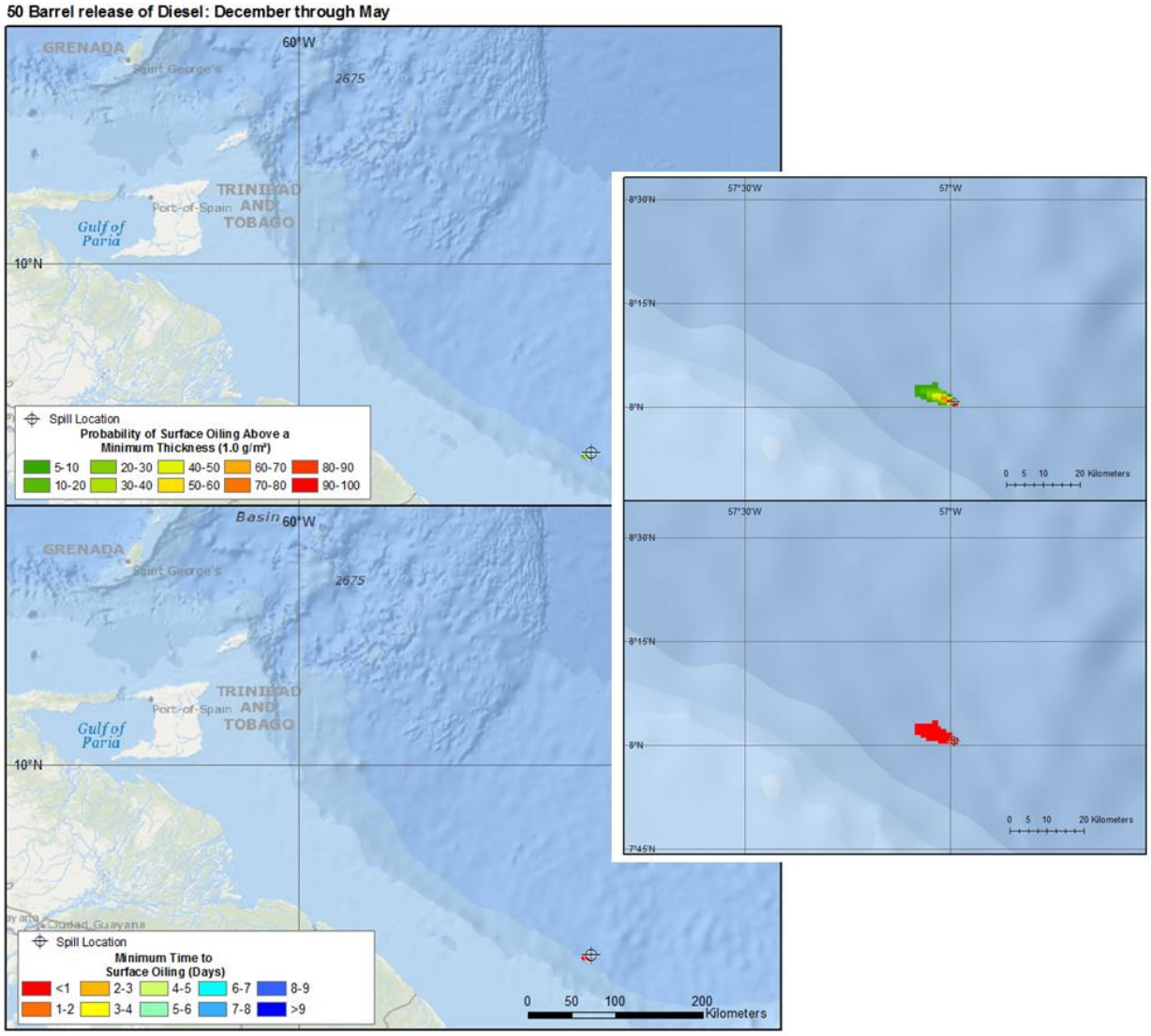


Figure 25: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 50 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.2.2 Water Surface Results – 250 Barrel Scenario

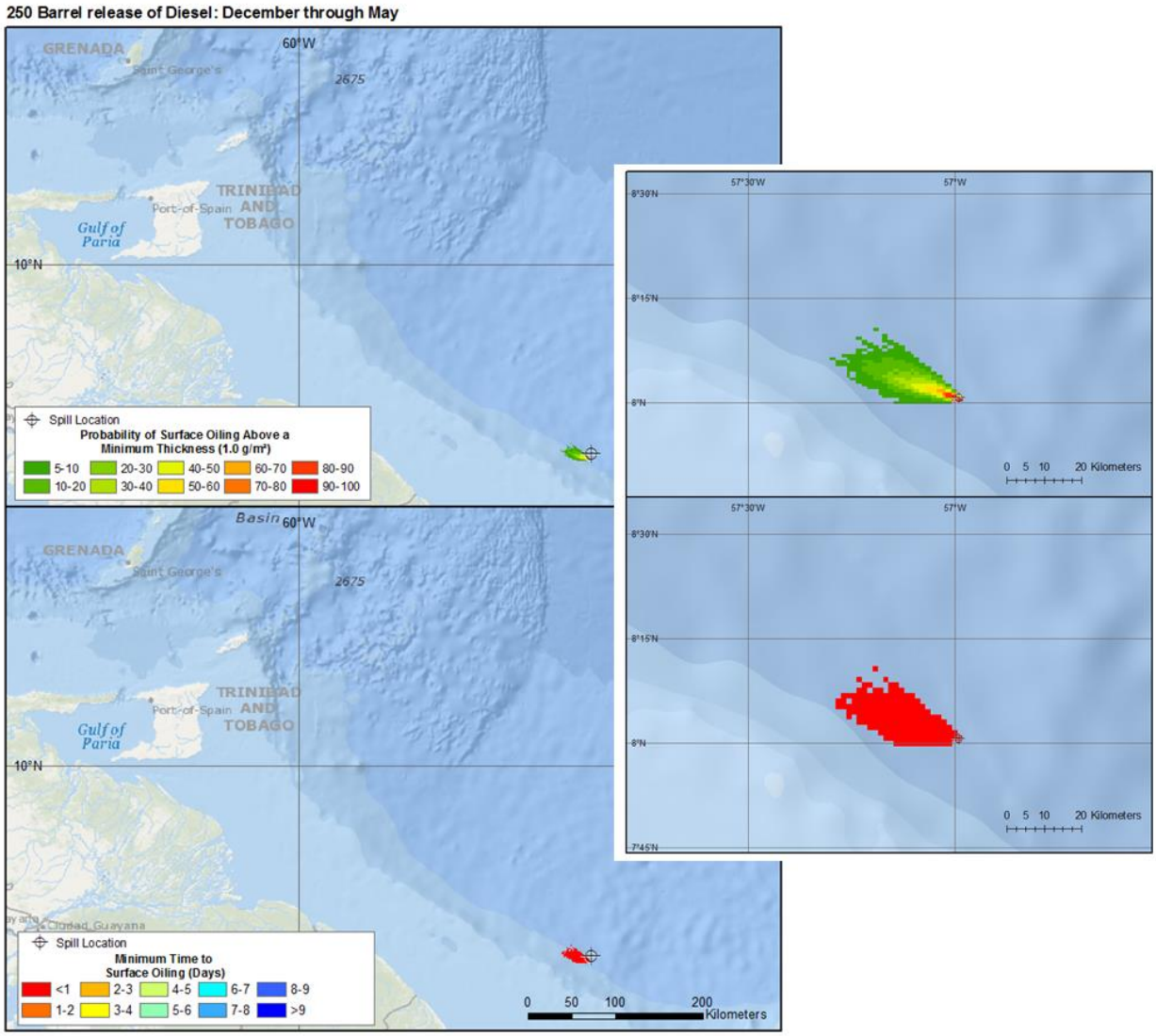


Figure 26: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 250 barrel release of Marine Diesel. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.3 Crude Oil Summer (June through November)

A.3.3.1 Water Surface Results – 50 Barrel Scenario

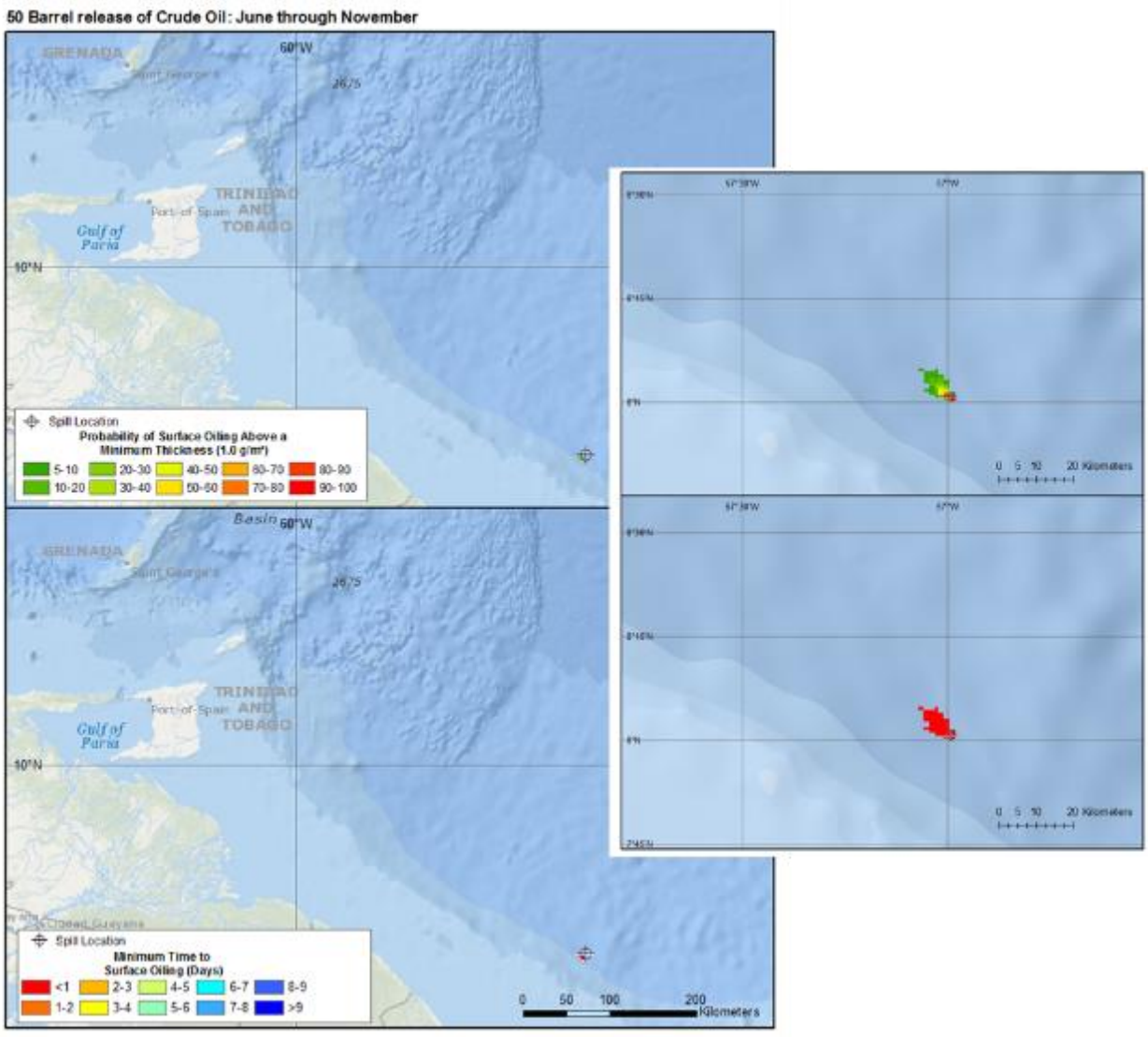


Figure 27: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 50 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.3.2 Water Surface Results – 2,500 Barrel Scenario

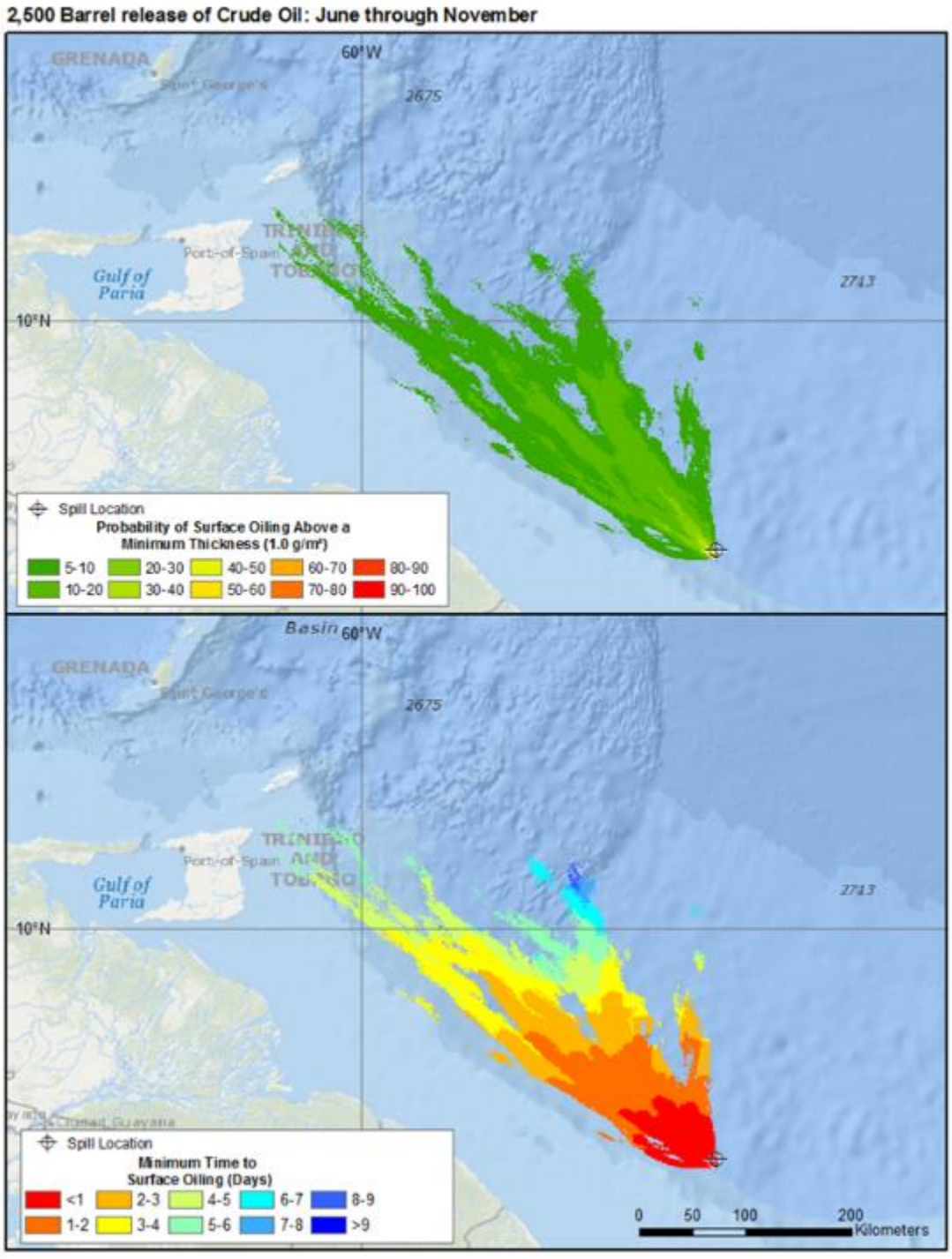


Figure 28: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from June through November for a 2,500 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.4 Crude Oil Winter (December through May)

A.3.4.1 Water Surface Results – 50 Barrel Scenario

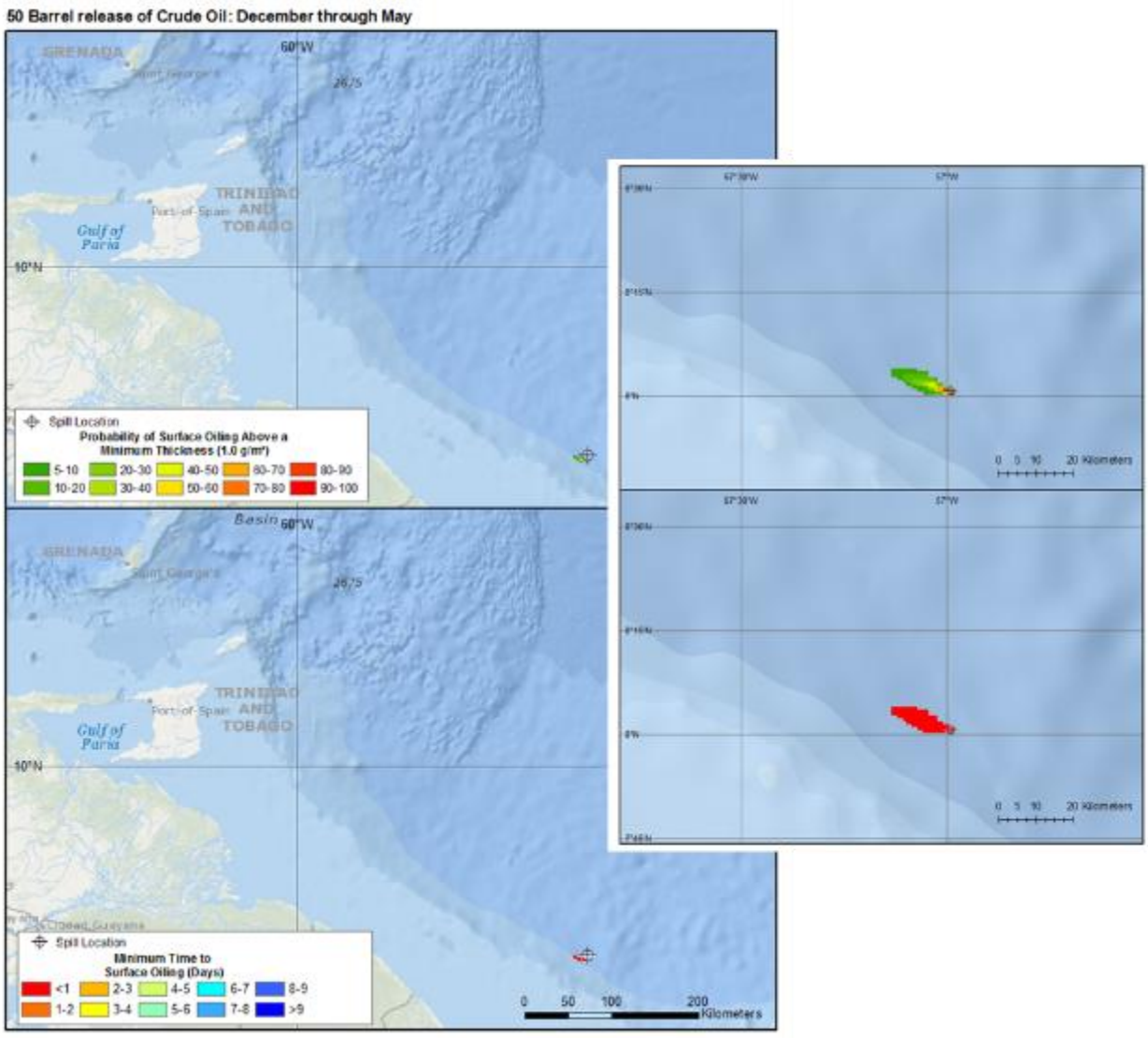


Figure 29: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 50 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.4.2 Water Surface Results – 2,500 Barrel Scenario

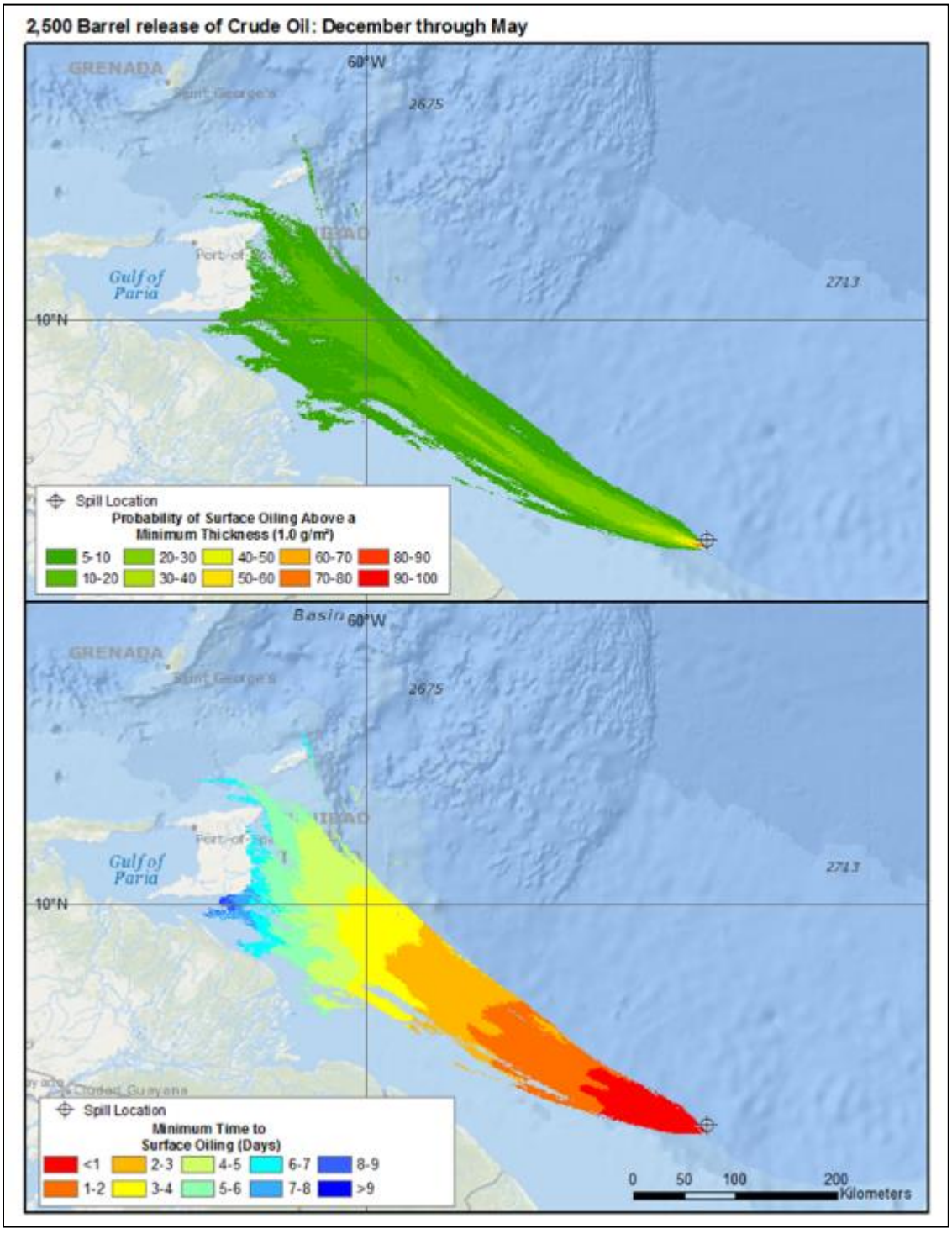


Figure 30: Top Panel – Probability of surface oiling above a minimum thickness of 1 µm from December through May for a 2,500 barrel release of Crude oil. Bottom Panel – Minimum time for surface oil thickness to exceed 1 µm

A.3.4.3 Oiled Shoreline Results – 2,500 Barrel Scenario

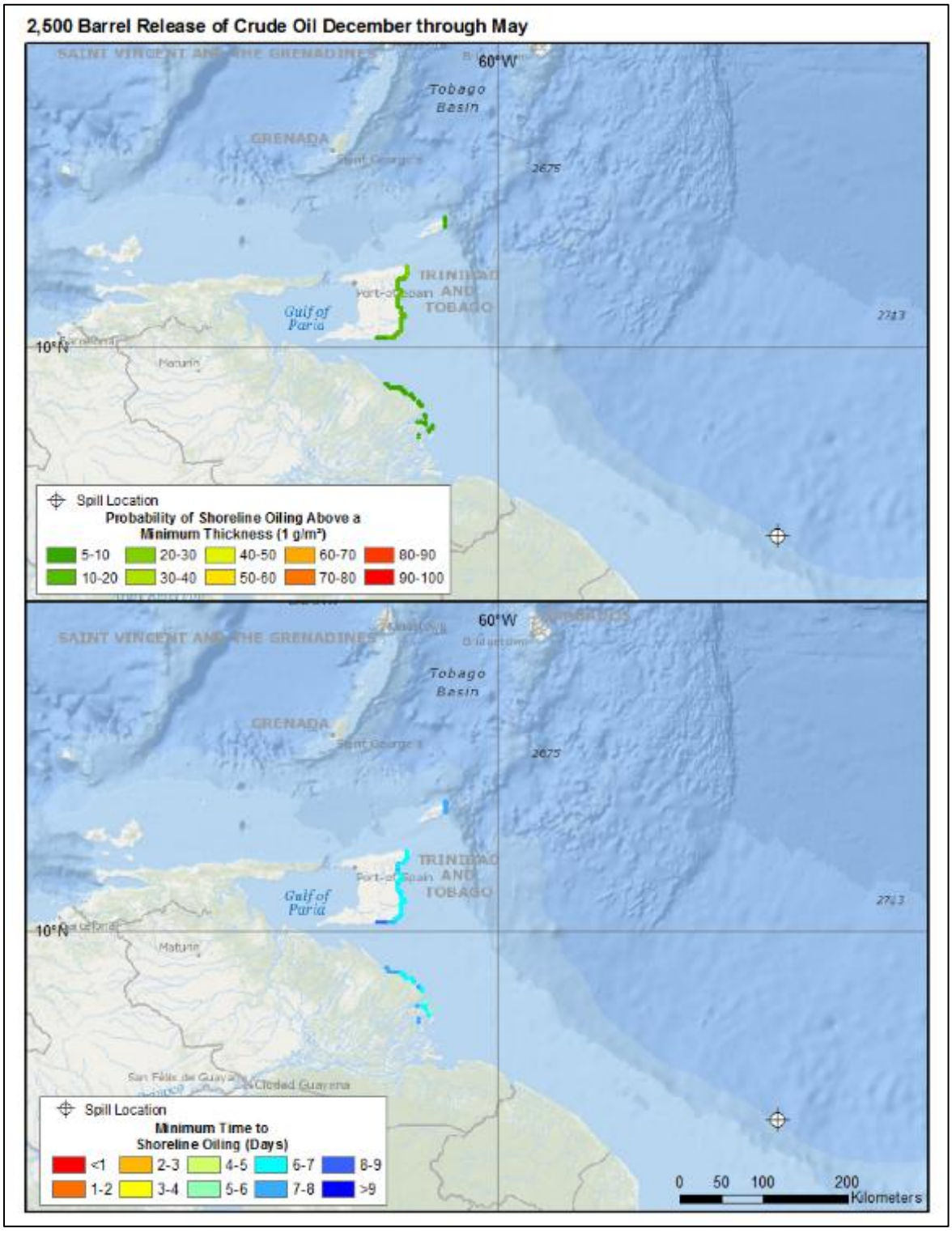


Figure 31: Top Panel – Probability of shoreline oiling above a minimum thickness of 1 µm for months December through May for a 2,500 barrel release of Crude oil. Bottom Panel – Minimum time for shoreline oil thickness to exceed 1 µm

A.3.5 Wellbore Fluids Summer (June through November)

A.3.5.1 Water Surface Results – 20,000 Barrel per Day Scenario for 30 days

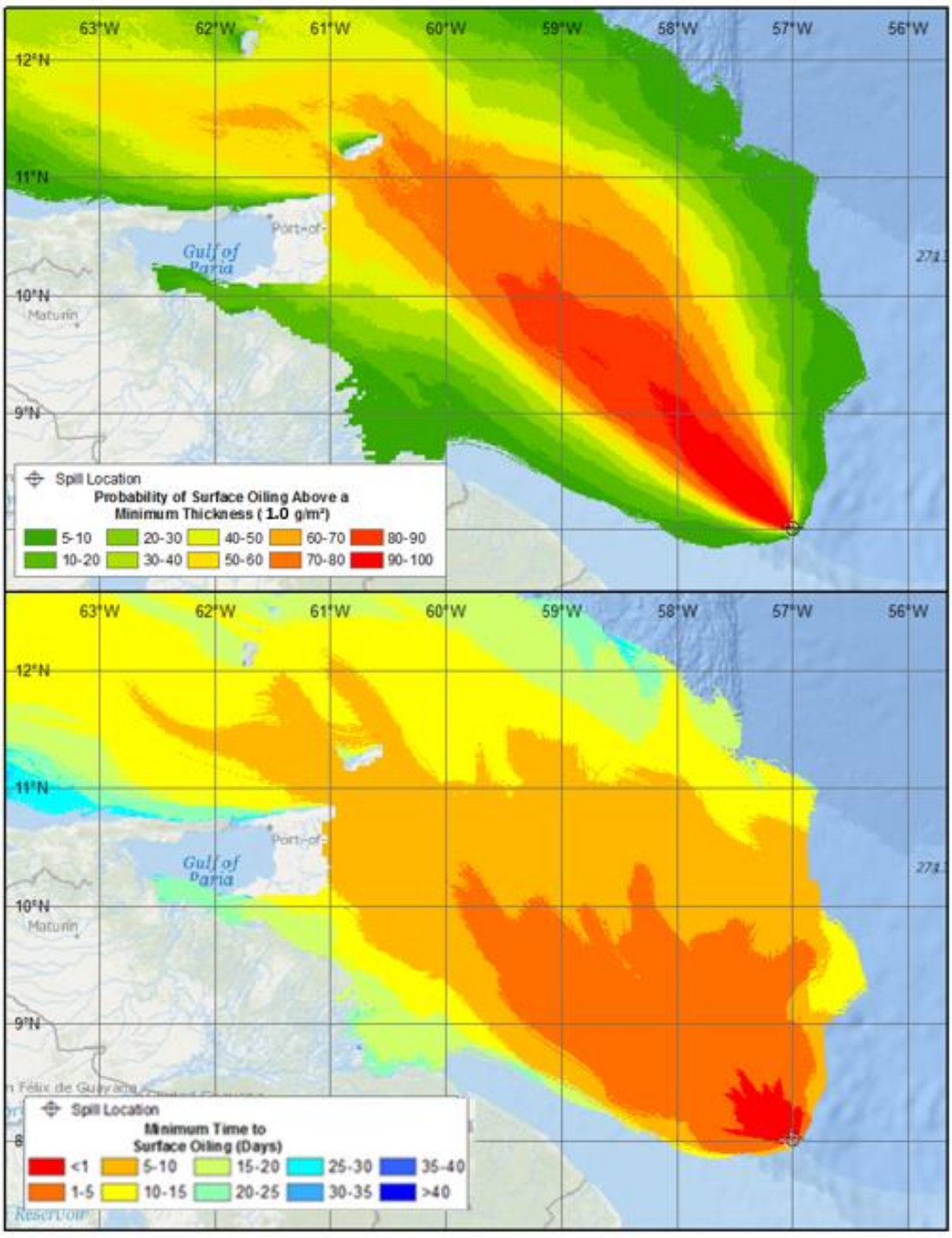


Figure 32: Top Panel – Probability of shoreline oiling above a minimum thickness of 1 µm for months June through November for a 20,000 barrel a day release of Crude oil for 30 days. Bottom Panel – Minimum time for shoreline oil thickness to exceed 1 µm

A.3.6 Wellbore Fluids Winter (December through May)

A.3.6.1 Water Surface Results – 20,000 Barrel per Day Scenario for 30 days

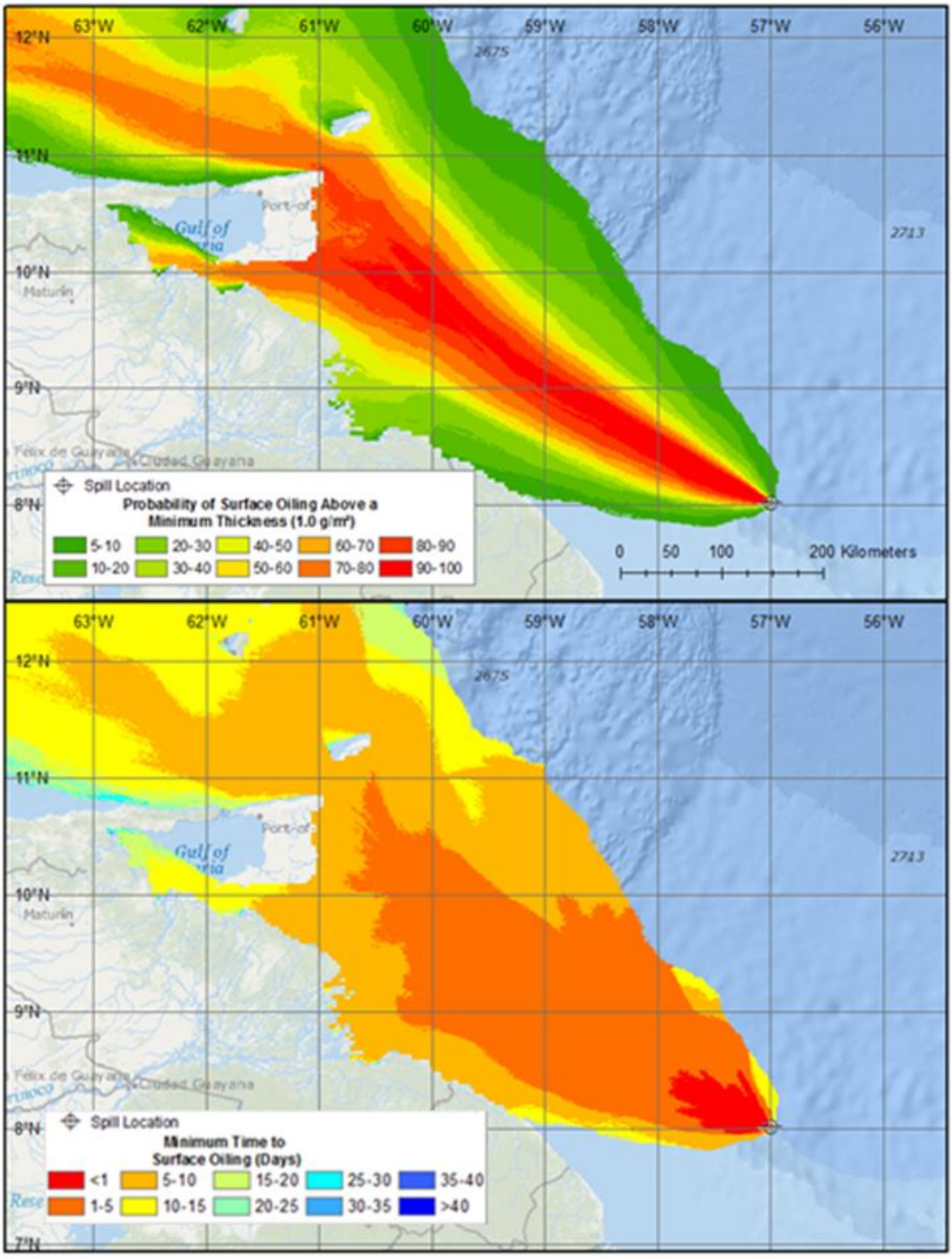


Figure 33: Top Panel – Probability of shoreline oiling above a minimum thickness of 1 µm for months December through May for a 20,000 barrel a day release of Crude oil for 30 days. Bottom Panel – Minimum time for shoreline oil thickness to exceed 1 µm

A.4 Deterministic Model Results (Unmitigated)

Each individual spill event simulated in a stochastic scenario produces a unique spill trajectory. Depending on environmental conditions at the time of release, the spill will take a different path, resulting in different impacts. The 95th percentile spill event for shoreline stranding by oil with a thickness greater than 0.01 µm was selected from each stochastic scenario in the summer and winter seasons. These deterministic results are presented in summary tables listing the sea surface area swept by oil with a thickness greater than 0.01 µm and the length of shoreline oiled with a thickness greater than 1 µm. (Table 17).

Oil effects summary for the 95th percentile spill event for sea surface area swept by oil above a thickness of 0.01µm. Surface area is the maximum sea surface area swept above a threshold of 0.01 µm thick. Shoreline length is the maximum length of shoreline oiled above a threshold of 1 µm thick.

The time of first arrival of oil on shore for the spill events that reached shore ranked as the 95th percentile ranges from 5.9 to 9.3 days (Table 17). Differences in seasonal wind speed and direction as well as small differences in spill site location result in a wide range in sea surface exposure to oil (835 km^2 through 900,200 km^2) and shoreline length oiled (25.1 km though 355 km). Stronger easterly winds result in more significant shoreline oiling, particularly in Venezuela and Trinidad and Tobago, while lower wind speeds allow the surface plume to be transported to the north of Trinidad and Tobago and swept into the Caribbean Sea.

Table 17: Oil Effects Summary for 95th Percentile

Spill Location	Season	Surface Area (km^2)	Shoreline Length (km)	Time to Shore (Days)
Marine Diesel – 50 bbl	Summer	854	0	n/a
	Winter	835	0	n/a
Marine Diesel – 250 bbl	Summer	5,450	0	n/a
	Winter	5,520	0	n/a
Crude Oil – 50 bbl	Summer	6,390	0	n/a
	Winter	6,500	25.1	5.9
Crude Oil – 2,500 bbl	Summer	13,800	56.6	9.25
	Winter	19,400	41.9	8.5
Wellbore Fluids – 20,000 bbls per day for 30 days	Summer	728,100	215	9.3
	Winter	900,200	355	6.4

A.4.1 Marine Diesel Summer (June through November) – 50 Barrel Scenario

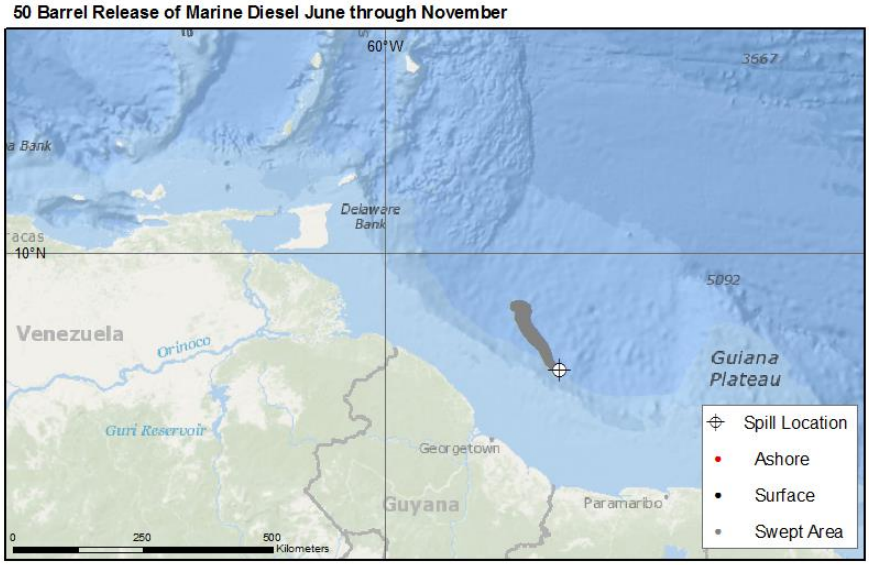


Figure 34: Area swept results for the 95th percentile surface area oiled 50 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black (none in this scenario), and shoreline oiling is displayed in red (none in this scenario)

A.4.2 Marine Diesel Summer (June through November) – 250 Barrel Scenario

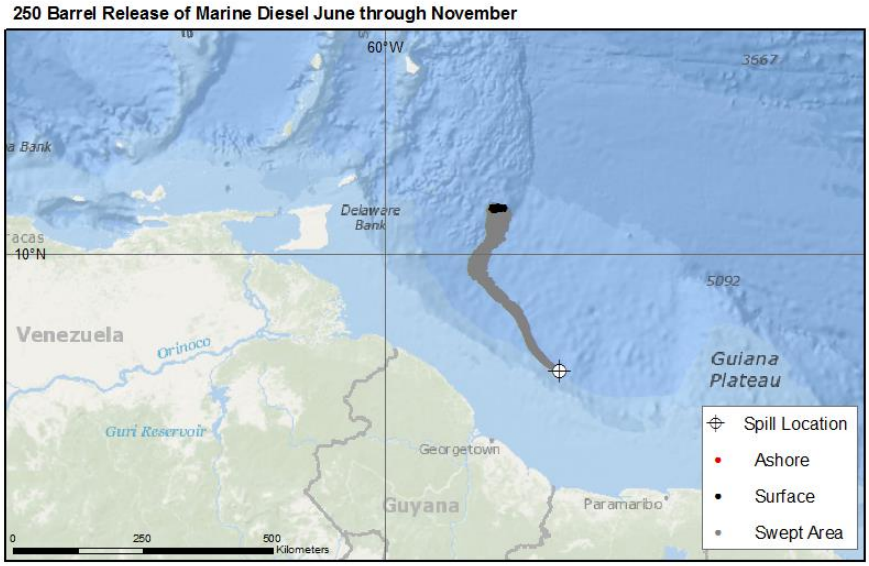


Figure 35: Area swept results for the 95th percentile surface area oiled 250 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red (none in this scenario)

A.4.3 Marine Diesel Winter (December through May) – 50 Barrel Scenario

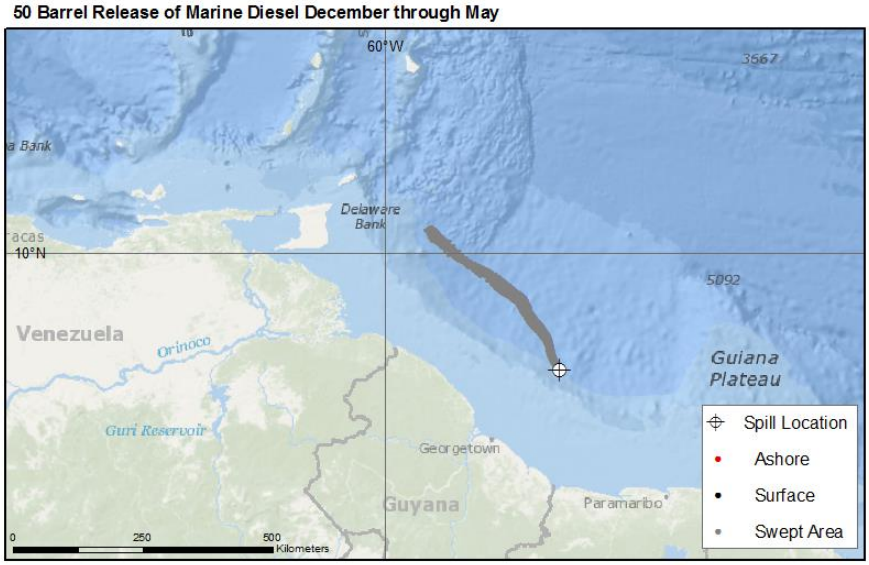


Figure 36: Area swept results for the 95th percentile surface area oiled 50 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black (none in this scenario), and shoreline oiling is displayed in red (none in this scenario)

A.4.4 Marine Diesel Winter (December through May) – 250 Barrel Scenario

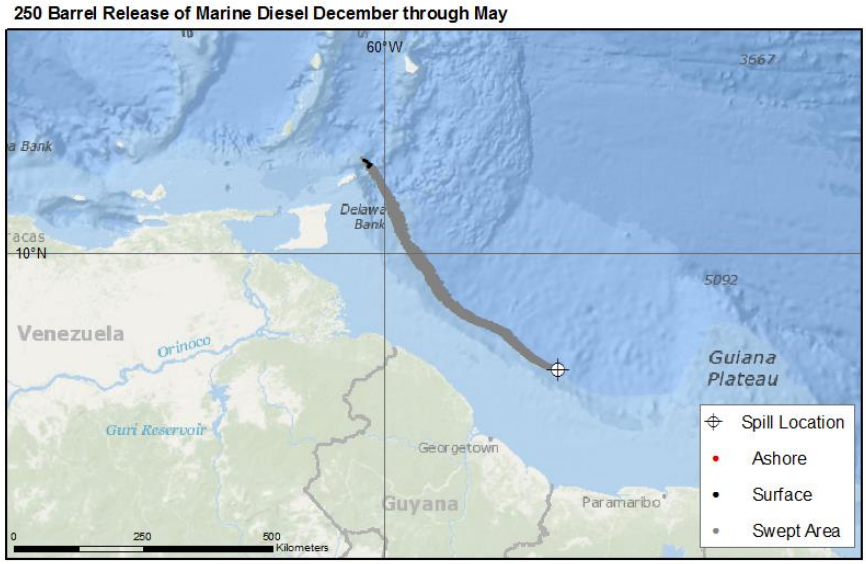


Figure 37: Area swept results for the 95th percentile surface area oiled 250 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red (none in this scenario)

A.4.5 Crude Oil Summer (June through November) – 50 Barrel Scenario

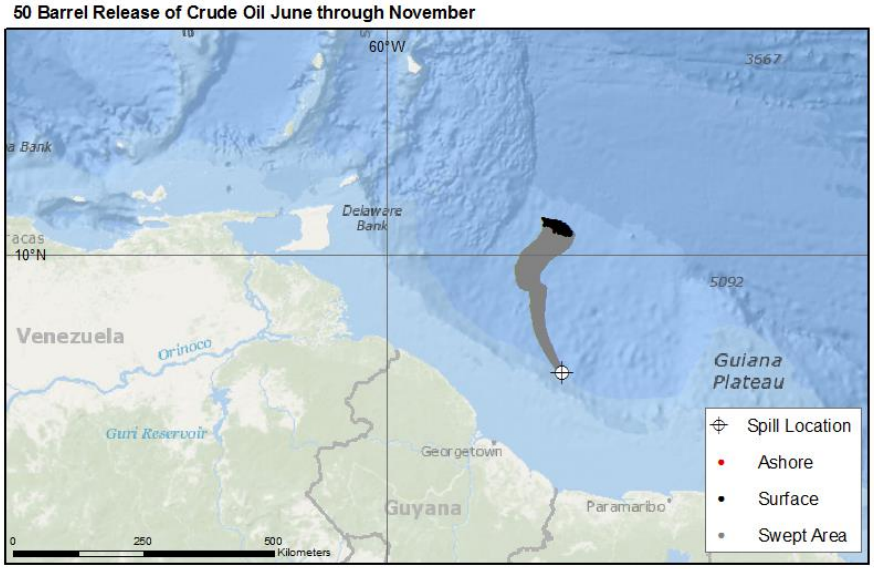


Figure 38: Area swept results for the 95th percentile surface area oiled 50 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red (none in this scenario)

A.4.6 Crude Oil Summer (June through November) – 2,500 Barrel Scenario

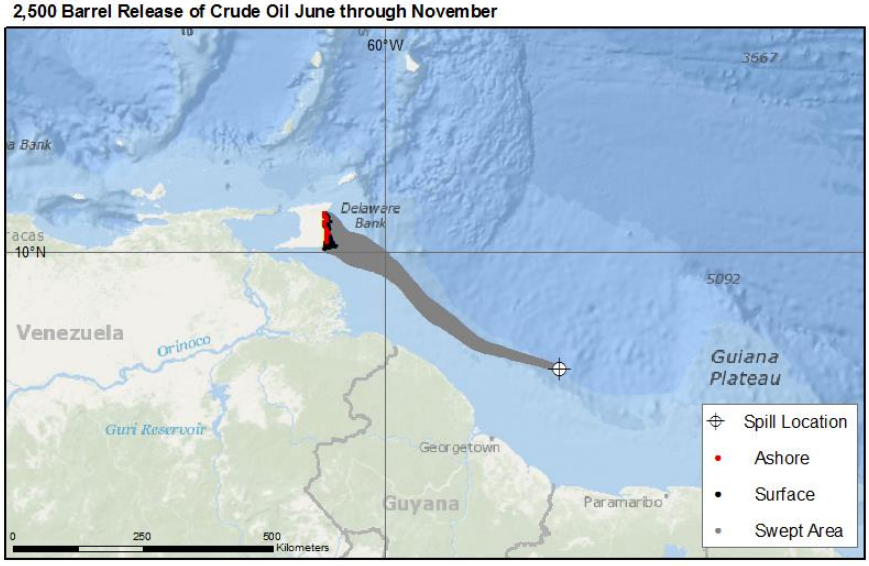


Figure 39: Area swept results for the 95th percentile surface area oiled 2,500 bbl release during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red

A.4.7 Crude Oil Winter (December through May) – 50 Barrel Scenario

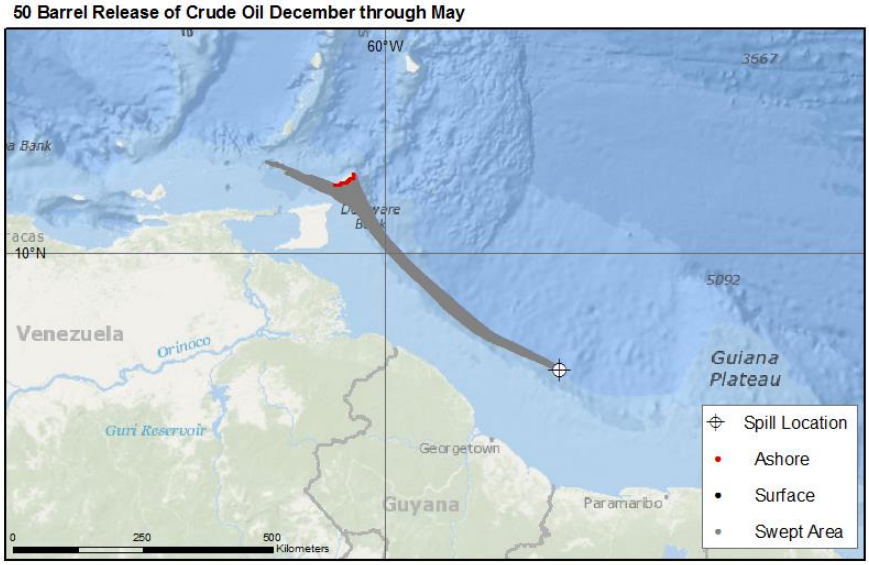


Figure 40: Area swept results for the 95th percentile surface area oiled 50 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red

A.4.8 Crude Oil Winter (December through May) – 2,500 Barrel Scenario

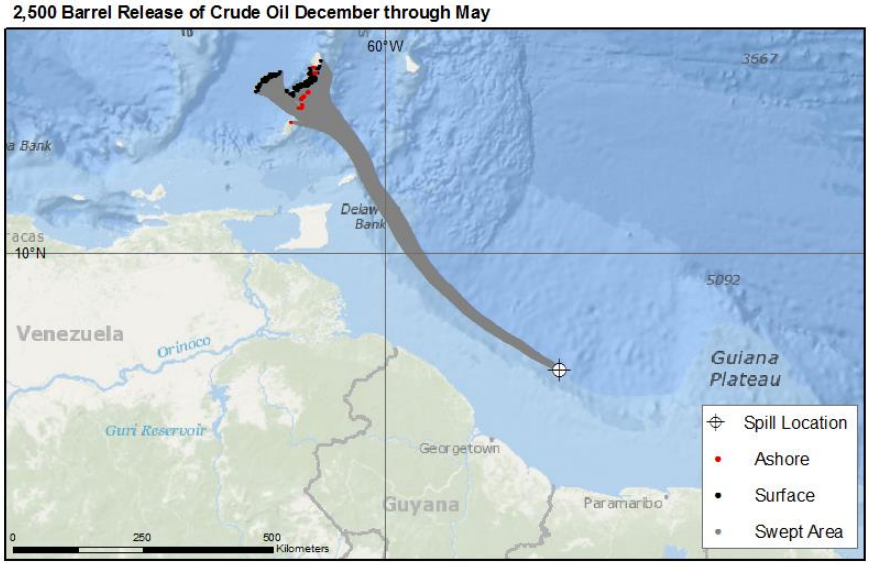


Figure 41: Area swept results for the 95th percentile surface area oiled 2,500 bbl release during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red

A.4.9 Wellbore Fluids Winter (December through May) – 20,000 Barrel per Day Scenario for 30 Days

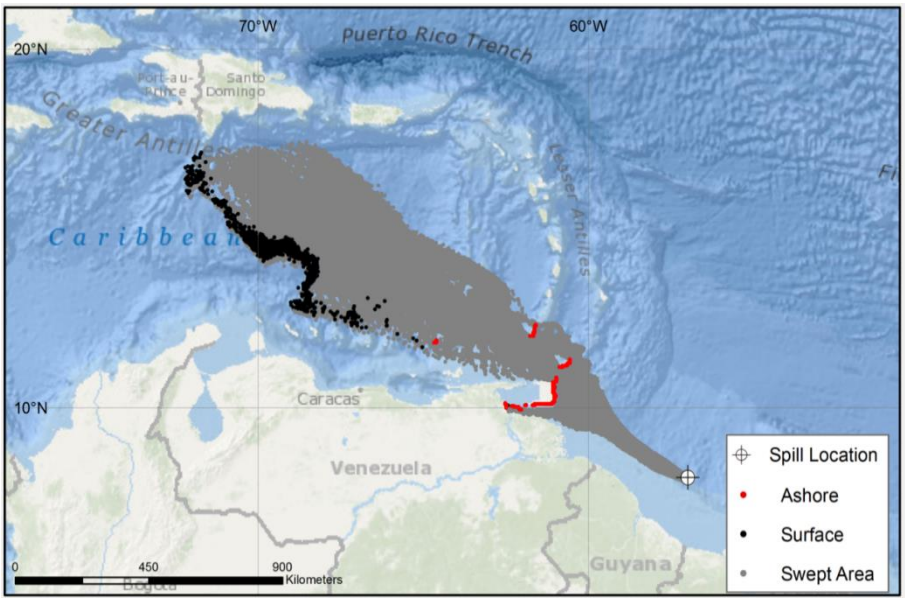


Figure 42: Area swept results for the 95th percentile surface area oiled 20,000 bbl per day release for 30 days during winter months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red

A.4.10 Wellbore Fluids Summer (June through November) – 20,000 Barrel per Day Scenario for 30 Days

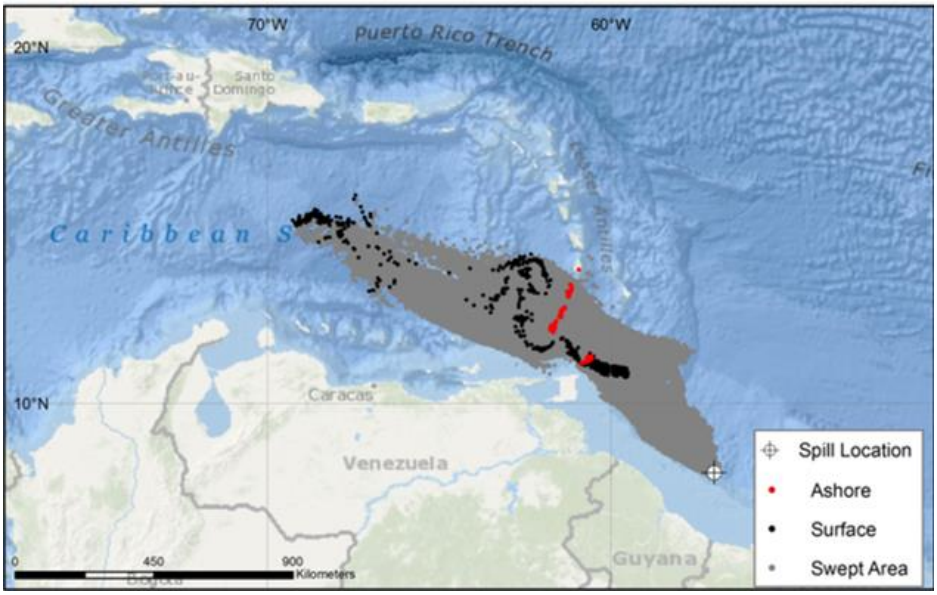
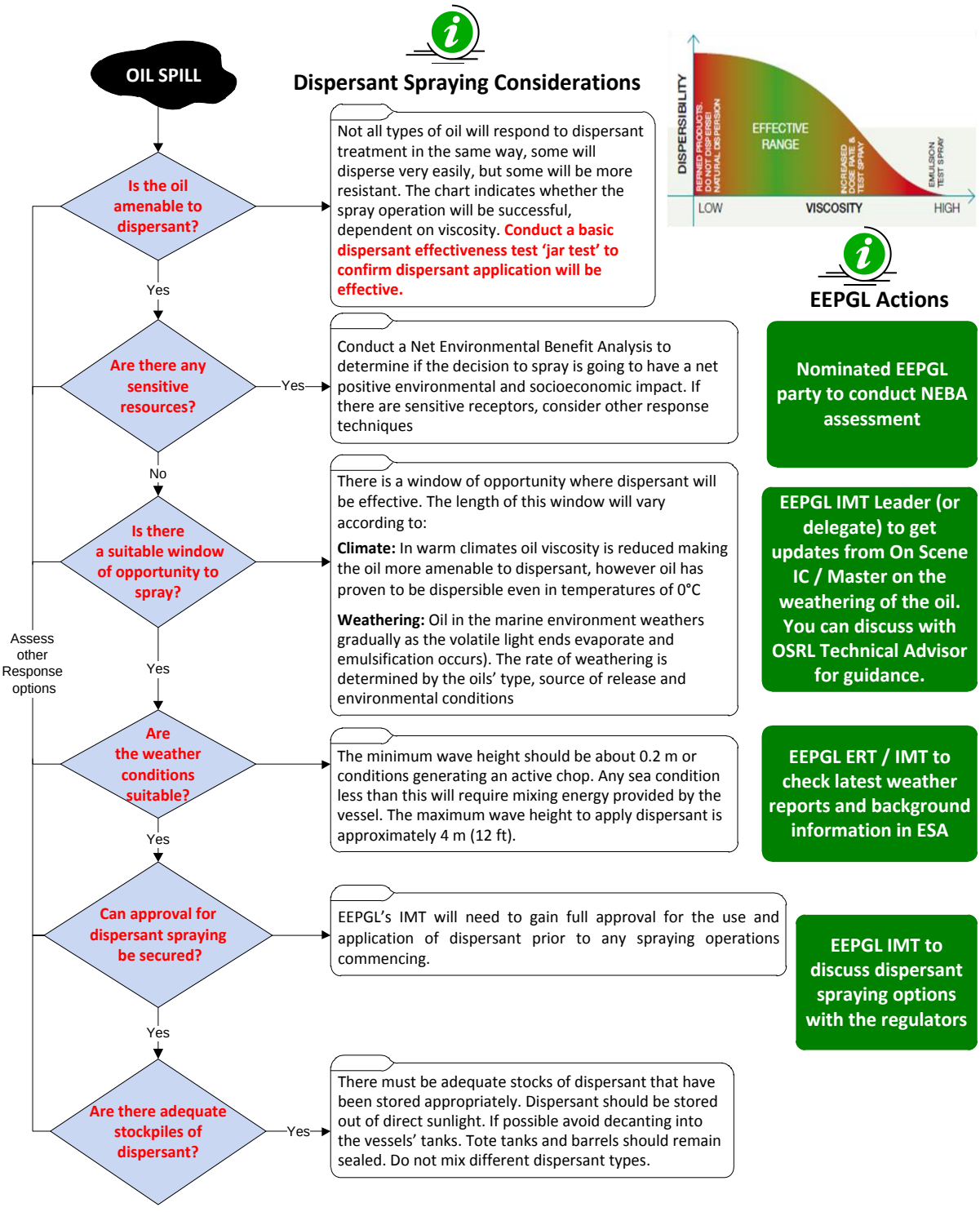


Figure 43: Area swept results for the 95th percentile surface area oiled 20,000 bbl per day release for 30 days during summer months. Area swept is displayed in grey, surface oil droplets remaining at the end of the 10 day scenario are presented in black, and shoreline oiling is displayed in red

Appendix B DISPERSANT SPRAYING CONSIDERATIONS



Appendix C FORMS

C.1 Initial Spill Report Form

Complete prior to conversation with Guyana Authorities and other agencies.

Contact Details					
Reportee			Company		
Contact Number			Position		
Alt. Contact Number					
Spill Details					
Date / Time					
Installation	Name				
	Operator				
	Licence Holder				
	Response Primacy				
Hydrocarbon Spilled	Type				
	Name of Product				
Location of Spill	Latitude		Block		
	Longitude		Field		
Any Casualties / Damage to Installation			HSE been Advised?	YES I NO	
Source of Spill (If Known)					
Cause of Spill (If Known)					
Spill Quantity / Potential (If Known)	Quantity		Is it on going?	YES I NO	
	Potential				
Has Installation been Shut down and / or will Incident affect Production					
Appearance of Oil			Travel Direction of Spill (If Known)		
Possibility of Pollution reaching Shoreline / crossing Median Lines?	Where				
	Time				
Current Weather at Spill Location					
Wind Direction & Speed					
Sea State & Wave Height					

C.2 Dispersant Use Request Form

Dispersant Use Request Form		
Request from		
Name and Position	Contact Details	Date and Time of Request
Request made to		
Name and Position	Contact Details	Date and Time Request Received
Reason for Dispersant Use Request		
Use of dispersants provides the important advantage of removing oil from the surface of the water thereby minimizing the effects of an oil spill by dispersing oil before it reaches shorelines or sensitive areas. Removing oil from the surface of the water can reduce the potential for impacts to wildlife including birds and marine mammals that could be found on or near the sea surface and limits the action of wind on spill movement. Dispersants can be applied and are effective across a wide range of environmental, metrological and oceanographic condition, where mechanical responses are limited. Dispersants can also be applied rapidly over a greater area in a given time than other response options.		
Expected Dispersant Effectiveness		
Has a Dispersant Effectiveness Test or Test Spray Run been carried out? Yes/No (If yes attach results to request form).	In this section, discuss the type of oil product spilled and its relative dispersibility. Reference available technical information or describe whether experience suggests that the spilled product is dispersible and will still be dispersible in the time frame of anticipated application of dispersants.	
Based on the assessment of the Incident what is the estimated timeframe available for a dispersant spraying operation to be effective?		

Dispersant Use Request Form	
Overview of Incident	
Describe the location and extent of spill, and spill volume (known or estimated).	
State oil type, API gravity, viscosity and pour point. (Attach MSDS if available).	
State whether the spill is in a location approved for Dispersant use by Caribbean Island OPRC Plan 2012 or provide details of why use dispersant approval is required if outside of these parameters.	
State whether spill is instantaneous or continuous (include flow rate if known).	
Predicted oil spill movement (attach oil spill modeling trajectory if available).	
Predicted sub-surface dispersant plume flow (attach oil spill modeling trajectory if available).	
Distance from shoreline.	
Depth of water.	
Weather Conditions	
Are current weather conditions suitable for a dispersant application operation? Yes/No	In this section, include current and forecasted weather conditions and whether they are suitable for dispersant application
Wind (from) direction.	
Wind speed (knots).	
Current velocity (knots).	
Current (to) direction.	
Visibility (nautical miles).	
Sea state	
Dispersant Application Details	
Dispersant type (Attach SDS) What is the current Dispersant stockpile level available for the dispersant spraying operation?	In this section, describe the dispersant product to be used (name). Attach an MSDS. Describe the dispersant application method, the expected amount of dispersant to be used and estimated timeline for the dispersant spaying operation.
Application Method. (Include proposed DOR, dosage rate (gpa /lpha) and maximum equipment application rate.	
Estimated Dispersant quantity to be used.	
Describe Dispersant Spraying Operational area. Include any environmental and socio-economic sensitivities in the region. Use maps / charts if available.	

<table>
<tr><th colspan="3">Dispersant Use Request Form</th></tr>
<tr><td colspan="3">Dispersant Effectiveness Monitoring Program</td></tr>
<tr><td>Describe the level of dispersant effectiveness monitoring to be applied during the dispersant spraying operations.</td><td colspan="2">State how observations will be carried out and documented. Describe how the dispersant spraying operations results will be communicated to the regulatory approvers.</td></tr>
<tr><td colspan="3">Dispersant Spraying Operation Approval Decision</td></tr>
<tr><td colspan="2">Approved

Provide Additional Comments as Required</td><td>Not Approved

Provide Details on Why Approval was Not Granted</td></tr>
<tr><td>Decision Makers Name and Position</td><td>Contact Details</td><td>Date and Time</td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

C.3 Oil Spill Response Notification Form

OSRL NOTIFICATION FORM			
WARNING! Ensure telephone contact has been established with OSRL's Duty Manager before using e-mail and fax communications.			
To	Duty Manager		
Southampton Emergency Fax	+44 (0)23 8072 4314	Fort Lauderdale Emergency Fax	+1 954 987 3001
Southampton Telephone	+44 (0)23 8033 1551	Fort Lauderdale Telephone	+1 954 983 9880
Email	dutymanagers@oilspillresponse.com		
Section 1	**Obligatory Information Required-Please Complete All Details**		
Name of person in charge			
Position			
Company			
Contact telephone number			
Contact Mobile number			
Contact fax number			
E-mail address			
Section 2	**Spill Details**		
Location of spill			
Description of slick (size, direction, appearance)			
Latitude / longitude			
Situation (cross box)	❑ Land ❑ River ❑ Estuary ❑ Coastal ❑ Offshore ❑ Port		
Date & time of spill	❑ GMT ❑ Local		
Source of spill			
Quantity (if known)	❑ Cross box if estimate		
Spill status (cross box)	❑ On-going ❑ Controlled ❑ Unknown		
Action taken so far			
Product name			
Viscosity			
API / SG			
Pour point			
Asphaltene			
Section 3	**Weather**		
Wind speed & direction			
Sea state			
Sea temperature			
Tides			
Forecast			

Section 4	Additional Information Required – Please Complete Details if Known
Resources at risk	
Clean-up resources	
On-site / Ordered	
Nearest airport (if known)	
Runway length	
Handling facilities	
Customs	
Handling agent	
Section 5	**Vessel Availability**
Equipment deployed	
Recovered oil storage	
Section 6	**Equipment Logistics**
Transport	
Secure storage	
Port of embarkation	
Location of command centre	
Other designated contacts	
Section 7	**Special Requirements of Country**
Security	
Visa	
Medical advice	
Vaccinations	
Others (specify)	
Section 8	**Climate Information**
Section 9	**Other Information**

C.4 Oil Spill Response Mobilization Form

OSRL MOBILIZATION FORM
WARNING! Ensure telephone contact has been established with OSRL's Duty Manager before using e-mail and fax communications.

To	Duty Manager
Southampton Emergency Fax	+44 (0)23 8072 4314
Southampton Telephone	+44 (0)23 8033 1551
Email	dutymanagers@oilspillresponse.com

Authorizer's Details	
Subject	Mobilization of OSRL
Date	
Name	
Company	
Position	
Contact Telephone Number	
Contact Mobile Number	
Contact Email Address	
Incident Name	
Invoice Address	
I, authorize the activation of Oil Spill Response Limited and its resources in connection with the above incident under the terms of the Agreement in place between above stated Company and Oil Spill Response Limited.	
Signature:	

If OSRL personnel are to work under another party's direction please complete details below:

Additional Details	
Name	
Company	
Position	
Contact Telephone Number	
Contact Mobile Number	
Contact Email Address	

Appendix D COASTAL SENSITIVITY MAPS

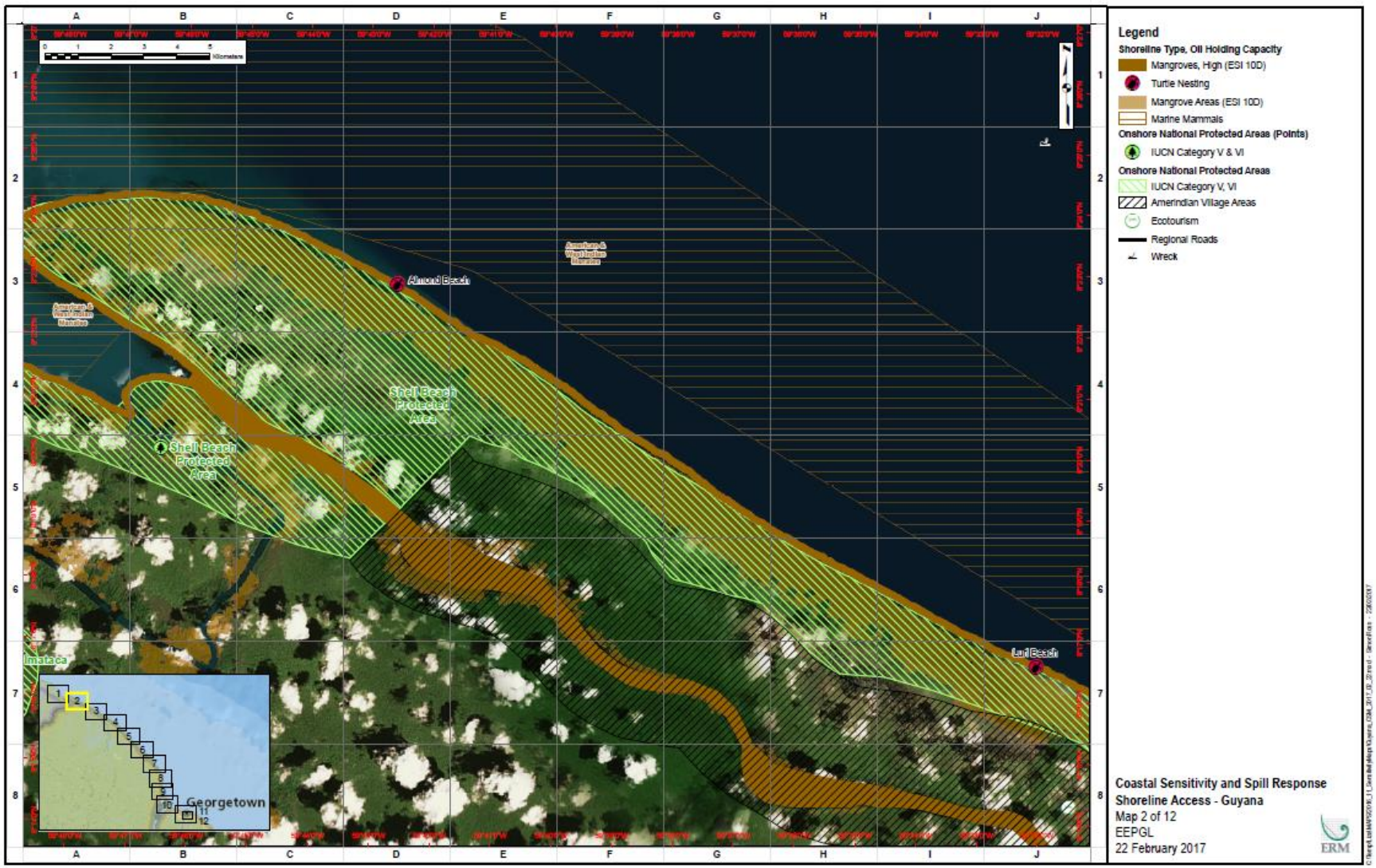
Coastal sensitivity mapping was conducted for the entire coastal area identified in the oil spill modeling as being potentially exposed to hydrocarbons as a result of a Tier III Marine Oil Spill (Scenario 9). The mapping included the following resources and receptors:

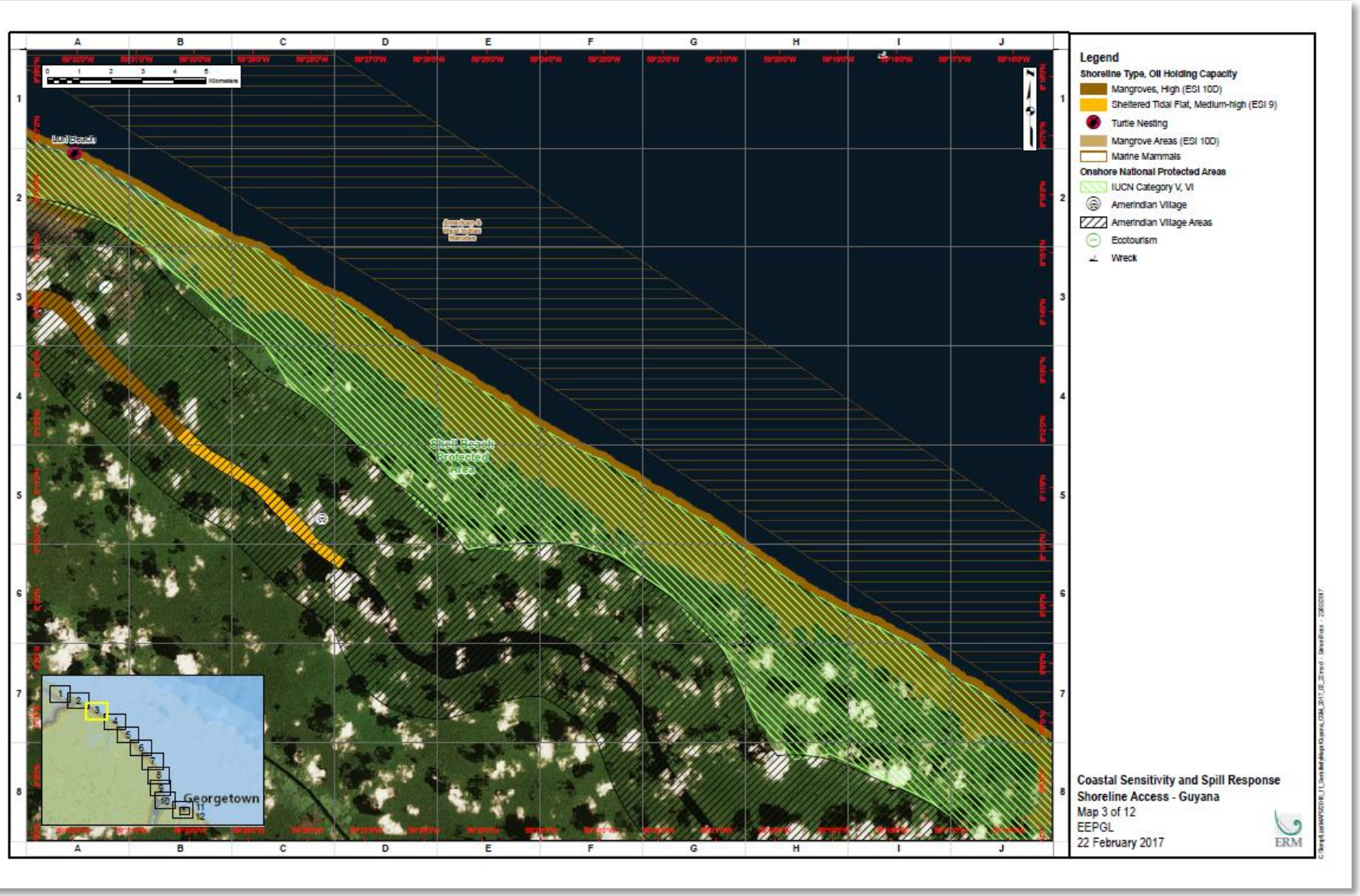
- Environmental – protected areas, wetlands, mangroves, beach types, seagrass beds, coral reefs, and other sensitive habitats; and
- Socioeconomic – coastal and/or indigenous peoples communities (e.g., location and socioeconomic characteristics), coast-dependent commercial and artisanal activities (e.g., fishing, foraging, etc.), other industrial activities, and infrastructure (e.g., water intake facilities).

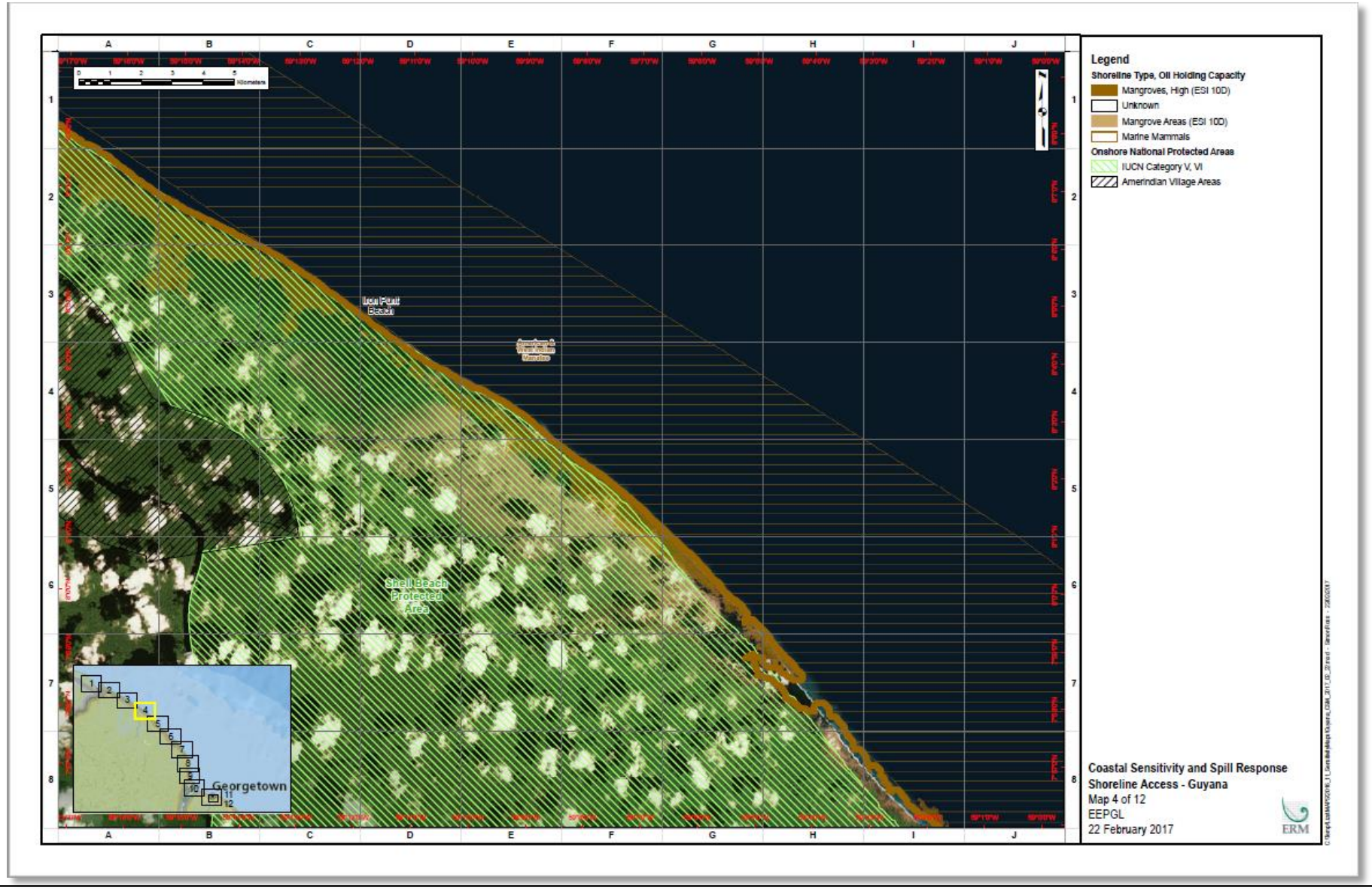
This information enabled EEPGL to prioritize the mobilization of emergency response resources (manpower and equipment) to those areas most sensitive to a spill. Unmitigated potential effects on the coastline of Guyana, portions of Venezuela, Trinidad and Tobago and several islands in the Lesser Antilles (e.g., Grenada, St. Vincent, the Grenadines, and St. Lucia) have been mapped. However, based on the multi-tiered emergency response actions that will be implemented and weathering and evaporative losses that occur for such hydrocarbons most of such coastal areas are not expected to be at risk. The results of this further environmental risk assessment and analysis will be incorporated into the oil spill planning and emergency response training and exercises that will be conducted during each stage of the Liza Phase 1 FPSO Project.

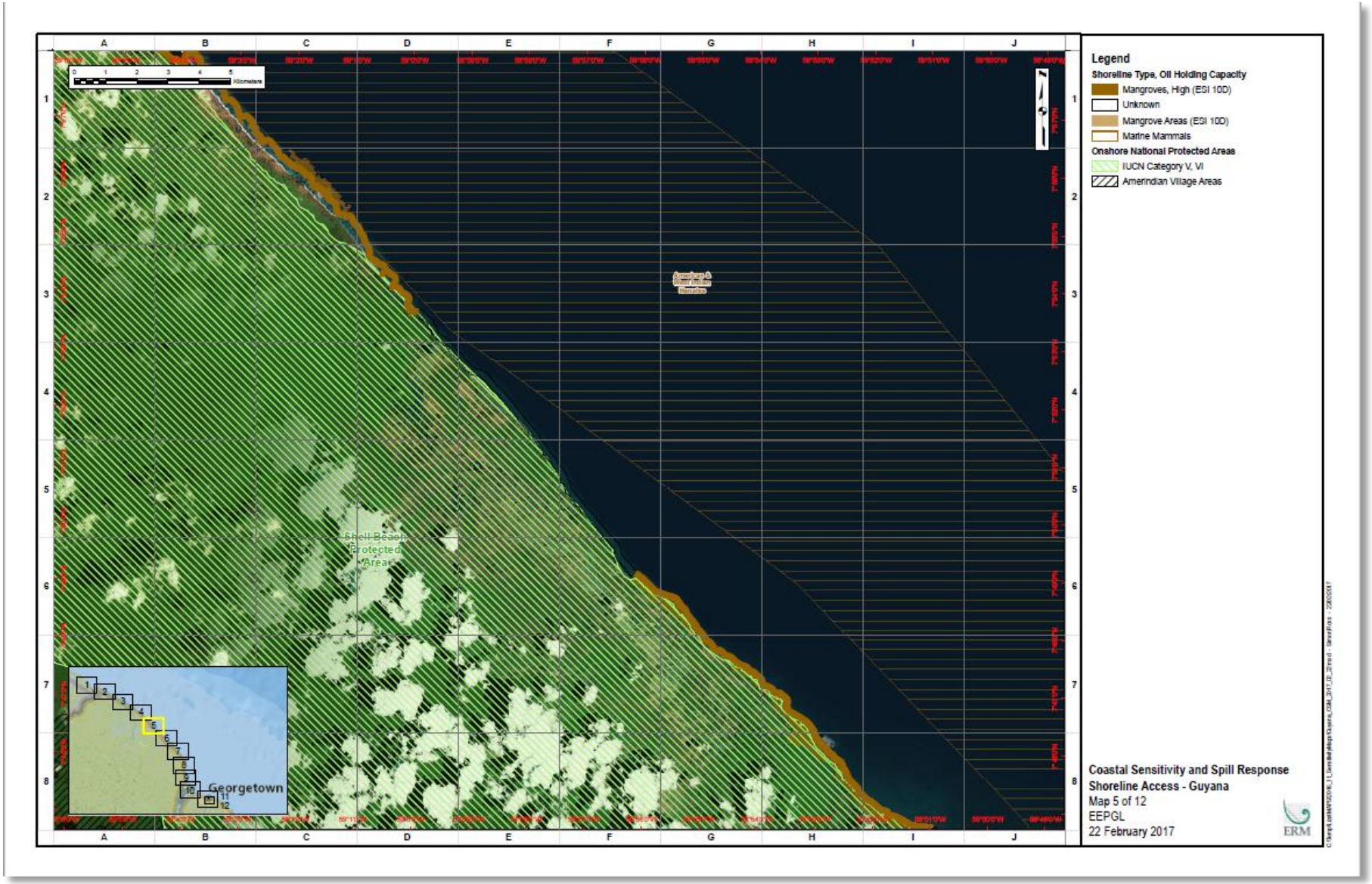
GUYANA
Coastal Sensitivity Maps

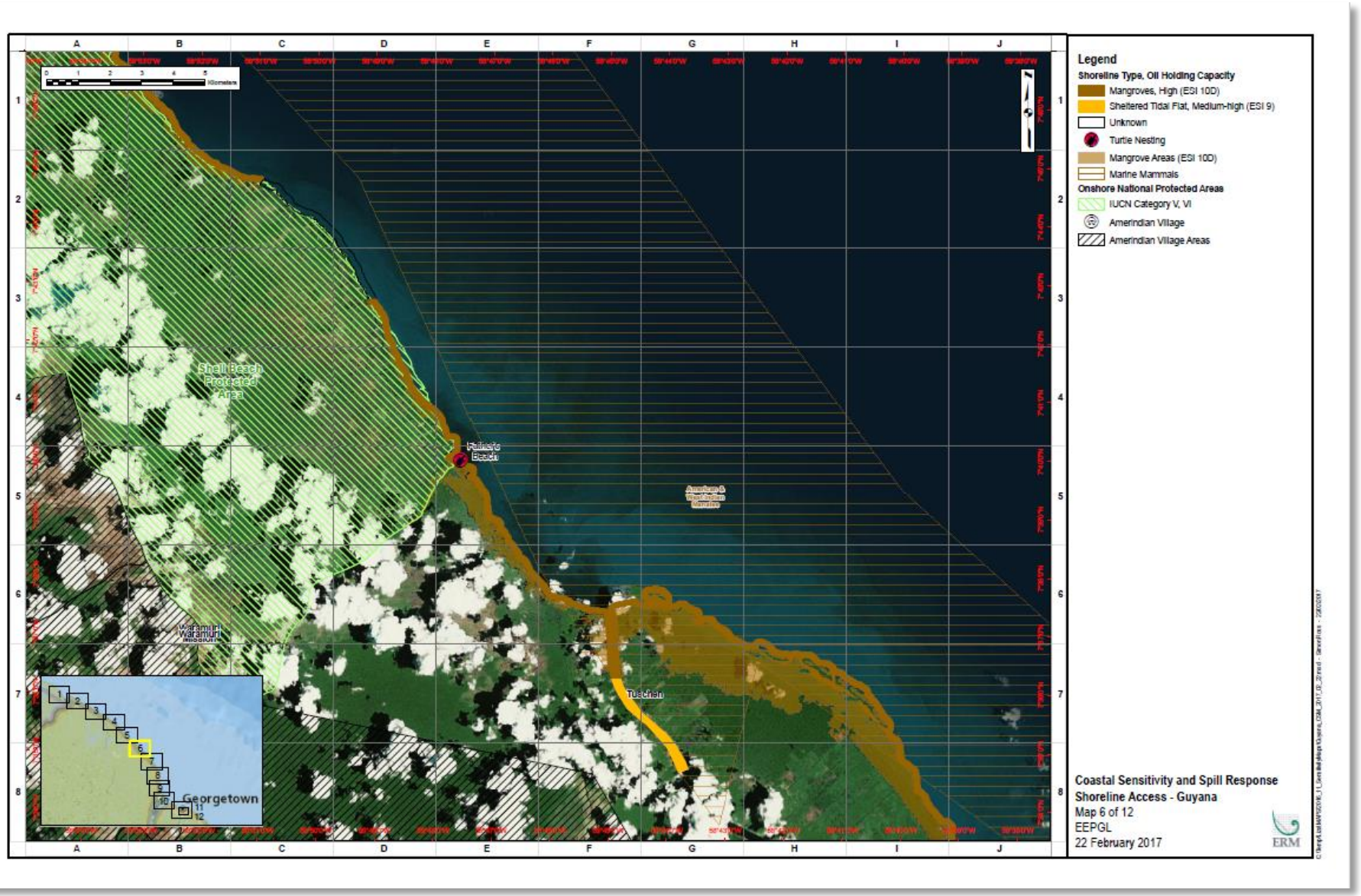

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas
IUCN Category V, VI
Underwater Danger /Underwater Hazard
Territorial Waters Boundary
Instore
Shell Beach Protected Area
Shell Beach Protected Area
La Linea
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 1 of 12
EEPGL
22 February 2017
ERM

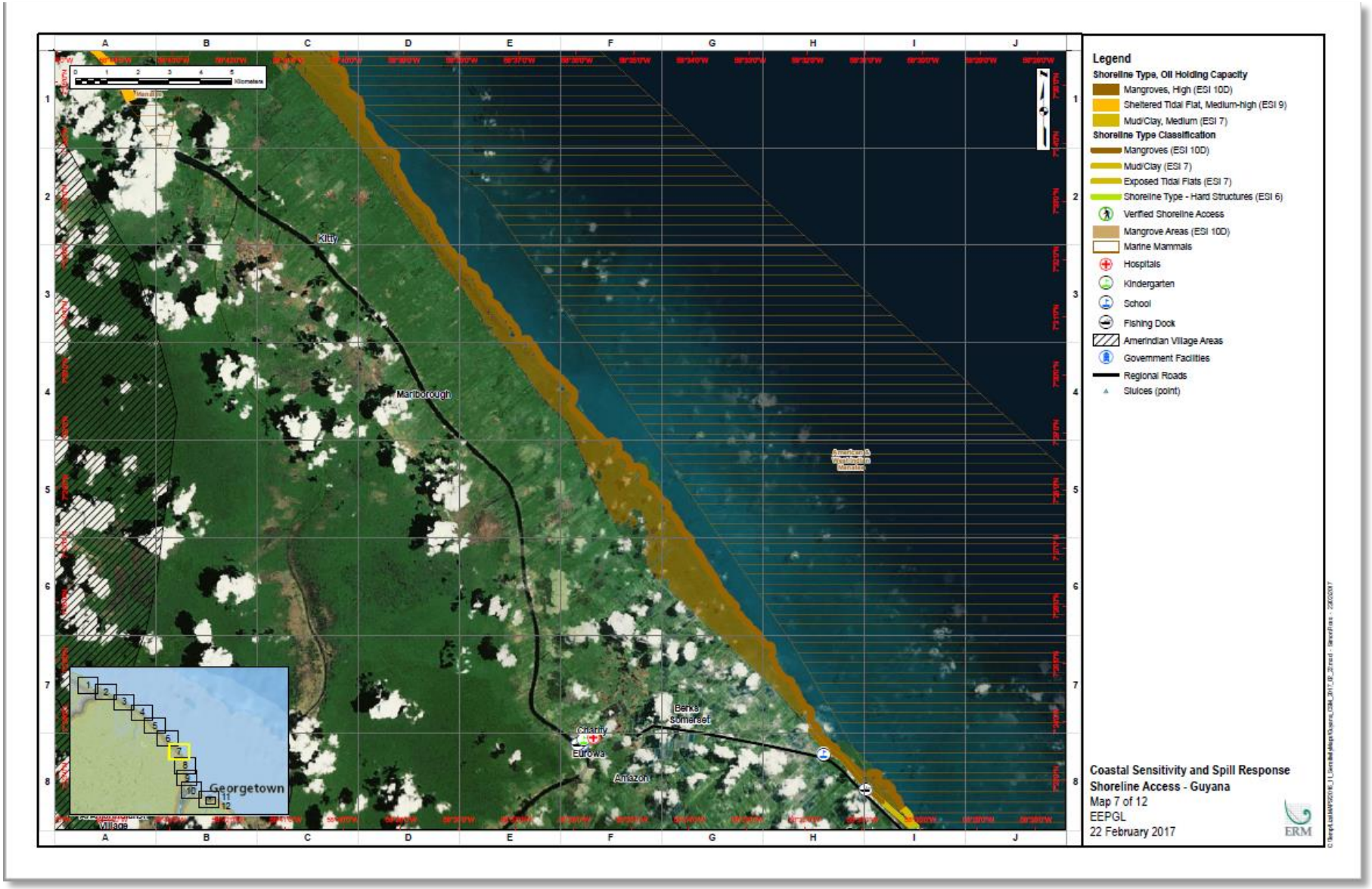

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Turtle Nesting
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas (Points)
IUCN Category V & VI
Onshore National Protected Areas
IUCN Category V, VI
Amerindian Village Areas
Ecotourism
Regional Roads
Wreck
Almond Beach
Shell Beach Protected Area
Shell Beach Protected Area
Mataca
Lal Beach
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 2 of 12
EEPGL
22 February 2017
ERM

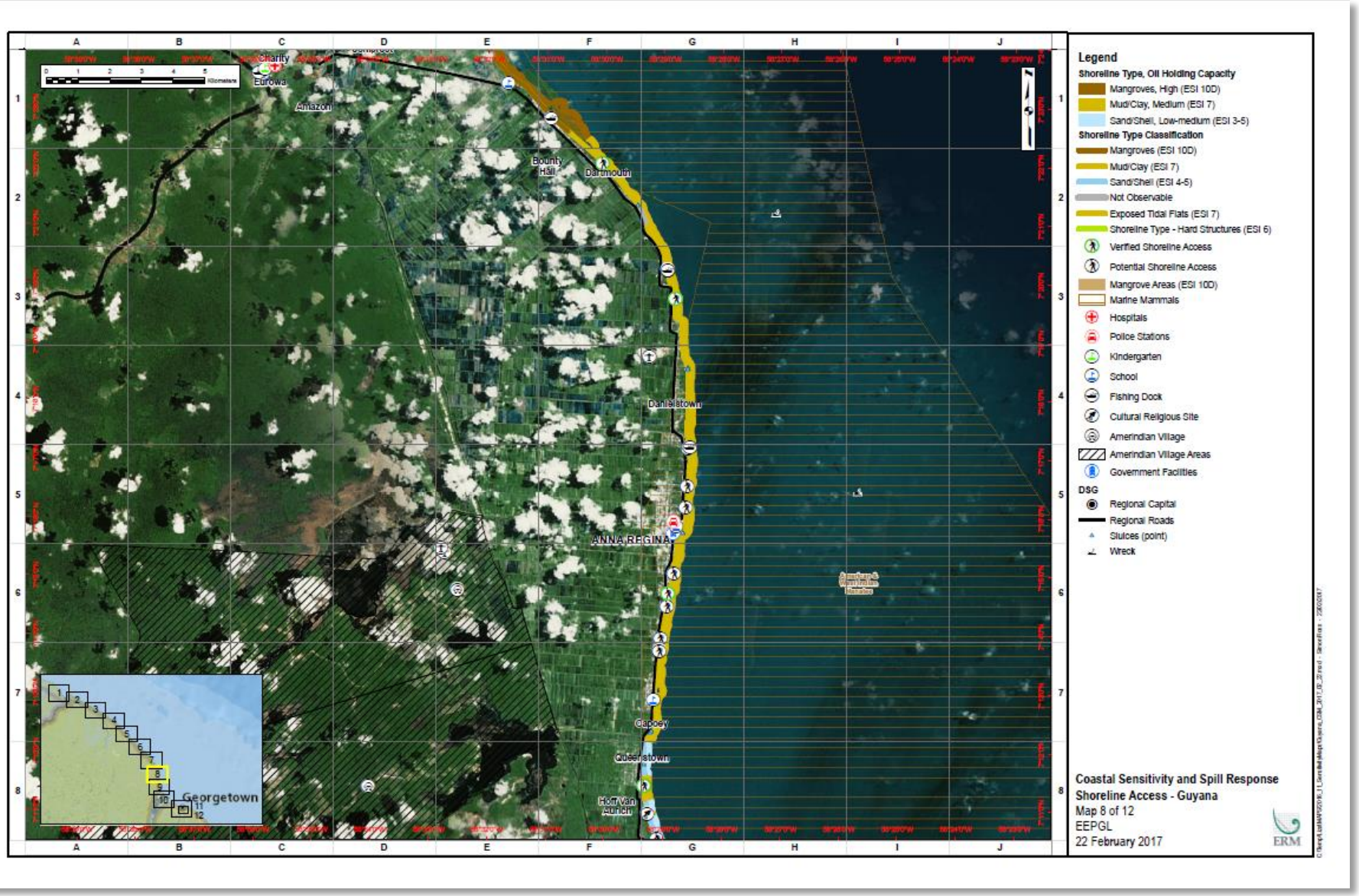

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Sheltered Tidal Flat, Medium-high (ESI 9)
Turtle Nesting
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas
IUCN Category V, VI
Amerindian Village
Amerindian Village Areas
Ecotourism
Wreck
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 3 of 12
EEPGL
22 February 2017
ERM
Georgetown
Shell Beach Protected Area

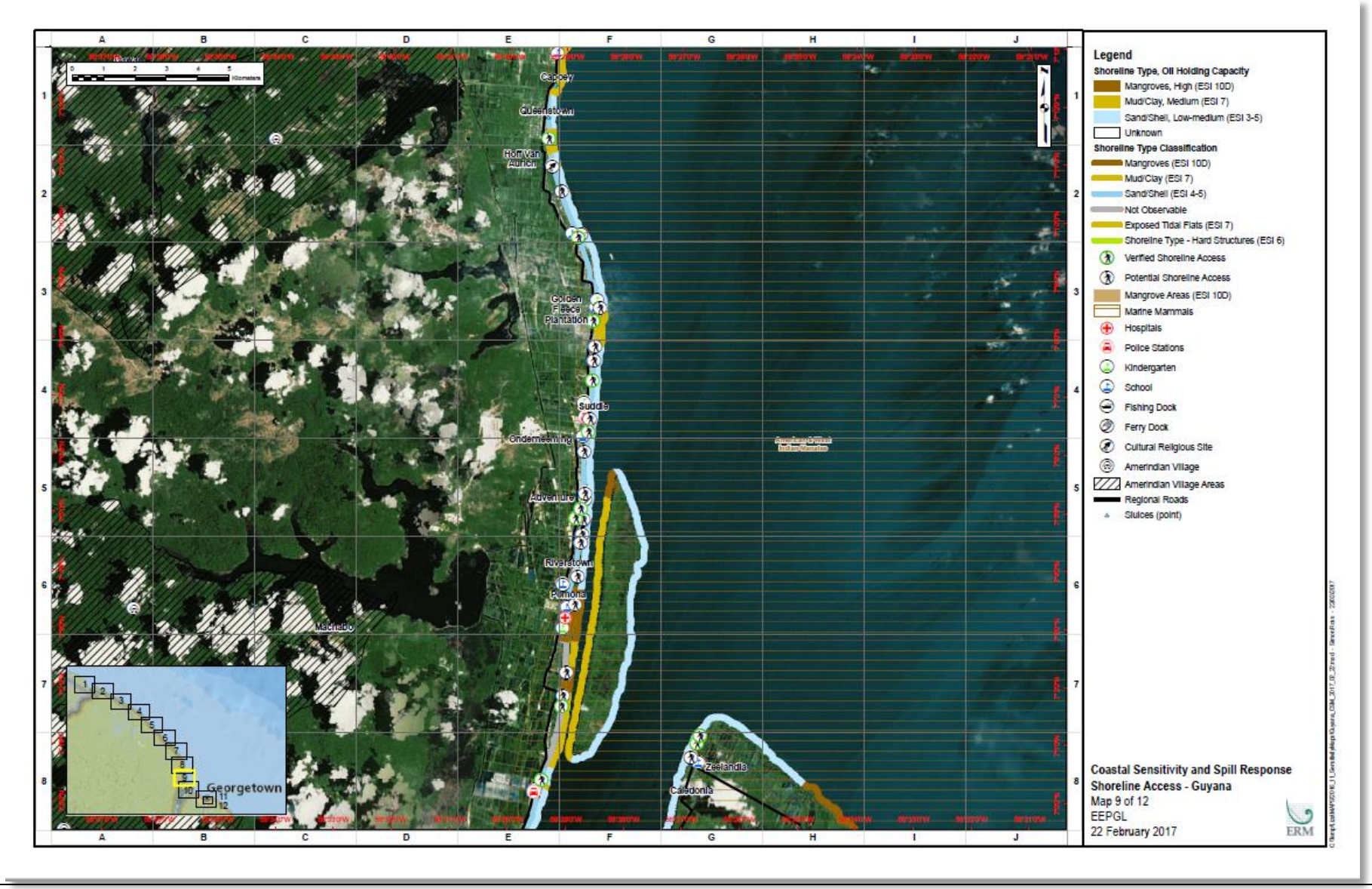

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Unknown
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas
IUCN Category V, VI
Amerindian Village Areas
Iron Post Beach
Shell Beach Protected Area
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 4 of 12
EEPGL
22 February 2017
ERM

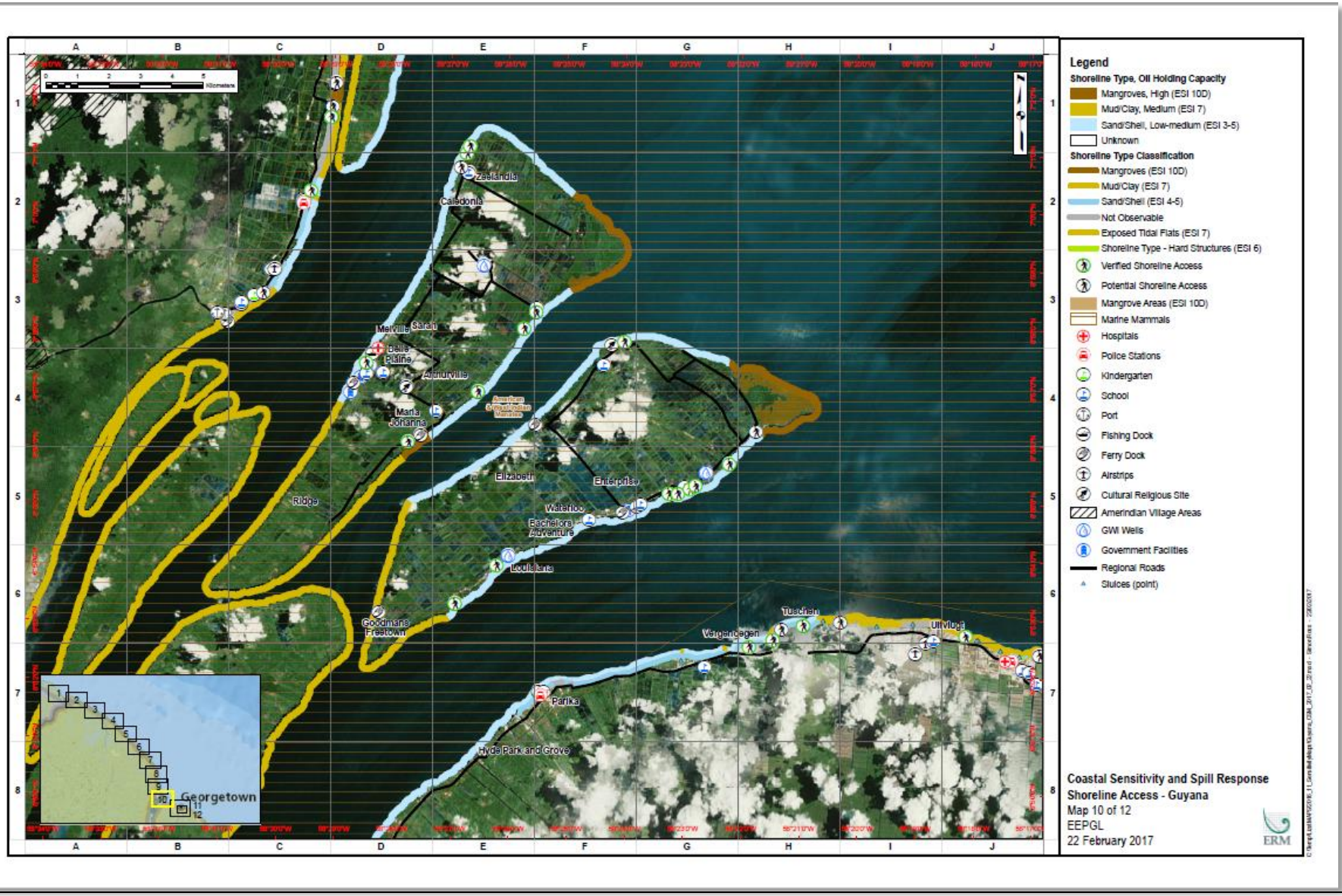

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Unknown
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas
IUCN Category V, VI
Amerindian Village Areas
Shell Beach Protected Area
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 5 of 12
EEPGL
22 February 2017
ERM


Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Sheltered Tidal Flat, Medium-high (ESI 9)
Unknown
Turtle Nesting
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas
IUCN Category V, VI
Amerindian Village
Amerindian Village Areas
Shell Beach Protected Area
Palmers Beach
Tuschen
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 6 of 12
EEPGL
22 February 2017
ERM

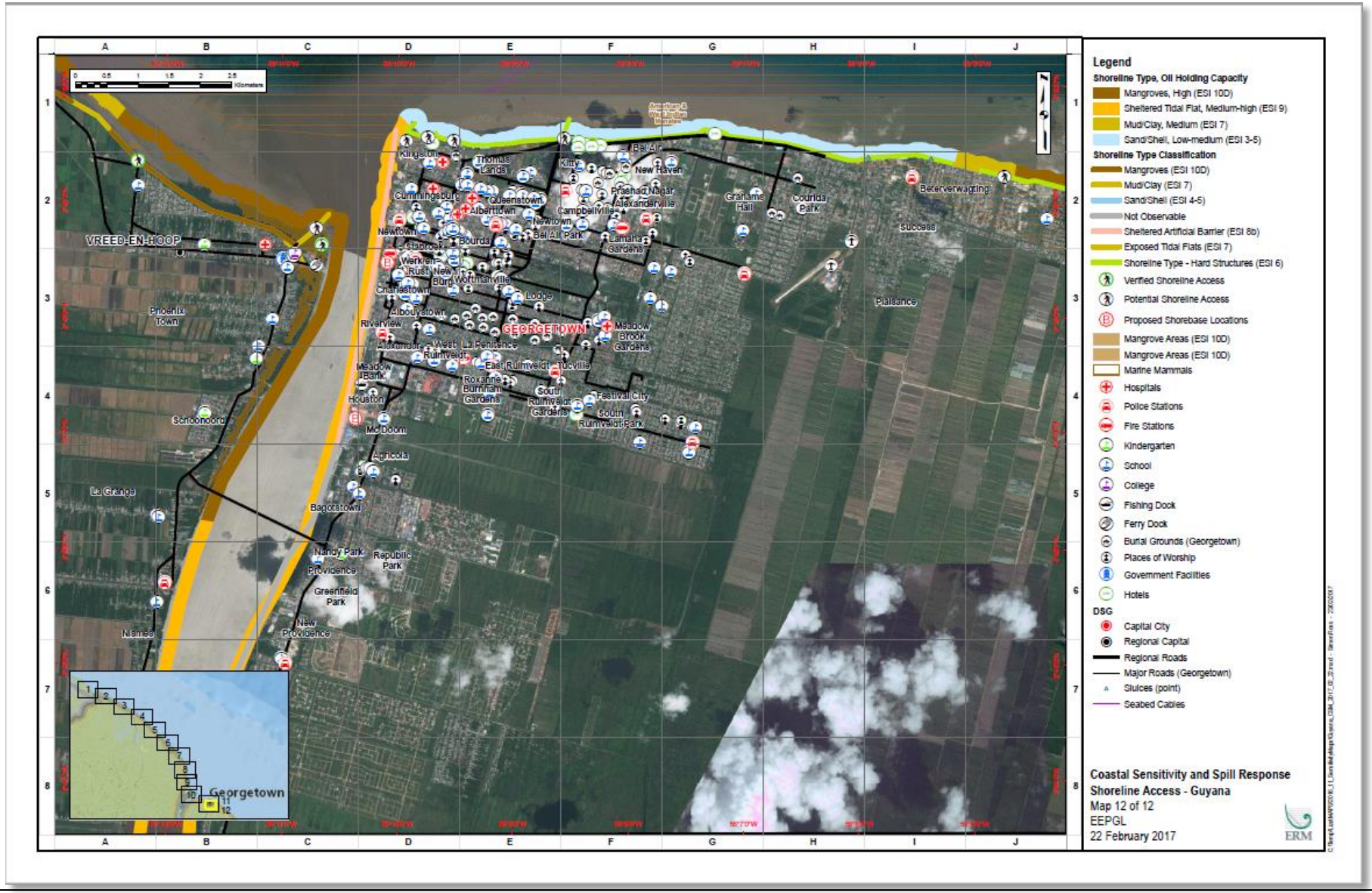

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Sheltered Tidal Flat, Medium-High (ESI 9)
Mud/Clay, Medium (ESI 7)
Shoreline Type Classification
Mangroves (ESI 10D)
Mud/Clay (ESI 7)
Exposed Tidal Flats (ESI 7)
Shoreline Type - Hard Structures (ESI 6)
Verified Shoreline Access
Mangrove Areas (ESI 10D)
Marine Mammals
Hospitals
Kindergarten
School
Fishing Dock
Amerindian Village Areas
Government Facilities
Regional Roads
Sluices (point)
Kitty
Marlborough
Georgetown
Berks Somerset
Charity
Edrowa
Amazon
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 7 of 12
EEPGL
22 February 2017
ERM


Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Mud/Clay, Medium (ESI 7)
Sand/Shell, Low-medium (ESI 3-5)
Shoreline Type Classification
Mangroves (ESI 10D)
Mud/Clay (ESI 7)
Sand/Shell (ESI 4-5)
Not Observable
Exposed Tidal Flats (ESI 7)
Shoreline Type - Hard Structures (ESI 6)
Verified Shoreline Access
Potential Shoreline Access
Mangrove Areas (ESI 10D)
Marine Mammals
Hospitals
Police Stations
Kindergarten
School
Fishing Dock
Cultural Religious Site
Amerindian Village
Amerindian Village Areas
Government Facilities
DSG
Regional Capital
Regional Roads
Sluices (point)
Wreck
Clarity
Eurowa
Amazon
Bounty Hall
Dartmouth
Danielstown
ANNA REGINA
Capoey
Queenstown
Hoff Van Acroch
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 8 of 12
EEPGL
22 February 2017
ERM

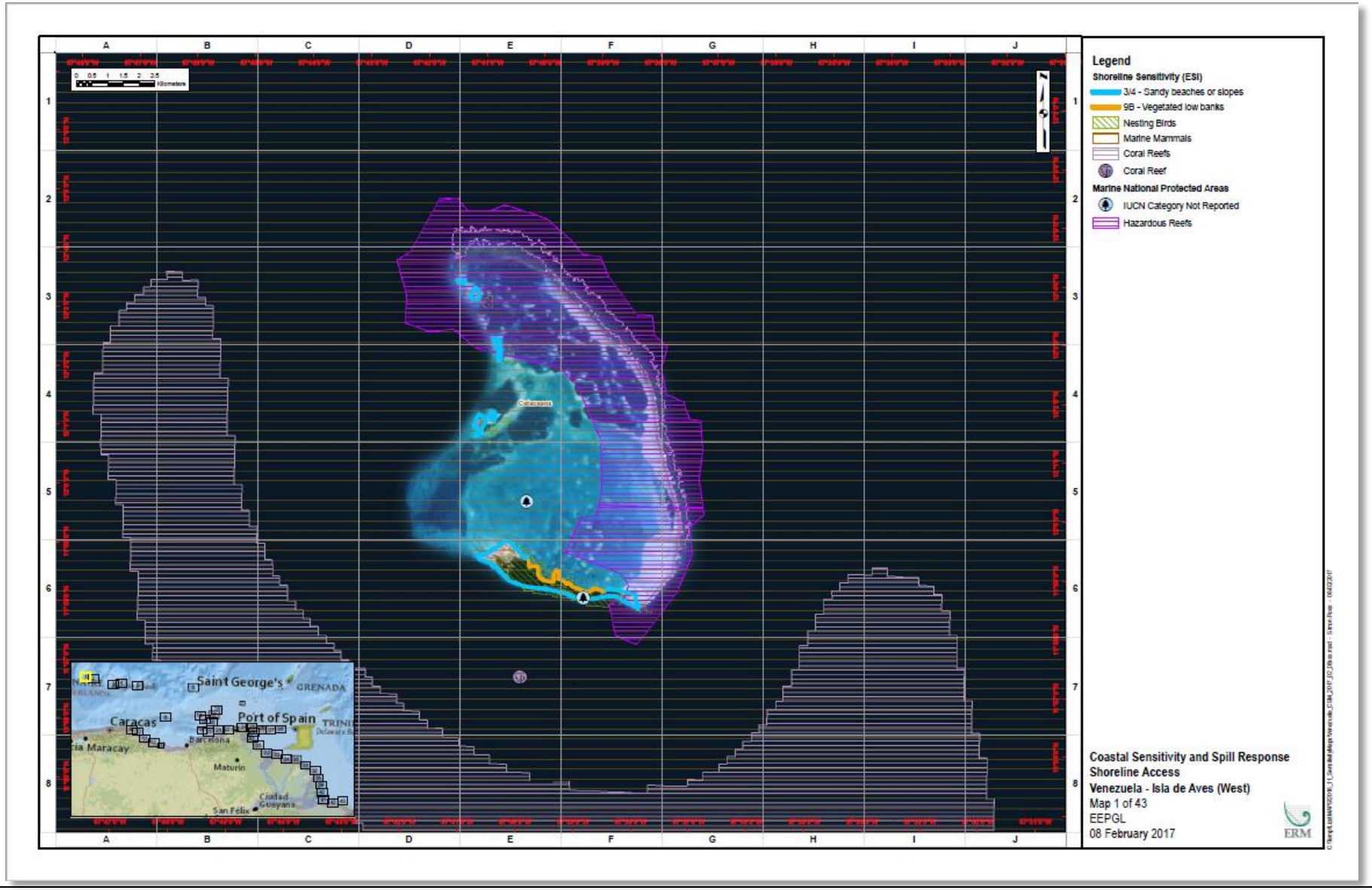

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Mud/Clay, Medium (ESI 7)
Sand/Shell, Low-medium (ESI 3-5)
Unknown
Shoreline Type Classification
Mangroves (ESI 10D)
Mud/Clay (ESI 7)
Sand/Shell (ESI 4-5)
Not Observable
Exposed Tidal Flats (ESI 7)
Shoreline Type - Hard Structures (ESI 6)
Verified Shoreline Access
Potential Shoreline Access
Mangrove Areas (ESI 10D)
Marine Mammals
Hospitals
Police Stations
Kindergarten
School
Fishing Dock
Ferry Dock
Cultural Religious Site
Amerindian Village
Amerindian Village Areas
Regional Roads
Sluices (point)
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 9 of 12
EEPGL
22 February 2017
ERM
Capsey
Queenstown
Hoff Van Aurich
Golden Fleece Plantation
Suddie
Onderneeming
Adventure
Riverstown
Ramona
Machabo
Zeelandia
Caledonia
Georgetown

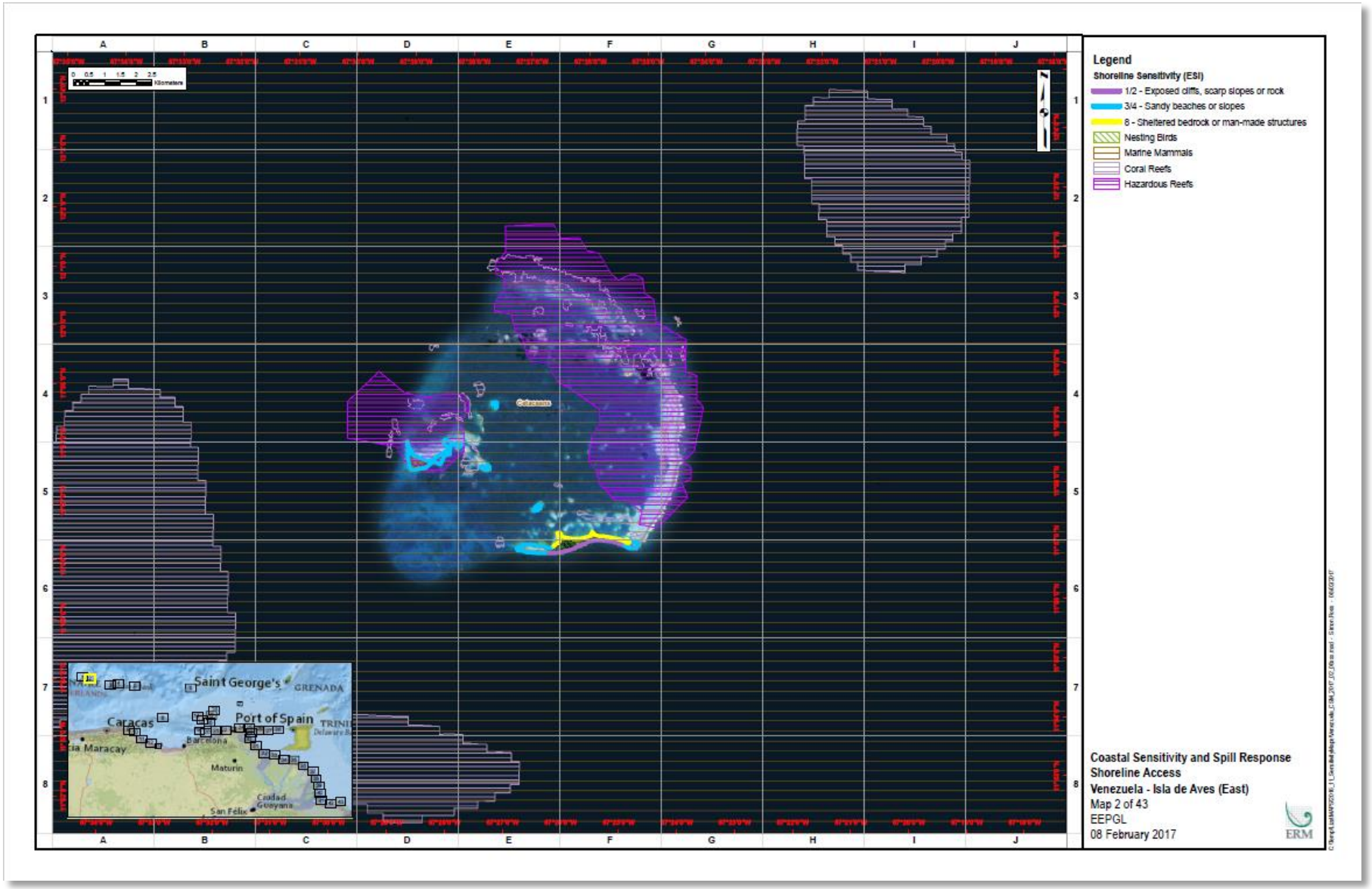

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Mud/Clay, Medium (ESI 7)
Sand/Shell, Low-medium (ESI 3-5)
Unknown
Shoreline Type Classification
Mangroves (ESI 10D)
Mud/Clay (ESI 7)
Sand/Shell (ESI 4-5)
Not Observable
Exposed Tidal Flats (ESI 7)
Shoreline Type - Hard Structures (ESI 6)
Verified Shoreline Access
Potential Shoreline Access
Mangrove Areas (ESI 10D)
Marine Mammals
Hospitals
Police Stations
Kindergarten
School
Port
Fishing Dock
Ferry Dock
Airstrips
Cultural Religious Site
Amerindian Village Areas
GWI Wells
Government Facilities
Regional Roads
Sluices (point)
Zeelandia
Caledonia
Melville
Sarah
Belle Plaine
Adrianville
Maria Johanna
Elizabeth
Enterprise
Waterloo
Bachelors Adventure
Louisiana
Ridge
Goodmans Freetown
Parika
Hyde Park and Grove
Vergenoegen
Tuschen
Ulivlogt
Georgetown
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 10 of 12
EEPGL
22 February 2017
ERM

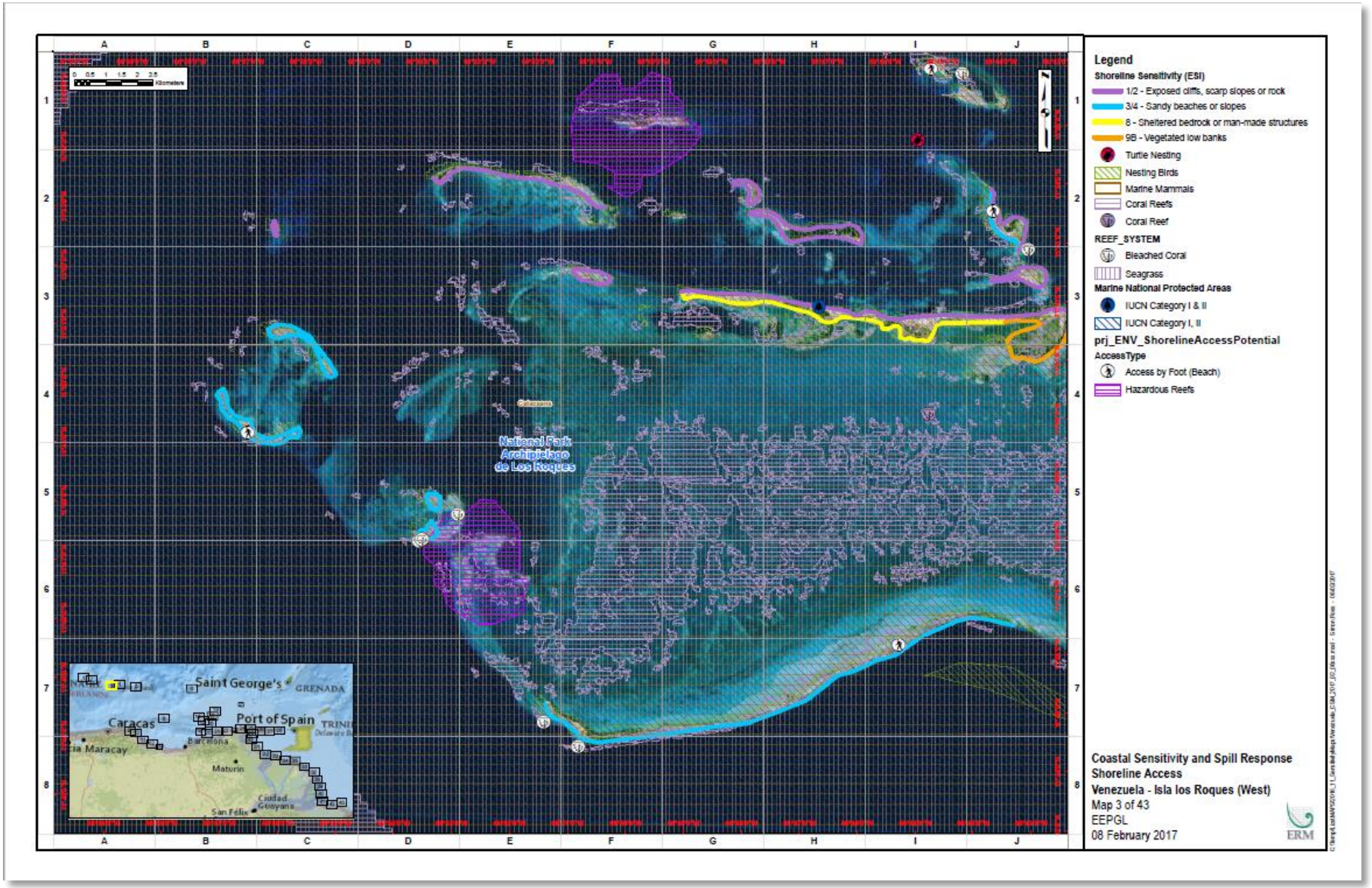

SEE MAP 12 FOR DETAIL
Uitvlugt
Anna Catherina
Den Amstel
La Jalousie
Windsor Forest
Harlem
VREED-EN-HOOP
Margot
Lusignan
Great Diamond
Good Intent
De Gezusters
Golden Grove
Lorenza Patentia
Good Success
Georgetown
Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Sheltered Tidal Flat, Medium-high (ESI 9)
Mud/Clay, Medium (ESI 7)
Sand/Shell, Low-medium (ESI 3-5)
Unknown
Shoreline Type Classification
Mangroves (ESI 10D)
Mud/Clay (ESI 7)
Sand/Shell (ESI 4-5)
Not Observable
Sheltered Artificial Barrier (ESI 8b)
Exposed Tidal Flats (ESI 7)
Shoreline Type - Hard Structures (ESI 6)
Verified Shoreline Access
Potential Shoreline Access
Proposed Shorebase Locations
Mangrove Areas (ESI 10D)
Mangrove Areas (ESI 10D)
Marine Mammals
Hospitals
Police Stations
Fire Stations
Kindergarten
School
College
Fishing Dock
Ferry Dock
Cultural Religious Site
Burial Grounds (Georgetown)
Places of Worship
Government Facilities
Hotels
DSG
Capital City
Regional Capital
Regional Roads
Major Roads (Georgetown)
Sluices (point)
Shipping Route
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 11 of 12
EEPGL
22 February 2017
ERM

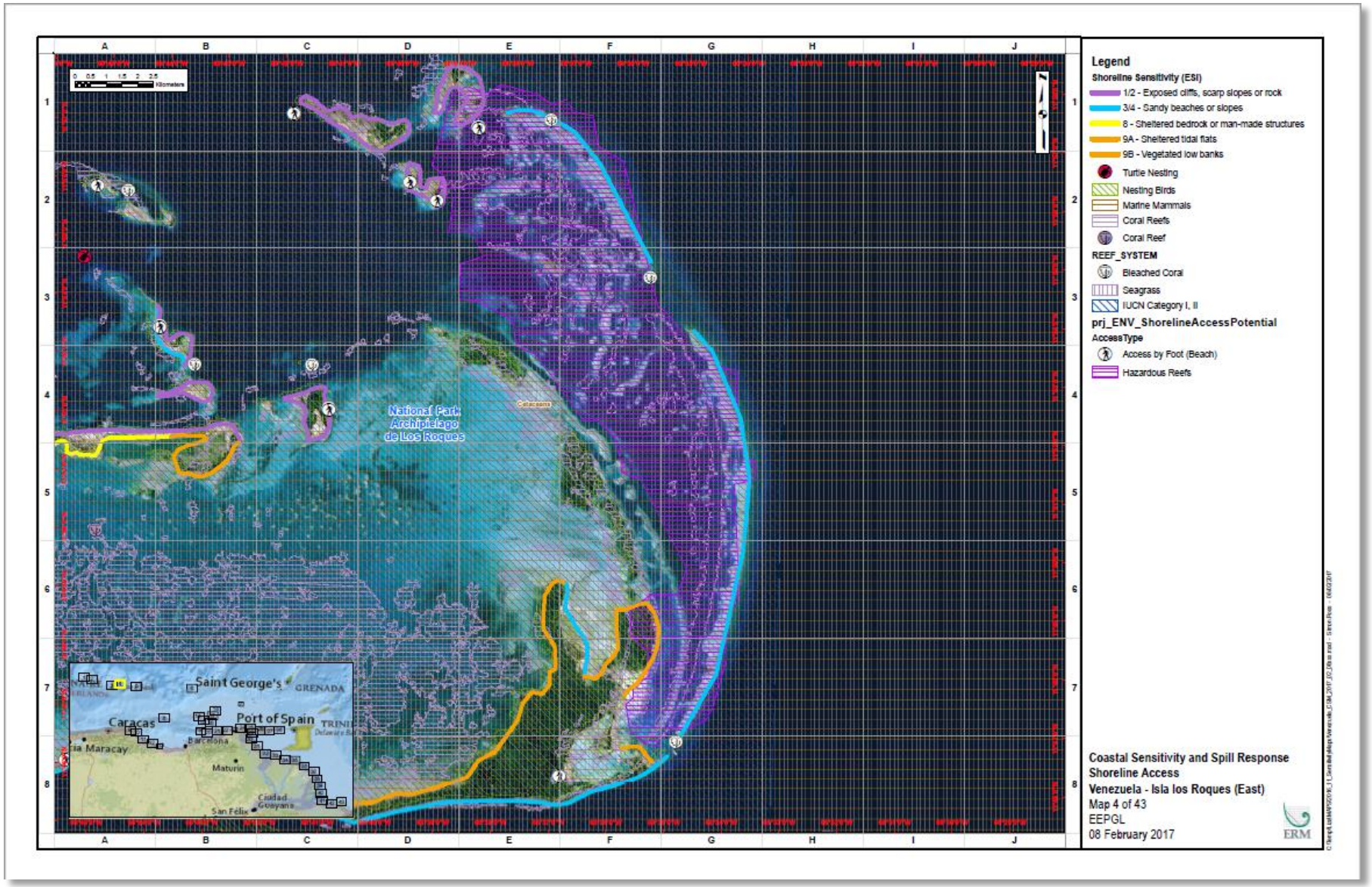

Legend
Shoreline Type, Oil Holding Capacity
Mangroves, High (ESI 10D)
Sheltered Tidal Flat, Medium-high (ESI 9)
Mud/Clay, Medium (ESI 7)
Sand/Shell, Low-medium (ESI 3-5)
Shoreline Type Classification
Mangroves (ESI 10D)
Mud/Clay (ESI 7)
Sand/Shell (ESI 4-5)
Not Observable
Sheltered Artificial Barrier (ESI 8b)
Exposed Tidal Flats (ESI 7)
Shoreline Type - Hard Structures (ESI 6)
Verified Shoreline Access
Potential Shoreline Access
Proposed Shorebase Locations
Mangrove Areas (ESI 10D)
Mangrove Areas (ESI 10D)
Marine Mammals
Hospitals
Police Stations
Fire Stations
Kindergarten
School
College
Fishing Dock
Ferry Dock
Burial Grounds (Georgetown)
Places of Worship
Government Facilities
Hotels
DSG
Capital City
Regional Capital
Regional Roads
Major Roads (Georgetown)
Sluices (point)
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access - Guyana
Map 12 of 12
EEPGL
22 February 2017
ERM
GEORGETOWN
VREED-EN-HOOP
Georgetown

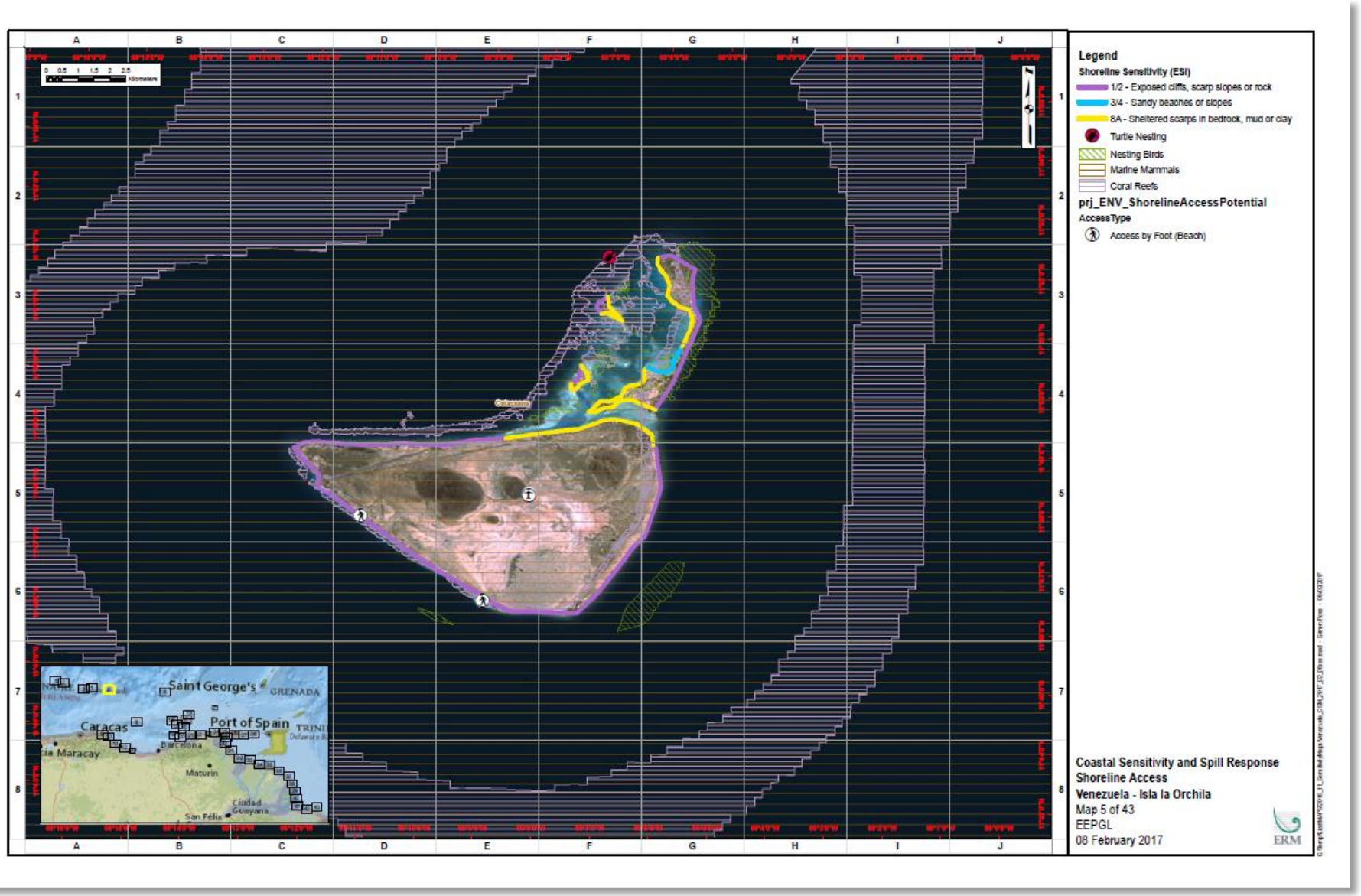
VENEZUELA
Coastal Sensitivity Maps

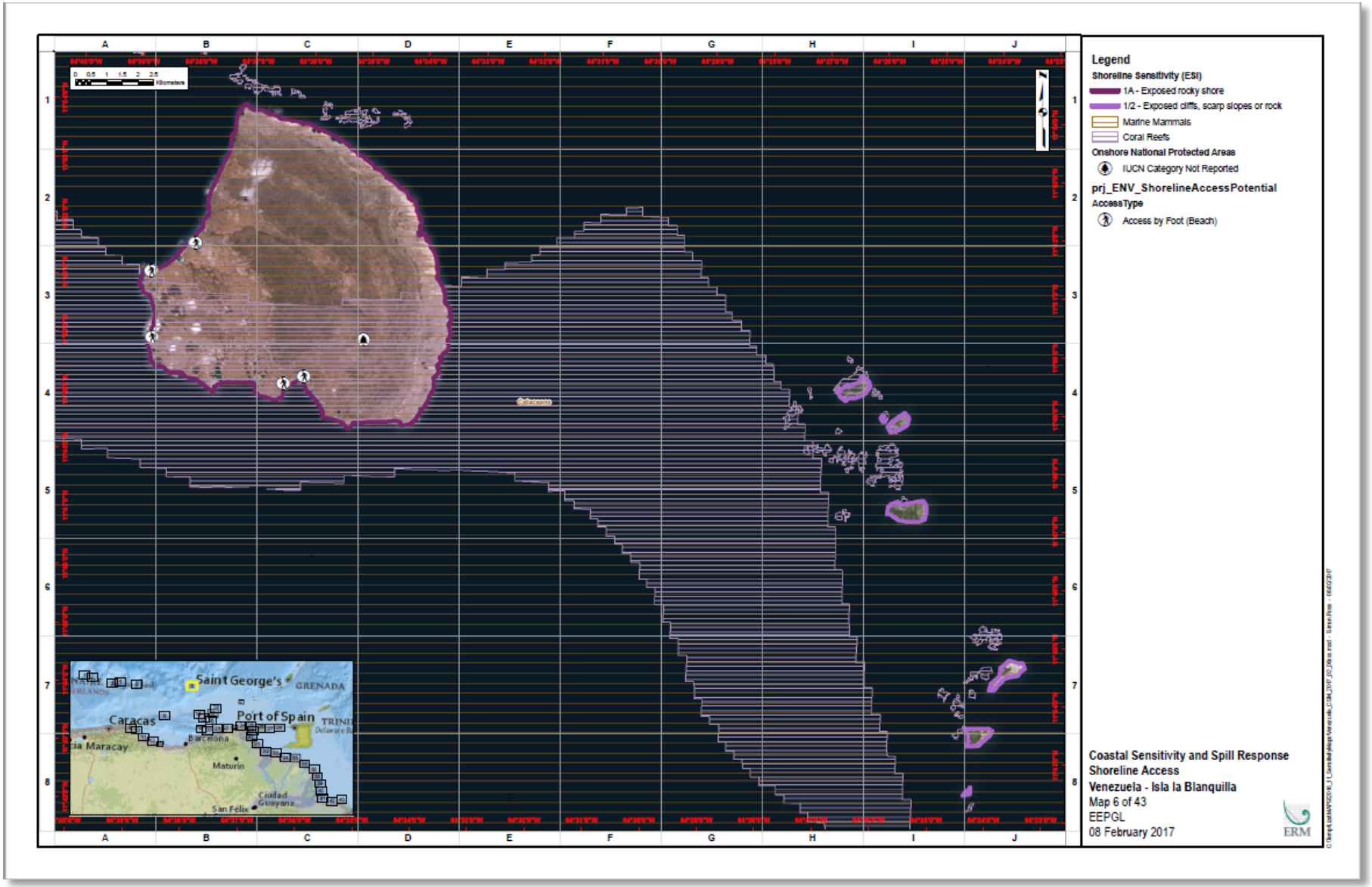

Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
9B - Vegetated low banks
Nesting Birds
Marine Mammals
Coral Reefs
Coral Reef
Marine National Protected Areas
IUCN Category Not Reported
Hazardous Reefs
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla de Aves (West)
Map 1 of 43
EEPGL
08 February 2017
ERM

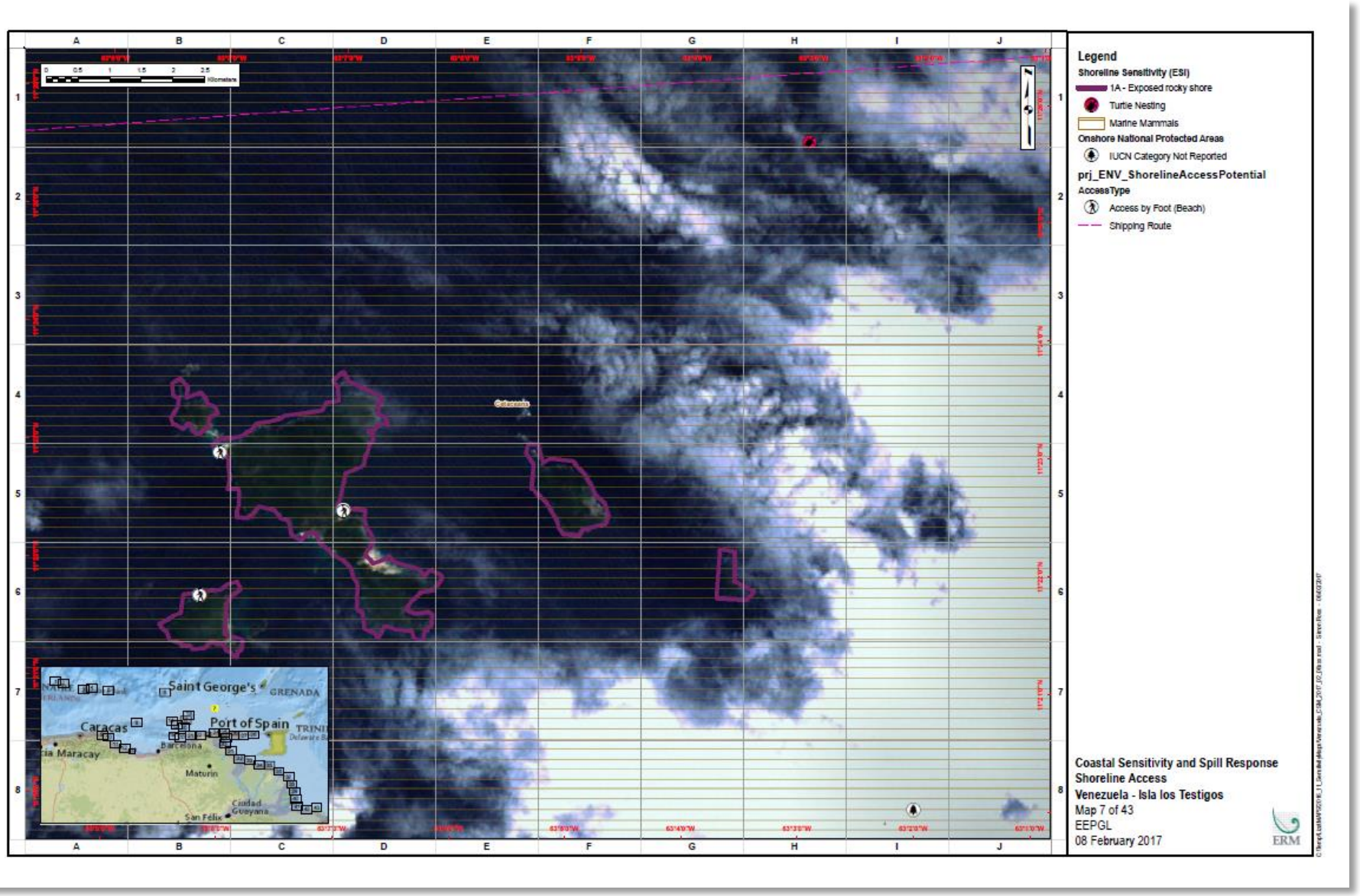

Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
8 - Sheltered bedrock or man-made structures
Nesting Birds
Marine Mammals
Coral Reefs
Hazardous Reefs
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla de Aves (East)
Map 2 of 43
EEPGL
08 February 2017
ERM

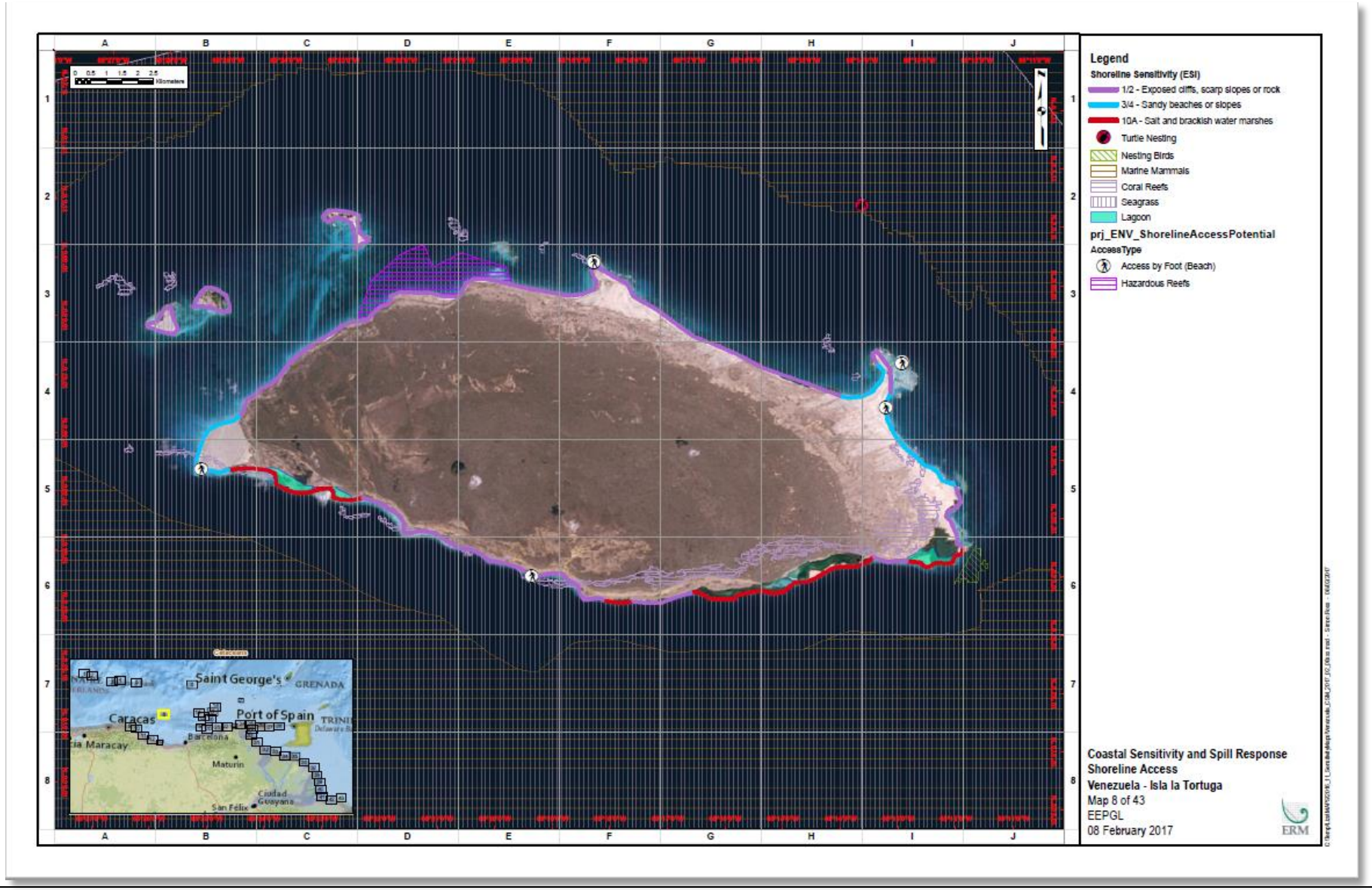

Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
Turtle Nesting
Nesting Birds
Marine Mammals
Coral Reefs
Coral Reef
REEF_SYSTEM
Bleached Coral
Seagrass
Marine National Protected Areas
IUCN Category I & II
IUCN Category I, II
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Hazardous Reefs
National Park Archipielago de Los Roques
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla los Roques (West)
Map 3 of 43
EEPGL
08 February 2017
ERM

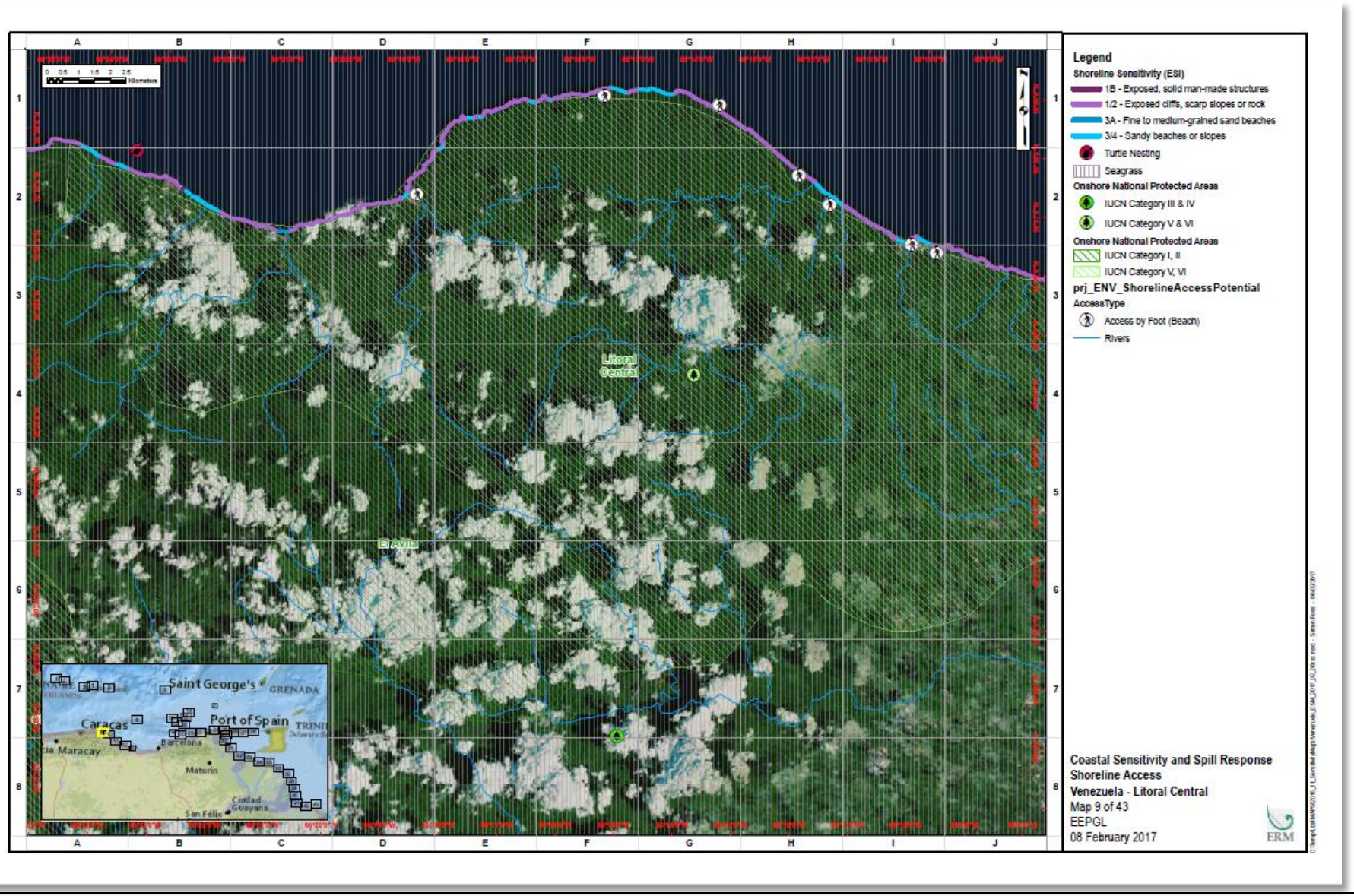

Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
8 - Sheltered bedrock or man-made structures
9A - Sheltered tidal flats
9B - Vegetated low banks
Turtle Nesting
Nesting Birds
Marine Mammals
Coral Reefs
Coral Reef
REEF_SYSTEM
Bleached Coral
Seagrass
IUCN Category I, II
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Hazardous Reefs
National Park
Archipielago
de Los Roques
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla los Roques (East)
Map 4 of 43
EEPGL
08 February 2017
ERM

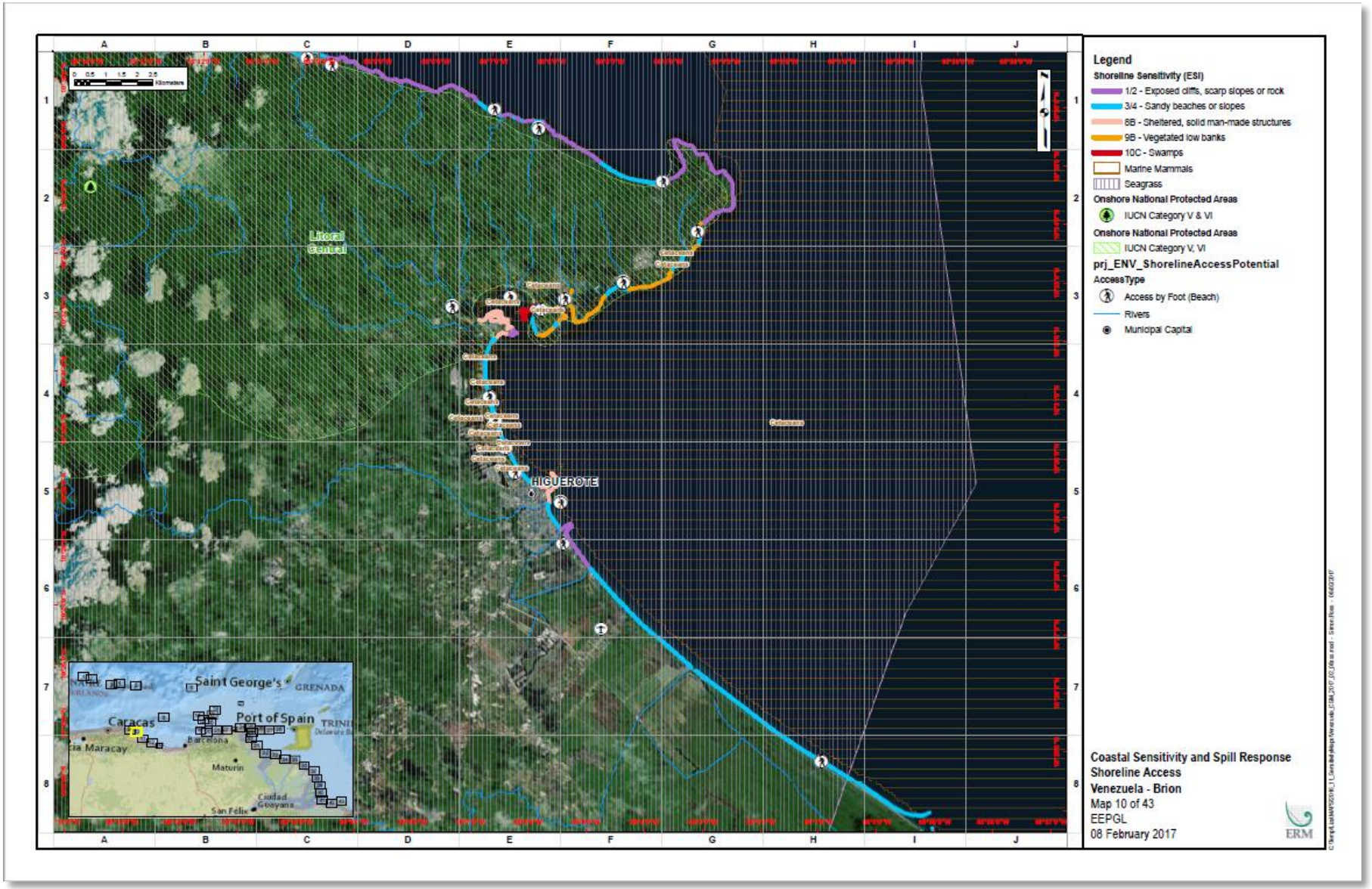

Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
8A - Sheltered scarps in bedrock, mud or clay
Turtle Nesting
Nesting Birds
Marine Mammals
Coral Reefs
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla la Orchila
Map 5 of 43
EEPGL
08 February 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix

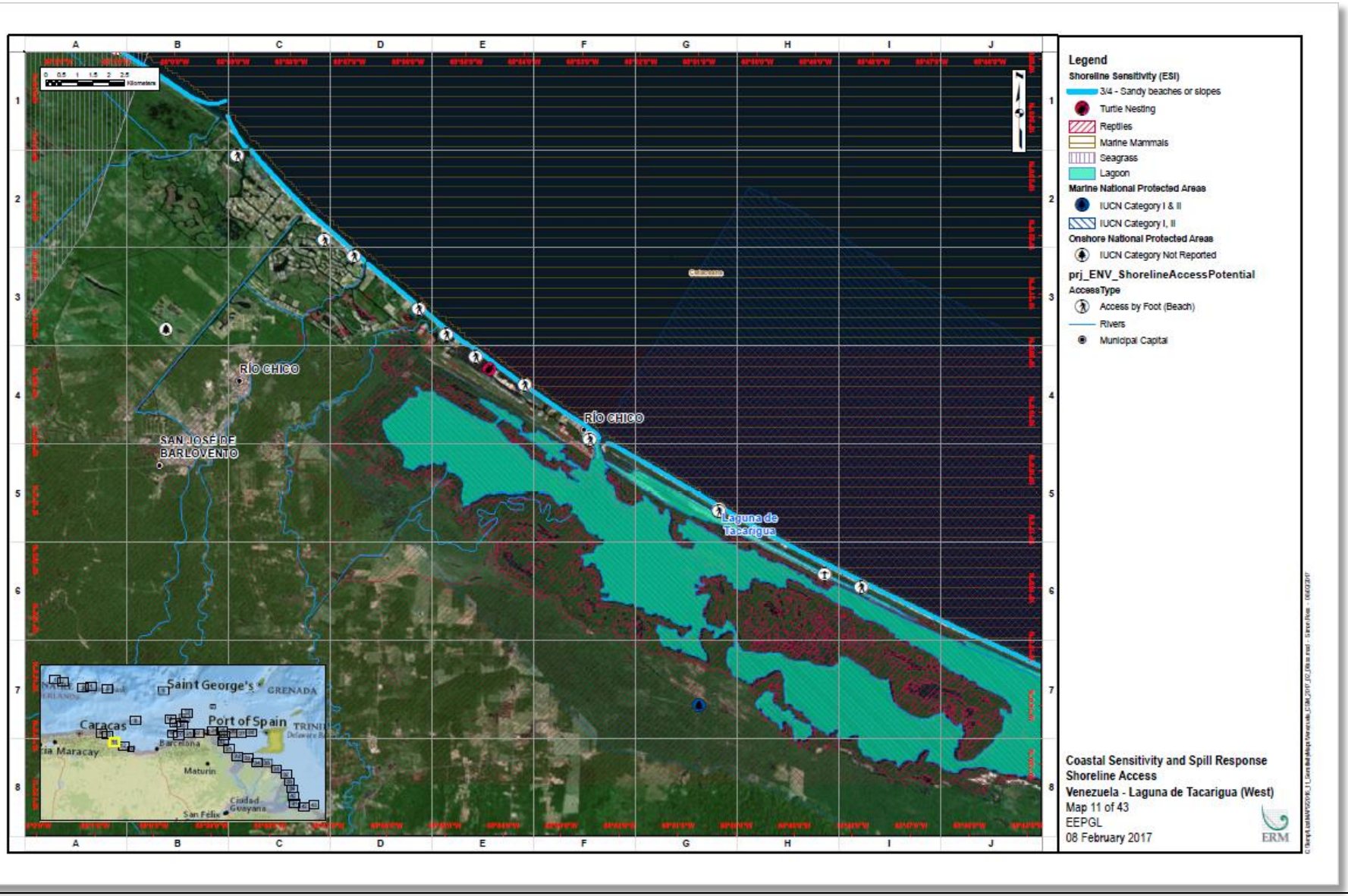

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1/2 - Exposed cliffs, scarp slopes or rock
Marine Mammals
Coral Reefs
Onshore National Protected Areas
IUCN Category Not Reported
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla la Blanquilla
Map 6 of 43
EEPGL
08 February 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix

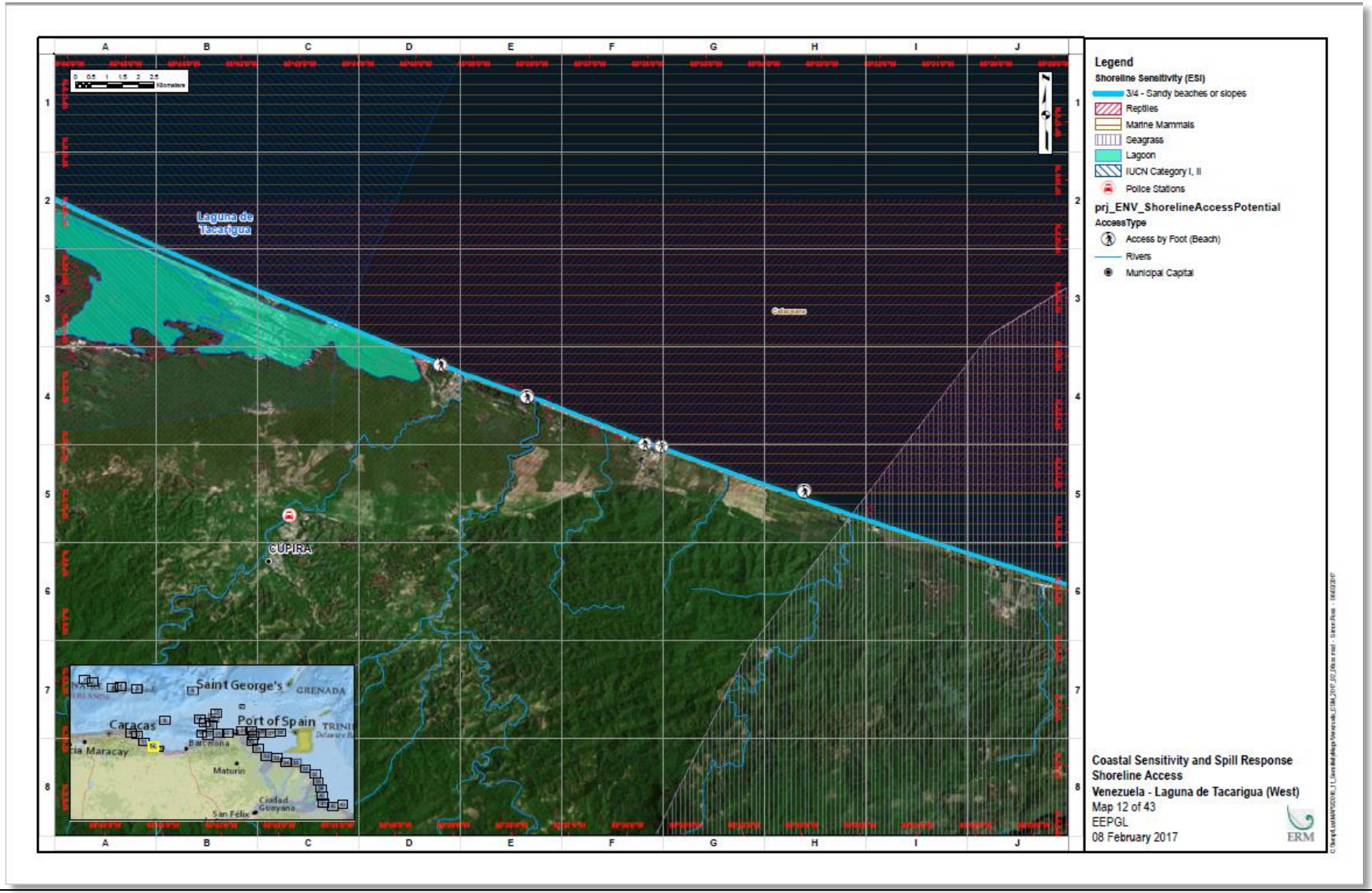

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
Turtle Nesting
Marine Mammals
Onshore National Protected Areas
IUCN Category Not Reported
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla los Testigos
Map 7 of 43
EEPGL
08 February 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix

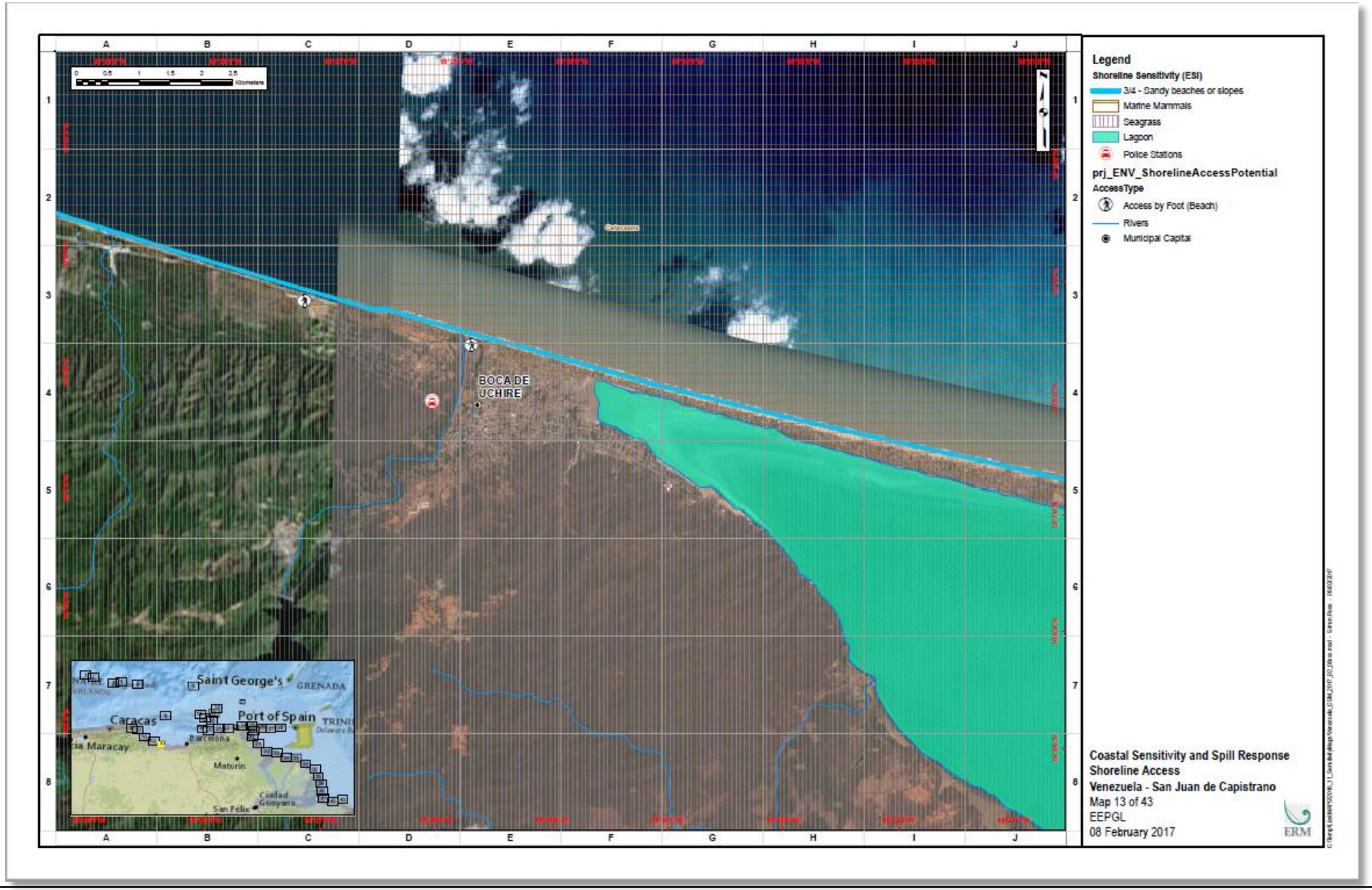

Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
10A - Salt and brackish water marshes
Turtle Nesting
Nesting Birds
Marine Mammals
Coral Reefs
Seagrass
Lagoon
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Hazardous Reefs
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla la Tortuga
Map 8 of 43
EEPGL
08 February 2017
ERM

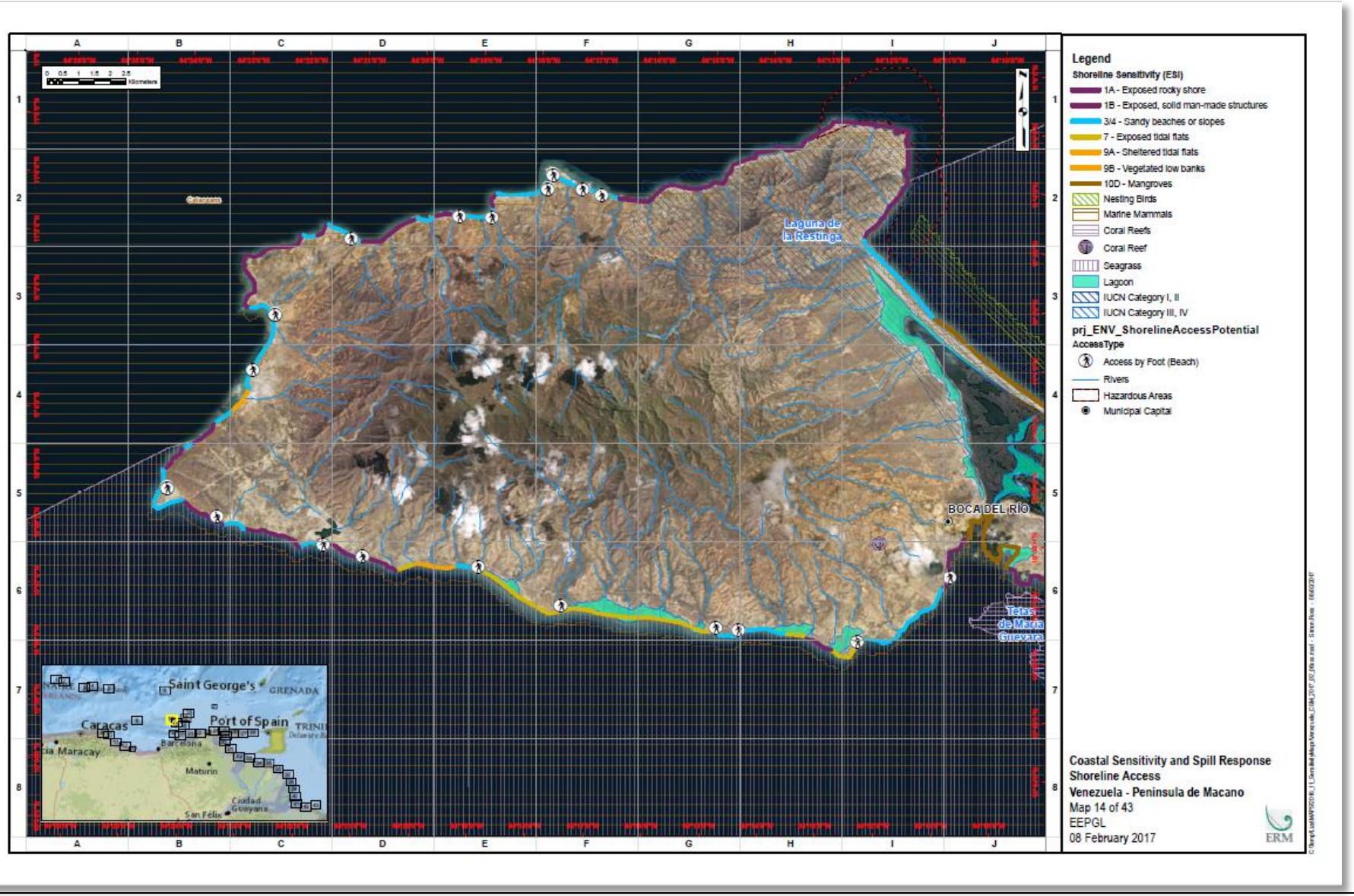

Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
3A - Fine to medium-grained sand beaches
3/4 - Sandy beaches or slopes
Turtle Nesting
Seagrass
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category V & VI
Onshore National Protected Areas
IUCN Category I, II
IUCN Category V, VI
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Litoral Central
El Avila
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Litoral Central
Map 9 of 43
EEPGL
08 February 2017
ERM

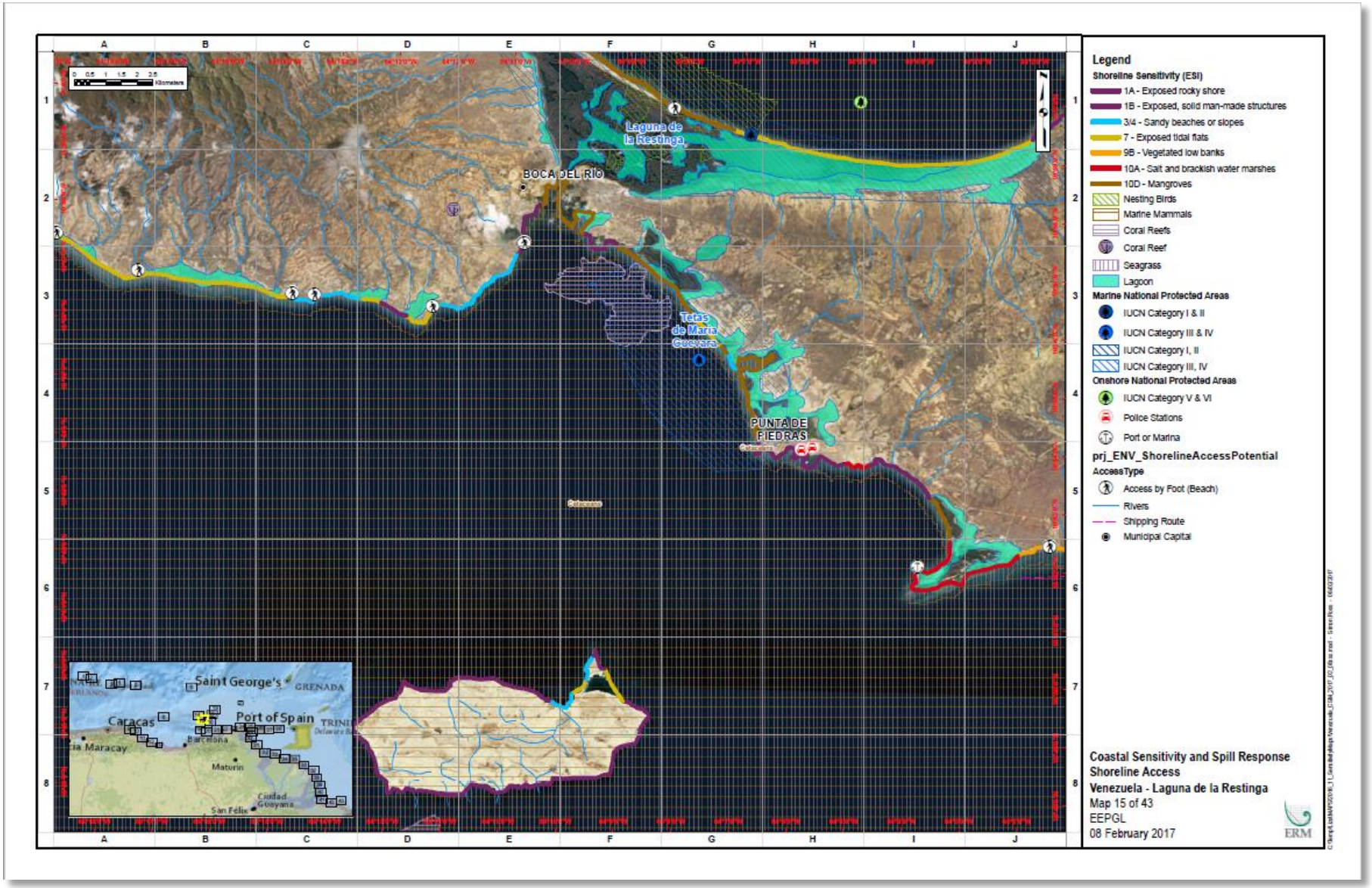

Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
8B - Sheltered, solid man-made structures
9B - Vegetated low banks
10C - Swamps
Marine Mammals
Seagrass
Onshore National Protected Areas
IUCN Category V & VI
Onshore National Protected Areas
IUCN Category V, VI
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Municipal Capital
Litoral Central
HIGUEROTE
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Brion
Map 10 of 43
EEPGL
08 February 2017
ERM

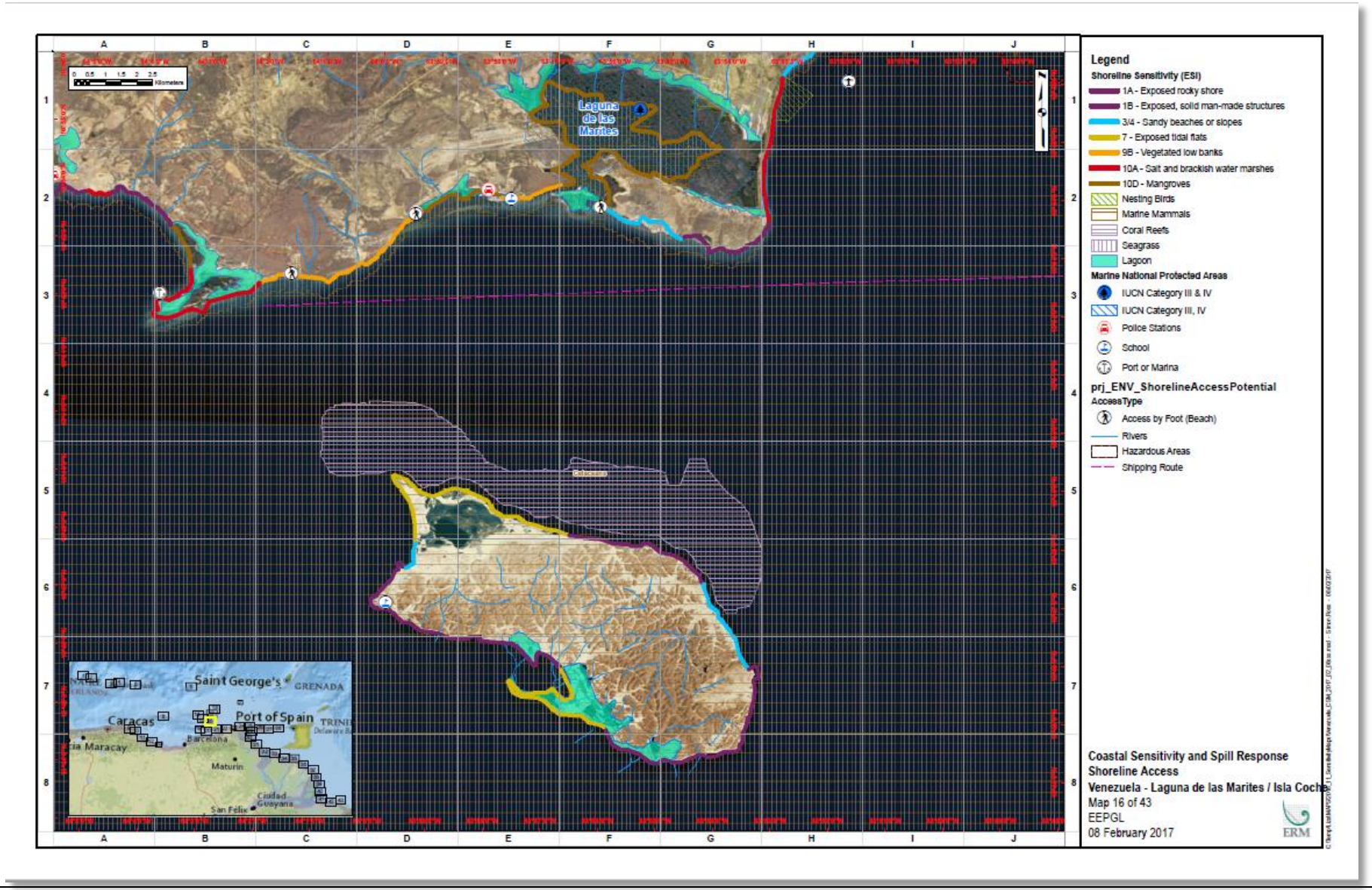

Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
Turtle Nesting
Reptiles
Marine Mammals
Seagrass
Lagoon
Marine National Protected Areas
IUCN Category I & II
IUCN Category I, II
Onshore National Protected Areas
IUCN Category Not Reported
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Municipal Capital
RÍO CHICO
SAN JOSÉ DE BARLOVENTO
RÍO CHICO
Laguna de Tacarigua
Saint George's
GRENADA
Caracas
Port of Spain
Maturín
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Laguna de Tacarigua (West)
Map 11 of 43
EEPGL
08 February 2017
ERM

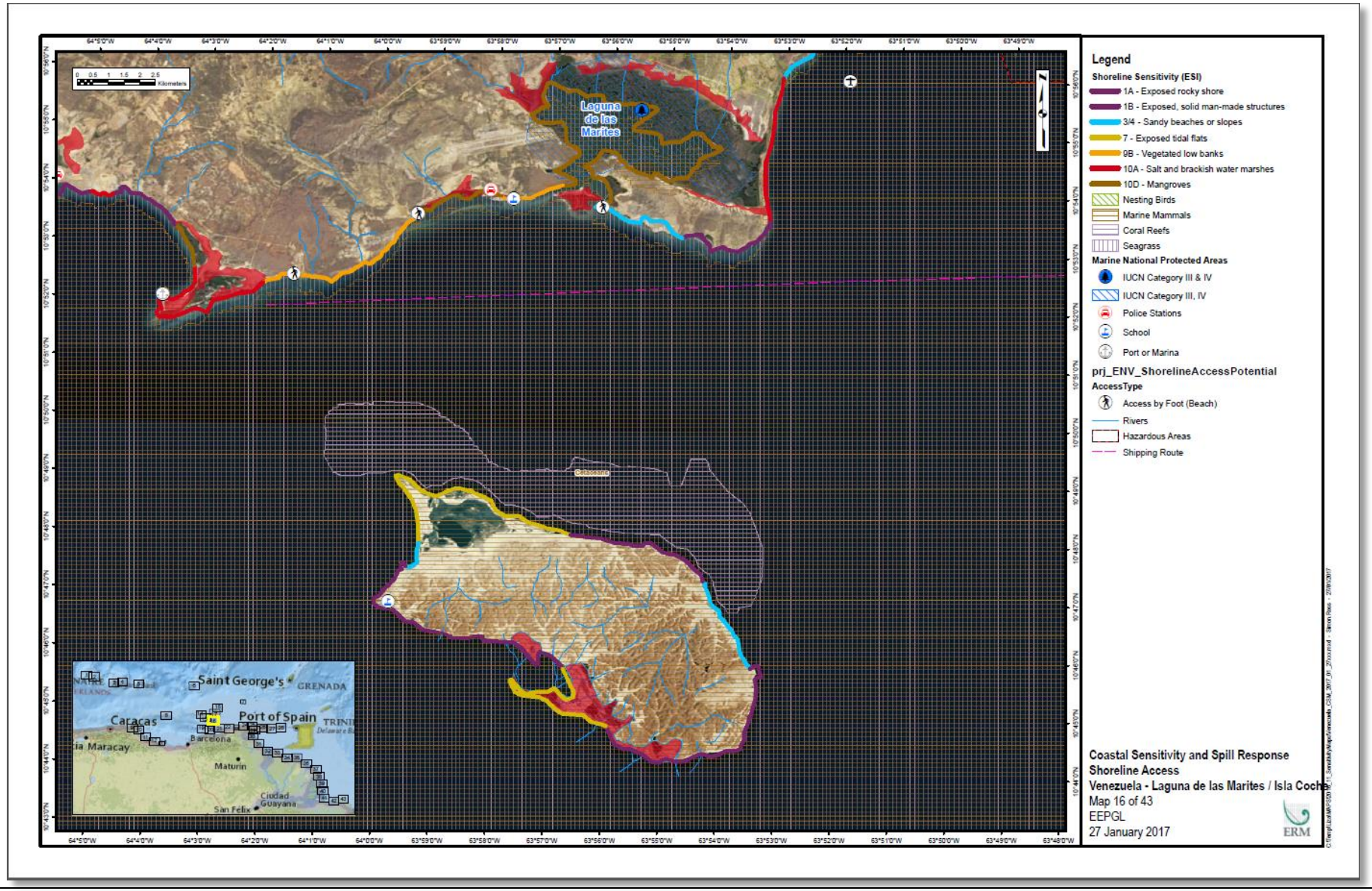

Laguna de Tacarigua
CUPIRA
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
Reptiles
Marine Mammals
Seagrass
Lagoon
IUCN Category I, II
Police Stations
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Municipal Capital
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Laguna de Tacarigua (West)
Map 12 of 43
EEPGL
08 February 2017
ERM

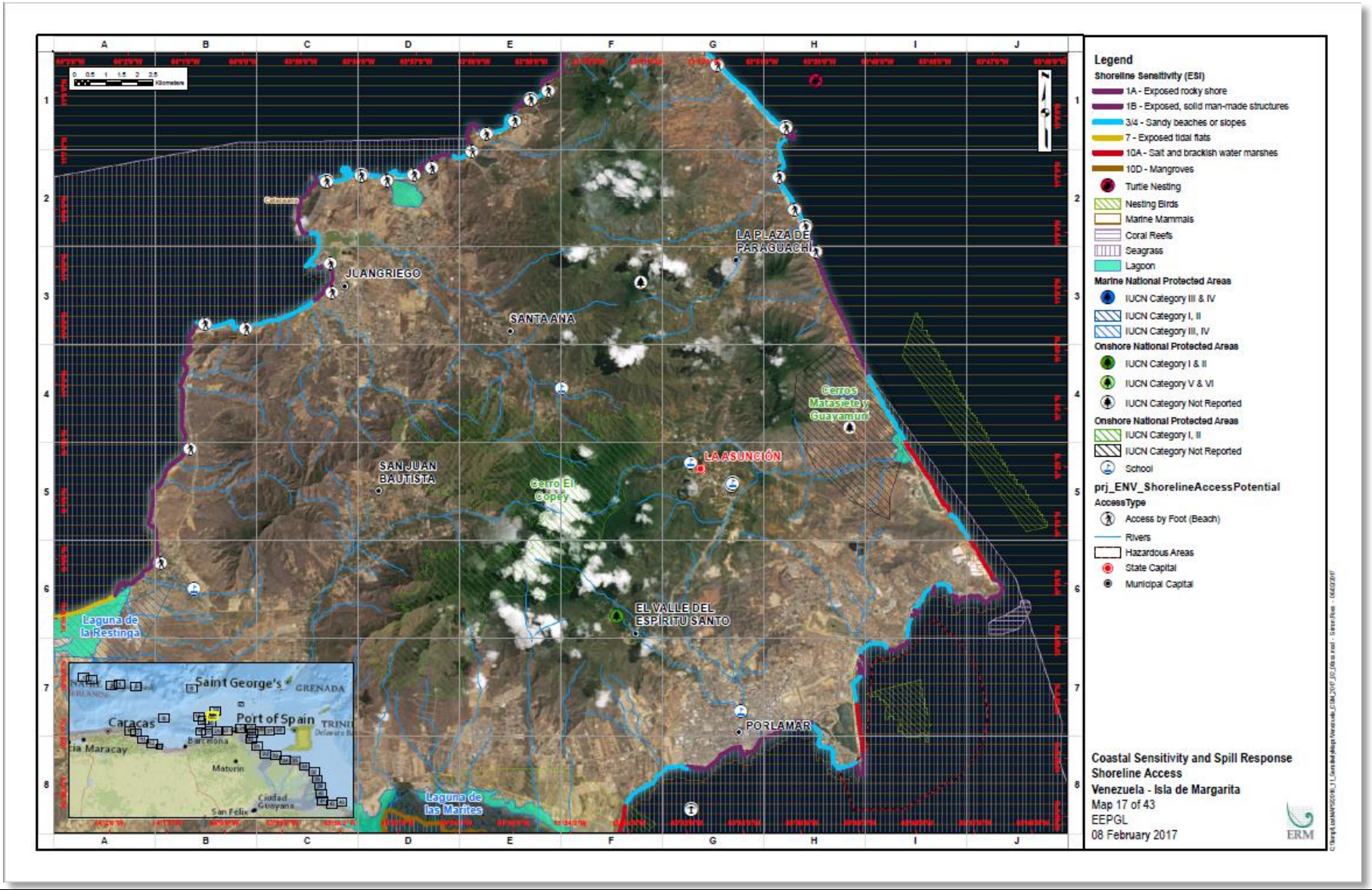

Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
Marine Mammals
Seagrass
Lagoon
Police Stations
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Municipal Capital
BOCA DE UCHIRE
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - San Juan de Capistrano
Map 13 of 43
EEPGL
08 February 2017
ERM

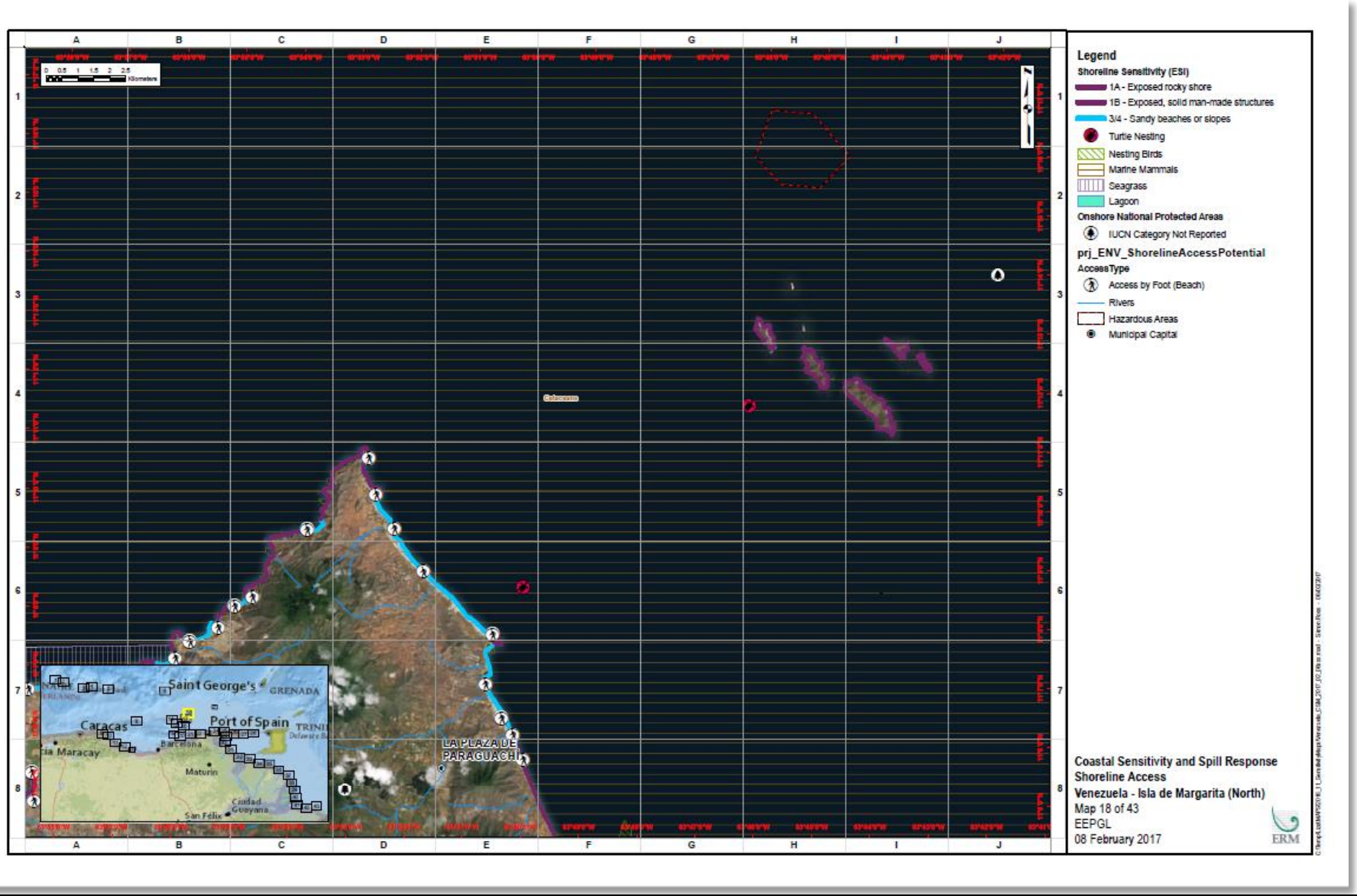

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9A - Sheltered tidal flats
9B - Vegetated low banks
10D - Mangroves
Nesting Birds
Marine Mammals
Coral Reefs
Coral Reef
Seagrass
Lagoon
IUCN Category I, II
IUCN Category III, IV
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Hazardous Areas
Municipal Capital
Laguna de la Restinga
BOCA DEL RIO
Tetas de Maria Guevara
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Peninsula de Macano
Map 14 of 43
EEPGL
08 February 2017
ERM

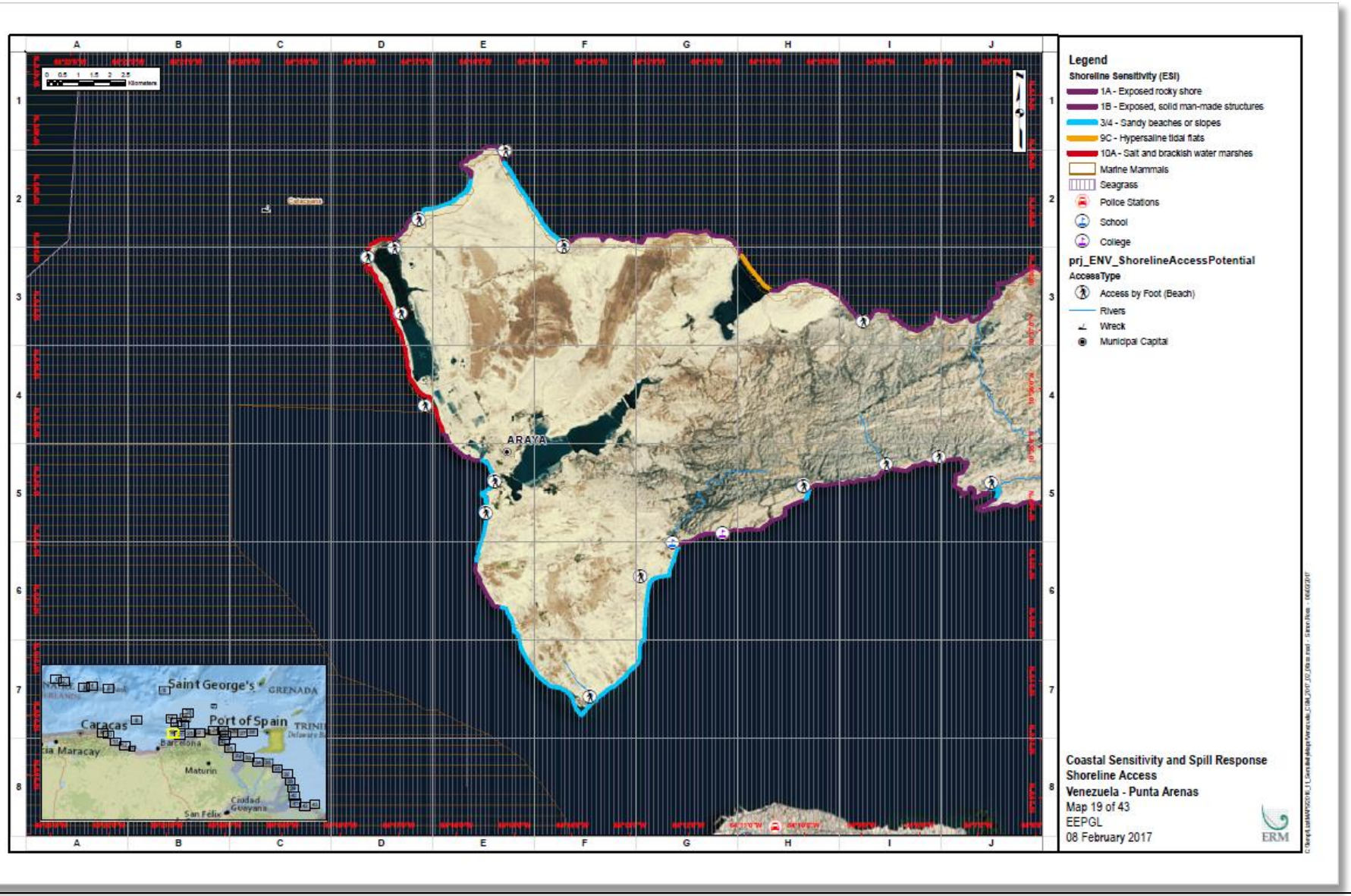

Laguna de la Restinga
BOCA DEL RÍO
Tetas de María Guevara
PUNTA DE PIEDRAS
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturín
Ciudad Guayana
San Félix
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9B - Vegetated low banks
10A - Salt and brackish water marshes
10D - Mangroves
Nesting Birds
Marine Mammals
Coral Reefs
Coral Reef
Seagrass
Lagoon
Marine National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Onshore National Protected Areas
IUCN Category V & VI
Police Stations
Port or Marina
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Shipping Route
Municipal Capital
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Laguna de la Restinga
Map 15 of 43
EEPGL
08 February 2017
ERM

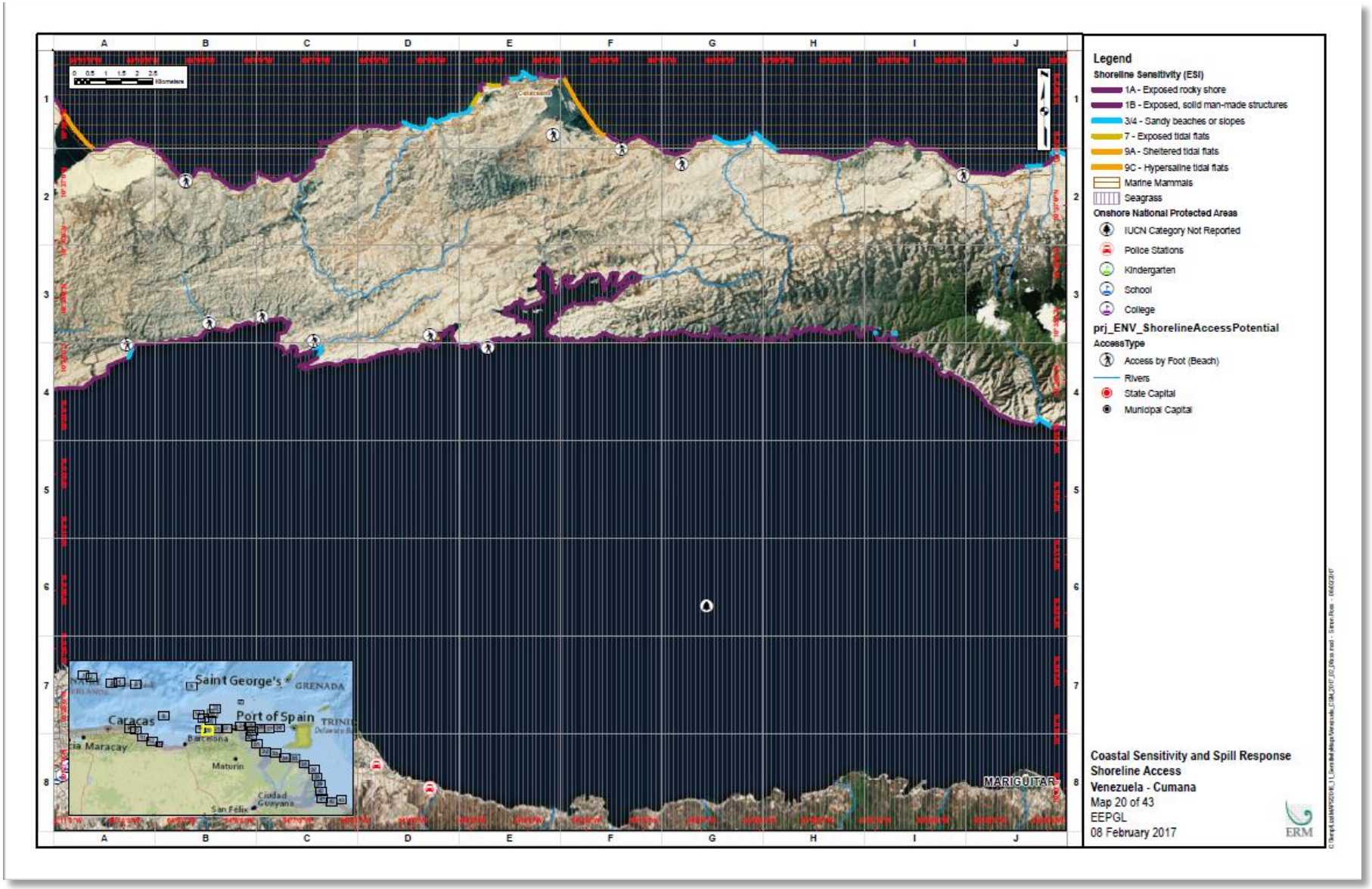

Laguna de las Marites
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Felix
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9B - Vegetated low banks
10A - Salt and brackish water marshes
10D - Mangroves
Nesting Birds
Marine Mammals
Coral Reefs
Seagrass
Lagoon
Marine National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Police Stations
School
Port or Marina
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Hazardous Areas
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Laguna de las Marites / Isla Coche
Map 16 of 43
EEPGL
08 February 2017
ERM

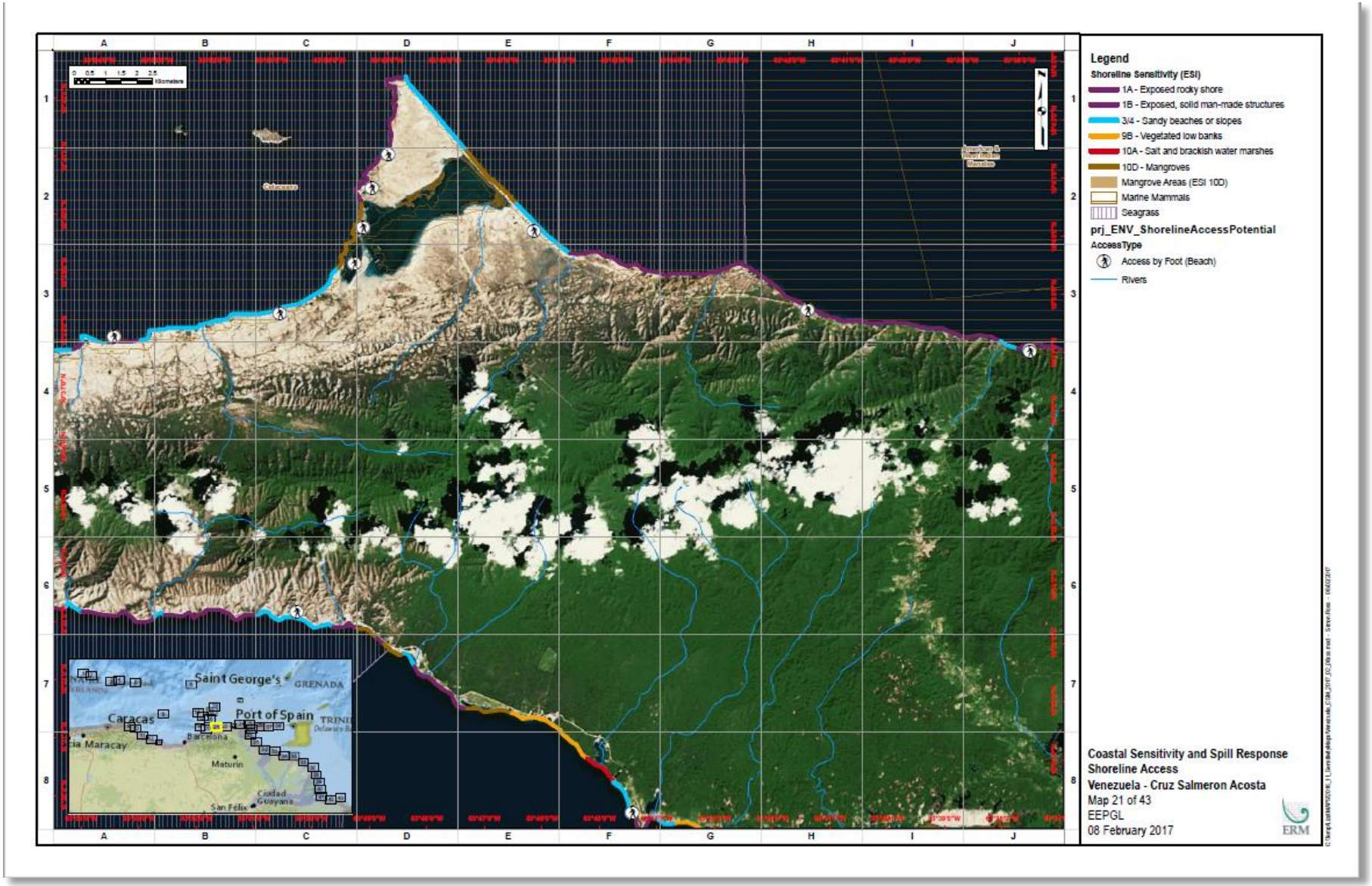

Laguna de las Marites
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9B - Vegetated low banks
10A - Salt and brackish water marshes
10D - Mangroves
Nesting Birds
Marine Mammals
Coral Reefs
Seagrass
Marine National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Police Stations
School
Port or Marina
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Hazardous Areas
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Laguna de las Marites / Isla Coche
Map 16 of 43
EEPGL
27 January 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Felix


Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
10A - Salt and brackish water marshes
10D - Mangroves
Turtle Nesting
Nesting Birds
Marine Mammals
Coral Reefs
Seagrass
Lagoon
Marine National Protected Areas
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Onshore National Protected Areas
IUCN Category I & II
IUCN Category V & VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I, II
IUCN Category Not Reported
School
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Hazardous Areas
State Capital
Municipal Capital
JUANGRIEGO
SANTA ANA
LA PLAZA DE PARAGUACHI
Cerros Matasiete y Guayanuri
SAN JUAN BAUTISTA
LA ASUNCIÓN
Cerro El Copey
EL VALLE DEL ESPIRITU SANTO
PORLAMAR
Laguna de la Restinga
Laguna de las Marites
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla de Margarita
Map 17 of 43
EEPGL
08 February 2017
ERM

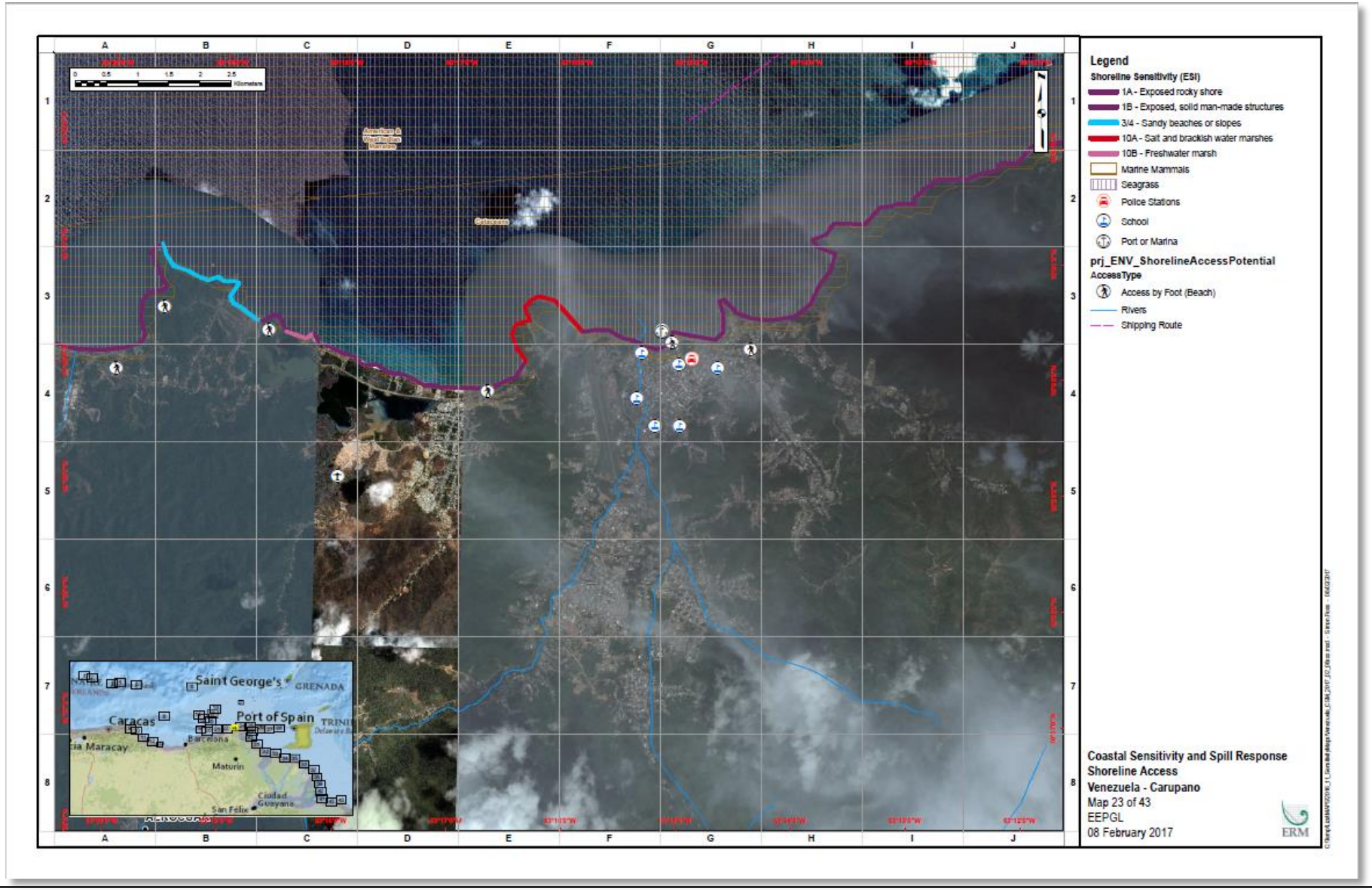

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
Turtle Nesting
Nesting Birds
Marine Mammals
Seagrass
Lagoon
Onshore National Protected Areas
IUCN Category Not Reported
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Hazardous Areas
Municipal Capital
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Isla de Margarita (North)
Map 18 of 43
EEPGL
08 February 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
LA PLAZA DE PARAGUACHÍ

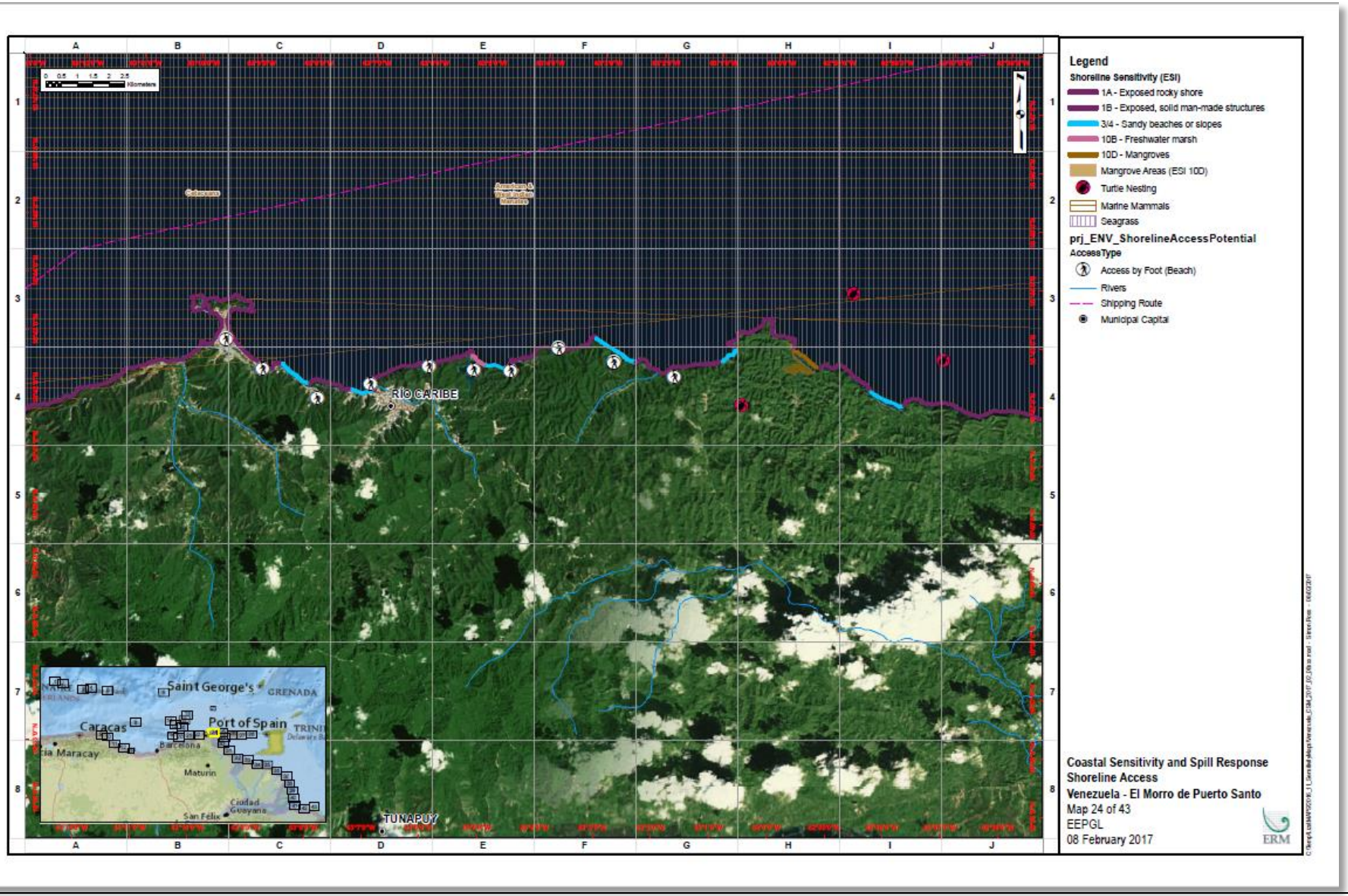

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
9C - Hypersaline tidal flats
10A - Salt and brackish water marshes
Marine Mammals
Seagrass
Police Stations
School
College
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Wreck
Municipal Capital
ARAYA
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Felix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Punta Arenas
Map 19 of 43
EEPGL
08 February 2017
ERM

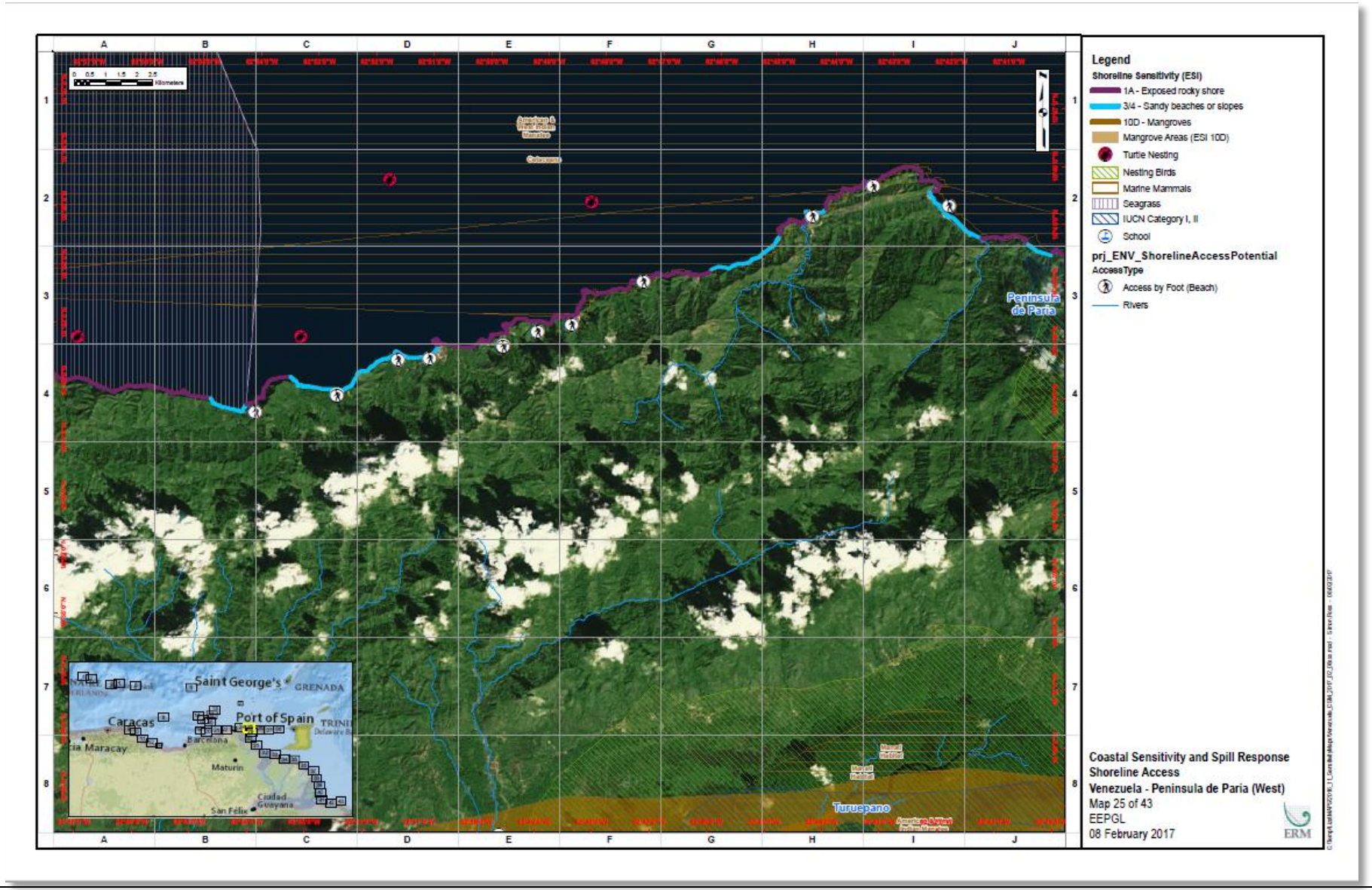

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9A - Sheltered tidal flats
9C - Hypersaline tidal flats
Marine Mammals
Seagrass
Onshore National Protected Areas
IUCN Category Not Reported
Police Stations
Kindergarten
School
College
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
State Capital
Municipal Capital
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
MARIGUITAR
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Cumana
Map 20 of 43
EEPGL
08 February 2017
ERM

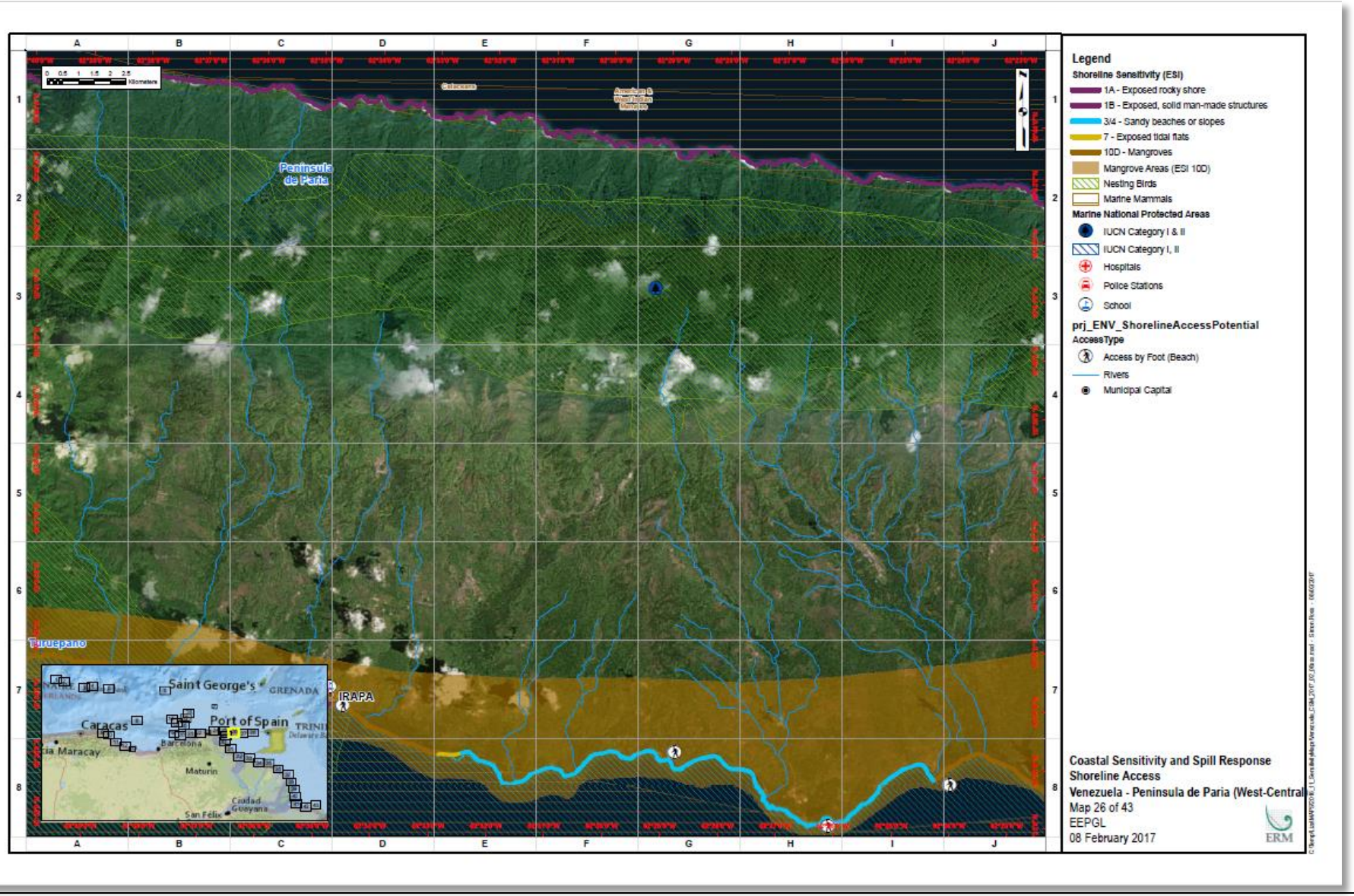

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
9B - Vegetated low banks
10A - Salt and brackish water marshes
10D - Mangroves
Mangrove Areas (ESI 10D)
Marine Mammals
Seagrass
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Cruz Salmeron Acosta
Map 21 of 43
EEPGL
08 February 2017
ERM

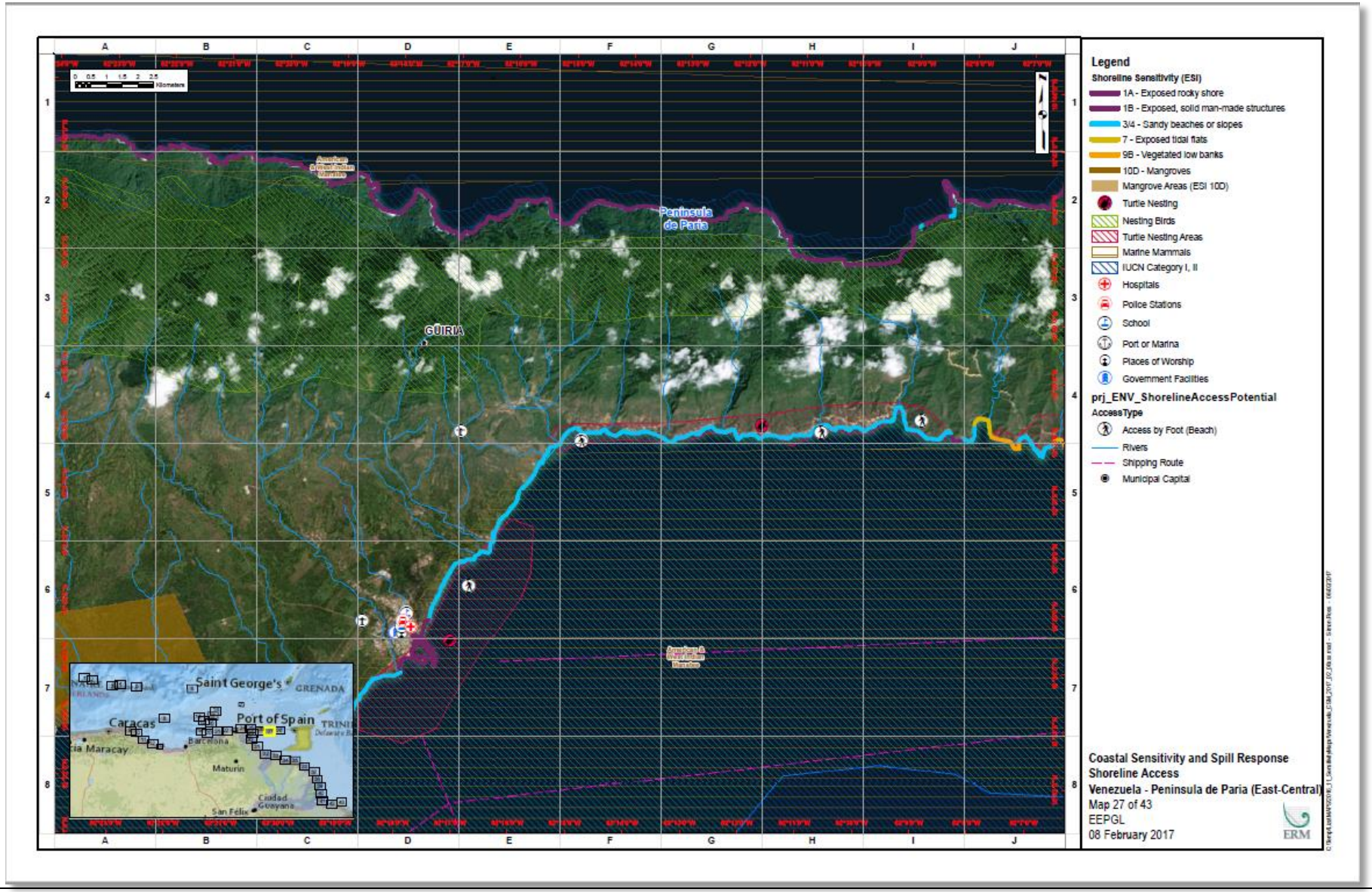

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
10A - Salt and brackish water marshes
Marine Mammals
Seagrass
Lagoon
Police Stations
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Rock
Municipal Capital
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Saucedo to La Esmeralda
Map 22 of 43
EEPGL
08 February 2017
ERM
CASANAY
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Felix

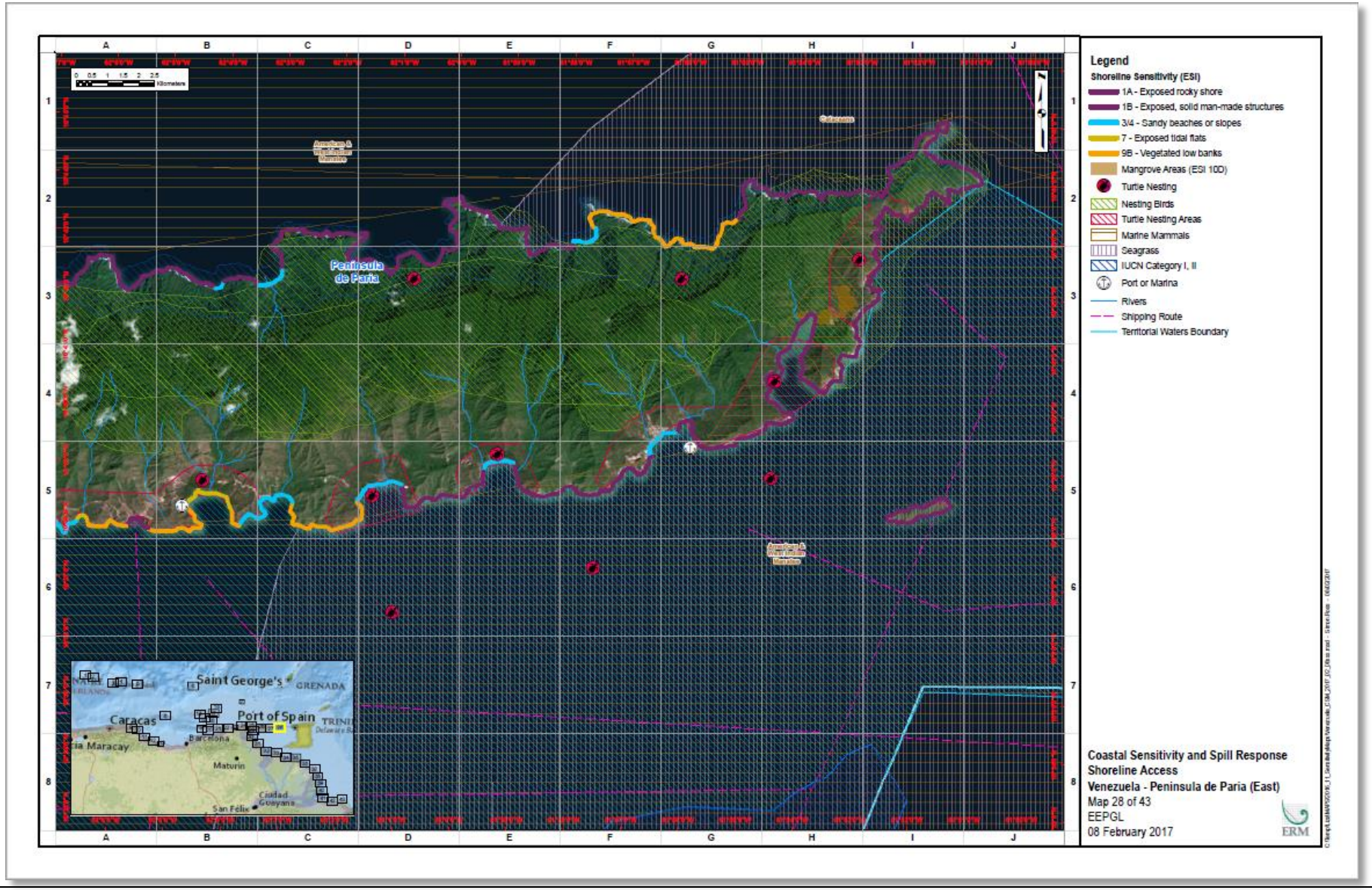

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
10A - Salt and brackish water marshes
10B - Freshwater marsh
Marine Mammals
Seagrass
Police Stations
School
Port or Marina
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Carupano
Map 23 of 43
EEPGL
08 February 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix

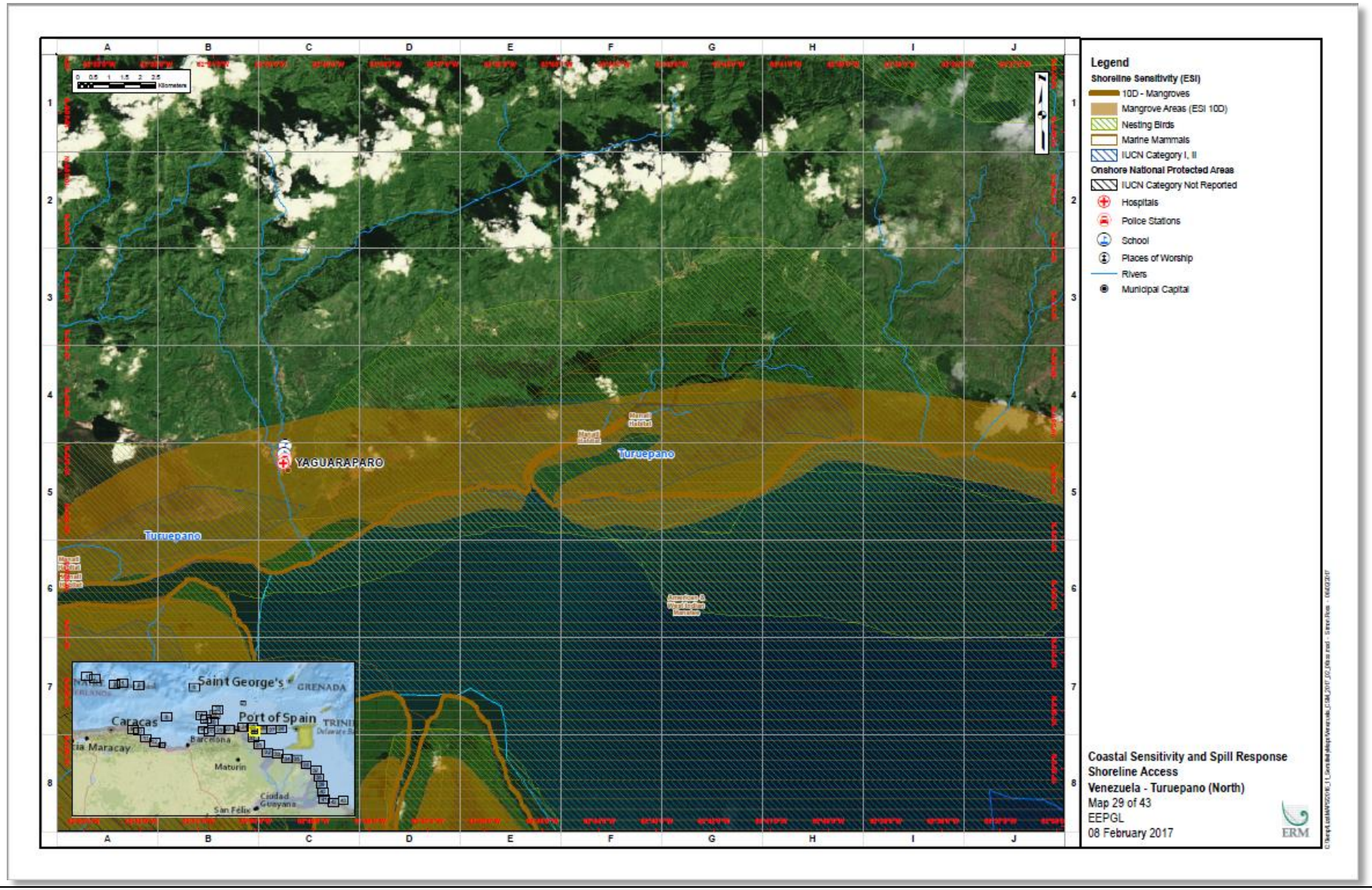

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
10B - Freshwater marsh
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Marine Mammals
Seagrass
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Shipping Route
Municipal Capital
RIO CARIBE
TUNAPUY
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - El Morro de Puerto Santo
Map 24 of 43
EEPGL
08 February 2017
ERM

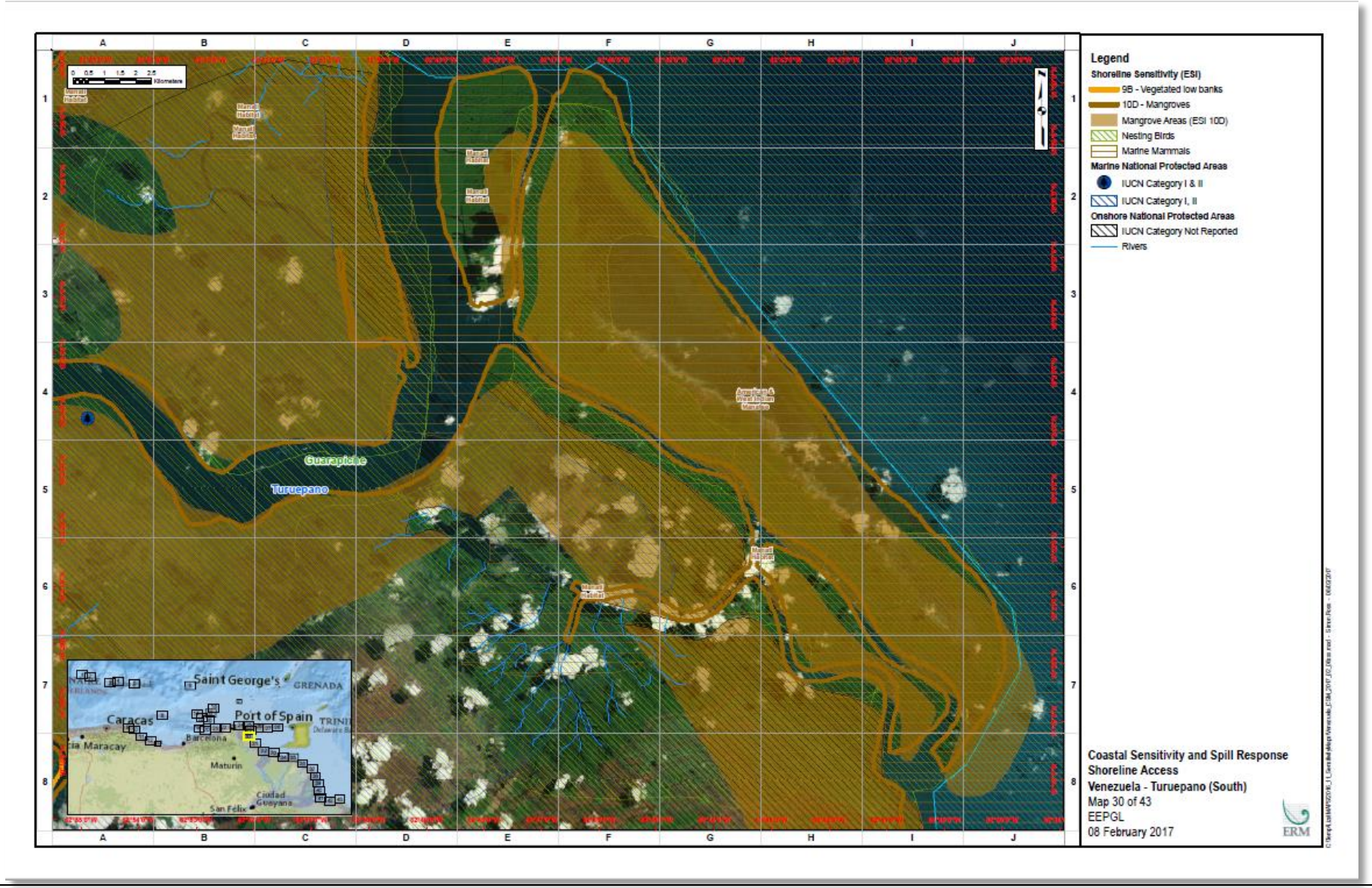

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
3/4 - Sandy beaches or slopes
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Marine Mammals
Seagrass
IUCN Category I, II
School
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Peninsula de Paria
Turuepano
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Peninsula de Paria (West)
Map 25 of 43
EEPGL
08 February 2017
ERM


Peninsula de Paria
Guiria
IRAPA
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
Marine National Protected Areas
IUCN Category I & II
IUCN Category I, II
Hospitals
Police Stations
School
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Municipal Capital
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Peninsula de Paria (West-Central)
Map 26 of 43
EEPGL
08 February 2017
ERM

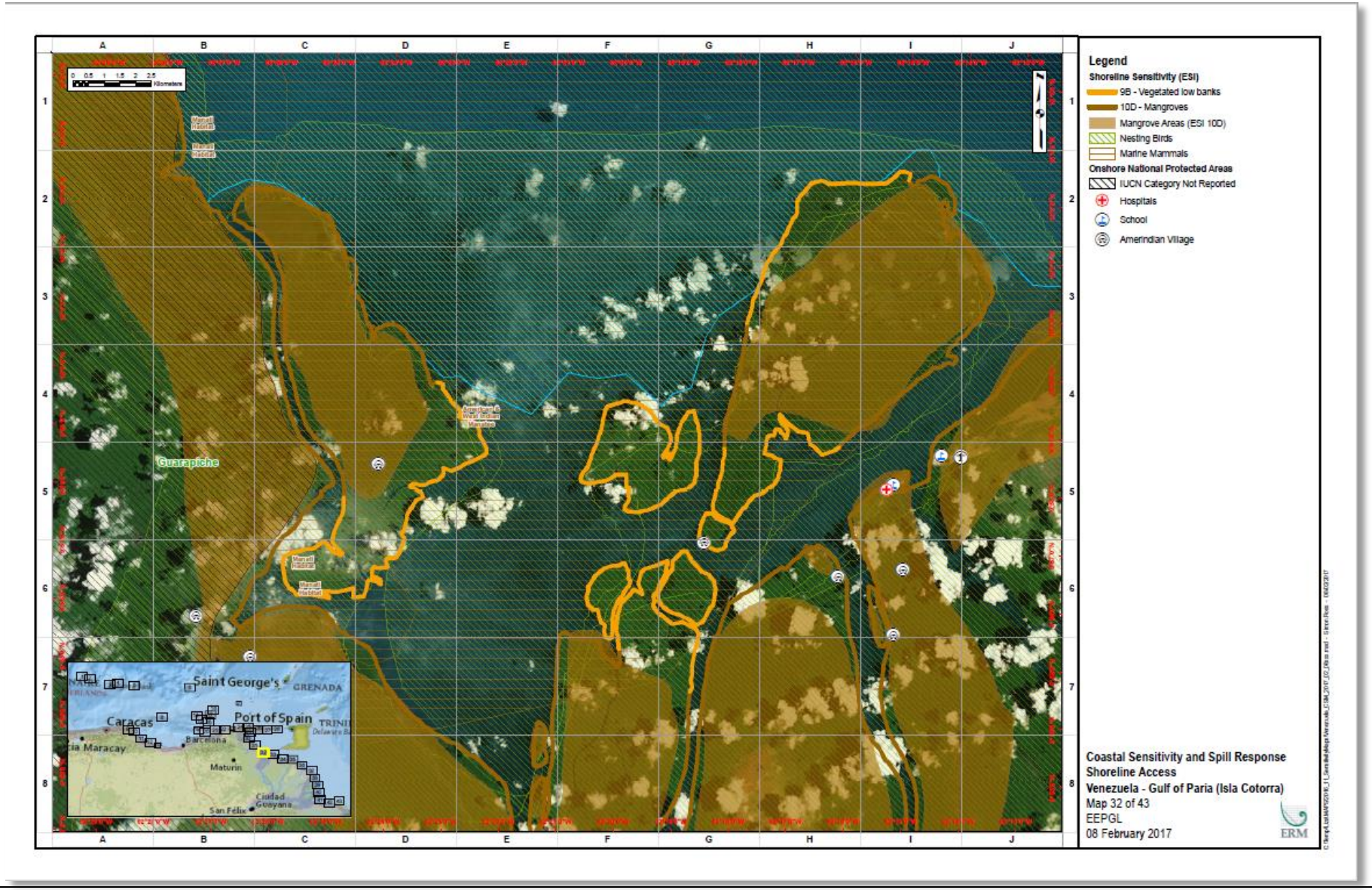

Peninsula de Paria
GÜIRIA
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Turtle Nesting Areas
Marine Mammals
IUCN Category I, II
Hospitals
Police Stations
School
Port or Marina
Places of Worship
Government Facilities
prj_ENV_ShorelineAccessPotential
AccessType
Access by Foot (Beach)
Rivers
Shipping Route
Municipal Capital
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Peninsula de Paria (East-Central)
Map 27 of 43
EEPGL
08 February 2017
ERM

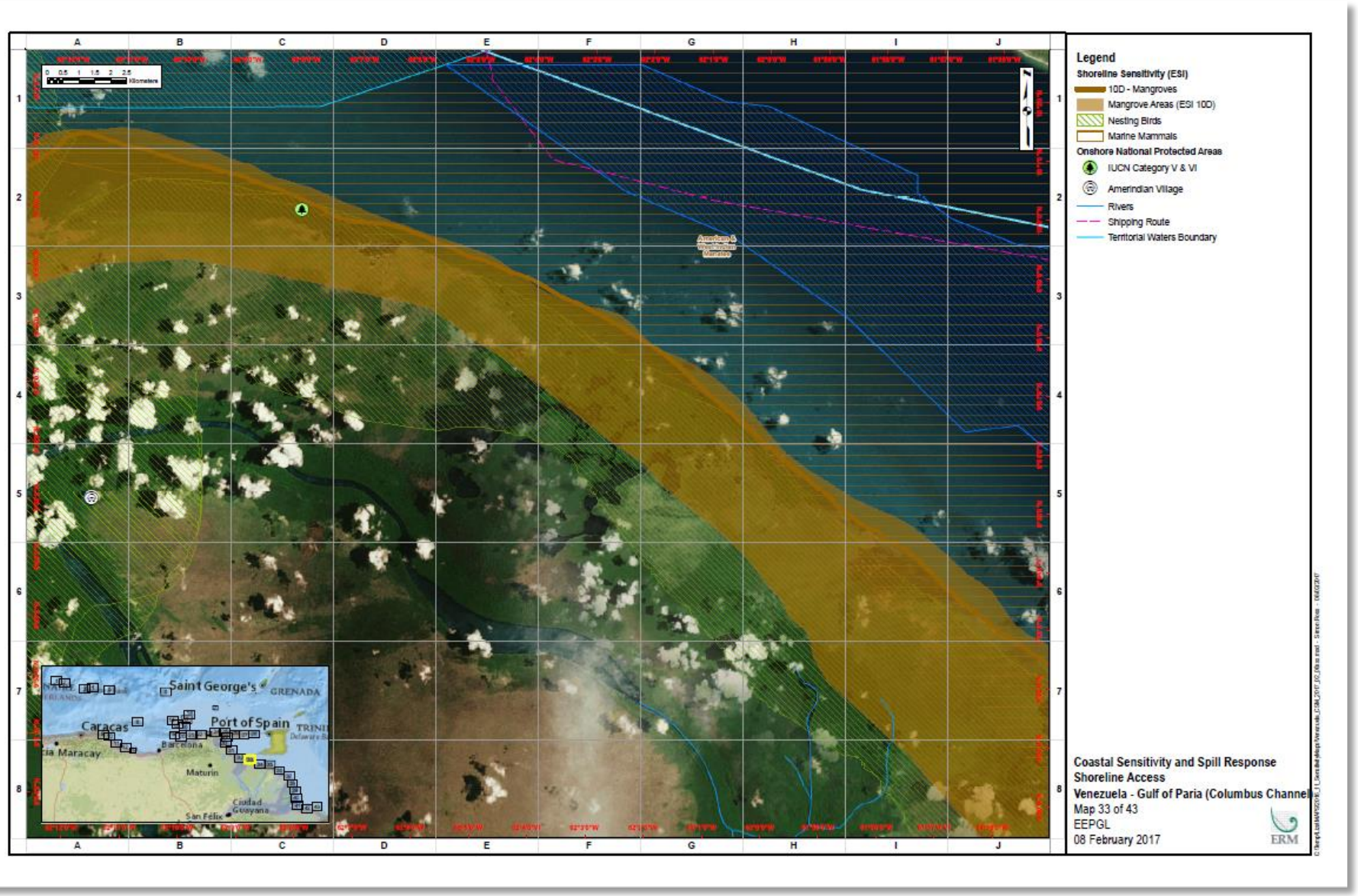

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9B - Vegetated low banks
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Turtle Nesting Areas
Marine Mammals
Seagrass
IUCN Category I, II
Port or Marina
Rivers
Shipping Route
Territorial Waters Boundary
Península de Paria
Saint George's
GRENADA
Caracas
Port of Spain
Maturín
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Peninsula de Paria (East)
Map 28 of 43
EEPGL
08 February 2017
ERM

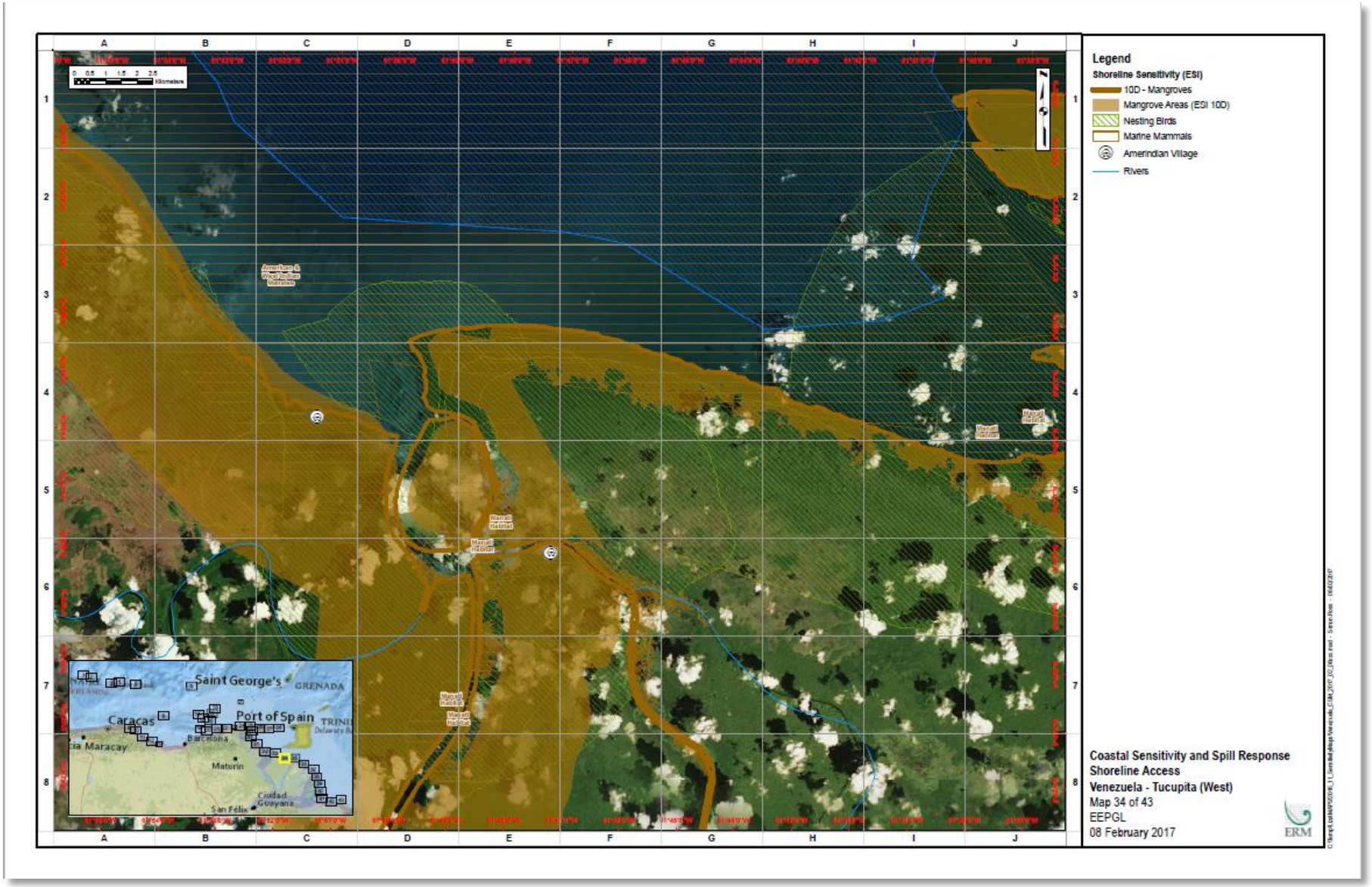

Legend
Shoreline Sensitivity (ESI)
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
IUCN Category I, II
Onshore National Protected Areas
IUCN Category Not Reported
Hospitals
Police Stations
School
Places of Worship
Rivers
Municipal Capital
YAGUARAPARO
Turuepano
Turuepano
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Turuepano (North)
Map 29 of 43
EEPGL
08 February 2017
ERM

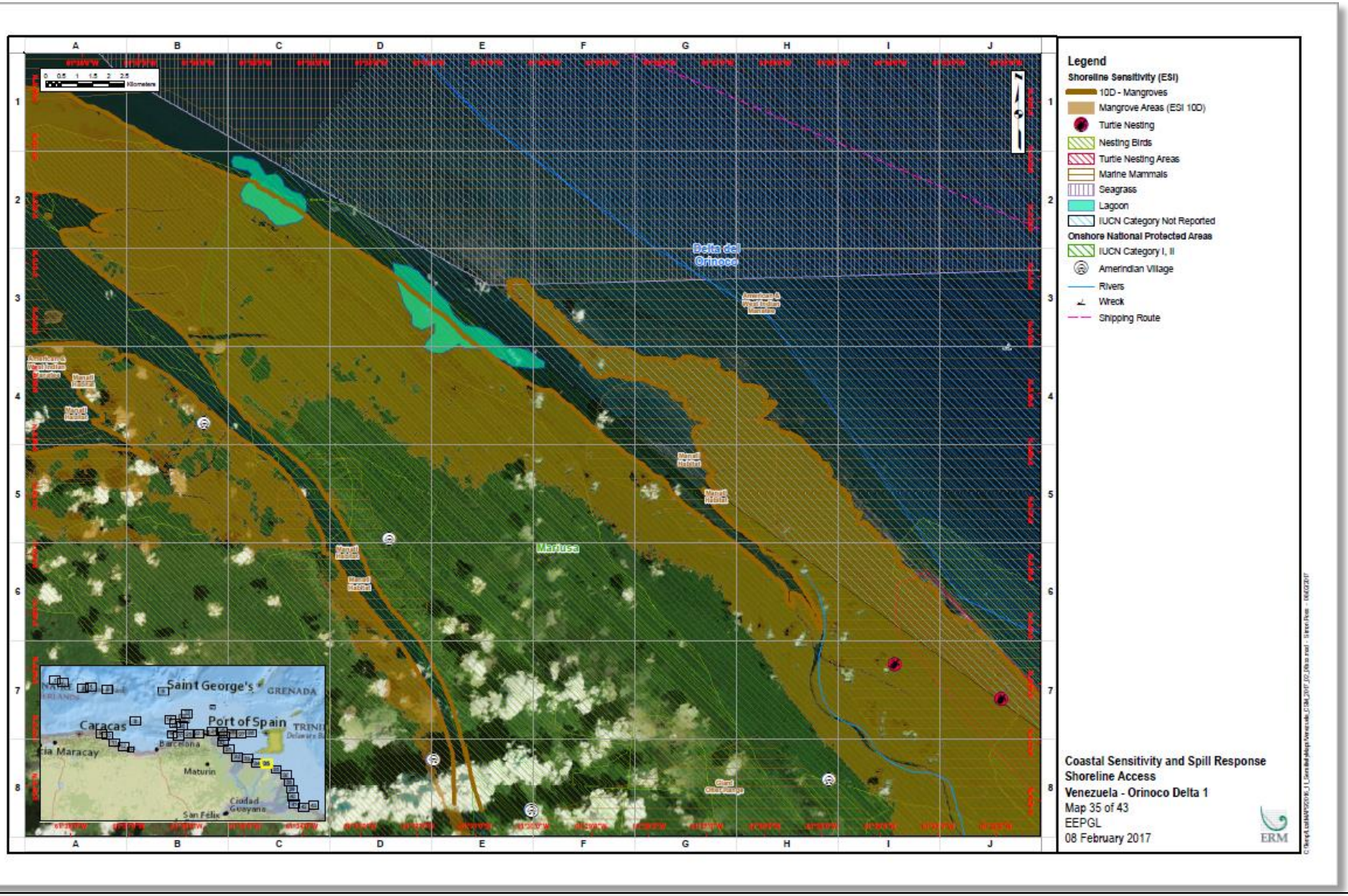

Legend
Shoreline Sensitivity (ESI)
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
Marine National Protected Areas
IUCN Category I & II
IUCN Category I, II
Onshore National Protected Areas
IUCN Category Not Reported
Rivers
Guarapiche
Turuepano
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
San Félix
Ciudad Guayana
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Turuepano (South)
Map 30 of 43
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
Onshore National Protected Areas
IUCN Category Not Reported
Rivers
Shipping Route
Guarapiche
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Gulf of Paria (Rio de San Juan)
Map 31 of 43
EEPGL
08 February 2017
ERM

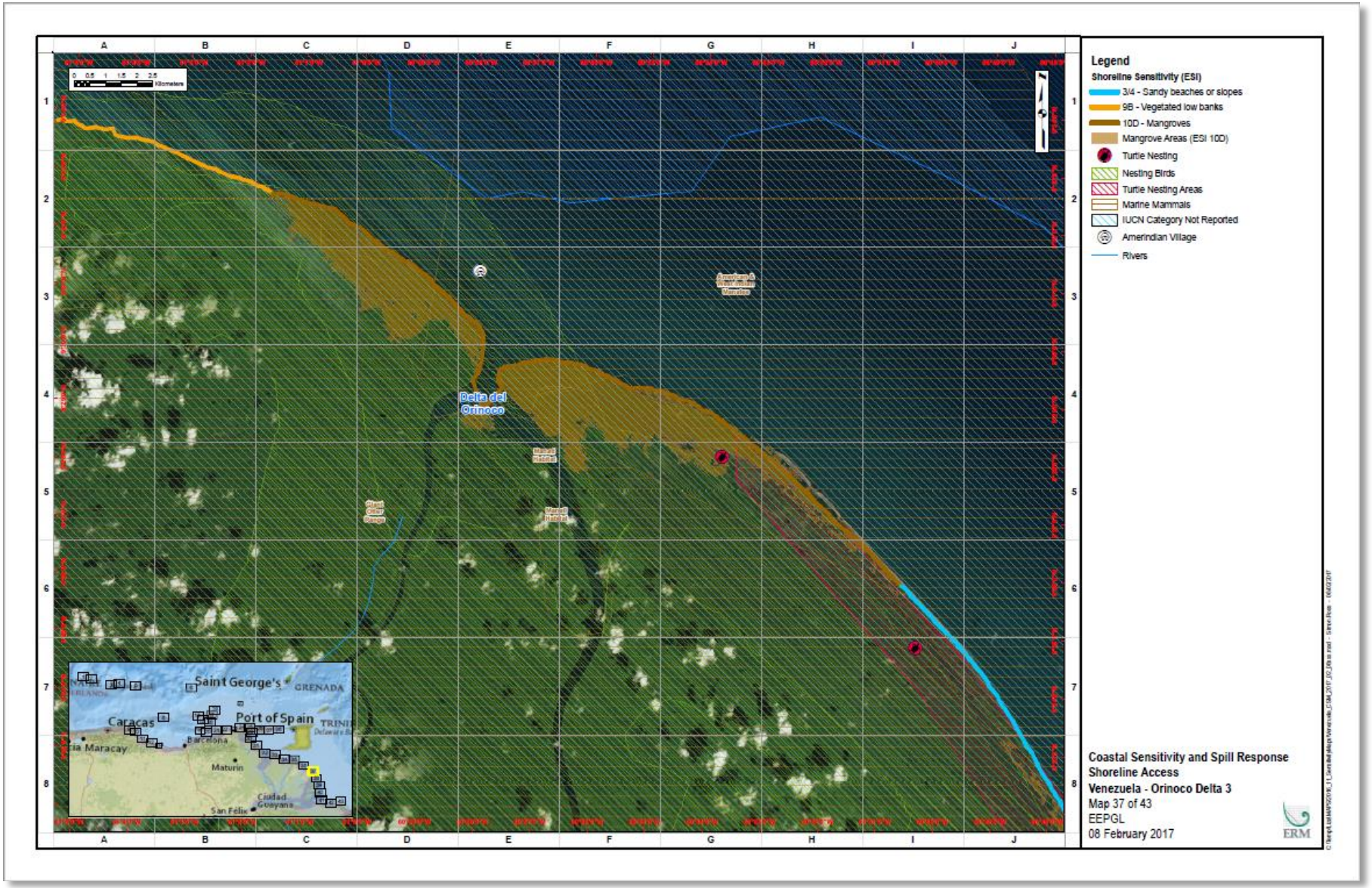

Legend
Shoreline Sensitivity (ESI)
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
Onshore National Protected Areas
IUCN Category Not Reported
Hospitals
School
Amerindian Village
Guarapiche
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Gulf of Paria (Isla Cotorra)
Map 32 of 43
EEPGL
08 February 2017
ERM

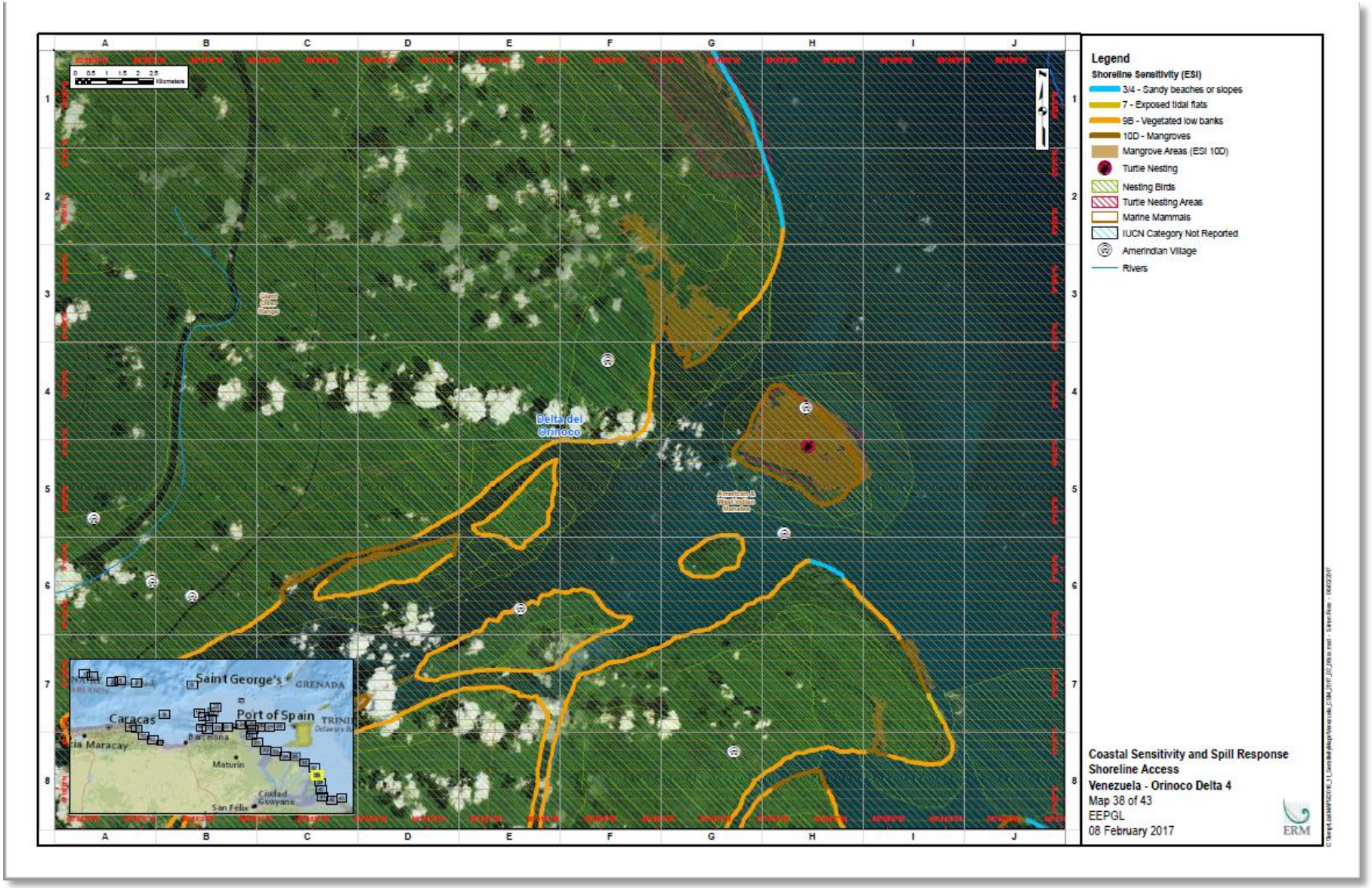

Legend
Shoreline Sensitivity (ESI)
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
Onshore National Protected Areas
IUCN Category V & VI
Amerindian Village
Rivers
Shipping Route
Territorial Waters Boundary
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maracay
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Gulf of Paria (Columbus Channel)
Map 33 of 43
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
Amerindian Village
Rivers
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Tucupita (West)
Map 34 of 43
EEPGL
08 February 2017
ERM
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix


Legend
Shoreline Sensitivity (ESI)
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Turtle Nesting Areas
Marine Mammals
Seagrass
Lagoon
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I, II
Amerindian Village
Rivers
Wreck
Shipping Route
Delta del Orinoco
Maripa
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 1
Map 35 of 43
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Turtle Nesting Areas
Marine Mammals
Seagrass
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I, II
Amerindian Village
Rivers
Delta del Orinoco
Mariusa
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 2
Map 36 of 43
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Turtle Nesting Areas
Marine Mammals
IUCN Category Not Reported
Amerindian Village
Rivers
Delta del Orinoco
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 3
Map 37 of 43
EEPGL
08 February 2017
ERM

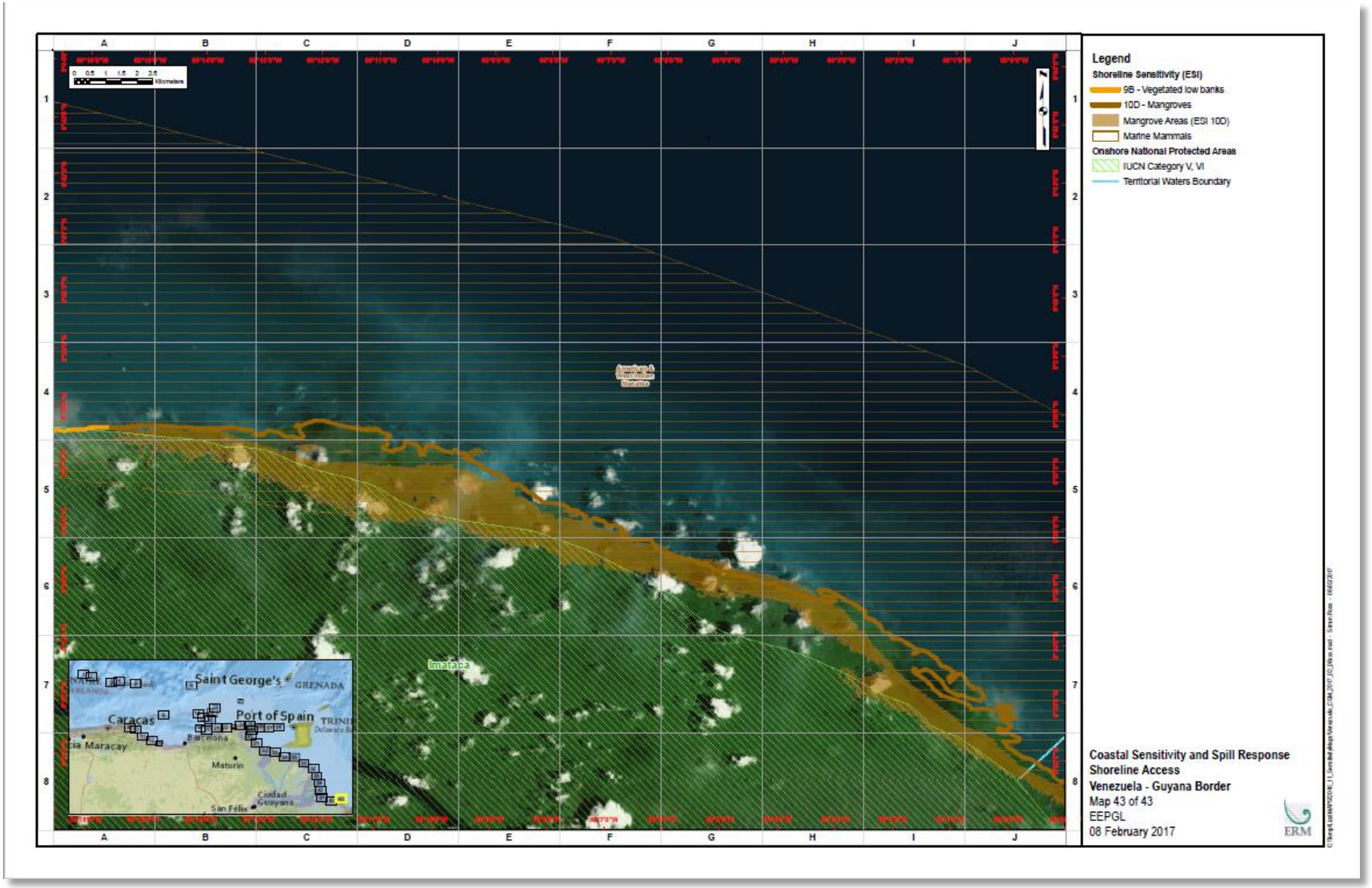

Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
7 - Exposed tidal flats
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Turtle Nesting
Nesting Birds
Turtle Nesting Areas
Marine Mammals
IUCN Category Not Reported
Amerindian Village
Rivers
Delta del Orinoco
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 4
Map 38 of 43
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
3/4 - Sandy beaches or slopes
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
IUCN Category Not Reported
Amerindian Village
Rivers
Delta del Orinoco
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 5
Map 39 of 43
EEPGL
08 February 2017
ERM

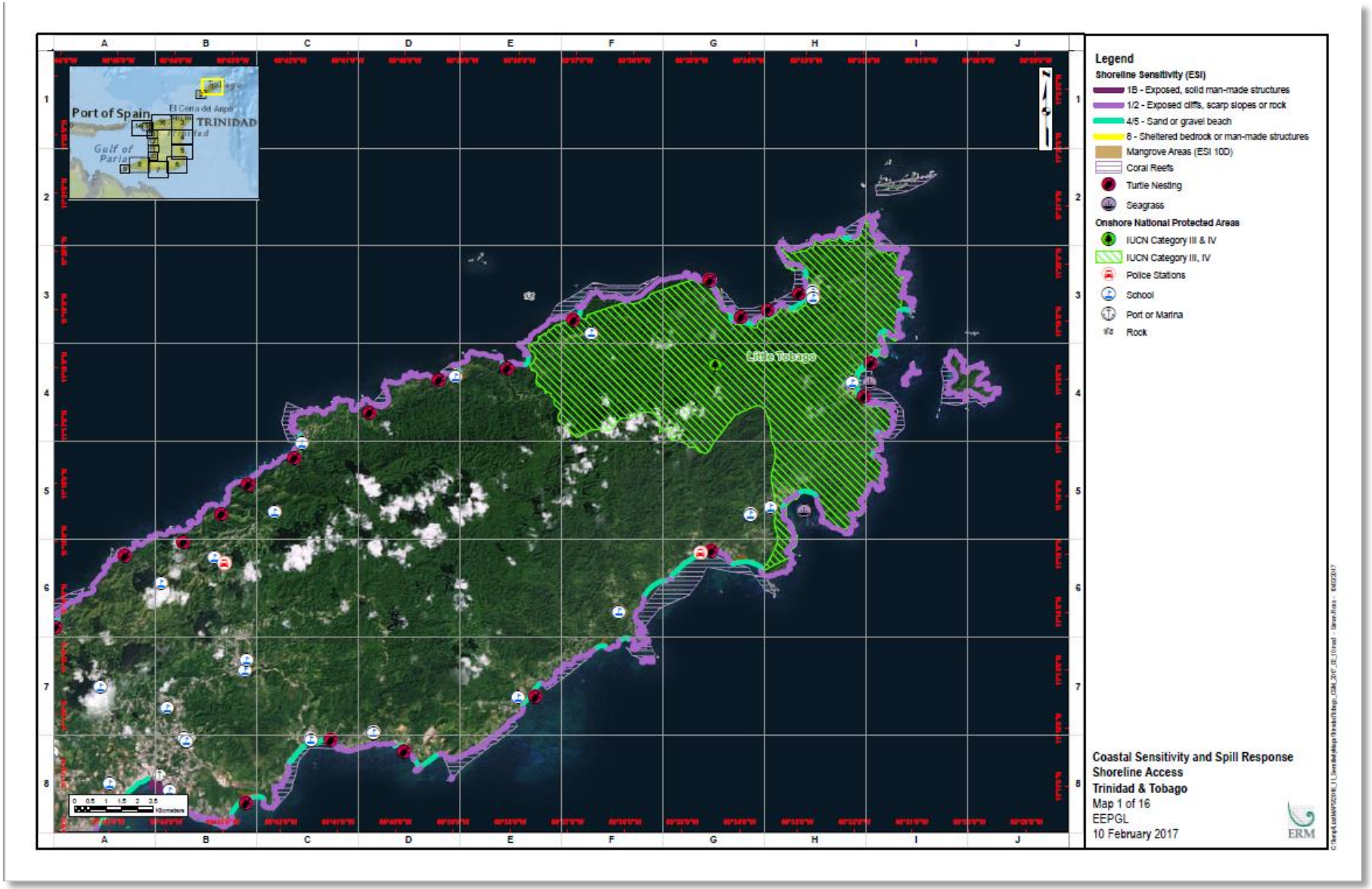

Legend
Shoreline Sensitivity (ESI)
7 - Exposed tidal flats
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
IUCN Category Not Reported
Amerindian Village
Rivers
Delta del Orinoco
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 6
Map 40 of 43
EEPGL
08 February 2017
ERM

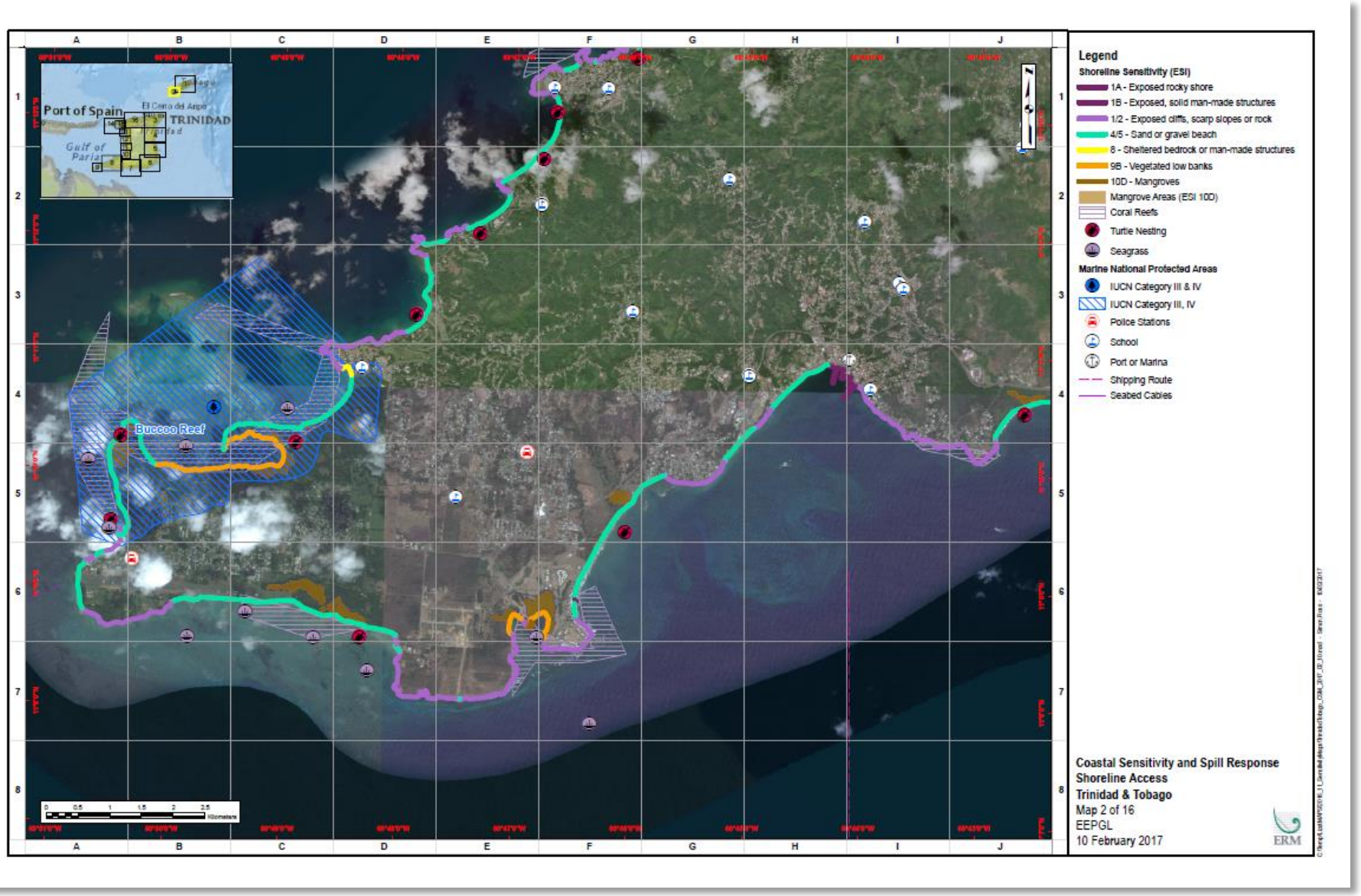

Legend
Shoreline Sensitivity (ESI)
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Nesting Birds
Marine Mammals
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category V, VI
Amerindian Village
Rivers
Delta del Orinoco
Imataca
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 7
Map 41 of 43
EEPGL
08 February 2017
ERM

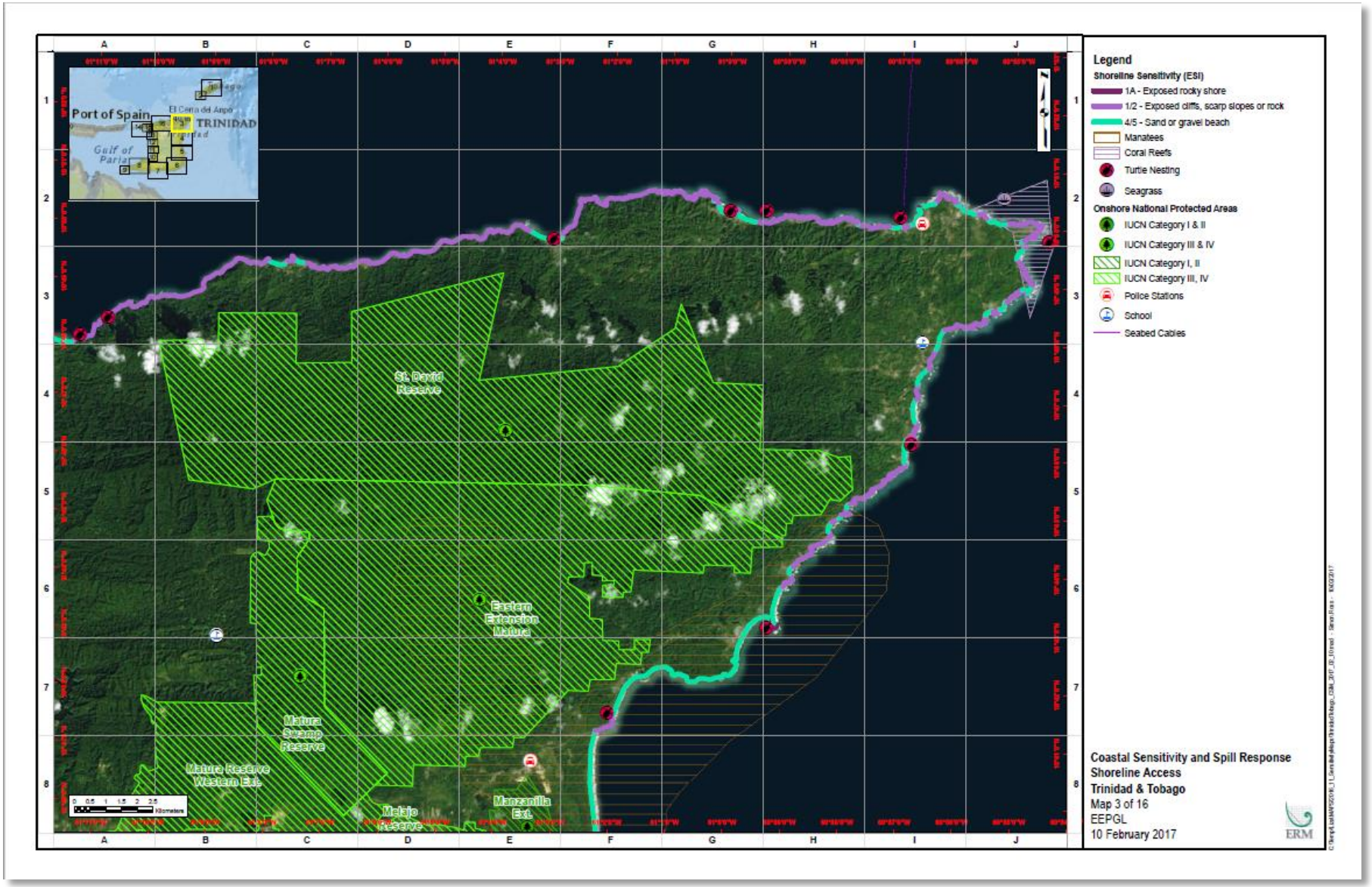

Legend
Shoreline Sensitivity (ESI)
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Marine Mammals
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category V, VI
Delta del Orinoco
Imataca
Saint George's
GRENADA
Caracas
Port of Spain
Maturin
Ciudad Guayana
San Félix
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Orinoco Delta 8
Map 42 of 43
EEPGL
08 February 2017
ERM

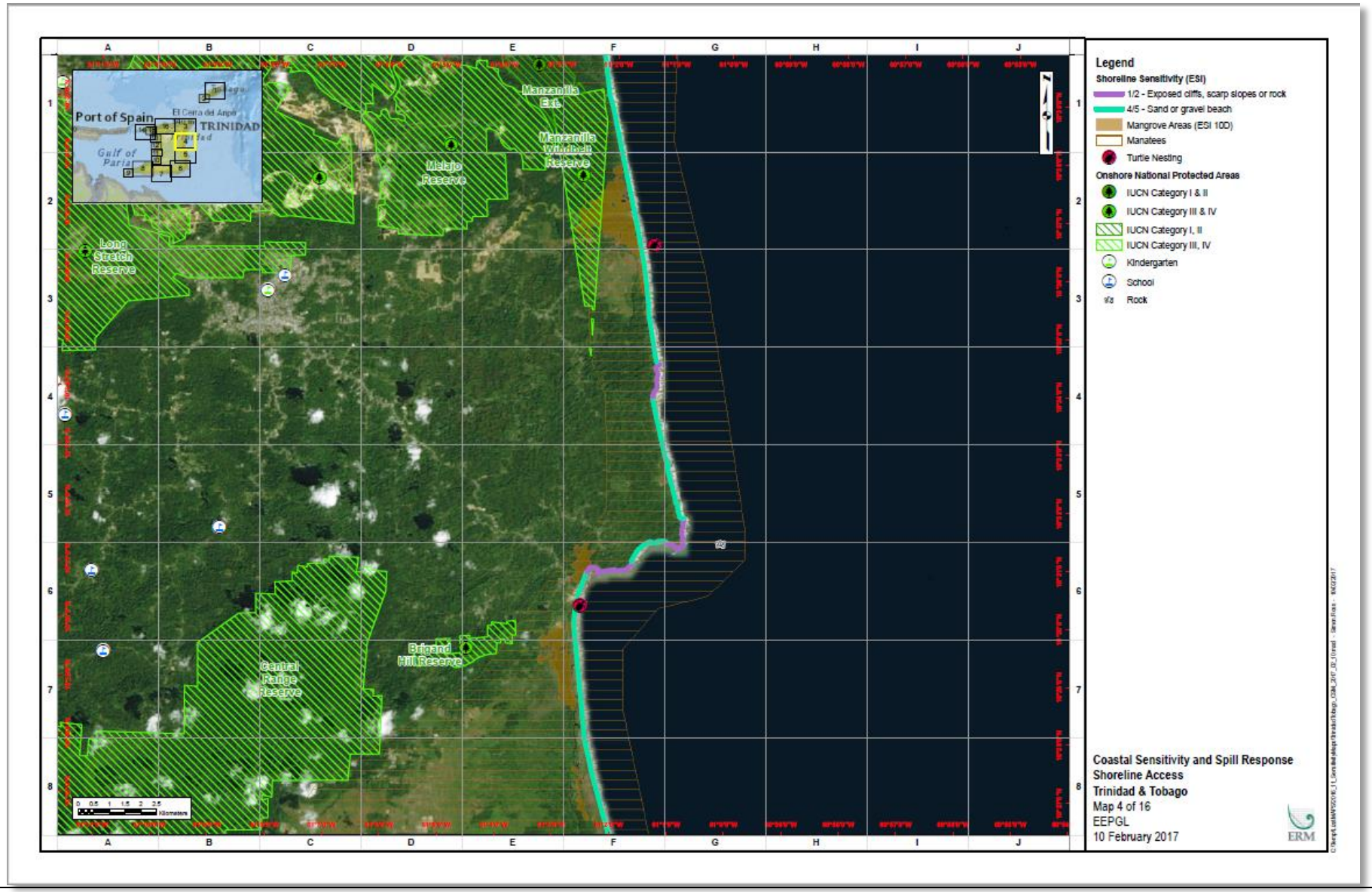

Legend
Shoreline Sensitivity (ESI)
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Marine Mammals
Onshore National Protected Areas
IUCN Category V, VI
Territorial Waters Boundary
Coastal Sensitivity and Spill Response
Shoreline Access
Venezuela - Guyana Border
Map 43 of 43
EEPGL
08 February 2017
ERM
Imataca
Saint George's
GRENADA
Caracas
Port of Spain
Barcelona
Maturin
Ciudad Guayana
San Félix

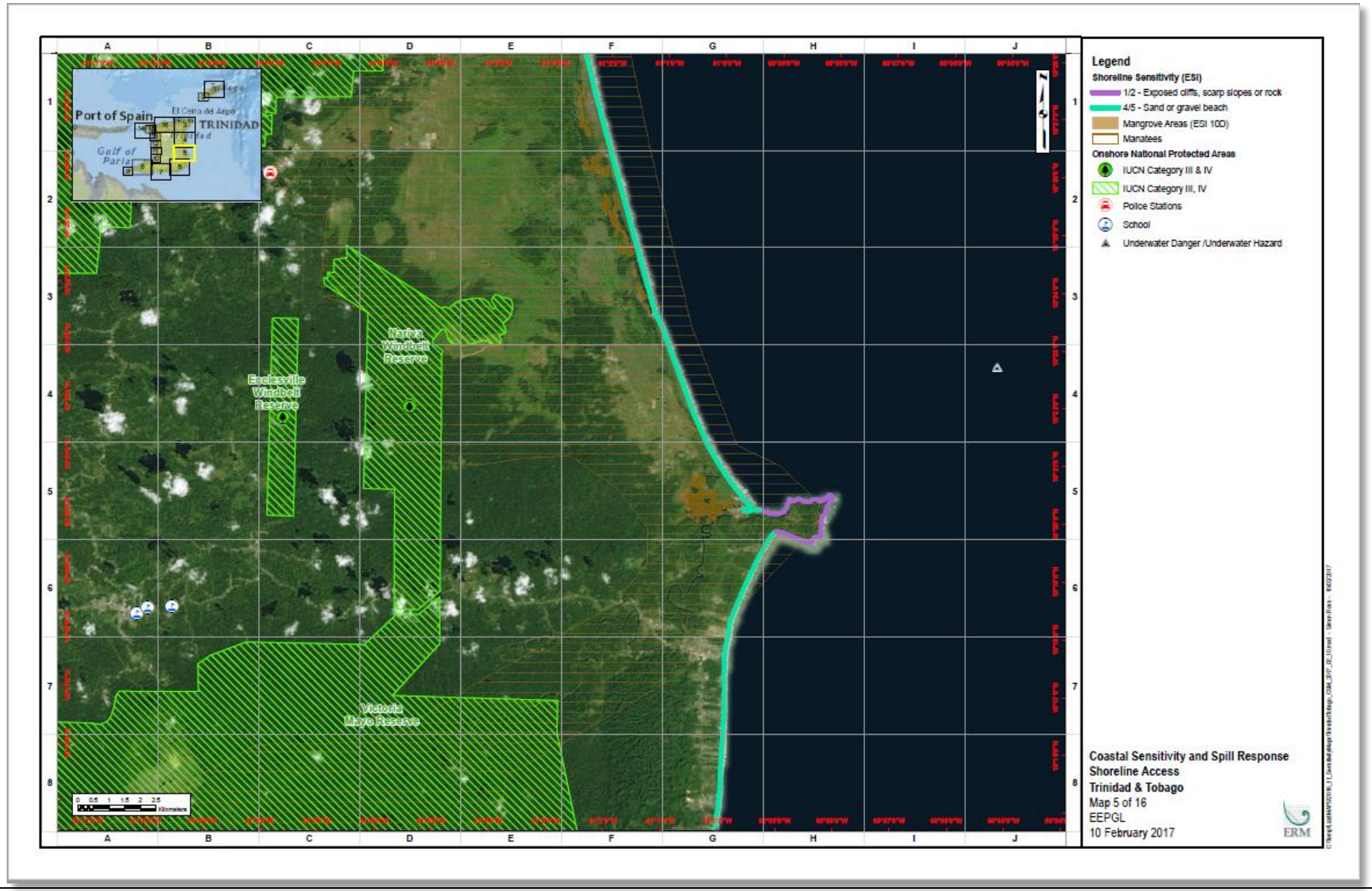
TRINIDAD AND TOBAGO
Coastal Sensitivity Maps

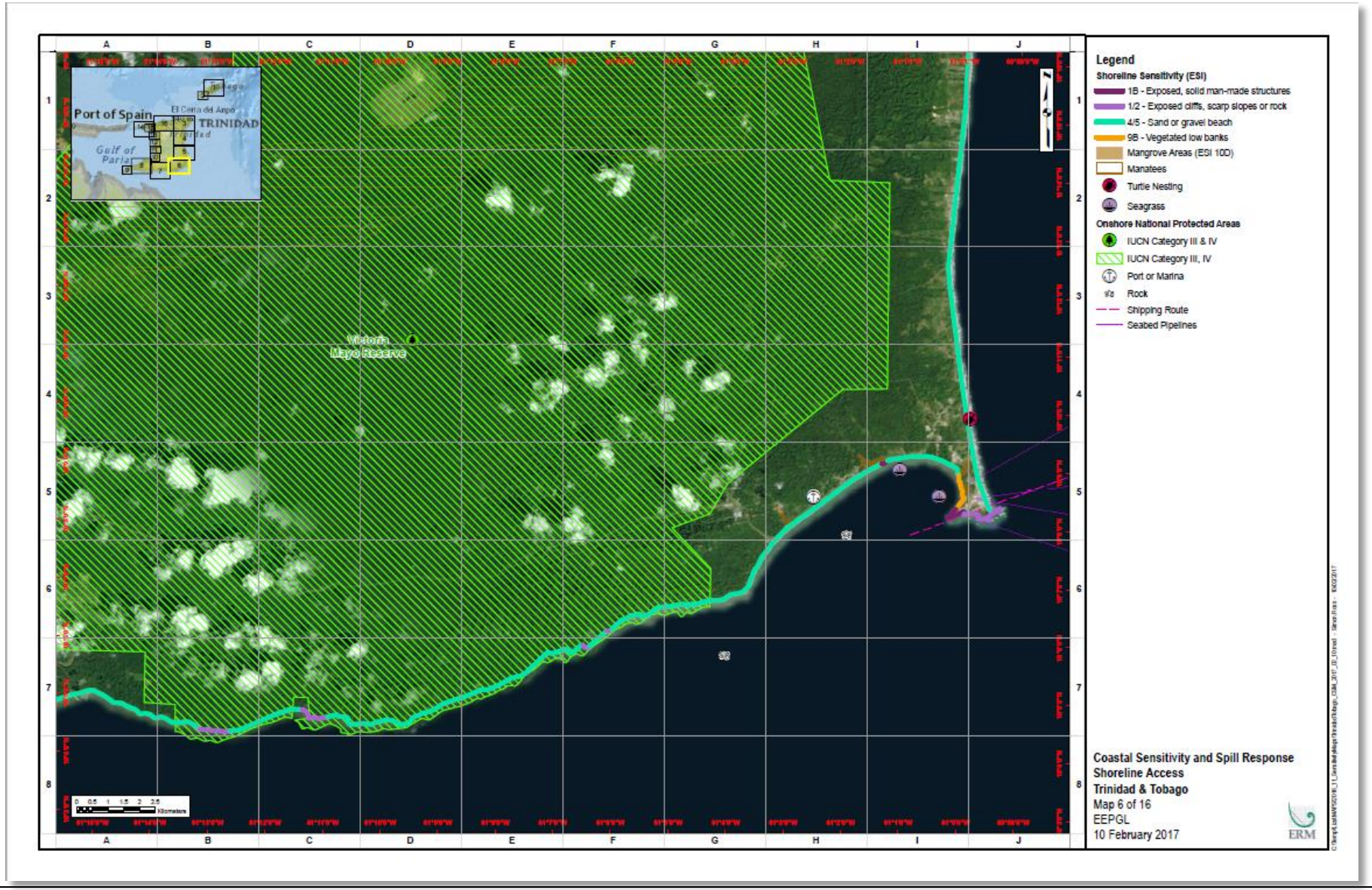

Port of Spain
TRINIDAD
Gulf of Paria
Little Tobago
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
Mangrove Areas (ESI 10D)
Coral Reefs
Turtle Nesting
Seagrass
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Police Stations
School
Port or Marina
Rock
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 1 of 16
EEPGL
10 February 2017
ERM

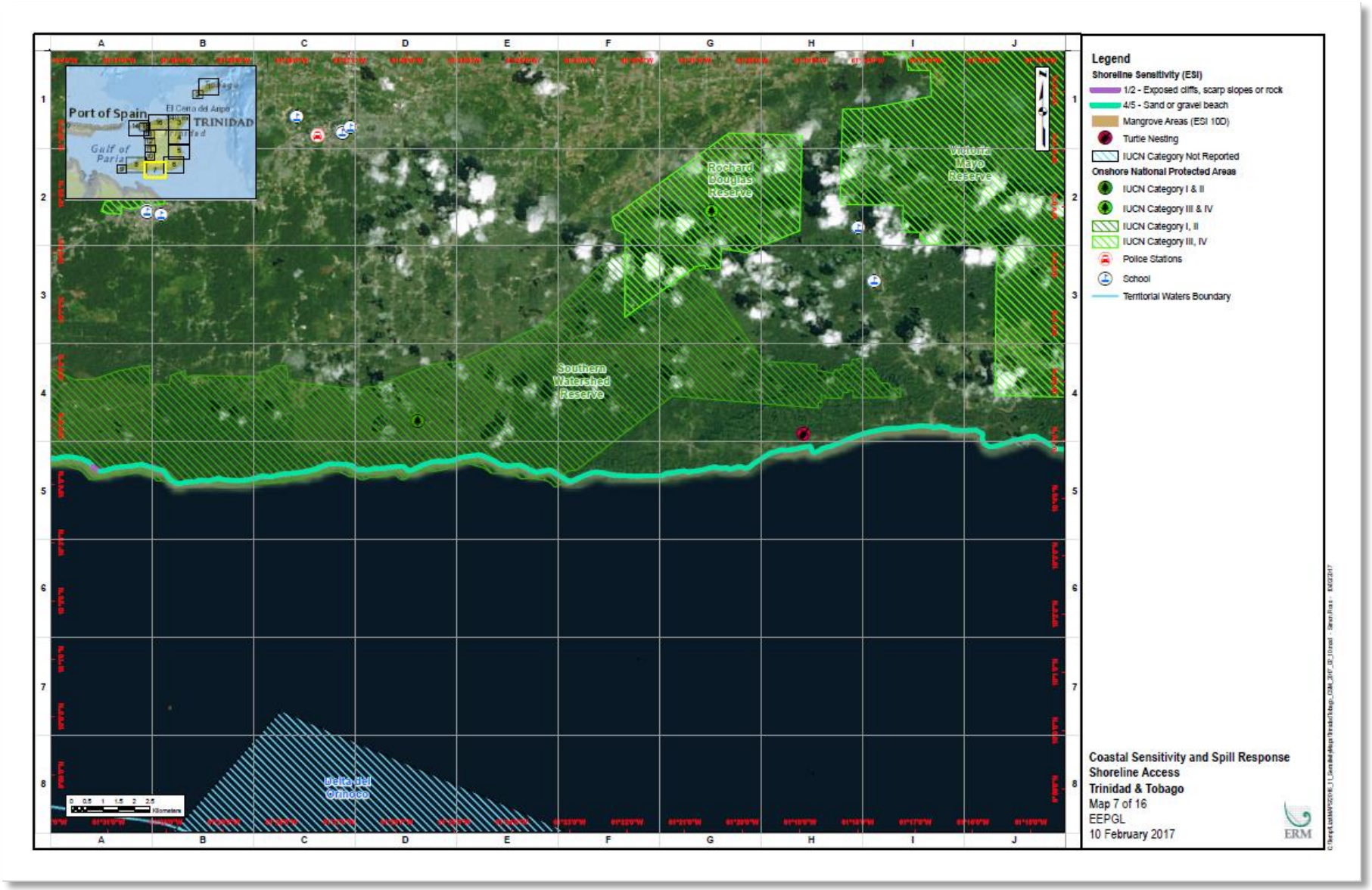

Port of Spain
TRINIDAD
Gulf of Paria
Buccoo Reef
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
10D - Mangroves
Mangrove Areas (ESI 10D)
Coral Reefs
Turtle Nesting
Seagrass
Marine National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Police Stations
School
Port or Marina
Shipping Route
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 2 of 16
EEPGL
10 February 2017
ERM


Port of Spain
TRINIDAD
Gulf of Paria
St. David Reserve
Eastern Extension Matura
Matura Swamp Reserve
Matura Reserve Western Ext.
Melajo Reserve
Manzanilla Ext.
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Manatees
Coral Reefs
Turtle Nesting
Seagrass
Onshore National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Police Stations
School
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 3 of 16
EEPGL
10 February 2017
ERM

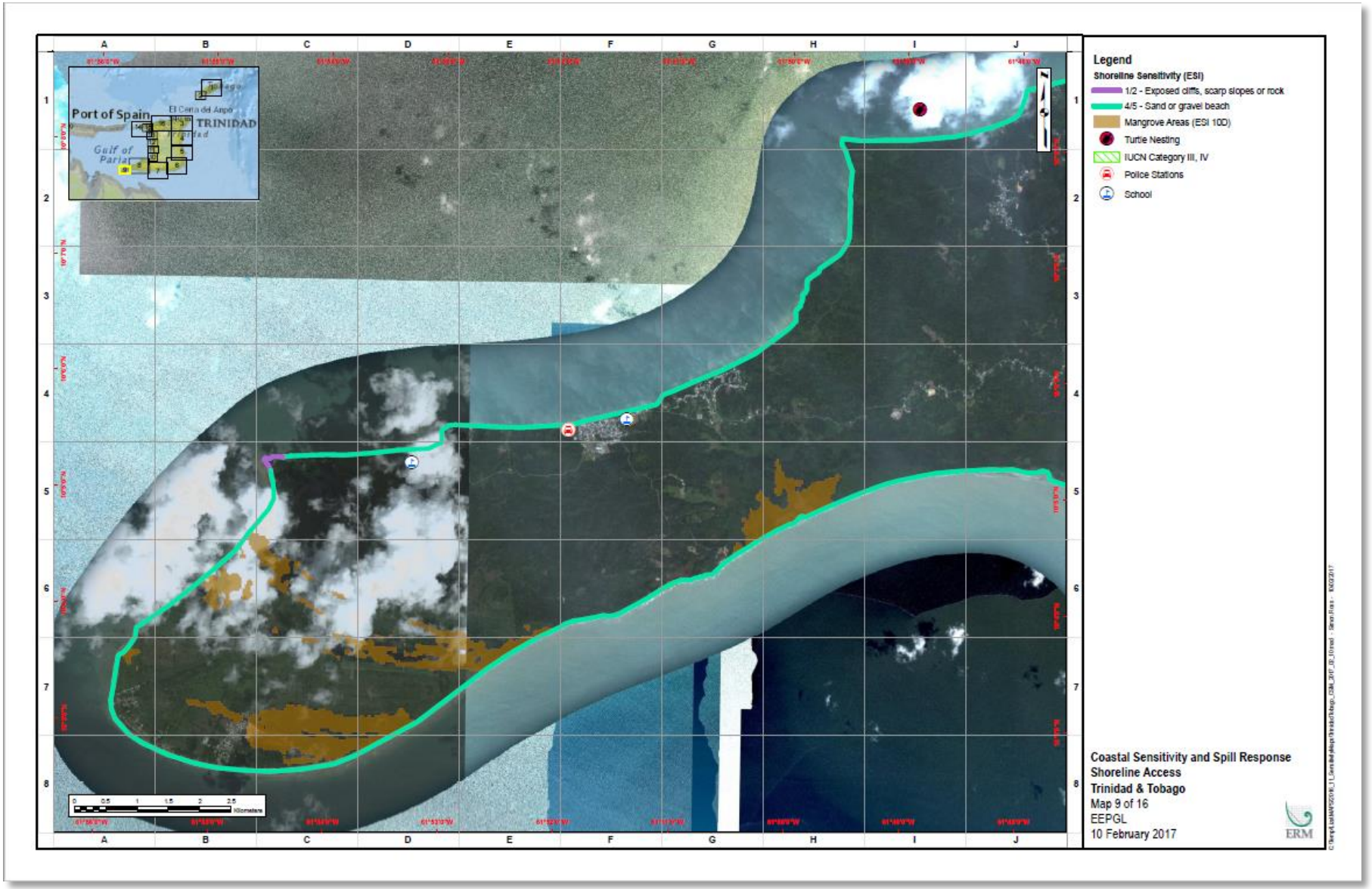

Port of Spain
El Cerro del Aripo
TRINIDAD
Gulf of Paria
Manzanilla Ext.
Manzanilla Wildbird Reserve
Melajo Reserve
Long Stretch Reserve
Central Range Reserve
Brigand Hill Reserve
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Mangrove Areas (ESI 10D)
Manatees
Turtle Nesting
Onshore National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Kindergarten
School
Rock
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 4 of 16
EEPGL
10 February 2017
ERM

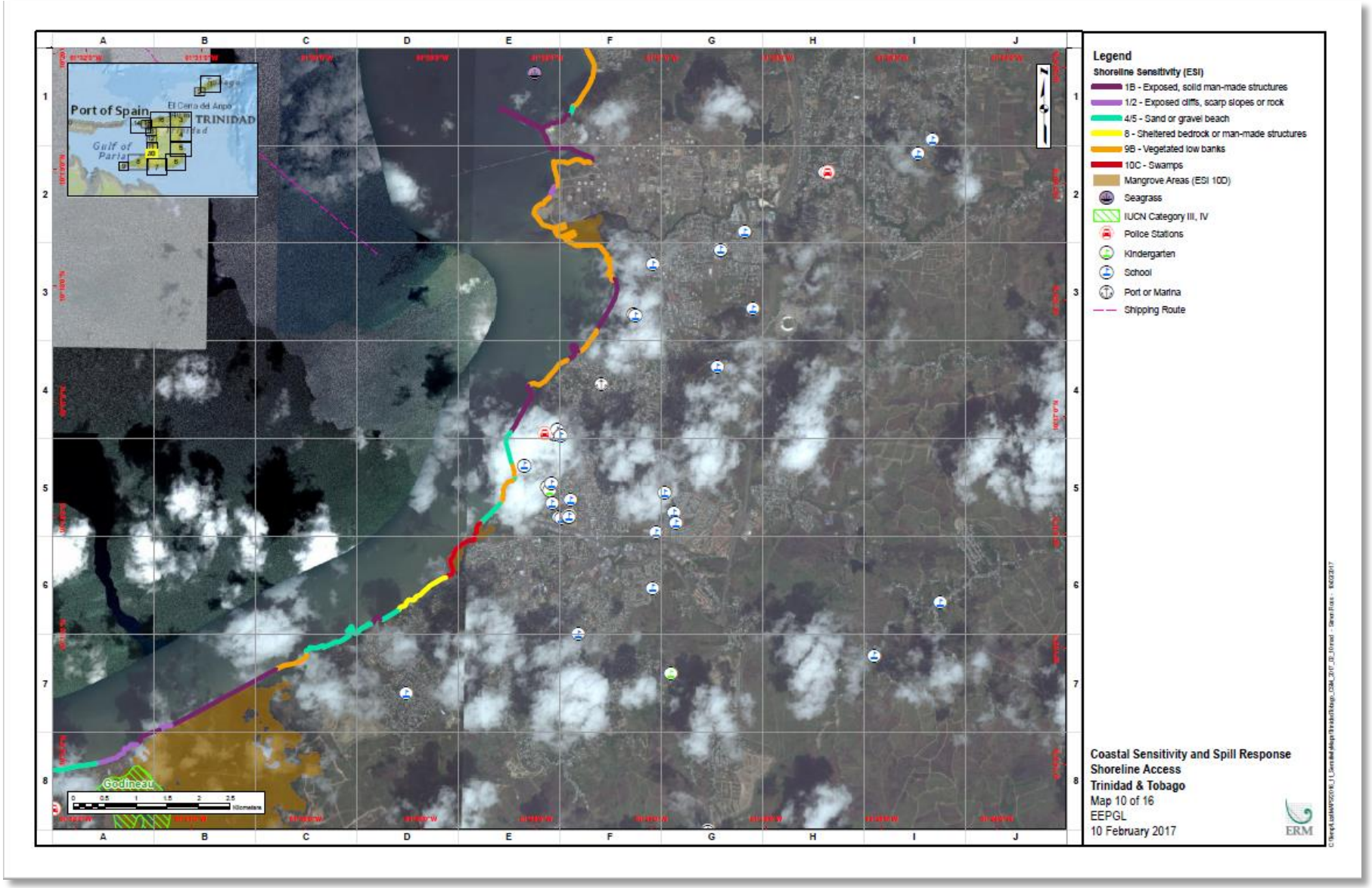

Port of Spain
TRINIDAD
Gulf of Paria
Nariva Windbelt Reserve
Ecclesville Windbelt Reserve
Victoria Mayo Reserve
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Mangrove Areas (ESI 10D)
Manatees
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Police Stations
School
Underwater Danger /Underwater Hazard
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 5 of 16
EEPGL
10 February 2017
ERM

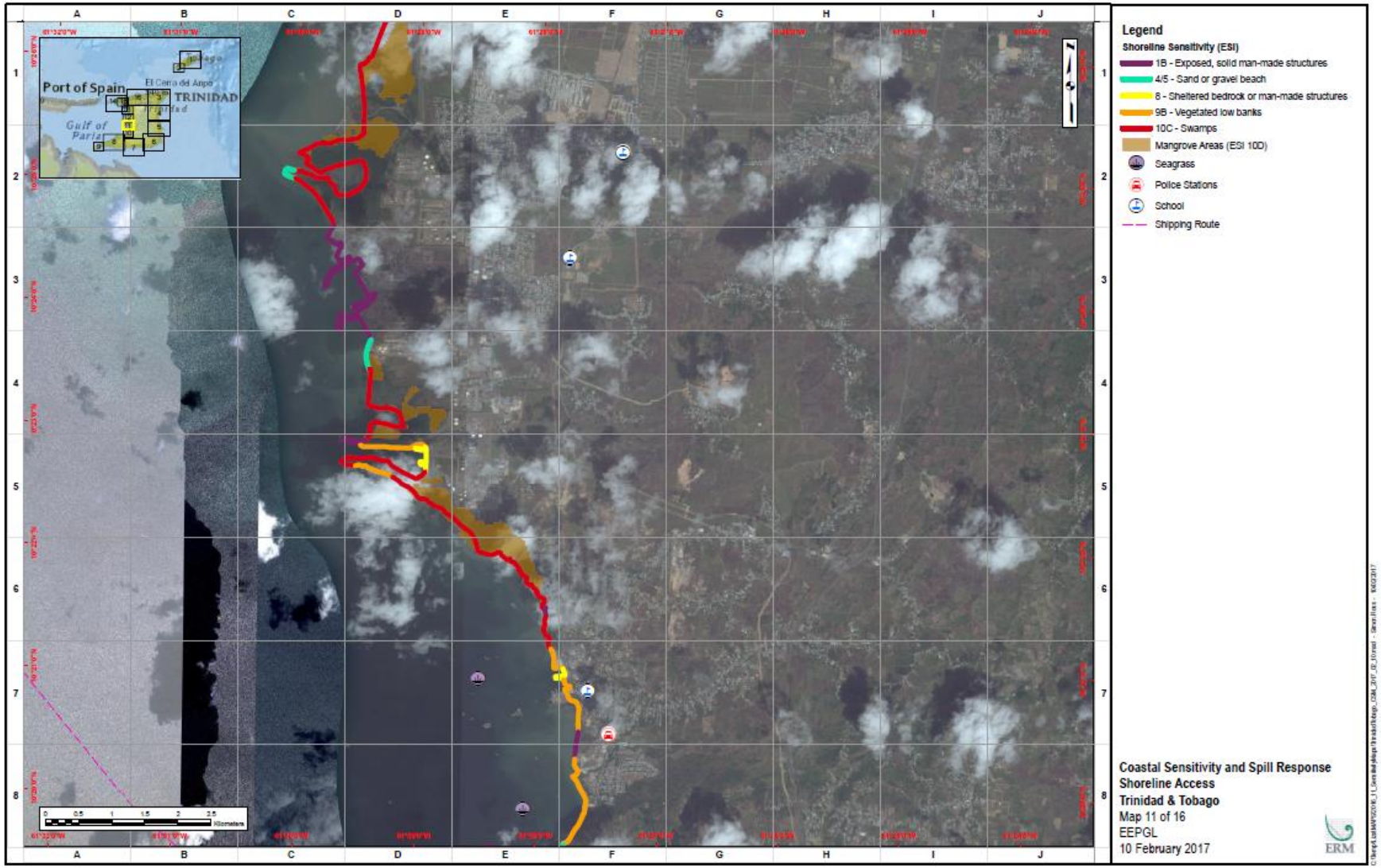

Port of Spain
TRINIDAD
Gulf of Paria
Victoria Mayo Reserve
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
9B - Vegetated low banks
Mangrove Areas (ESI 10D)
Manatees
Turtle Nesting
Seagrass
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Port or Marina
Rock
Shipping Route
Seabed Pipelines
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 6 of 16
EEPGL
10 February 2017
ERM

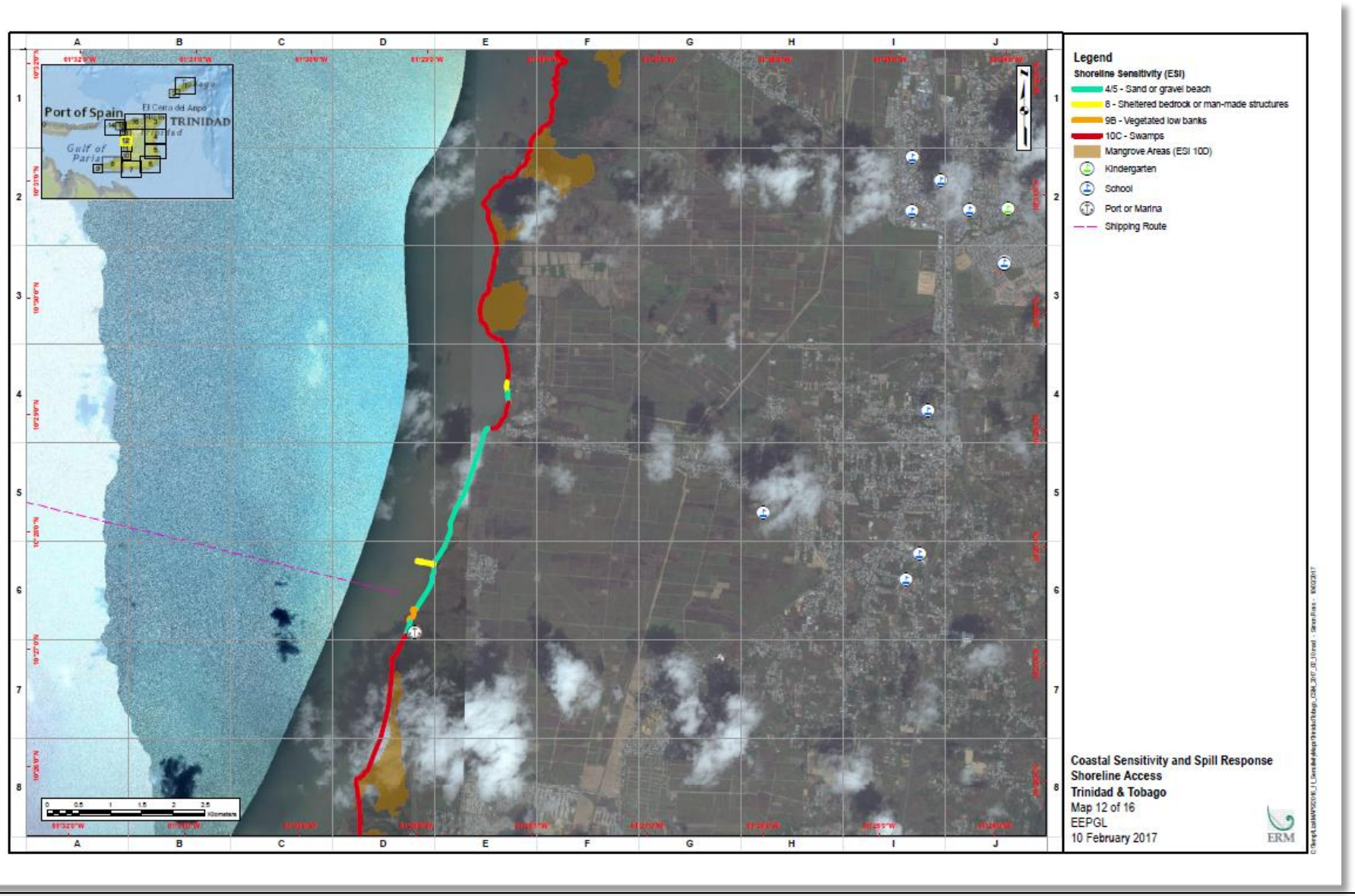

Port of Spain
TRINIDAD
Gulf of Paria
Richard Douglas Reserve
Victoria Mayo Reserve
Southern Watershed Reserve
Delta del Orinoco
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Mangrove Areas (ESI 10D)
Turtle Nesting
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Police Stations
School
Territorial Waters Boundary
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 7 of 16
EEPGL
10 February 2017
ERM

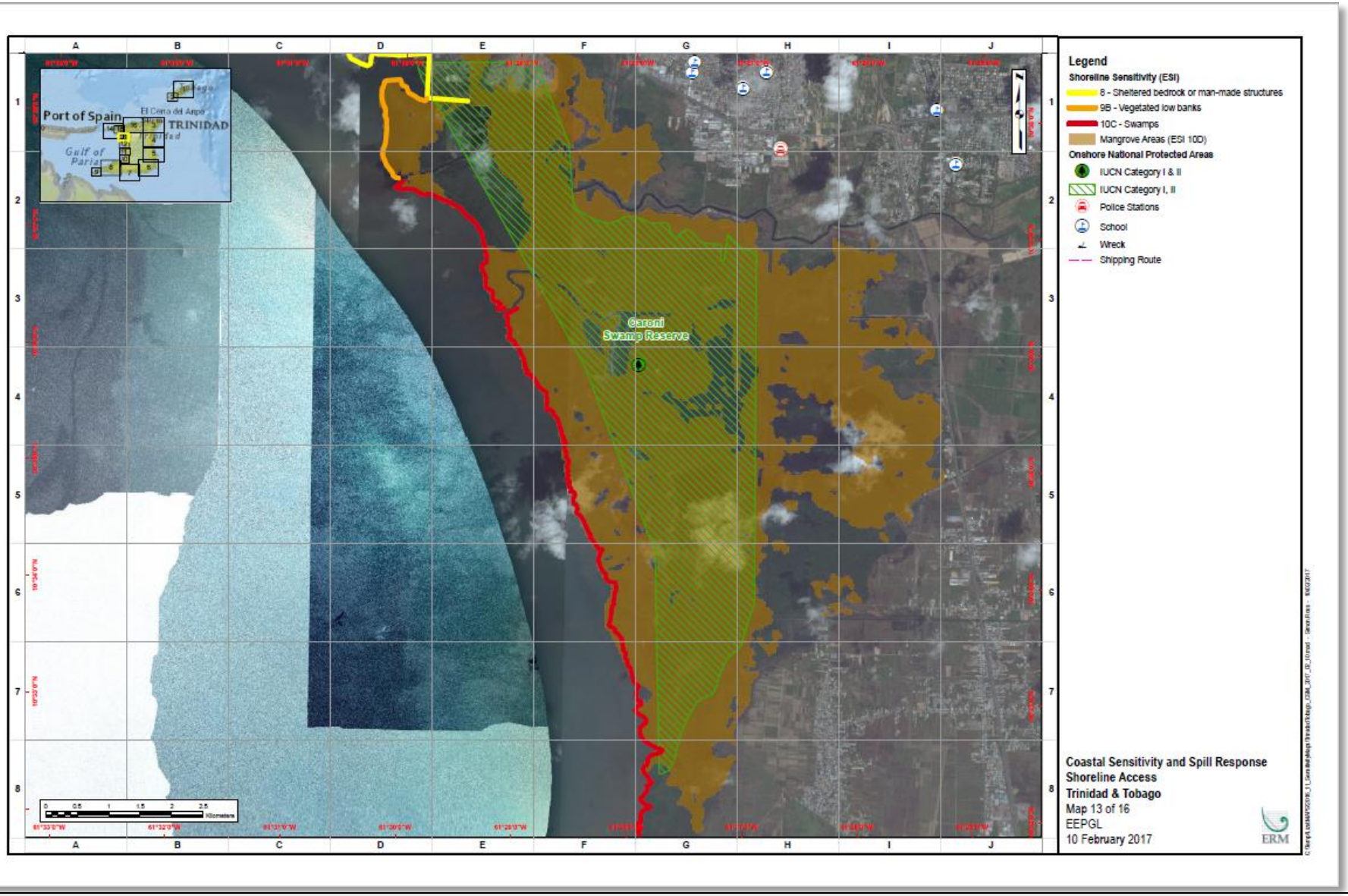

Port of Spain
El Cerro del Aripo
TRINIDAD
Gulf of Paria
Godineau Swamp Reserve
Morne L'Enfer Reserve
Sipara Reserve
Cap de Ville Reserve
Erin Reserve
Cedros Reserve
Southern Watershed Reserve
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
10C - Swamps
Mangrove Areas (ESI 10D)
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category Not Reported
IUCN Category I, II
IUCN Category III, IV
IUCN Category Not Reported
Police Stations
School
Port or Marina
Shipping Route
Seabed Pipelines
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 8 of 16
EEPGL
10 February 2017
ERM

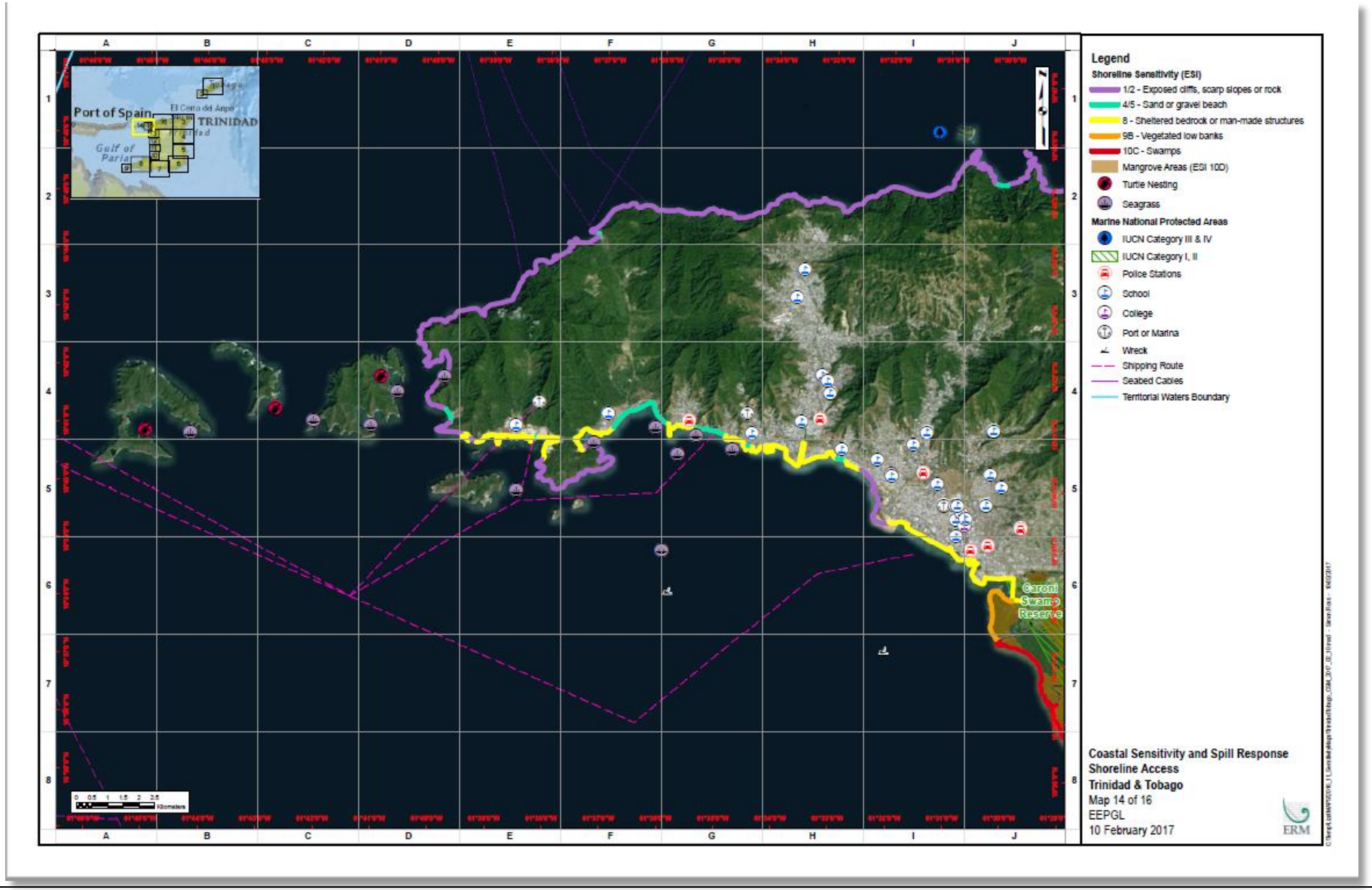

Port of Spain
TRINIDAD
Gulf of Paria
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Mangrove Areas (ESI 10D)
Turtle Nesting
IUCN Category III, IV
Police Stations
School
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 9 of 16
EEPGL
10 February 2017
ERM

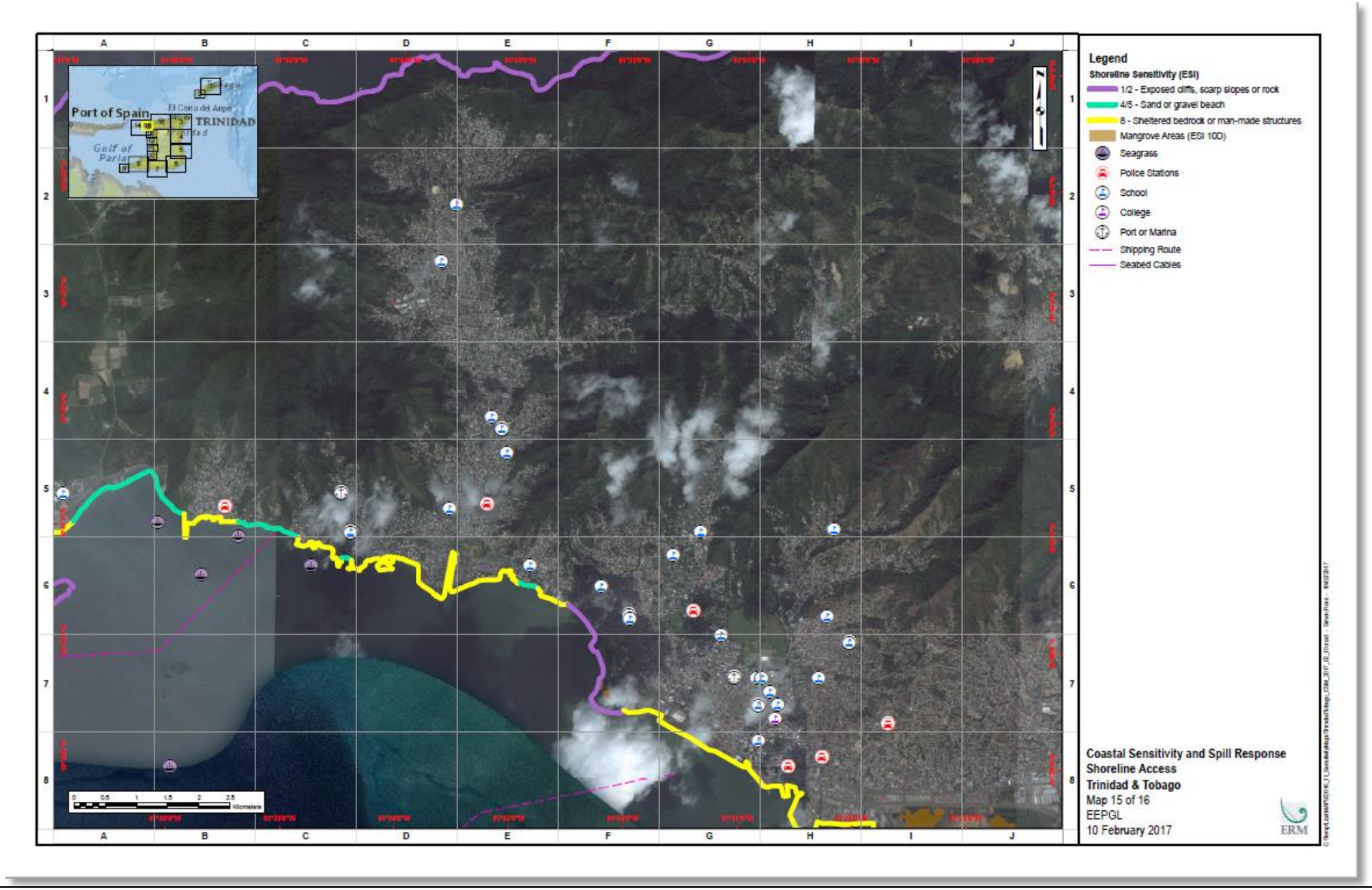

Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
10C - Swamps
Mangrove Areas (ESI 10D)
Seagrass
IUCN Category III, IV
Police Stations
Kindergarten
School
Port or Marina
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 10 of 16
EEPGL
10 February 2017
ERM
Port of Spain
TRINIDAD
Gulf of Paria
Godineau


Port of Spain
TRINIDAD
Gulf of Paria
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
10C - Swamps
Mangrove Areas (ESI 10D)
Seagrass
Police Stations
School
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 11 of 16
EEPGL
10 February 2017
ERM


Port of Spain
TRINIDAD
Gulf of Paria
Legend
Shoreline Sensitivity (ESI)
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
10C - Swamps
Mangrove Areas (ESI 10D)
Kindergarten
School
Port or Marina
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 12 of 16
EEPGL
10 February 2017
ERM

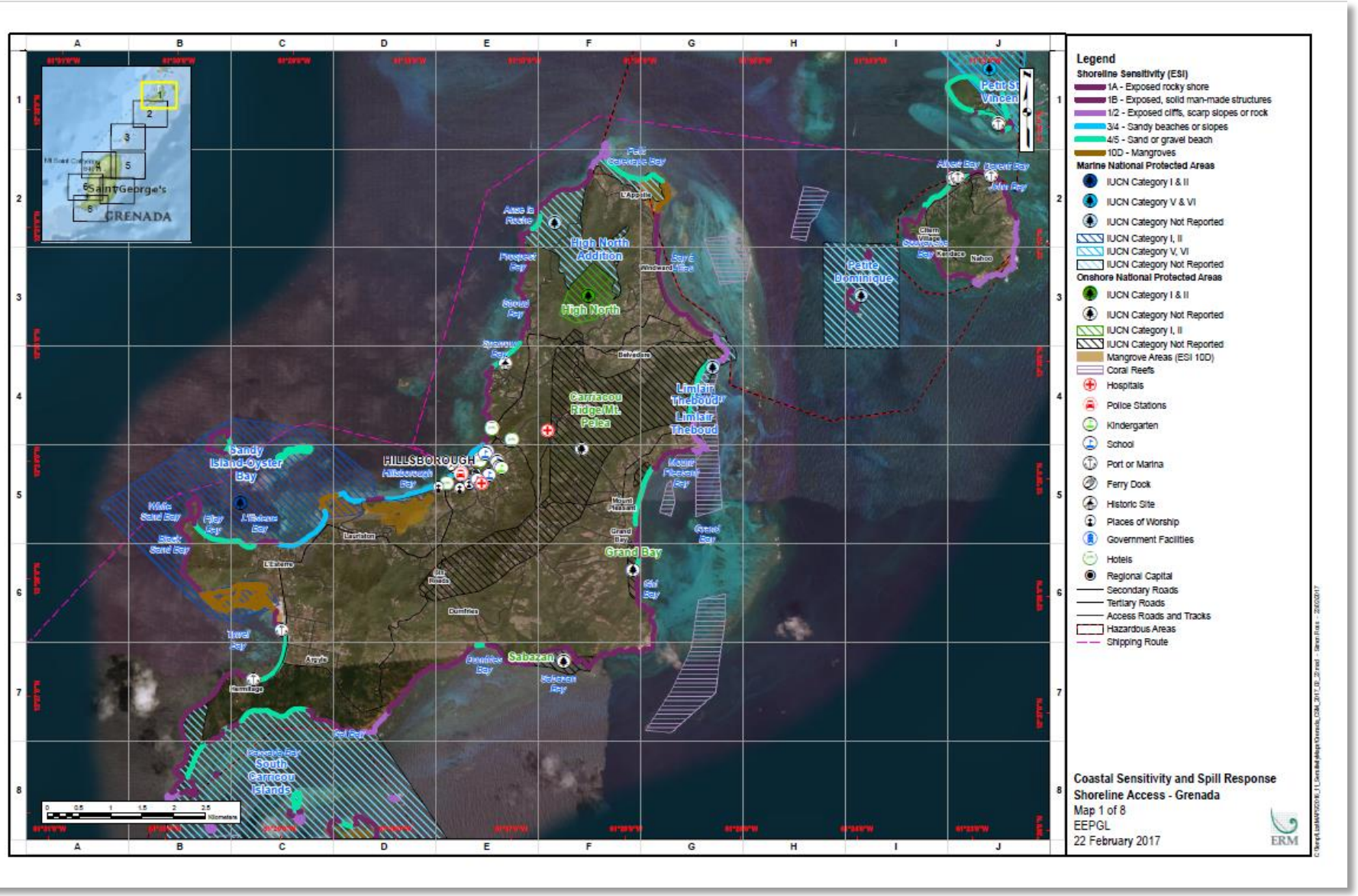

Port of Spain
TRINIDAD
Gulf of Paria
Caroni
Swamp Reserve
Legend
Shoreline Sensitivity (ESI)
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
10C - Swamps
Mangrove Areas (ESI 10D)
Onshore National Protected Areas
IUCN Category I & II
IUCN Category I, II
Police Stations
School
Wreck
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 13 of 16
EEPGL
10 February 2017
ERM

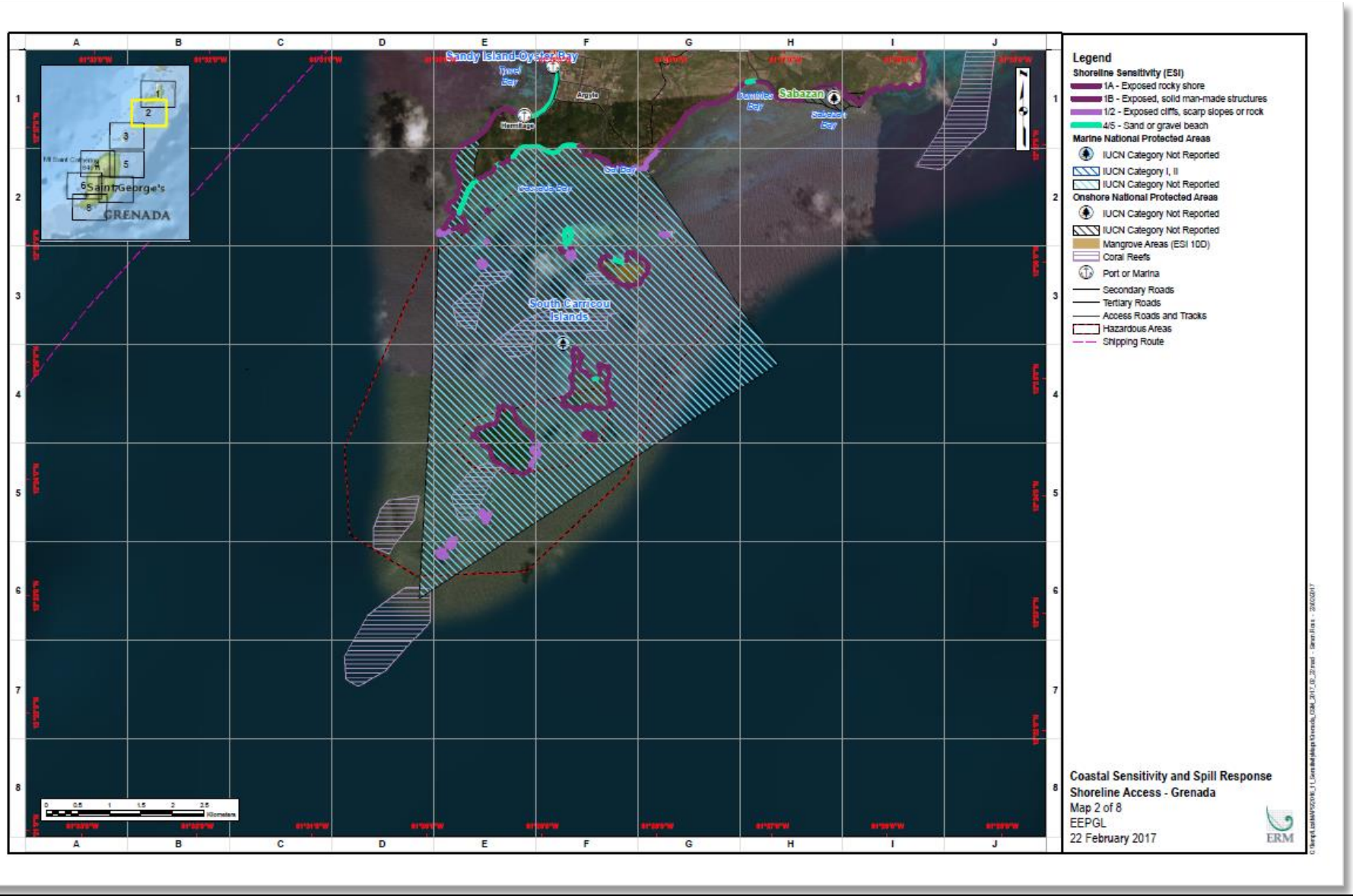

Port of Spain
El Cerro del Aripo
TRINIDAD
Gulf of Paria
Caroni Swamp Reserve
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
10C - Swamps
Mangrove Areas (ESI 10D)
Turtle Nesting
Seagrass
Marine National Protected Areas
IUCN Category III & IV
IUCN Category I, II
Police Stations
School
College
Port or Marina
Wreck
Shipping Route
Seabed Cables
Territorial Waters Boundary
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 14 of 16
EEPGL
10 February 2017
ERM

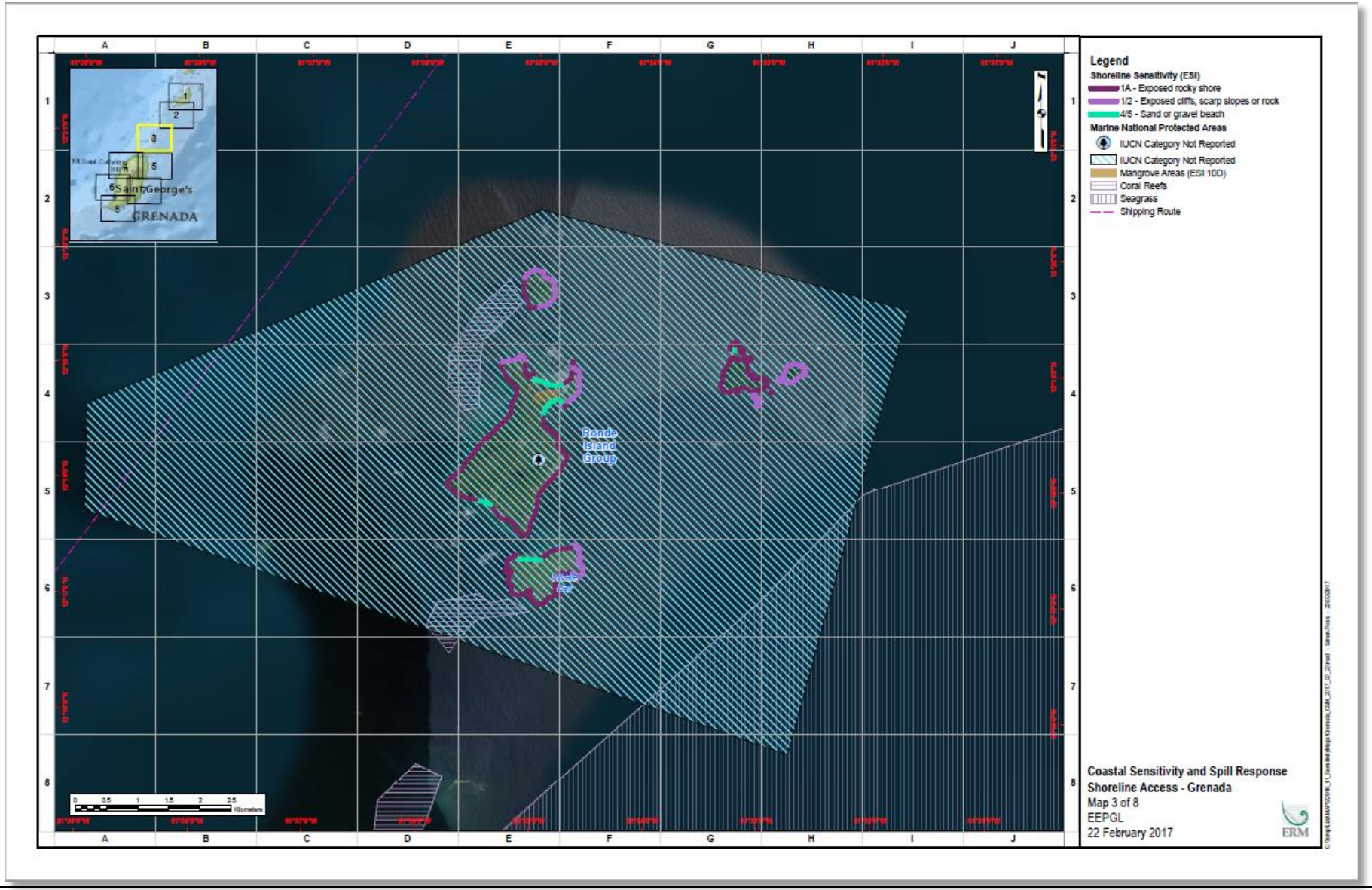

Port of Spain
TRINIDAD
Gulf of Paria
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
Mangrove Areas (ESI 10D)
Seagrass
Police Stations
School
College
Port or Marina
Shipping Route
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 15 of 16
EEPGL
10 February 2017
ERM

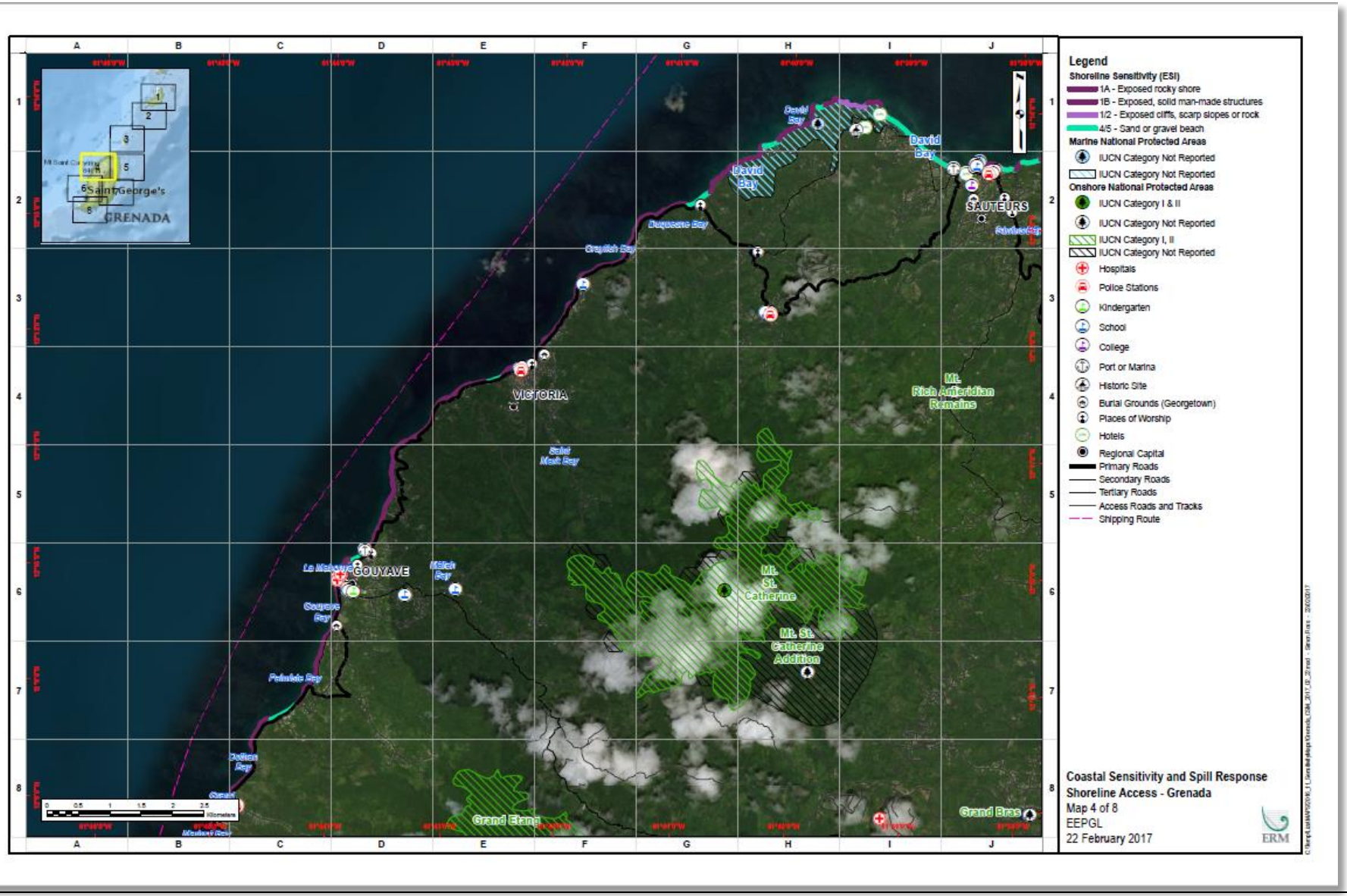

Port of Spain
TRINIDAD
Gulf of Paria
Las Cuevas Reserve
Yarra Reserve
Blanchisseuse Reserve
Paria Reserve
Nrb.
Nrc
Nrd.
Tacarigua Reserve
Arima Reserve
Legend
Shoreline Sensitivity (ESI)
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Turtle Nesting
Onshore National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Police Stations
School
Coastal Sensitivity and Spill Response
Shoreline Access
Trinidad & Tobago
Map 16 of 16
EEPGL
10 February 2017
ERM

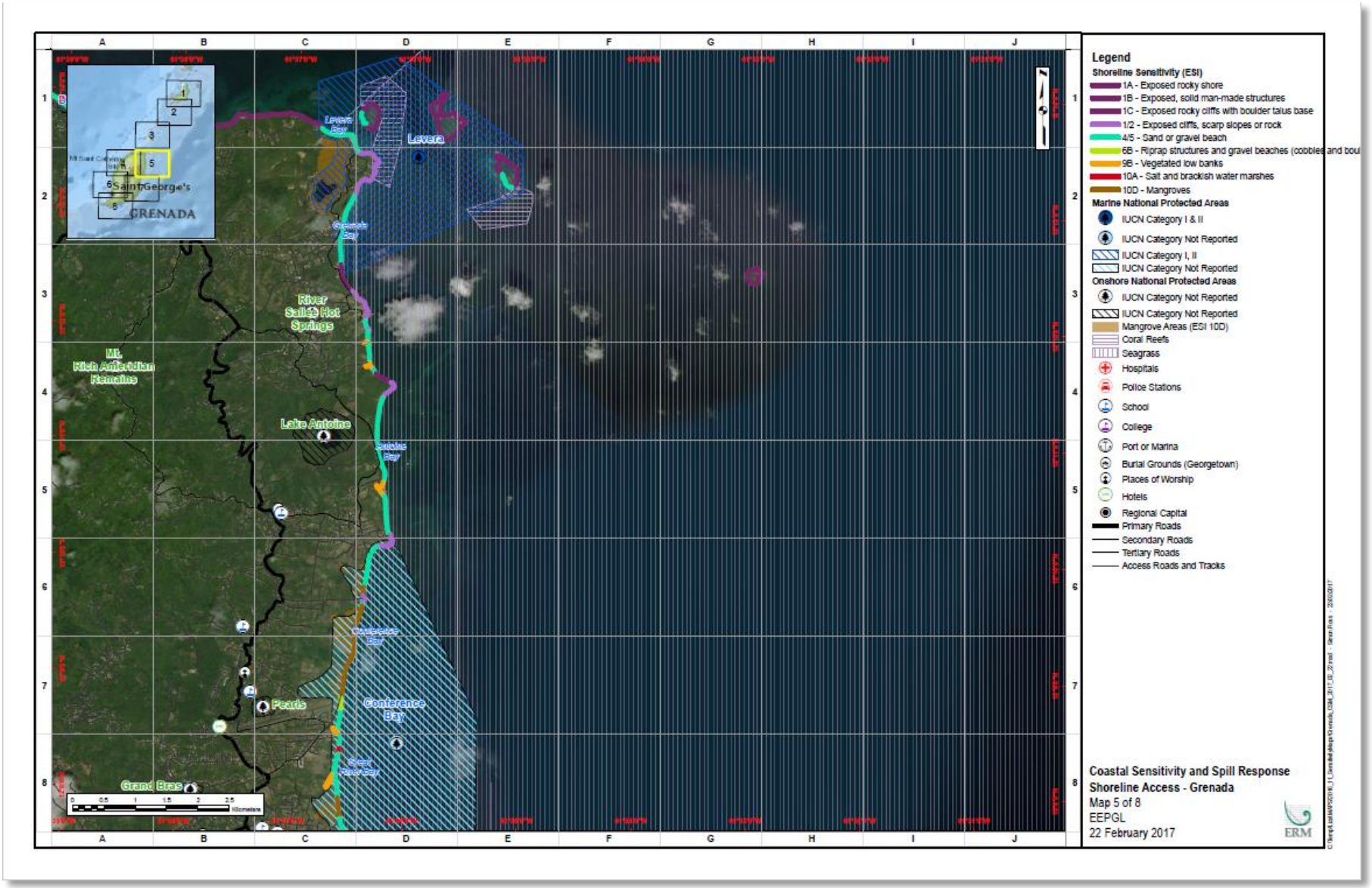
GRENADA
Coastal Sensitivity Maps

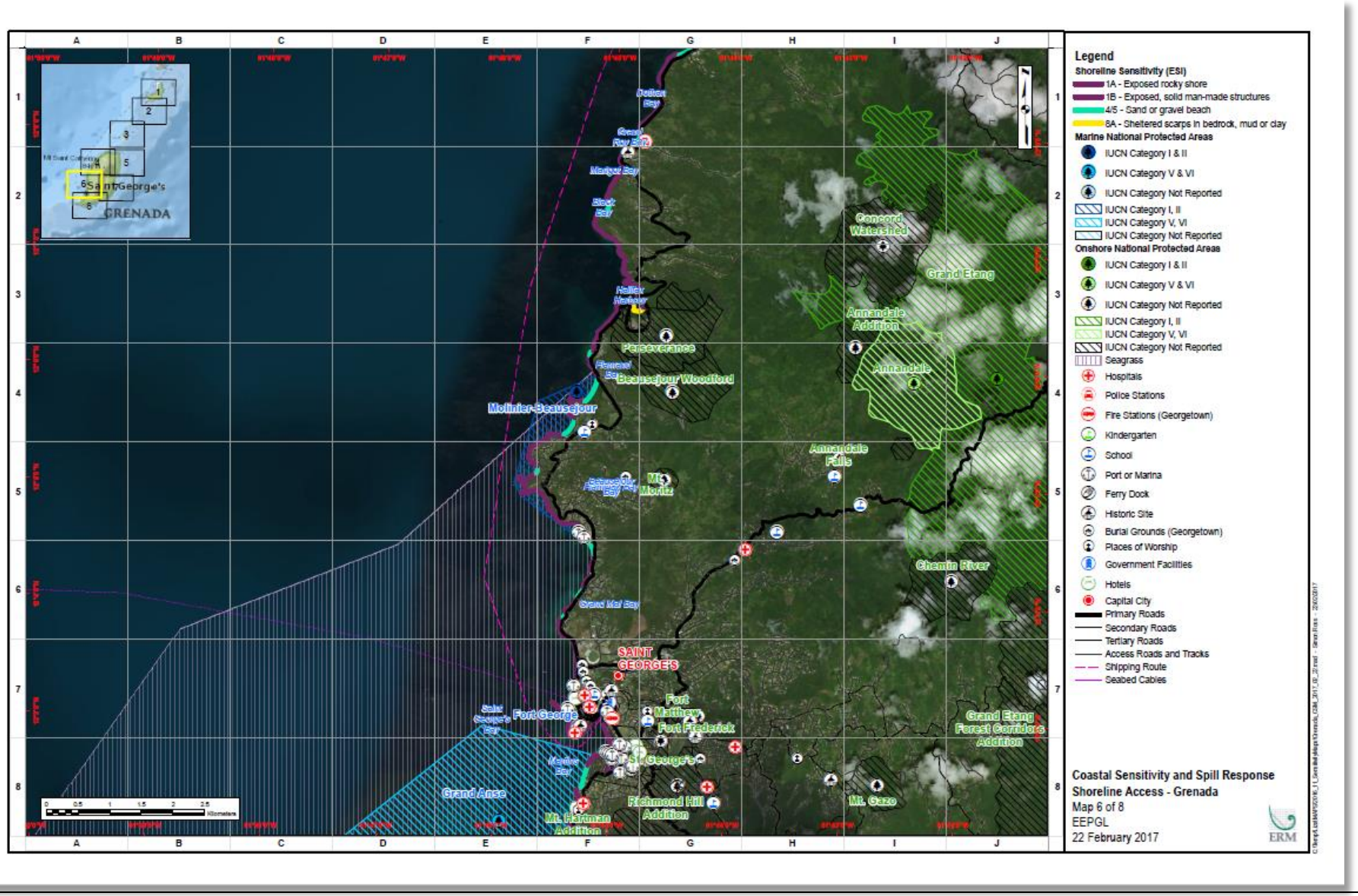

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
3/4 - Sandy beaches or slopes
4/5 - Sand or gravel beach
10D - Mangroves
Marine National Protected Areas
IUCN Category I & II
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I & II
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Mangrove Areas (ESI 10D)
Coral Reefs
Hospitals
Police Stations
Kindergarten
School
Port or Marina
Ferry Dock
Historic Site
Places of Worship
Government Facilities
Hotels
Regional Capital
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Hazardous Areas
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 1 of 8
EEPGL
22 February 2017
ERM
Saint George's
GRENADA
HILLSBOROUGH
Grand Bay
Sabazan
High North Addition
High North
Carriacou Ridge/Mt. Pelea
Limlair Theboud
Petite Dominique
Petit St Vincent
Sandy Island-Oyster Bay
South Carriacou Islands

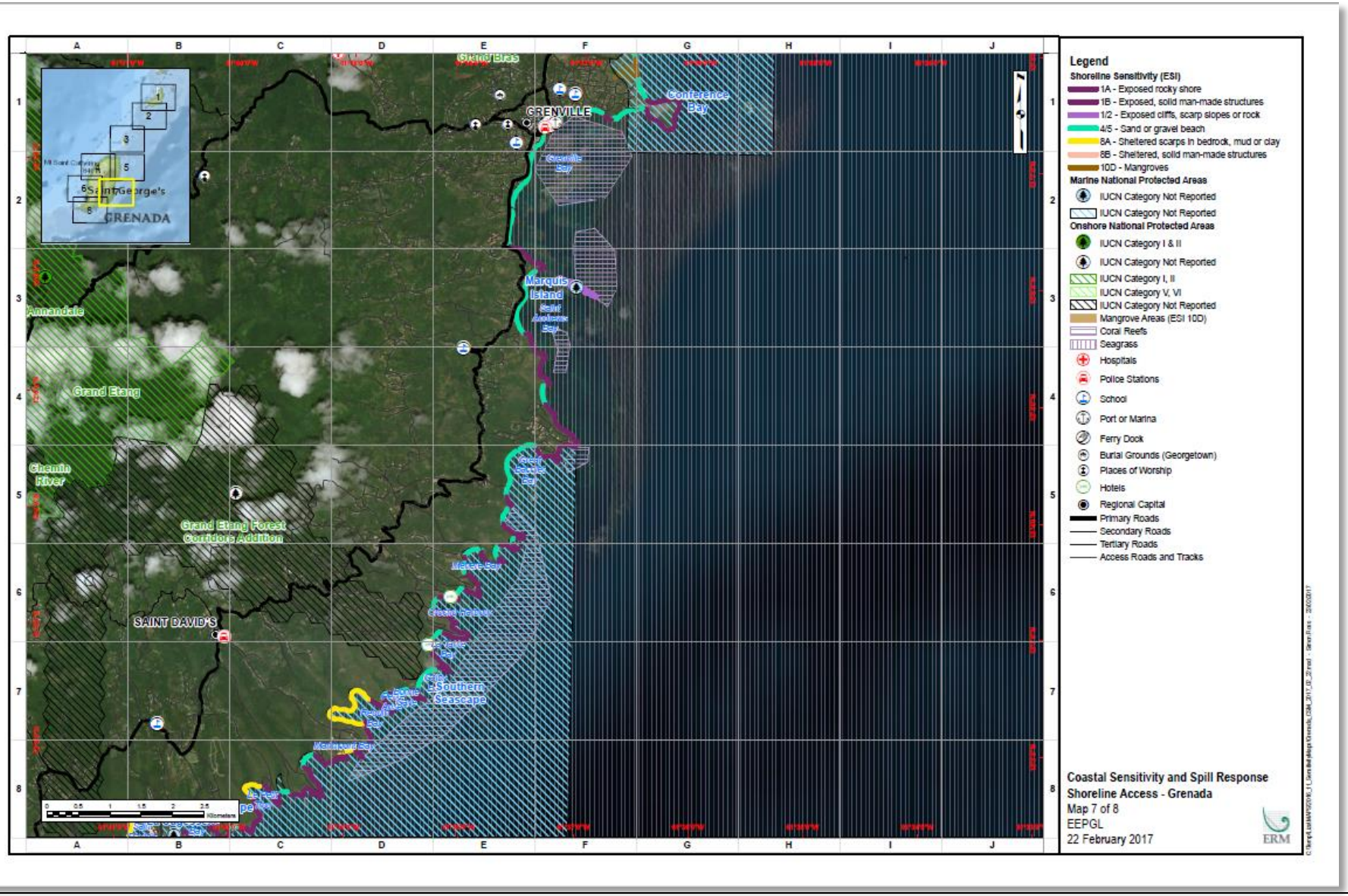

Sandy Island-Oyster Bay
Sabazan
South Carriacou Islands
Saint George's
GRENADA
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Marine National Protected Areas
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category Not Reported
IUCN Category Not Reported
Mangrove Areas (ESI 10D)
Coral Reefs
Port or Marina
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Hazardous Areas
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 2 of 8
EEPGL
22 February 2017
ERM

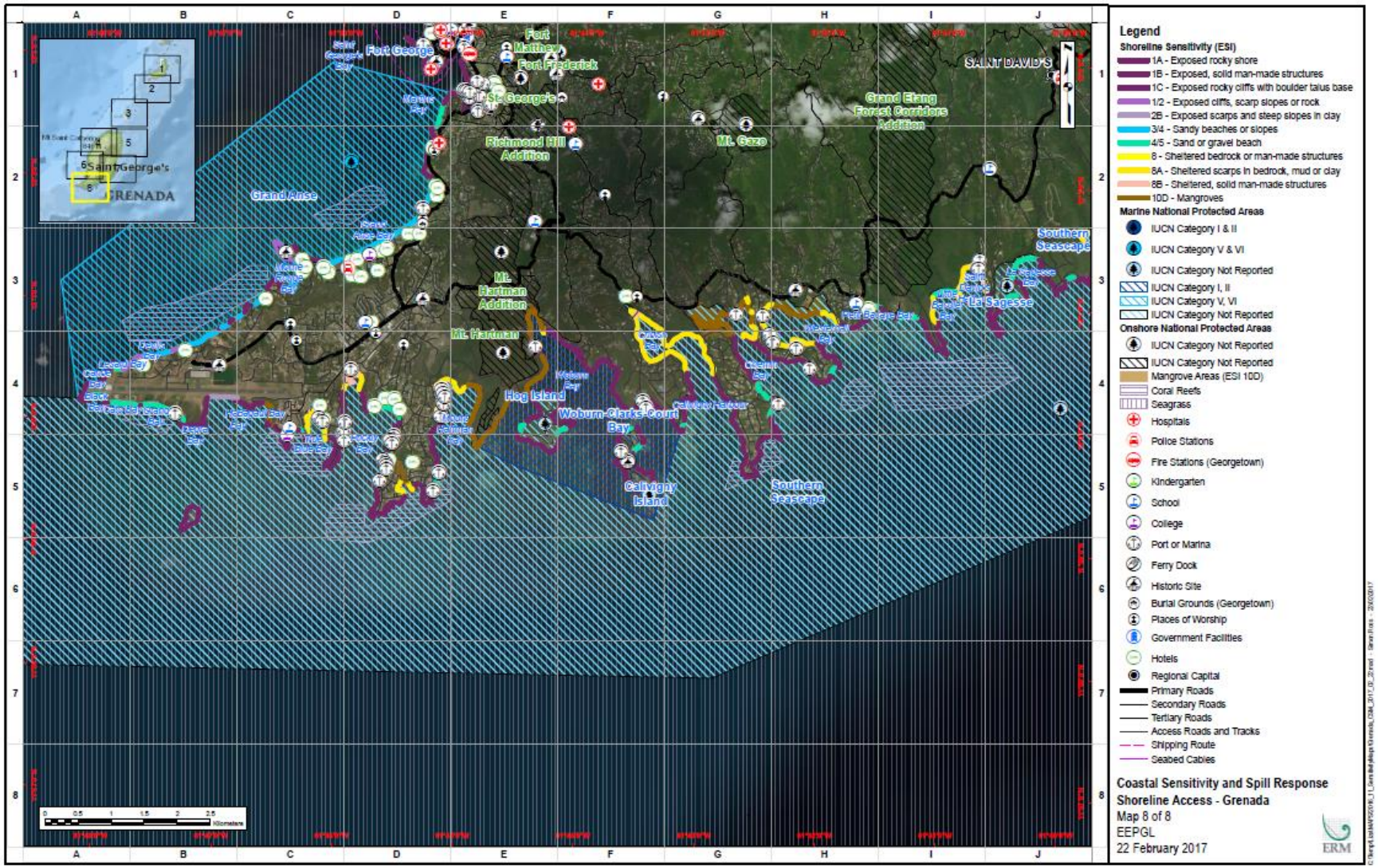

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Marine National Protected Areas
IUCN Category Not Reported
IUCN Category Not Reported
Mangrove Areas (ESI 10D)
Coral Reefs
Seagrass
Shipping Route
Ronde Island Group
Saint George's
GRENADA
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 3 of 8
EEPGL
22 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
Marine National Protected Areas
IUCN Category Not Reported
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I & II
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Hospitals
Police Stations
Kindergarten
School
College
Port or Marina
Historic Site
Burial Grounds (Georgetown)
Places of Worship
Hotels
Regional Capital
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 4 of 8
EEPGL
22 February 2017
ERM
VICTORIA
GOUYAVE
SAUTEURS
Mt. Rich Amerindian Remains
Mt. St. Catherine
Mt. St. Catherine Addition
Grand Etang
Grand Bras
David Bay
Duquesne Bay
Saint George's
GRENADA

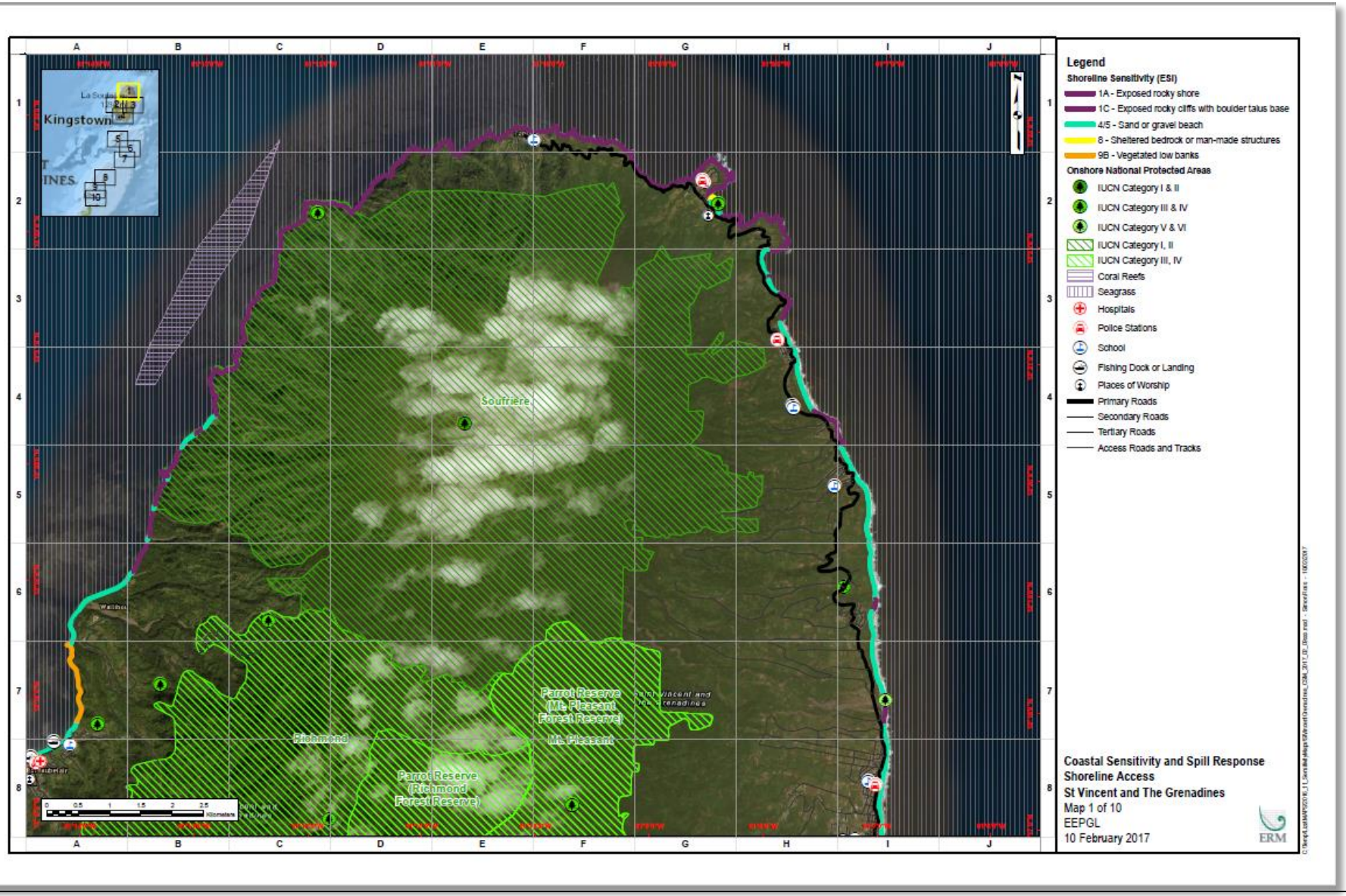

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
6B - Riprap structures and gravel beaches (cobbles and bou
9B - Vegetated low banks
10A - Salt and brackish water marshes
10D - Mangroves
Marine National Protected Areas
IUCN Category I & II
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category Not Reported
IUCN Category Not Reported
Mangrove Areas (ESI 10D)
Coral Reefs
Seagrass
Hospitals
Police Stations
School
College
Port or Marina
Burial Grounds (Georgetown)
Places of Worship
Hotels
Regional Capital
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 5 of 8
EEPGL
22 February 2017
ERM
Levera
Levera Bay
Grenada Bay
River Sallee Hot Springs
Mt. Rich Amelioration Remains
Lake Antoine
Swine Bay
Lawrence Bay
Pearls
Conference Bay
Great Harbour
Grand Bras
Saint George's
GRENADA

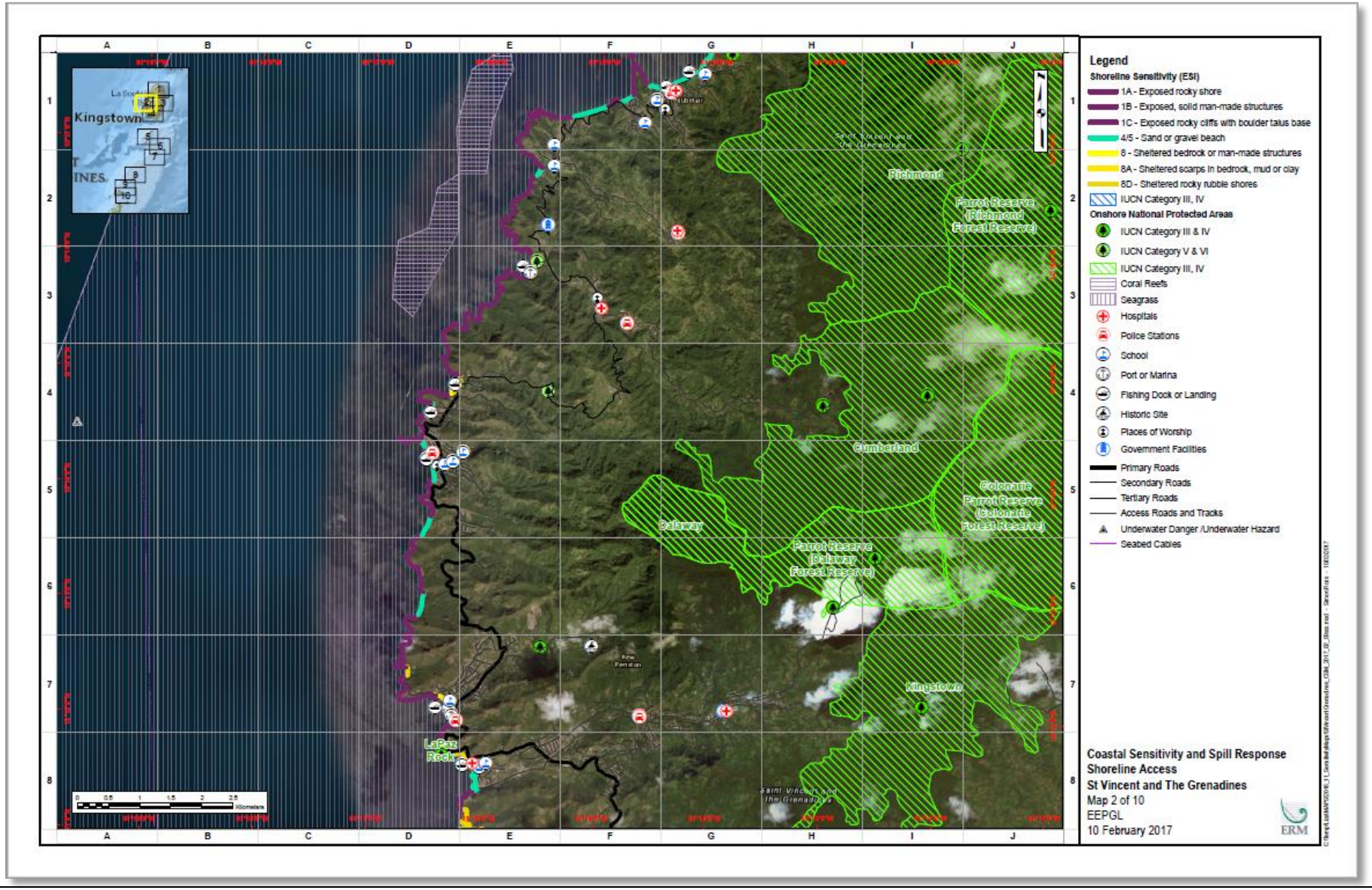

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
4/5 - Sand or gravel beach
8A - Sheltered scarps in bedrock, mud or clay
Marine National Protected Areas
IUCN Category I & II
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I & II
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
Port or Marina
Ferry Dock
Historic Site
Burial Grounds (Georgetown)
Places of Worship
Government Facilities
Hotels
Capital City
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 6 of 8
EEPGL
22 February 2017
ERM
SAINT GEORGE'S
Fort George
Fort Matthew
Fort Frederick
St. George's
Grand Anse
Mt. Harman Addition
Richmond Hill Addition
Mt. Gazo
Grand Etang Forest Corridors Addition
Chemin River
Annandale Falls
Annandale
Annandale Addition
Grand Etang
Concord Watershed
Perseverance
Beausejour Woodford
Molinier-Beausejour
Mt. Moritz
Grand Mal Bay
Mt Hartman Bay
Mt Gazo Cemetery
Saint George's
GRENADA

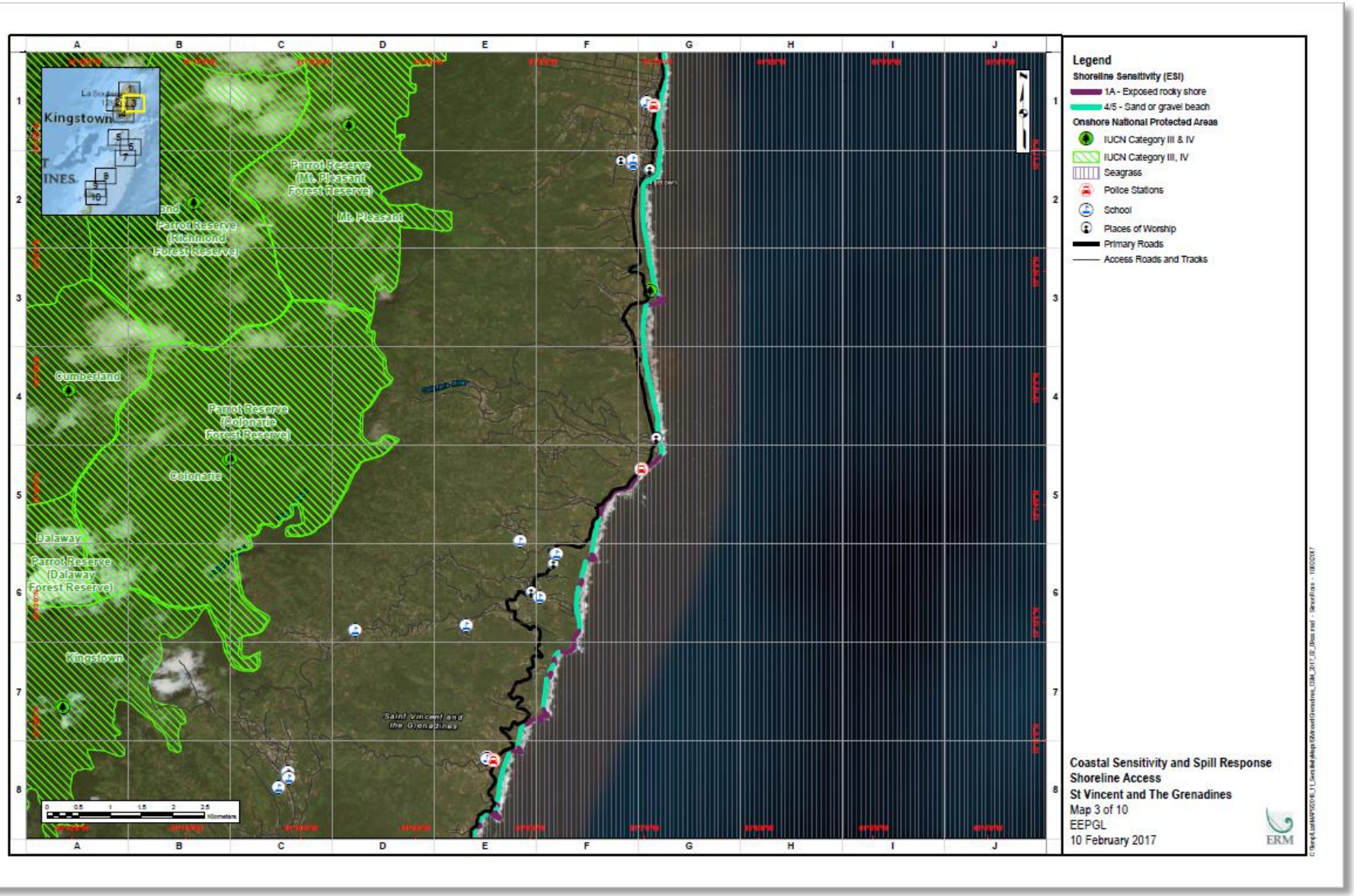

GRENVILLE
Conference Bay
Marquis Island
Annandale
Grand Etang
Chemin River
Grand Etang Forest Corridore Addition
SAINT DAVID'S
Southern Seascape
GRENADA
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8A - Sheltered scarps in bedrock, mud or clay
8B - Sheltered, solid man-made structures
10D - Mangroves
Marine National Protected Areas
IUCN Category Not Reported
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I & II
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Mangrove Areas (ESI 10D)
Coral Reefs
Seagrass
Hospitals
Police Stations
School
Port or Marina
Ferry Dock
Burial Grounds (Georgetown)
Places of Worship
Hotels
Regional Capital
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 7 of 8
EEPGL
22 February 2017
ERM

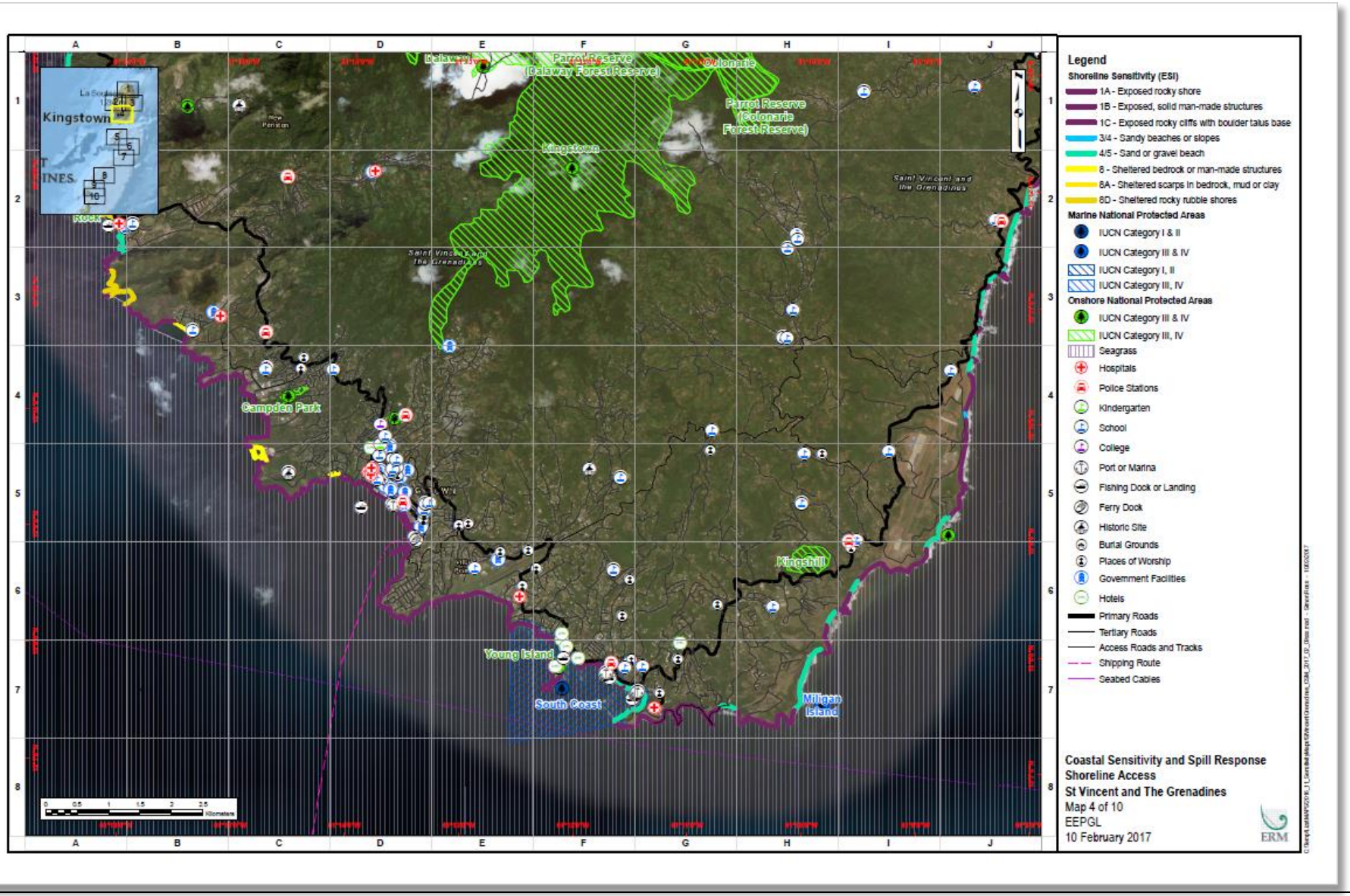

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
1/2 - Exposed cliffs, scarp slopes or rock
2B - Exposed scarps and steep slopes in clay
3/4 - Sandy beaches or slopes
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8A - Sheltered scarps in bedrock, mud or clay
8B - Sheltered, solid man-made structures
10D - Mangroves
Marine National Protected Areas
IUCN Category I & II
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category Not Reported
IUCN Category Not Reported
Mangrove Areas (ESI 10D)
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
College
Port or Marina
Ferry Dock
Historic Site
Burial Grounds (Georgetown)
Places of Worship
Government Facilities
Hotels
Regional Capital
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access - Grenada
Map 8 of 8
EEPGL
22 February 2017
ERM
Fort George
Fort Matthew
Fort Frederick
St. George's
SAINT DAVID'S
Grand Etang Forest Corridors Addition
Mt. Gaze
Richmond Hill Addition
Grand Anse
Southern Seascape
Mt. Hartman Addition
Mt. Hartman
La Sagesse
Hog Island
Woburn-Clarks-Court Bay
Calivigny Island
Southern Seascape
Saint George's
GRENADA

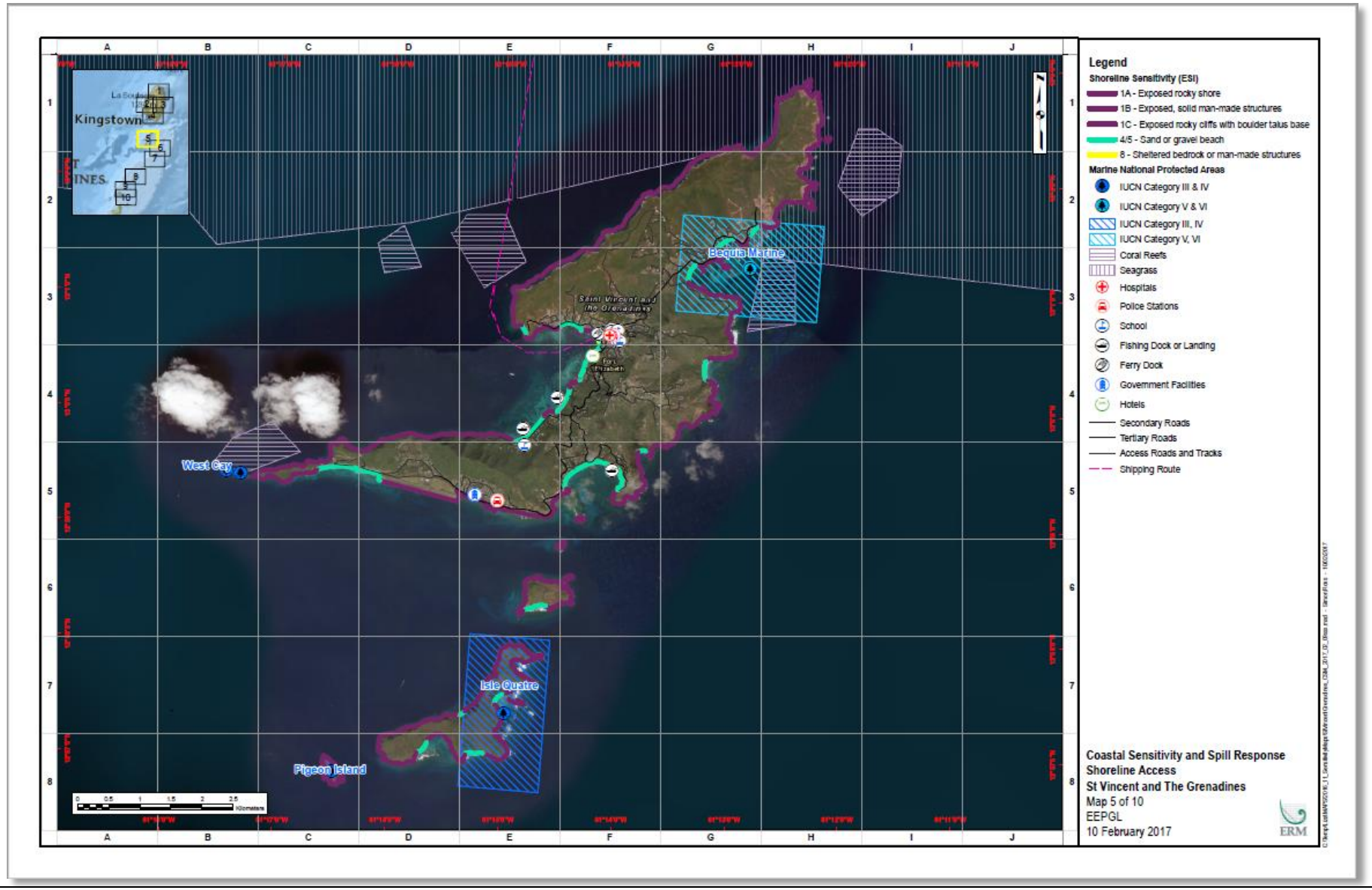
ST. VINCENT AND GRENADINES
Coastal Sensitivity Maps

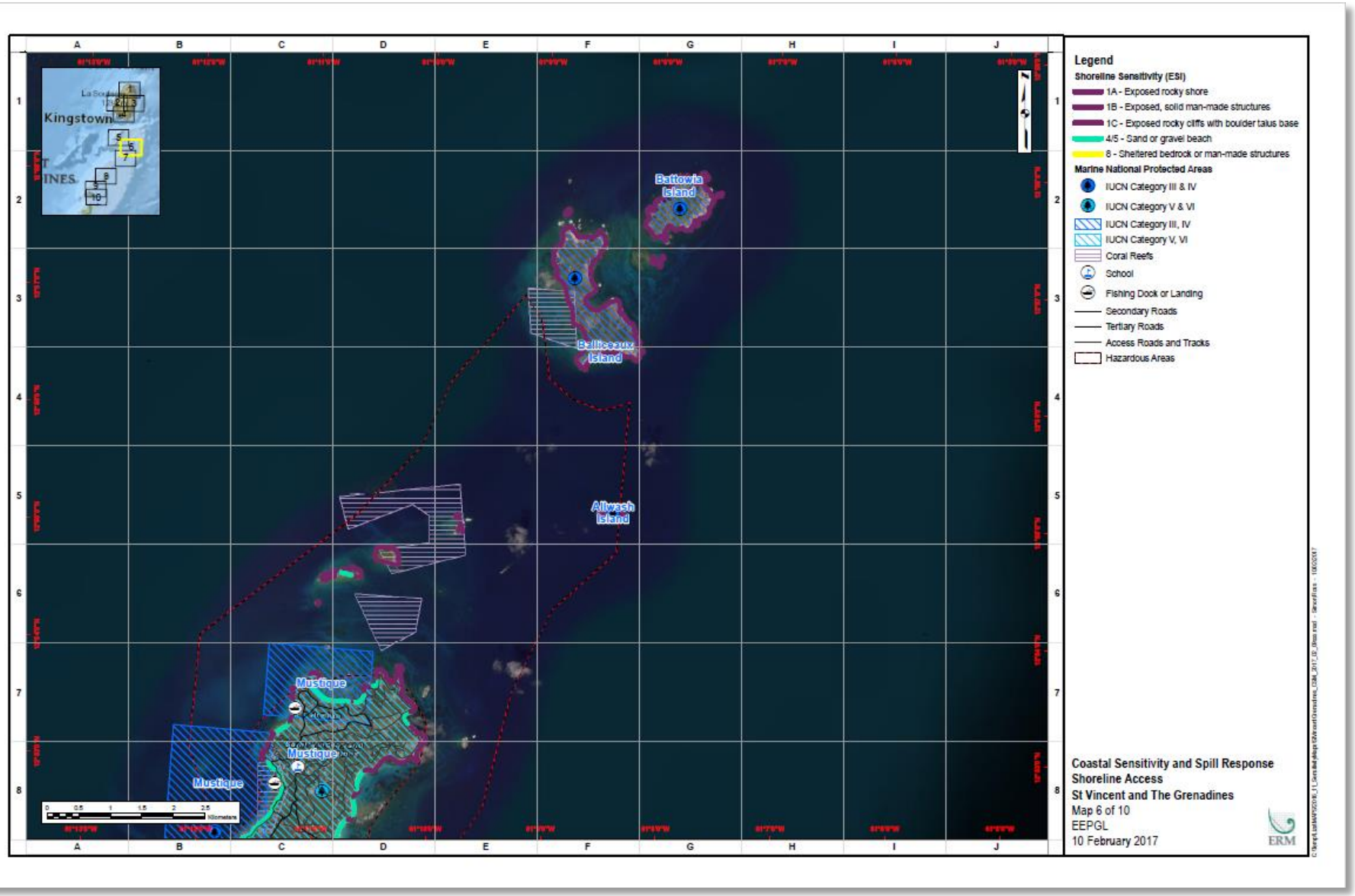

Kingstown
Soufrière
Richmond
Parrot Reserve (Mt. Pleasant Forest Reserve)
Mt. Pleasant
Parrot Reserve (Richmond Forest Reserve)
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
9B - Vegetated low banks
Onshore National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category V & VI
IUCN Category I, II
IUCN Category III, IV
Coral Reefs
Seagrass
Hospitals
Police Stations
School
Fishing Dock or Landing
Places of Worship
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 1 of 10
EEPGL
10 February 2017
ERM

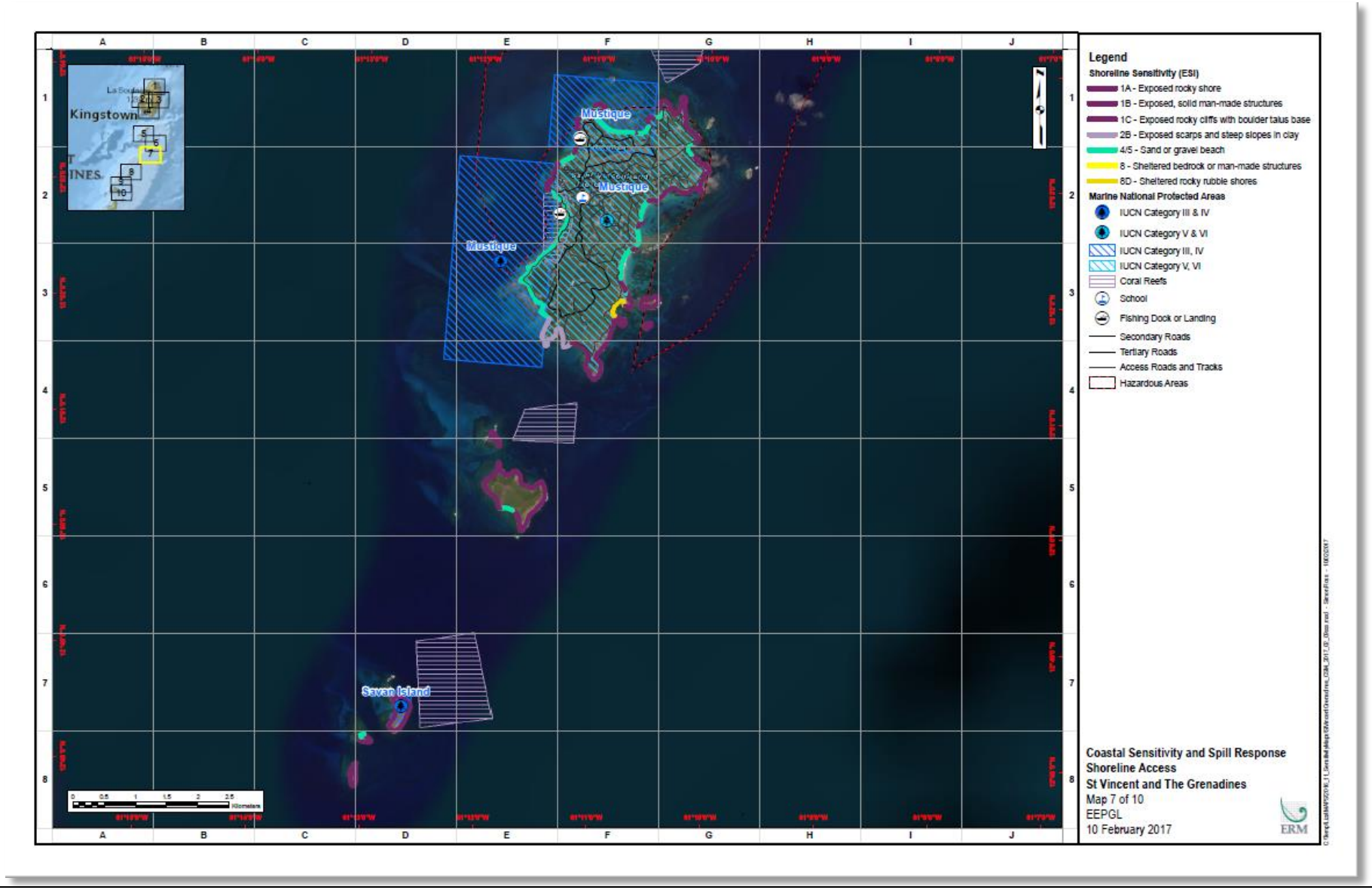

Kingstown
Richmond
Parrot Reserve (Richmond Forest Reserve)
Cumberland
Colonarie Parrot Reserve (Colonarie Forest Reserve)
Dalaway
Parrot Reserve (Dalaway Forest Reserve)
Kingstown
LaPaz Rock
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8A - Sheltered scarps in bedrock, mud or clay
8D - Sheltered rocky rubble shores
IUCN Category III, IV
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category V & VI
IUCN Category III, IV
Coral Reefs
Seagrass
Hospitals
Police Stations
School
Port or Marina
Fishing Dock or Landing
Historic Site
Places of Worship
Government Facilities
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Underwater Danger /Underwater Hazard
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 2 of 10
EEPGL
10 February 2017
ERM

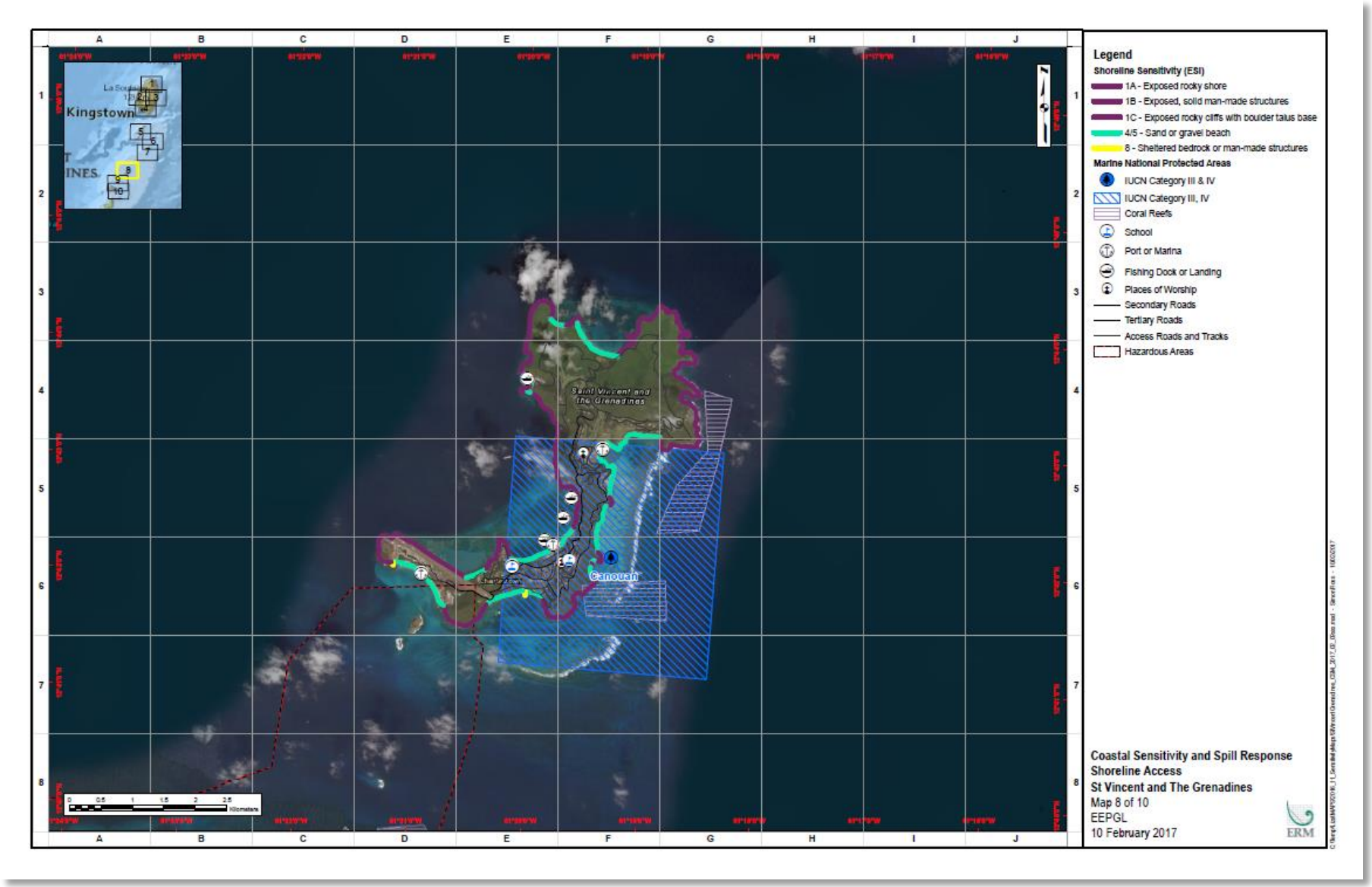

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
4/5 - Sand or gravel beach
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Seagrass
Police Stations
School
Places of Worship
Primary Roads
Access Roads and Tracks
Kingstown
Parrot Reserve (Mt. Pleasant Forest Reserve)
Mt. Pleasant
Parrot Reserve (Richmond Forest Reserve)
Cumberland
Parrot Reserve (Colonarie Forest Reserve)
Colonarie
Dalaway
Parrot Reserve (Dalaway Forest Reserve)
Kingstown
Saint Vincent and the Grenadines
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 3 of 10
EEPGL
10 February 2017
ERM

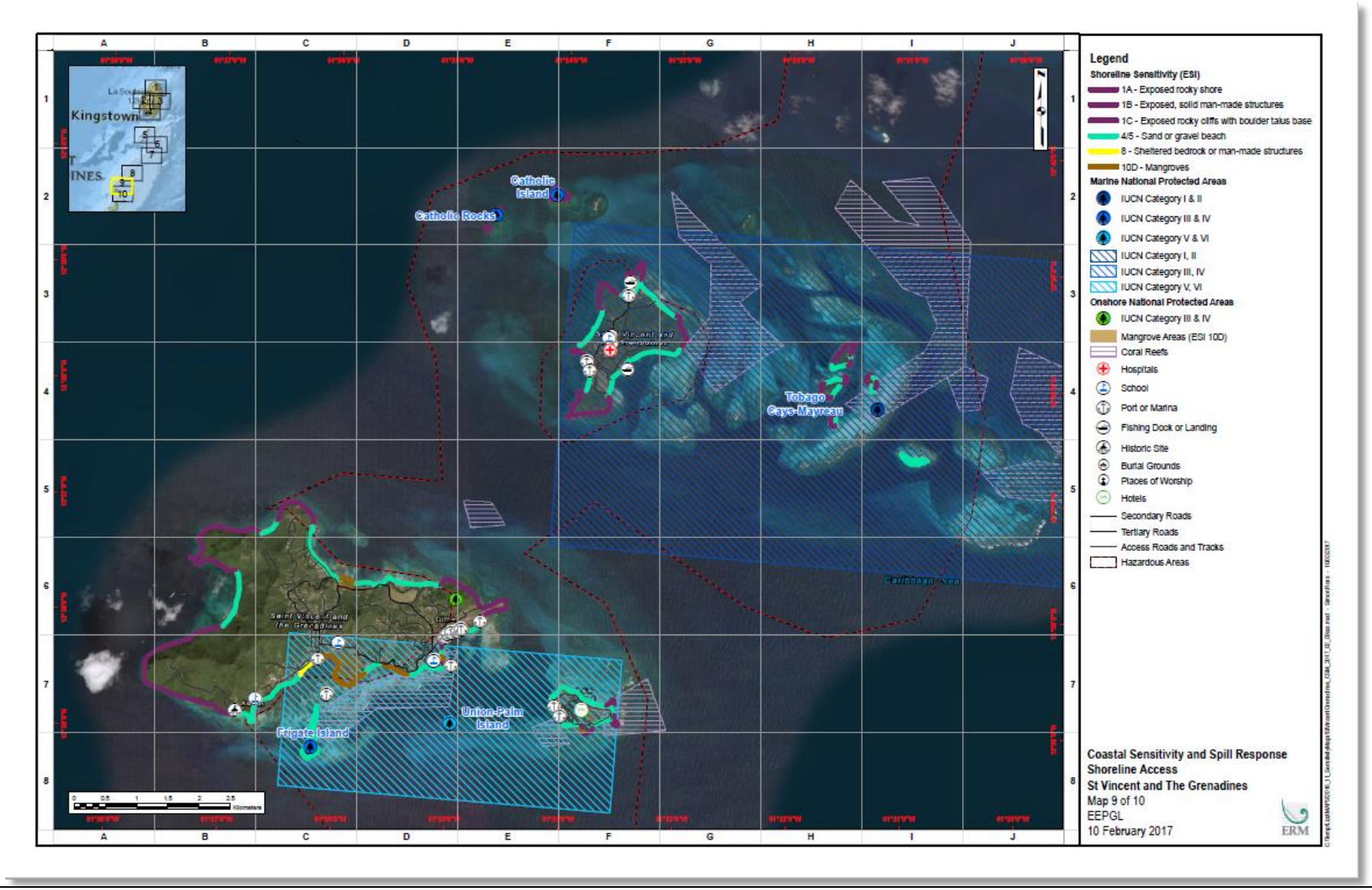

Kingstown
Dalaway River
Parrot Reserve (Dalaway Forest Reserve)
Parrot Reserve (Colonaire Forest Reserve)
Kingstown
Saint Vincent and the Grenadines
Campden Park
Kingshill
Young Island
South Coast
Milligan Island
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
3/4 - Sandy beaches or slopes
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8A - Sheltered scarps in bedrock, mud or clay
8D - Sheltered rocky rubble shores
Marine National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category I, II
IUCN Category III, IV
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Seagrass
Hospitals
Police Stations
Kindergarten
School
College
Port or Marina
Fishing Dock or Landing
Ferry Dock
Historic Site
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Seabed Cables
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 4 of 10
EEPGL
10 February 2017
ERM

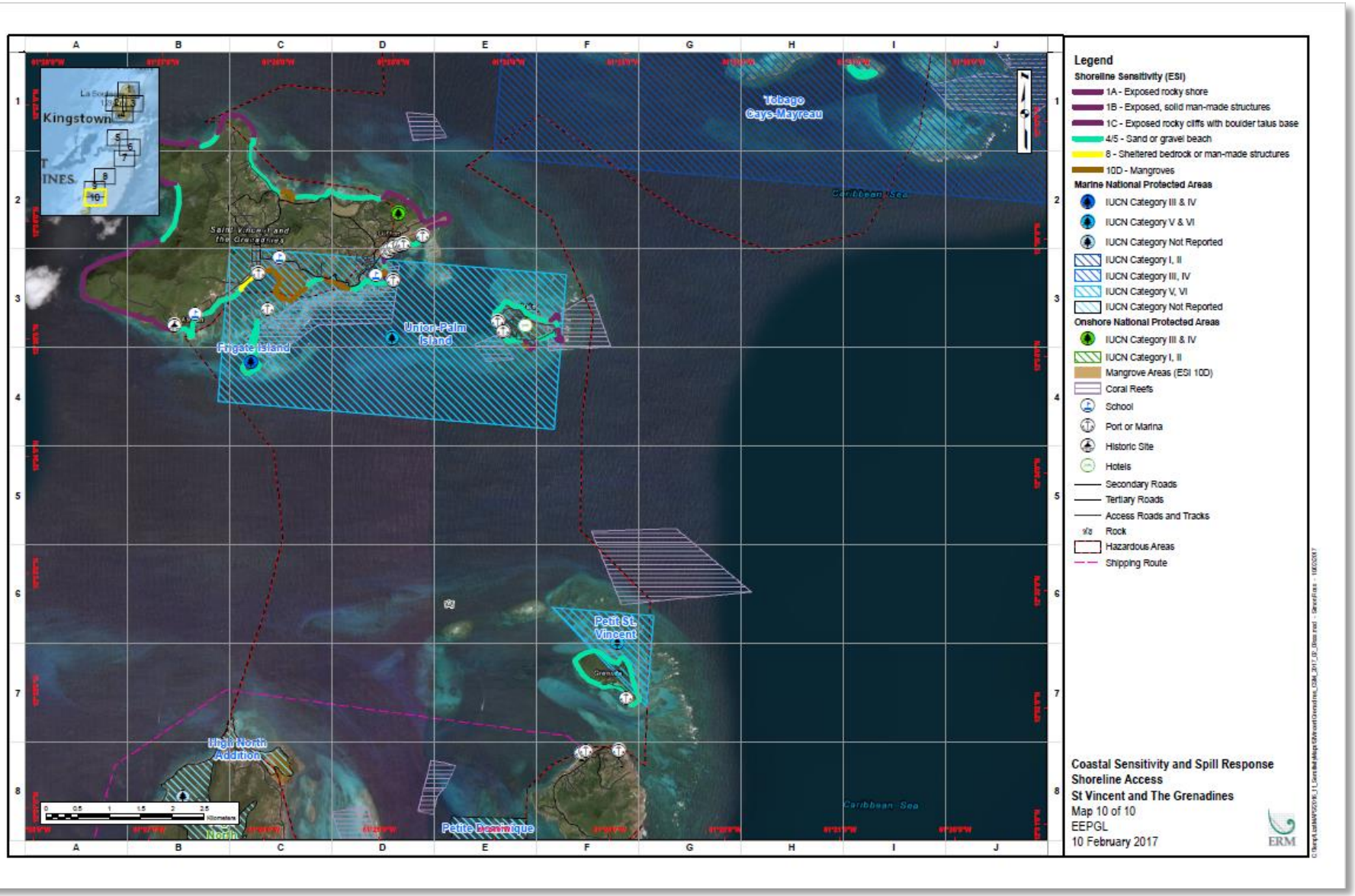

Kingstown
Bequia Marine
West Cay
Isle Quatre
Pigeon Island
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
Marine National Protected Areas
IUCN Category III & IV
IUCN Category V & VI
IUCN Category III, IV
IUCN Category V, VI
Coral Reefs
Seagrass
Hospitals
Police Stations
School
Fishing Dock or Landing
Ferry Dock
Government Facilities
Hotels
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 5 of 10
EEPGL
10 February 2017
ERM


Kingstown
Battowia Island
Baillicaux Island
Allwash Island
Mustique
Mustique
Mustique
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
Marine National Protected Areas
IUCN Category III & IV
IUCN Category V & VI
IUCN Category III, IV
IUCN Category V, VI
Coral Reefs
School
Fishing Dock or Landing
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Hazardous Areas
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 6 of 10
EEPGL
10 February 2017
ERM

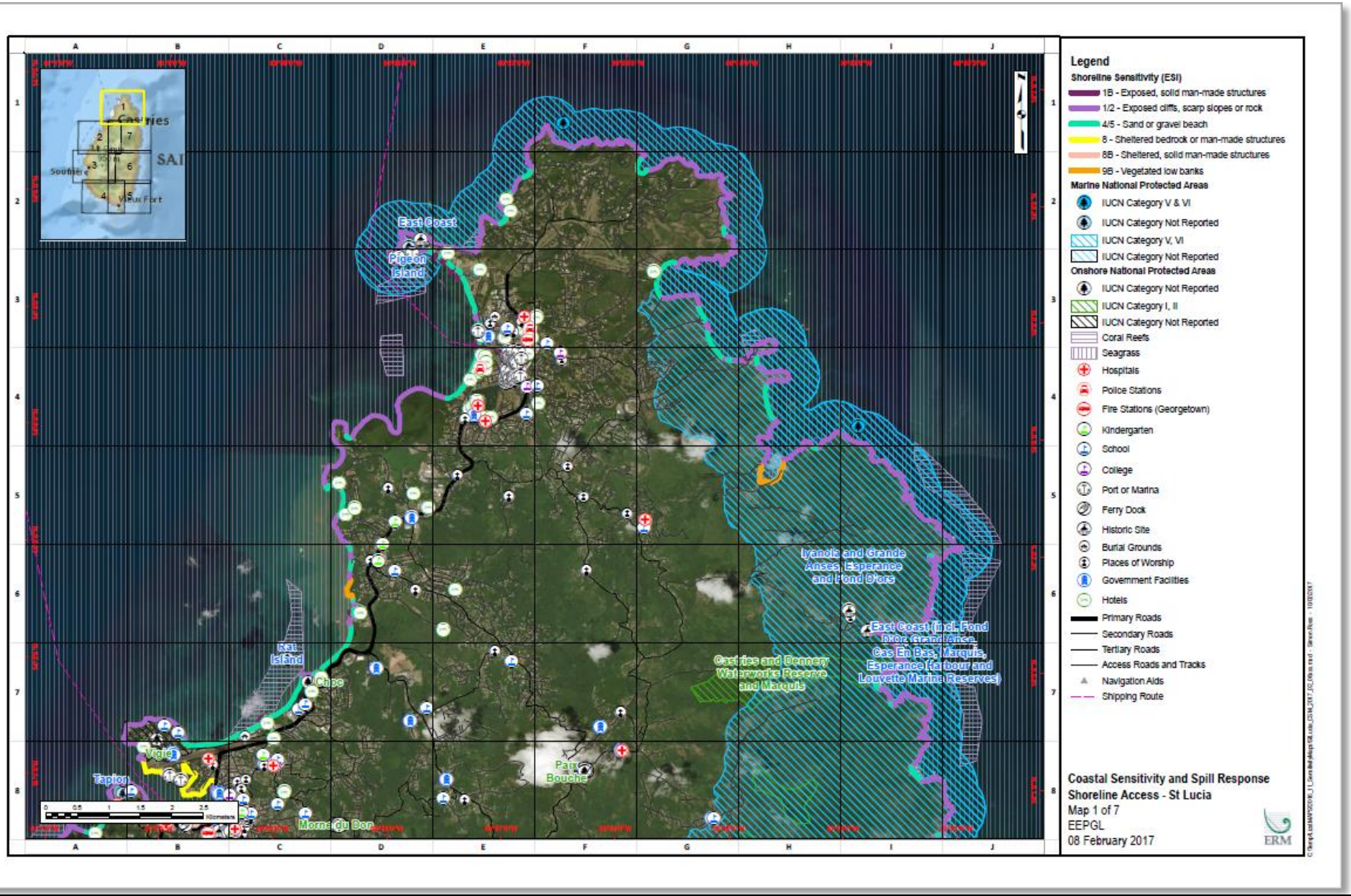

Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
2B - Exposed scarps and steep slopes in clay
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8D - Sheltered rocky rubble shores
Marine National Protected Areas
IUCN Category III & IV
IUCN Category V & VI
IUCN Category III, IV
IUCN Category V, VI
Coral Reefs
School
Fishing Dock or Landing
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Hazardous Areas
Kingstown
Mustique
Mustique
Mustique
Savan Island
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 7 of 10
EEPGL
10 February 2017
ERM

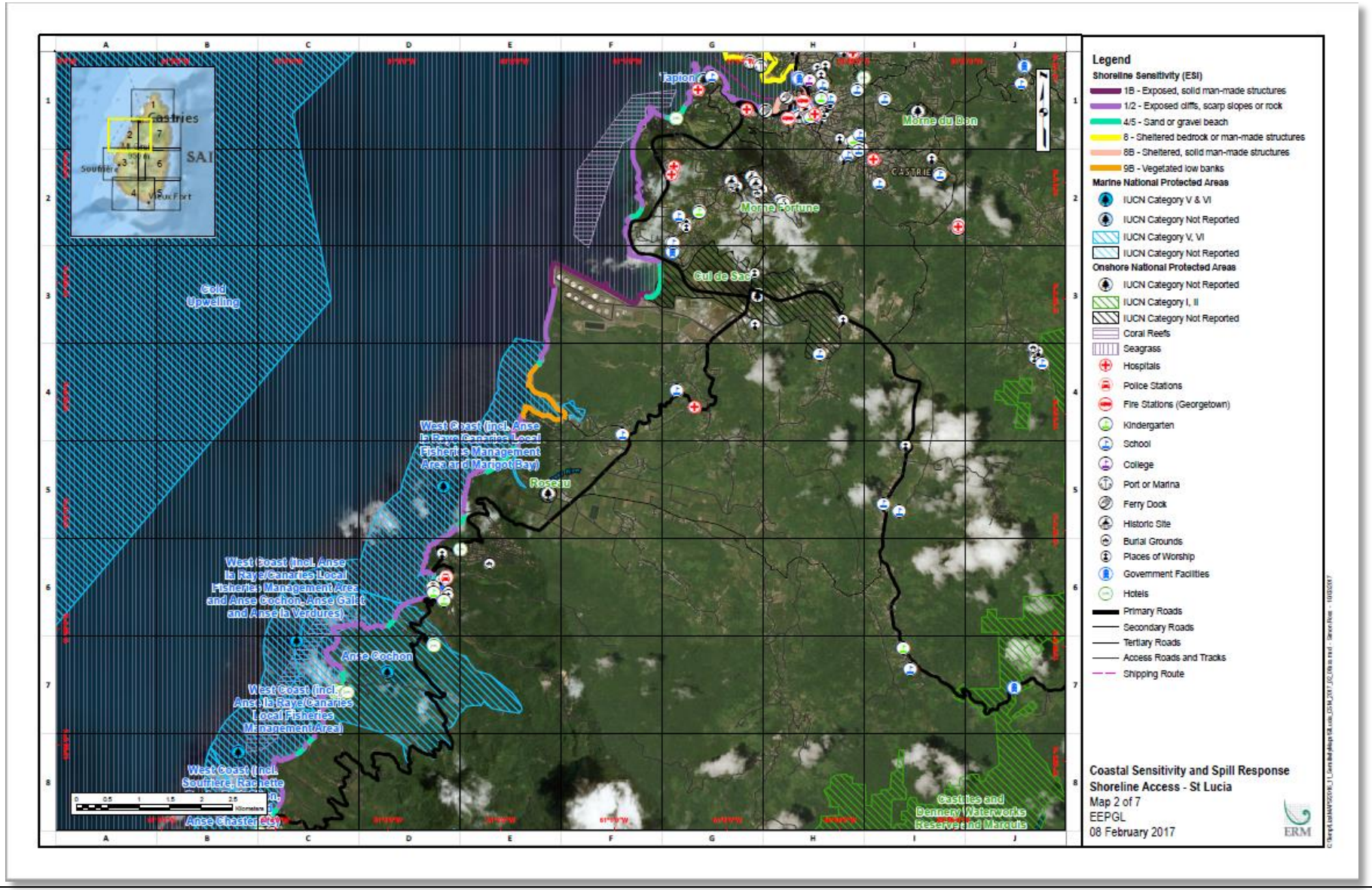

Kingstown
Saint Vincent and the Grenadines
Canouan
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
Marine National Protected Areas
IUCN Category III & IV
IUCN Category III, IV
Coral Reefs
School
Port or Marina
Fishing Dock or Landing
Places of Worship
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Hazardous Areas
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 8 of 10
EEPGL
10 February 2017
ERM

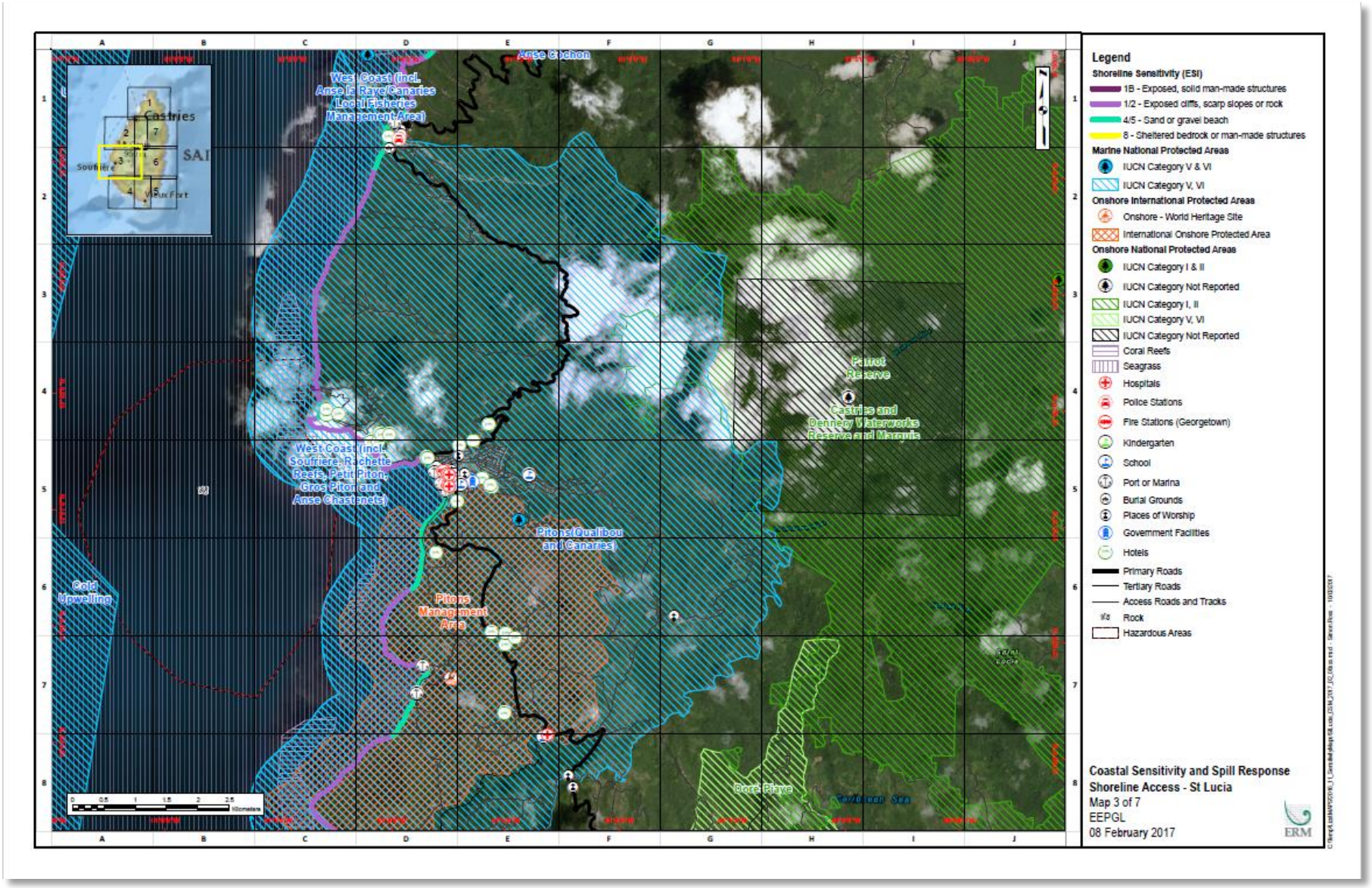

Kingstown
Catholic Island
Catholic Rocks
Tobago Cays-Mayreau
Union-Palm Island
Frigate Island
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
10D - Mangroves
Marine National Protected Areas
IUCN Category I & II
IUCN Category III & IV
IUCN Category V & VI
IUCN Category I, II
IUCN Category III, IV
IUCN Category V, VI
Onshore National Protected Areas
IUCN Category III & IV
Mangrove Areas (ESI 10D)
Coral Reefs
Hospitals
School
Port or Marina
Fishing Dock or Landing
Historic Site
Burial Grounds
Places of Worship
Hotels
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Hazardous Areas
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 9 of 10
EEPGL
10 February 2017
ERM

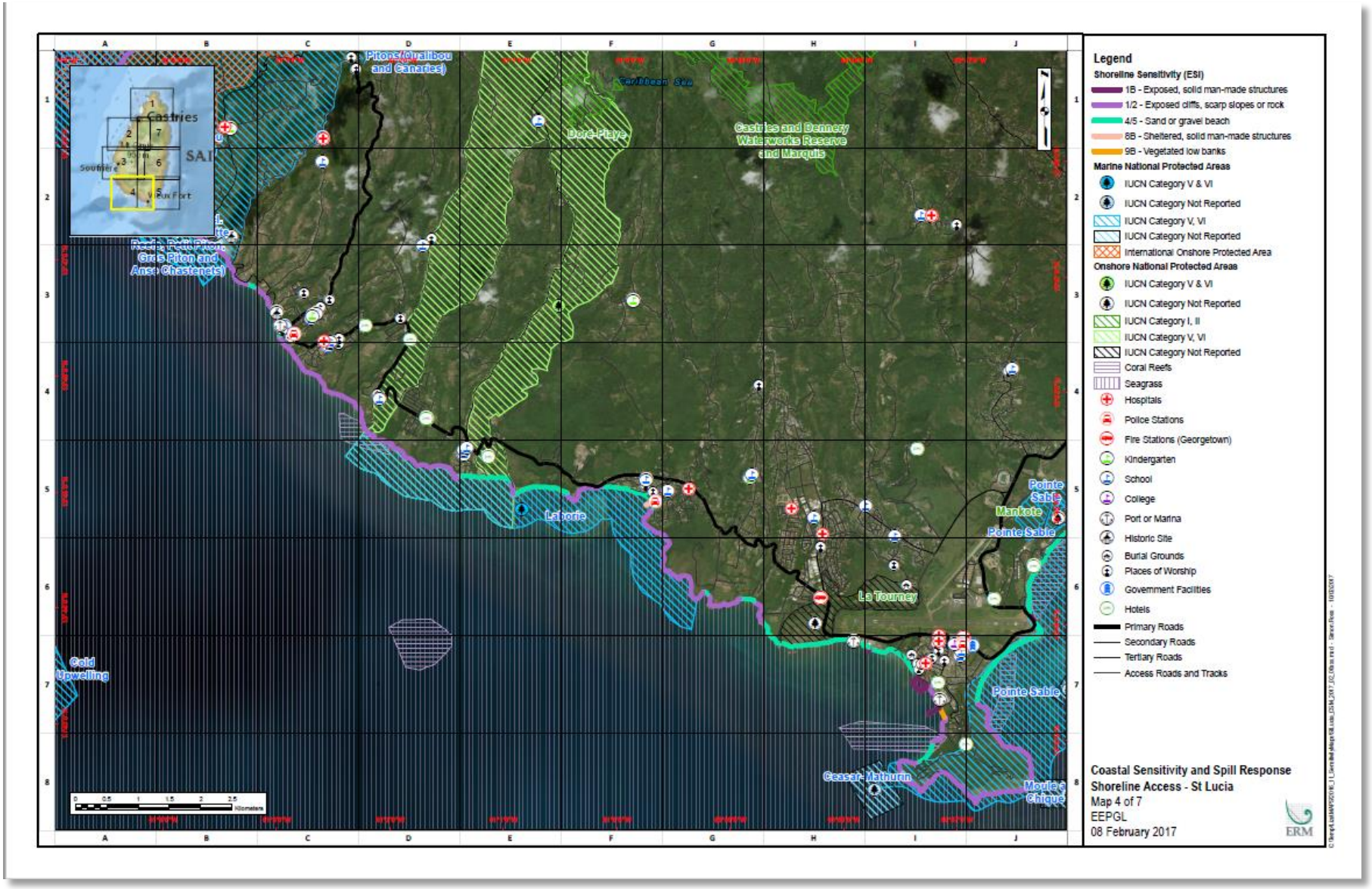

Kingstown
Tobago Cays-Mayreau
Caribbean Sea
Union-Palm Island
Frigate Island
Petit St. Vincent
High North Addition
Petite Martinique
Legend
Shoreline Sensitivity (ESI)
1A - Exposed rocky shore
1B - Exposed, solid man-made structures
1C - Exposed rocky cliffs with boulder talus base
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
10D - Mangroves
Marine National Protected Areas
IUCN Category III & IV
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category III, IV
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category III & IV
IUCN Category I, II
Mangrove Areas (ESI 10D)
Coral Reefs
School
Port or Marina
Historic Site
Hotels
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Rock
Hazardous Areas
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access
St Vincent and The Grenadines
Map 10 of 10
EEPGL
10 February 2017
ERM

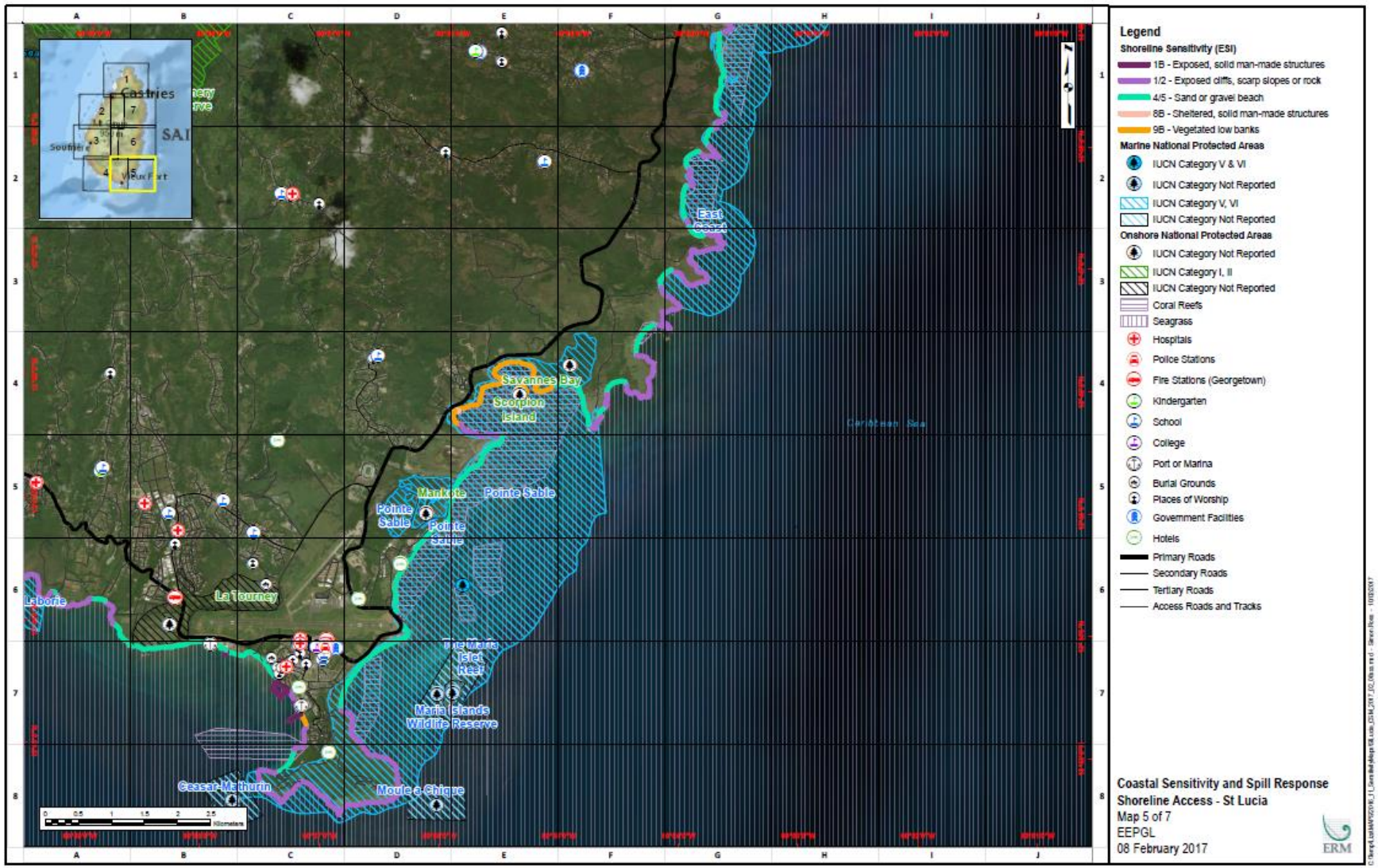
ST. LUCIA
Coastal Sensitivity Maps

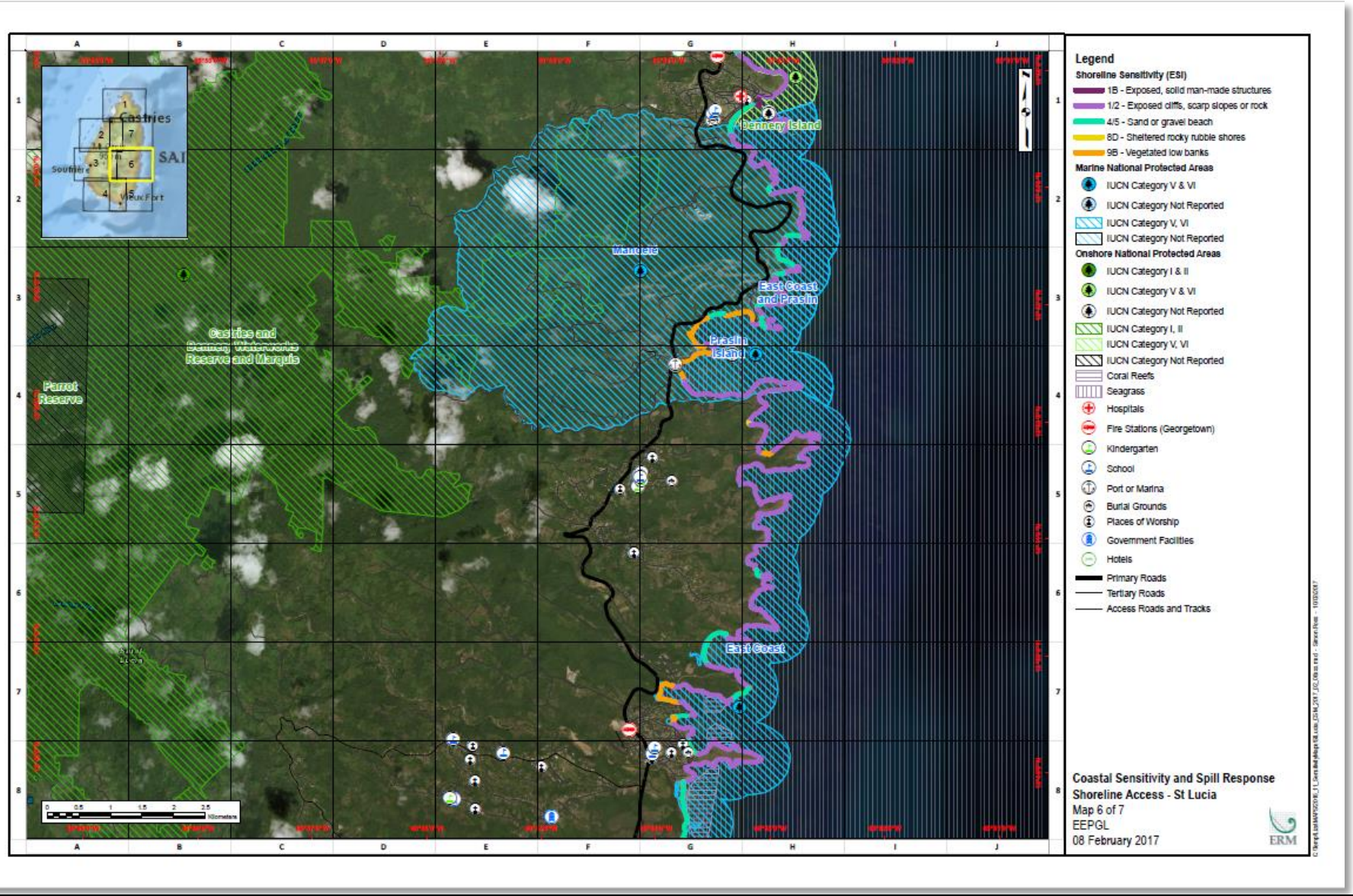

Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8B - Sheltered, solid man-made structures
9B - Vegetated low banks
Marine National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
College
Port or Marina
Ferry Dock
Historic Site
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Navigation Aids
Shipping Route
East Coast
Pigeon Island
Iyanola and Grande Anses, Esperance and Fond D'or
East Coast (incl. Fond D'or, Grand Anse, Cas En Bas, Marquis, Esperance Harbour and Louvette Marine Reserves)
Castries and Dennery Waterworks Reserve and Marquis
Rat Island
Choc
Vigie
Tapion
Pain Bouche
Morne du Bor
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 1 of 7
EEPGL
08 February 2017
ERM

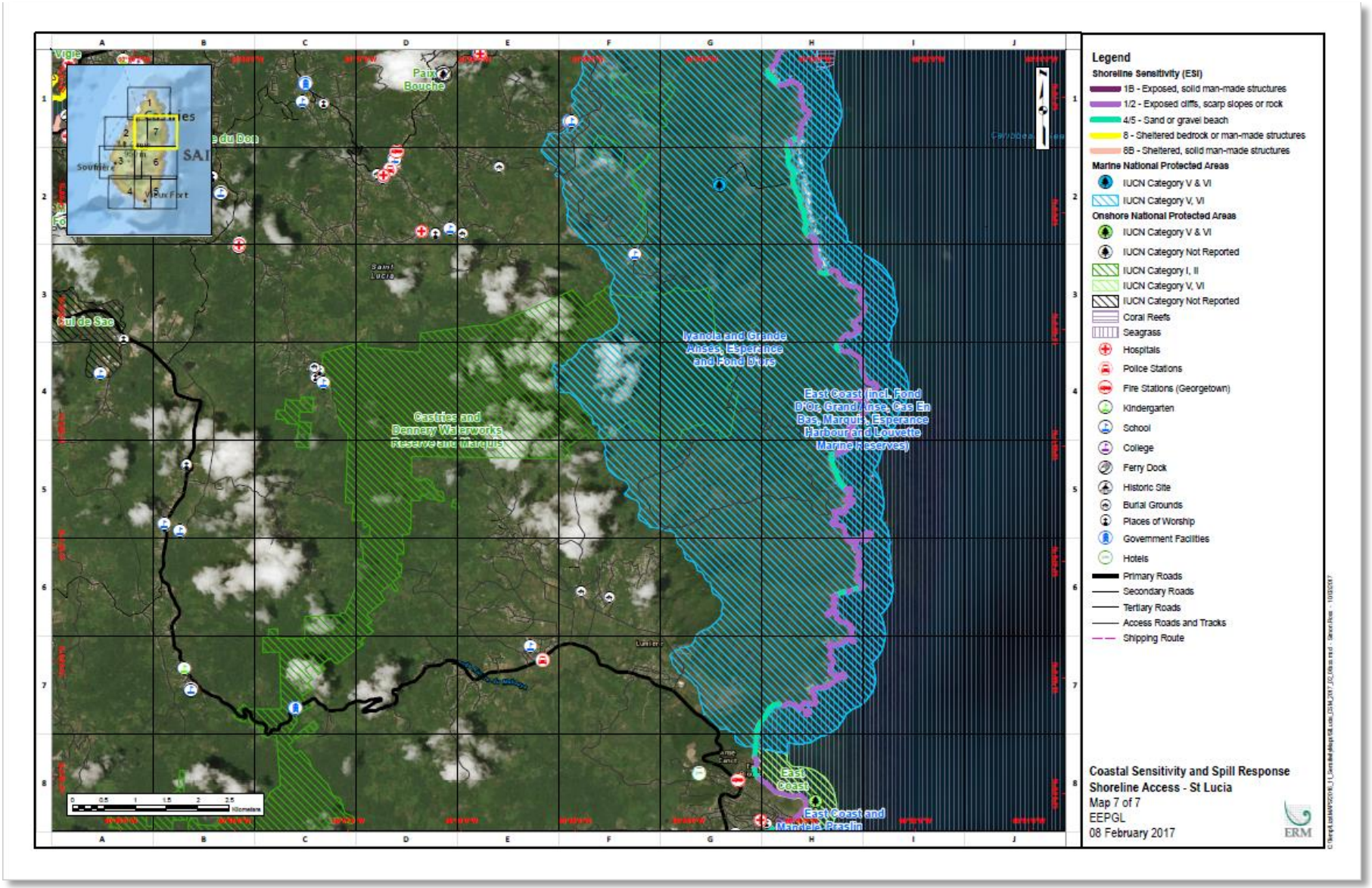

Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8B - Sheltered, solid man-made structures
9B - Vegetated low banks
Marine National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
College
Port or Marina
Ferry Dock
Historic Site
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 2 of 7
EEPGL
08 February 2017
ERM
Tapion
Morne du Don
CASTRIE
Morne Fortune
Cul de Sac
Cold Upwelling
West Coast (incl. Anse la Raye/Canaries Local Fisheries Management Area and Marigot Bay)
Roseau
West Coast (incl. Anse la Raye/Canaries Local Fisheries Management Area and Anse Cochon, Anse Galet and Anse la Verdures)
Anse Cochon
West Coast (incl. Anse la Raye/Canaries Local Fisheries Management Area)
West Coast (incl. Soufriere, Rachette
Anse Chastanet
Castries and Dennery Waterworks Reserve and Marquis
Castries
Soufriere
Vieux Fort
SAINT LUCIA


Anse Cochon
West Coast (incl. Anse la Raye/Canaries Local Fisheries Management Area)
Castries
SAI
Soufriere
Vieux Fort
Petrot Reserve
Castries and Dennery Waterworks Reserve and Maquis
West Coast (incl. Soufriere, Rachette Reefs, Petit Piton, Gros Piton and Anse Chastenet)
Pitons (Qualibou and Canaries)
Cold Upwelling
Pitons Management Area
Dore Playe
Caribbean Sea
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
Marine National Protected Areas
IUCN Category V & VI
IUCN Category V, VI
Onshore International Protected Areas
Onshore - World Heritage Site
International Onshore Protected Area
Onshore National Protected Areas
IUCN Category I & II
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
Port or Marina
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Tertiary Roads
Access Roads and Tracks
Rock
Hazardous Areas
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 3 of 7
EEPGL
08 February 2017
ERM


Pitons (Gros Piton and Petit Piton)
Caribbean Sea
Dore-Piaye
Castries and Dennery Waterworks Reserve and Marquis
Gros Piton and Anse Chastenets
Laborie
Pointe Sable
Mankote
Pointe Sable
La Tourney
Cold Upwelling
Pointe Sable
Ceasar Mathurin
Morne à Chique
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8B - Sheltered, solid man-made structures
9B - Vegetated low banks
Marine National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category V, VI
IUCN Category Not Reported
International Onshore Protected Area
Onshore National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
College
Port or Marina
Historic Site
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 4 of 7
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
6B - Sheltered, solid man-made structures
9B - Vegetated low banks
Marine National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category Not Reported
IUCN Category I, II
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
College
Port or Marina
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 5 of 7
EEPGL
08 February 2017
ERM
Castries
Savannes Bay
Scorpion Island
Pointe Sable
Laborie
La Tourney
Maria Islands Wildlife Reserve
Ceasar Mathurin
Moule a Chique
East
Caribbean Sea


Castries
Vieux Fort
Pennery Island
Marie Ile
East Coast and Praslin
Praslin Island
Castries and
Reserve and Marquis
Parrot Reserve
East Coast
Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8D - Sheltered rocky rubble shores
9B - Vegetated low banks
Marine National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category V, VI
IUCN Category Not Reported
Onshore National Protected Areas
IUCN Category I & II
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Fire Stations (Georgetown)
Kindergarten
School
Port or Marina
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Tertiary Roads
Access Roads and Tracks
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 6 of 7
EEPGL
08 February 2017
ERM


Legend
Shoreline Sensitivity (ESI)
1B - Exposed, solid man-made structures
1/2 - Exposed cliffs, scarp slopes or rock
4/5 - Sand or gravel beach
8 - Sheltered bedrock or man-made structures
8B - Sheltered, solid man-made structures
Marine National Protected Areas
IUCN Category V & VI
IUCN Category V, VI
Onshore National Protected Areas
IUCN Category V & VI
IUCN Category Not Reported
IUCN Category I, II
IUCN Category V, VI
IUCN Category Not Reported
Coral Reefs
Seagrass
Hospitals
Police Stations
Fire Stations (Georgetown)
Kindergarten
School
College
Ferry Dock
Historic Site
Burial Grounds
Places of Worship
Government Facilities
Hotels
Primary Roads
Secondary Roads
Tertiary Roads
Access Roads and Tracks
Shipping Route
Coastal Sensitivity and Spill Response
Shoreline Access - St Lucia
Map 7 of 7
EEPGL
08 February 2017
ERM
Vigie
Pointe du Dom
Saint Lucia
Cul de Sac
Castries and Dennery Waterworks Reserve and Marquis
Ivanola and Grande Anses, Esperance and Fond D'or
East Coast (incl. Fond D'or, Grand Anse, Cas En Bas, Marquis, Esperance Harbour and Louvette Marine Reserves)
East Coast
East Coast and Mamiku Praslin

Appendix E WILDLIFE RESPONSE PLAN

Wildlife Response Plan

Prepared for

Esso Exploration and Production Guyana Limited (EEPGL)



ExxonMobil Biomedical Sciences, Inc.

Richard A. Davi

January 27, 2017

1. Introduction

Objective

Prevention of oil spills remains the top priority for EEPGL. In the unlikely event of a spill, it is important to be prepared to minimize the duration and impact of any release. For a subsea well release, capping and containment measures are available to serve this purpose. Beyond those mitigation measures, it is important to have a robust spill response capability utilizing all appropriate tools. The proper selection and use of those tools should be based on minimizing overall harm to environmental and economic resources. A critical aspect of protecting wildlife once oil is released is to minimize the formation of floating slicks and when formed to prevent such slicks from coming ashore driven by wind/currents. As this is not always possible more detailed wildlife response planning is necessary.

This Wildlife Response Plan is supplemental to the Esso Exploration and Production Guyana Limited (EEPGL) Oil Spill Response Plan (OSRP) and is intended to serve as general guidance for wildlife deterrence (hazing), capture, and rehabilitation during an oil spill response. The principal objectives of Wildlife Operations during a spill are:

- Provide the best achievable protection of wildlife and habitats from contamination;
- Minimize injuries to wildlife and habitats from contamination;
- Minimize injuries to wildlife from the cleanup;
- Provide the best achievable capture and care for injured wildlife;
- Document adverse effects that result from the spill and cleanup; and
- Prevent injuries to responders and the public.

In the event of potential wildlife impacts, EEPGL personnel will immediately contact and request assistance/expertise from the ExxonMobil Regional Response Team (RRT), ExxonMobil Biomedical Sciences Inc. (EMBSI), and Sea Alarm/Oil Spill Response Ltd (OSRL). Contact numbers are listed in Table 3-1. Initial wildlife response guidance is provided in Appendix G of this plan.

Potential Oil Spill Impacts on Wildlife

Wildlife may be vulnerable to oiling depending on their behavior, food preferences, and habitat requirements. They may encounter oil in near-shore and intertidal areas, and at sea. The number of individuals and species affected by an oil spill will depend on the size of the spill, chemistry of the petroleum product spilled, meteorological and oceanographic conditions, time of year, and the location of the spill. Species feeding in intertidal and near-shore areas are often vulnerable to oiling. Many important bird and turtle habitats are located in near-shore and intertidal areas. Some mammals may scavenge for food in intertidal areas and may encounter oiled carcasses. Foraging animals may encounter and ingest oil-contaminated vegetation or other oil-contaminated food sources in coastal areas.

Seabirds are highly vulnerable to oiling since they feed and rest on the water surface. Whales and dolphins have low vulnerability to oiling as these animals tend to avoid areas that are oiled.

Turtles generally have a low vulnerability to oiling, but vulnerability may increase during nesting seasons.

Exposure to oil can occur from swimming or wading through oil. Ingestion of oil may occur if an animal attempts to clean its oiled feathers or fur. Another route of oil exposure is through the consumption of oil-contaminated food or water.

General effects of oil on wildlife can be separated into physical and toxicological effects. An example of a physical effect is loss of water repellency and insulating properties of feathers when birds become oiled. As a result, the ability to thermo-regulate may be impaired or lost.

Toxicological effects of oil on wildlife include irritation of the eyes, skin, mucous membranes, lungs, and digestive tract. Organ damage and disruption of immune responses may occur. Effects of oil on wildlife reproduction may include altered breeding behavior, decreased hatching success, and decreased survival rates of the young.

Protected Species and Areas of Special Value

Protected species and associated habitats that are at risk of oiling should be given priority protection during an oil spill response. In oiled wildlife response planning, it is important to consider:

- Input from appropriate regulatory agencies;
- Seasonality of species occurrences (breeding, nesting, and migration periods);
- Habitats important for breeding, nesting, feeding, or resting;
- Areas of high density occurrences; and
- Prioritization for protection of important habitats identified in the oil spill response plans.

Appendices A, B, C and D of this plan describe some of the habitats, birds, and marine reptile and mammal species that are at risk of oiling from EEPGL operations. In these appendices, information is provided for key sensitive periods (nesting, molting, migration, breeding, and rearing).

Basis for Wildlife Response Plan

Under the country's Environmental Protection Act, companies active in oil and gas exploration or drilling must prepare an Emergency Response Plan / Oil Spill Contingency Plan that includes provisions for rescuing and restoring plants, animals, etc. (i.e., Oiled Wildlife Response Plan, and Environmental Management or Pollution Prevention Plan). An oiled wildlife response plan provides for pre-planning for the protection of sensitive habitats and species while considering seasonal effects and behaviors. The plan facilitates the identification of protocols, and resources (equipment and personnel) necessary to respond to an incident in a timely manner. Lastly, the plan identifies the needs and capabilities necessary to reduce or avoid impacts to sensitive habitats and species during an oil spill response.

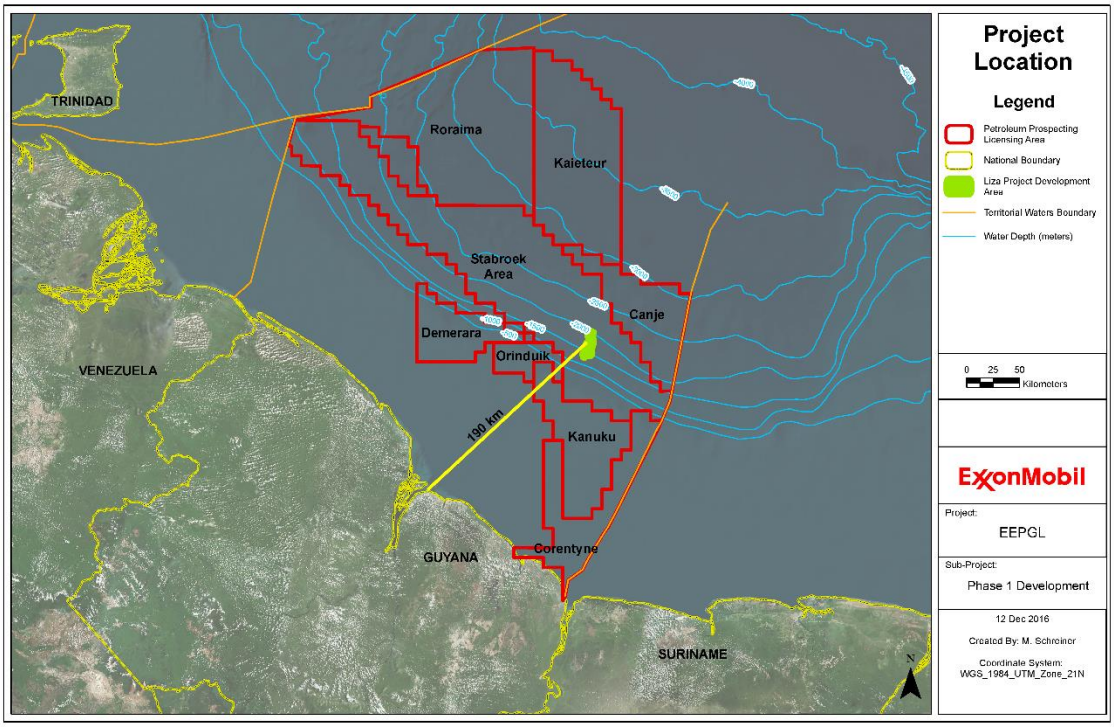
Geographical Extent of Response

The geographic area of concern for response activities for wildlife is typically defined by the extent of the influence of the Project and its alternatives. The normal extent of this Project's influence on relevant resources include the Liza Project Development Area (PDA), which is an

approximately 50 km^2 area located 190 km (~120 mi) offshore. In the case of an unplanned event in the form of a larger spill, the sea surface area that could be potentially affected ranges from 835 to 19,400 km^2 as further reflected in the modeling results provided in Appendix A of the OSRP.

The Project will also involve the use of onshore marine and aviation support facilities including shore-bases located in coastal harbours and rivers, heliports, and the associated routes that would be traversed by such support vessels and helicopters between these facilities and the drilling and production areas.

Seasonal winds and the prevailing Guiana Current may extend the area of an oil spill response outside of the Guyana Economic Exclusion Zone, north to the territorial waters of Venezuela, Trinidad and Tobago and several islands in the Lesser Antilles.



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana.*

Figure 1-1. Stabroek Area of Interest

2. Incident Command System and Tiered Response

This section provides a general overview of the Incident Command System (ICS) and a tiered approach used for oil spill response, with emphasis on wildlife response activities. The ICS designed to provide a framework for a consistent, efficient, and effective means to train, activate, and implement EEPGL's response resources. The ICS also facilitates interaction with Contractors, Subcontractors, Guyana government agencies, and non-government organizations that could become involved during a spill response. Table 2-1 shows the sections and key activities of the ICS.

Table 2-1 Key ICS Sections and Activities

ICS Function	Activities
Command Staff	• Overall Oil Spill Response Management • Management Liaison • Government Liaison • Community Liaison • Media/Public Affairs Liaison • Legal Support • Safety and Health Oversight
Operations Section	• Oil Spill Source Control • Site Safety and Security • Surveillance • Dispersant Application • *In-Situ* Burning • Offshore/Near-shore Containment and Recovery • On Land Containment and Recovery • Shoreline, River, and Resource Protection • Pre-Impact Debris Removal • Shoreline Treatment and Cleanup • Bioremediation • Waste Management • Wildlife Deterrence, Capture, and Rehabilitation
Planning Section	• Site Characterization and Analysis • Documentation • Spill Tracking and Surveillance • Sensitive Areas Identification and Characterization • Environmental Monitoring • Incident Action Plan Coordination • Oil Spill Sampling • Oil Spill Response Technical Support • Dispersant / *In-Situ* Burning Support • Waste Management Support • Demobilization
Finance and Logistics Sections	• Transportation (Air, Water, Land) • Housing • Catering • Telecommunications • Customs Clearance • Security • Field Operations Support • Personnel Resourcing • Material Distribution

The structure for the wildlife response organization is designed to fit within the ICS and allows for the integration of wildlife activities into the entire oil spill response plan (IPIECA, 2004).

Wildlife response is typically managed under the Wildlife Branch of the Operations Section of the ICS and coordinated through the Environmental Unit of the Planning Section. For example, the Planning Section identifies and characterizes environmentally sensitive areas and wildlife at risk. The Operations Section is responsible for wildlife deterrence, capture, rehabilitation, and shoreline protection. See Appendix G for initial response activities of the Wildlife Branch.

The tiered response system provides preparedness for the full range of scenarios that may be imaginable, from an insignificant wildlife incident (a few animals threatened or affected) to a worst-case incident (e.g. thousands of animals, a mix of species groups, large stretches of complicated shorelines).

In a tiered response, assets are mobilized locally or from further afield according to the size and complexity of the incident and the availability of appropriate resources. In a Tier 1 response, assets are mobilized within hours of notification of the incident; and can be sourced from pre-identified stocks located at either the Guyana Shorebase or the Trinidad Shorebase, to deal with an incident in its early stage of development. If a more complicated scenario begins to unfold (Tier 2 or 3), EEPGL would activate additional resources such as the ExxonMobil Regional Response Team or OSRL to mitigate the impacts of the spill.

3. Response Personnel

Only trained and qualified personnel should haze, capture, transport, and rehabilitate oiled wildlife. ExxonMobil has contracts in place with two internationally recognized oiled wildlife response organizations: International Bird Rescue (IBR) and Tri-State Bird Rescue & Research, Inc. Experts from these two organizations, and other available international organizations, can be mobilized to Guyana within days by contacting Sea Alarm. ExxonMobil is a participant in a Global Oiled Wildlife Response System (GOWRS) which is monitored by Sea Alarm. Wildlife response experts who are prepared to assist ExxonMobil during an oil spill are listed in Table 3-1.

The OSR Wildlife Plan will be implemented with the assistance of trained and qualified contractors and support groups. Upon notification, contractors and trained local experts (if applicable) will mobilize equipment and trained personnel to the spill site and begin wildlife response operations. Wildlife Response equipment for the initial response is available through OSRL in Fort Lauderdale, Florida, USA. Additional equipment will be brought in as needed. Wildlife response standard operational protocols can be supplied by wildlife experts at the time of response or developed ahead of time to cover Sections 4-9 below.

There are no wildlife rehabilitators in Guyana with oiled wildlife experience. There are also no permanent facilities for oiled wildlife rehabilitation and few organized wildlife rehabilitation programs in the country. The Karanambu Trust may be able to help should otters be affected by a spill. The Guyana Marine Turtles Conservation Society (GMTCS) would likely be involved in marine turtle response. Several small facilities in Trinidad and Tobago are available for Tier 1 responses, and are listed below.

Conservation organizations in Guyana include:

Government Ministries:

- Environmental Protection Agency;
- Protected Areas Commission;
- Guyana Forestry Commission;
- Wildlife Management Authority.

Non-Governmental and Academic Institutions:

- Conservation International;
- Guyana Marine Turtles Conservation Society (GMTCS);
- Guyana Tropical Birds Society;
- Guyana Mangrove Restoration Project;
- Centre for the Study of Biological Diversity;
- School of Earth and Environmental Sciences, University of Guyana;
- Environmental Clubs of Guyana.

Organizations in Trinidad and Tobago:

- Wildlife Orphanage and Rehabilitation Center – WORC (Trinidad);
- El Soccoro Center for Wildlife Conservation (Trinidad);
- Pointe-a-Pierre Wildfowl Trust (Trinidad);
- Tobago SPCA (Tobago).

Table 3-1. Contact Information for Wildlife Experts and Responders

Contact	Contact Name	Contact Information	Comments
GDF Coast Guard	Operations Center	+592-226-8488	Spill notifications
Guyana Environmental Protection Agency	Duty Officer	+592-225-5467 or +592-225-5469	Spill notifications
Guyana Ministry of Natural Resources and the Environment	Department of Governance	+592-231-2506 ministry@nre.gov.gy	Spill notifications
Harbour Master Starbroek, Georgetown	Duty Officer	+592-226-7842	Spill notifications
Guyana Marine Turtle Conservation Society (GMTCS)	Michelle Kalamandeen, Project Coordinator	+592-665-4876 gmtcs@bbgy.com	Conservation organization
The Karanambu Trust	Diane McTurk Executive Director	www.karanambutrustandlodge.org	Giant Otter expertize
ExxonMobil Biomedical Sciences, Inc. (EMBSI)	Richard Davi Richard Woods	+1 (908) 730-1111 richard.a.davi@exxonmobil.com richard.w.woods@exxonmobil.com	Wildlife Response Issues
Sea Alarm	Hugo Nijkamp	(Office) +322 2788 744 (Mobile) +32 494900012 (Mobile) +32 499624772 Nijkamp@sea-alarm.org	Oiled Wildlife Response facilitator
Oil Spill Response Ltd. (OSRL)	Duty Manager Fort Lauderdale, FL, USA	+1 (954) 983-9880 +44 (0)23 8033-1551 (UK)	Wildlife Response equipment
IBR (International Bird Rescue)	Barbara Callahan	+1 (907) 230-2492 barbara.callahan@bird-rescue.org	ExxonMobil has a contract in place with IBR

Contact	Contact Name	Contact Information	Comments
Tri-State Bird Rescue & Research, Inc., Delaware	Dr. Heidi Stout, veterinarian	Main +1 (302) 737-9543 hstout@tristatebird.org www.tristatebird.org	ExxonMobil has a contract in place with Tri-State
WORC (Trinidad)	No contact name available	299 Queen Elizabeth Avenue Petit Valley, Trinidad and Tobago, West Indies Tel: (868) 637-3842 Email: worctrinidad@gmail.com	Oiled wildlife facility in Trinidad (25 animal capacity)
El Socorro Center for Wildlife Conservation	Gia Narinesingh Ricardo Meade	Freeport, Trinidad and Tobago +1 (868) 673-5753	Wildlife facility in Trinidad (limited capacity)
Pointe-a-Pierre Wildfowl Trust	Molly Gaskin – Trust President	St. James, Trinidad +1 (868) 658-4200 ext. 2512	Wildlife facility in Trinidad (limited capacity)

A licensed veterinarian is integral to the oiled wildlife response organization. The veterinarian, using a pre-approved decision tree, will confer with the appropriate Guyana authorities and fauna experts to decide which oiled animals should be rehabilitated and which animals should be euthanized. For those animals that will be rehabilitated, the veterinarian administers or supervises the appropriate treatment.

According to the Guyana Agriculture Ministry, there are 45 active veterinarians in Guyana. Contact can be made through the Guyana Veterinary Association.

Trained and qualified personnel are essential to an oiled wildlife response. The training that each person receives will depend on the task that the person will perform during the response. Personnel may conduct wildlife deterrence operations or search for and capture oiled animals. Other personnel may stabilize and transport oiled animals to a treatment area. Once oiled animals arrive at the treatment area, additional personnel maintain records on the animals, clean pens, and prepare food for the animals. Qualified personnel that have received additional training may perform tasks such as administering fluids to dehydrated animals, take blood samples from animals, and wash oiled animals.

4. Training and Health and Safety

Worker health and safety are a priority during oiled wildlife response operations. The following is a summary list of safety precautions that need to be considered in the development of the Wildlife HSE Plan. Additional safety plans may need to be written for operation of specialized equipment (such as propane cannons, etc).

- Be proficient with Safety Data Sheets (SDS);
- Recognize that most common hazards are slips, trips, and falls;
- Maintain necessary immunizations, including tetanus and hepatitis;
- Observe all industrial hygiene safety precautions stated in the Safety Plan;
- Ensure proper training regarding hazards of the work task, and the proper use of personal protective equipment (PPE);
- ALWAYS work in teams; never conduct wildlife rescue work alone;
- Don’t overwork;

- Keep animals at or below one's waist level to protect the face and eyes from pokes, bites, and scratches;
- Wear approved personal protective equipment;
- Always remove PPE and wash hands and face with soap and water or approved cleaners before eating, drinking, or smoking;
- Never eat, drink, or smoke in wildlife handling areas;
- Minimize contact with contaminated materials and inhalation of vapors even when wearing PPE;
- Keep all oil, cleaning compounds, and contaminated materials away from face, eyes, and skin;
- Ensure work areas are clean and well ventilated;
- Report all injuries and illnesses to the supervisor and/or Command Center medical staff;
- Do not work with oiled wildlife if you are ill, pregnant, have an immunosuppressive condition, or are taking medication that might affect your natural immunity.

4.1 Training for Wildlife Response Personnel

In addition to being trained in specific wildlife response tasks, personnel will be trained to recognize and prevent oil-related and physical hazards associated with wildlife response operations. Complete training will be given to a core group prior to participation in oiled wildlife response activities.

4.1.1 Personal Protective Equipment (PPE)

To prevent exposure to oil and injury from wildlife, workers should wear approved personal protective equipment appropriate to their task. The following is a list of recommended PPE:

- Full eye protection (goggles or safety glasses) – eye protection is required when handling animals, especially birds. Birds will peck when under stress and should be considered dangerous as they will aim for eyes;
- Oil resistant rain gear or oil protective clothing (coated Tyvek, Saranex, etc.);
- Gloves (neoprene or nitrile rubber) that are oil resistant and waterproof and provide protection against beaks and claws;
- Non-skid shoes / boots, which are oil resistant and waterproof;
- Duct tape, used to tape rain jacket sleeves to gloves and rain pants to boots;
- Ear protection (muff or ear plug type) during deterrent operations, if appropriate;
- Respiratory protection, if appropriate.

In addition, the following PPE are recommended:

- Long-sleeved shirts;
- Hat (to provide shade in hot weather);
- Change of clothes (to rest or leave in);
- Clean towel / toiletries;
- No jewelry (birds will peck at bright, shiny objects).

Clothing and equipment to protect against bites and scratches should be worn underneath the oil protective equipment whenever necessary. Respiratory protection from organic vapor hazards may also be required for some operations. If respirators are used, respirator training and fit testing are required. Workers will be trained in the proper use and limitations of all PPE prior to using the equipment.

4.2 Worker Safety

Worker safety is the primary consideration in wildlife handling. Handling and restraint techniques appropriate for specific species need to be applied by trained and experienced personnel.

Oiled wildlife response is often physically and emotionally stressful. Dehydration, exhaustion, and poor nutrition can affect a person's ability to assess and react to a dangerous situation. It is therefore important that workers stay well hydrated and eat nutritionally sound meals. Rest is equally important. The safety of all depends on the alertness of each individual.

In addition to hazards from oil, numerous physical hazards may be associated with wildlife response activities. Workers should be aware of changing weather conditions, strong undertows in tidal areas, slick surfaces along shorelines. Personal flotation devices should be worn for all on-water and in-water operations.

4.3 Zoonosis

Wildlife may carry diseases that are transmissible to people. Diseases that are transmitted from animals to humans are called zoonoses, they may be viral, bacterial, fungal, or parasitic. **Individuals who have immunosuppressive conditions are more susceptible to contracting zoonotic diseases.**

Zoonoses can be transmitted to humans by:

- Inhalation of particles (spores, bacteria) in the air;
- Ingestion of feces (i.e. projectile feces, poor hygiene, etc.);
- Contact with the skin.

To reduce risk of contracting a zoonotic disease, wildlife handlers should always:

- Wash hands thoroughly with soap and water after handling wildlife;
- Wash hands well before and after eating or smoking;
- Smoke, drink, or eat in designated areas only and not near wildlife;
- Clean and treat all cuts and scratches;
- Use gloves as much as possible;
- Use surgical masks as appropriate.

In addition, there is a potential health risk to poultry, farm, and domestic animals (including pets) from clothing or equipment that has been in contact with wildlife. Return used oil spill response equipment and supplies for proper decontamination or disposal. Thoroughly wash, and disinfect as appropriate, all personal items after completing wildlife response tasks for the day.

5 Wildlife Deterrence (Hazing)

5.1 Introduction

The primary strategy for wildlife protection is controlling the spread of spilled oil to prevent or reduce oil contamination of potentially affected species and habitats. Removal of oiled debris and contaminated food sources also protects wildlife. Another method of wildlife protection is deterrence or hazing. Hazing is the term used when a variety of deterrents are used to prevent wildlife from entering areas already oiled or areas that are in the projected pathway of the oil. Hazing should be carefully planned and executed, since hazed wildlife could move into other oiled areas.

Common hazing techniques include:

- Making noise with pyrotechnics, firearms, air horns, motorized equipment, or recorded bird alarm sounds;
- Using scare devices such as mylar tape, helium-filled balloons, scarecrows, predator effigies in oiled areas;
- Herding wildlife using aircraft, boats, ATVs, UAVs, or other vehicles;
- Hazing by human presence.

Information necessary to help determine whether or not to begin hazing operations include time of year, availability of nearby uncontaminated habitat, proximity of nesting colonies and location of species in relation to the spill. The decision tree for hazing is presented in Figure 5-1. Once the decision to haze is made, review the hazing plan with the Operations Section Chief, Incident Commander, and other appropriate authorities and obtain all necessary approvals, and permits (if required). Initiate deterrence activities as soon as possible. Whether or not a deterrent operation will be effective depends on the habitat, season, species, and their residency status and age. Deterrent effectiveness can decrease for birds occupying key habitat areas (established nesting colonies, important foraging areas) or during molting season.

The potential effects of human activity and disturbance on sensitive habitats should be considered prior to starting a hazing operation. For example, take care not to trample fragile vegetation by foot traffic or off-road vehicles. If pyrotechnics or gas operated cannons are used, take care to prevent igniting vegetation. Wakes from boat operations should not push floating oil further into wetlands or mangroves. If nesting season, consider the potential effects of hazing on bird reproduction. Young birds are more susceptible to predation if they become separated from their parents.

Each spill situation will be unique and preplanned deterrence activities are considered tentative. Consultation with local experts is advisable. Regulations should be followed regarding the purchase, possession, and discharge of firearms or explosives, including shotgun and pistol-launched pyrotechnics.

No attempt should be made to haze oiled wildlife. Depending on the extent of oiling, wildlife that is already oiled may need to be captured and cleaned. Hazing is most effective if the area of concern can be hazed as continuously as possible. Avoid hazing in areas with oiled habitat or adjacent to oiled habitats where hazed wildlife could become contaminated with oil.

Habituation is the gradual decrease in response to a deterrence method due to increased familiarity and acceptance. Habituation can be minimized by using a combination of hazing methods and frequently changing the type, timing, and location of the hazing devices. It is recommended that human patrols be incorporated in hazing operations. Molting birds are not easily deterred and require a combination of different techniques.

Hazing is not generally recommended for marine mammals. Before hazing is being considered for marine mammals (whales, dolphins, seals, otters, manatees), consult the appropriate regulatory authorities and marine mammal experts. There are no established methods or data for hazing whales and dolphins. Attempts to haze seals from rookery or haul out areas may cause panic and a stampede, resulting in injuries or death, especially for pups. Pup mortalities can also result from abandonment.

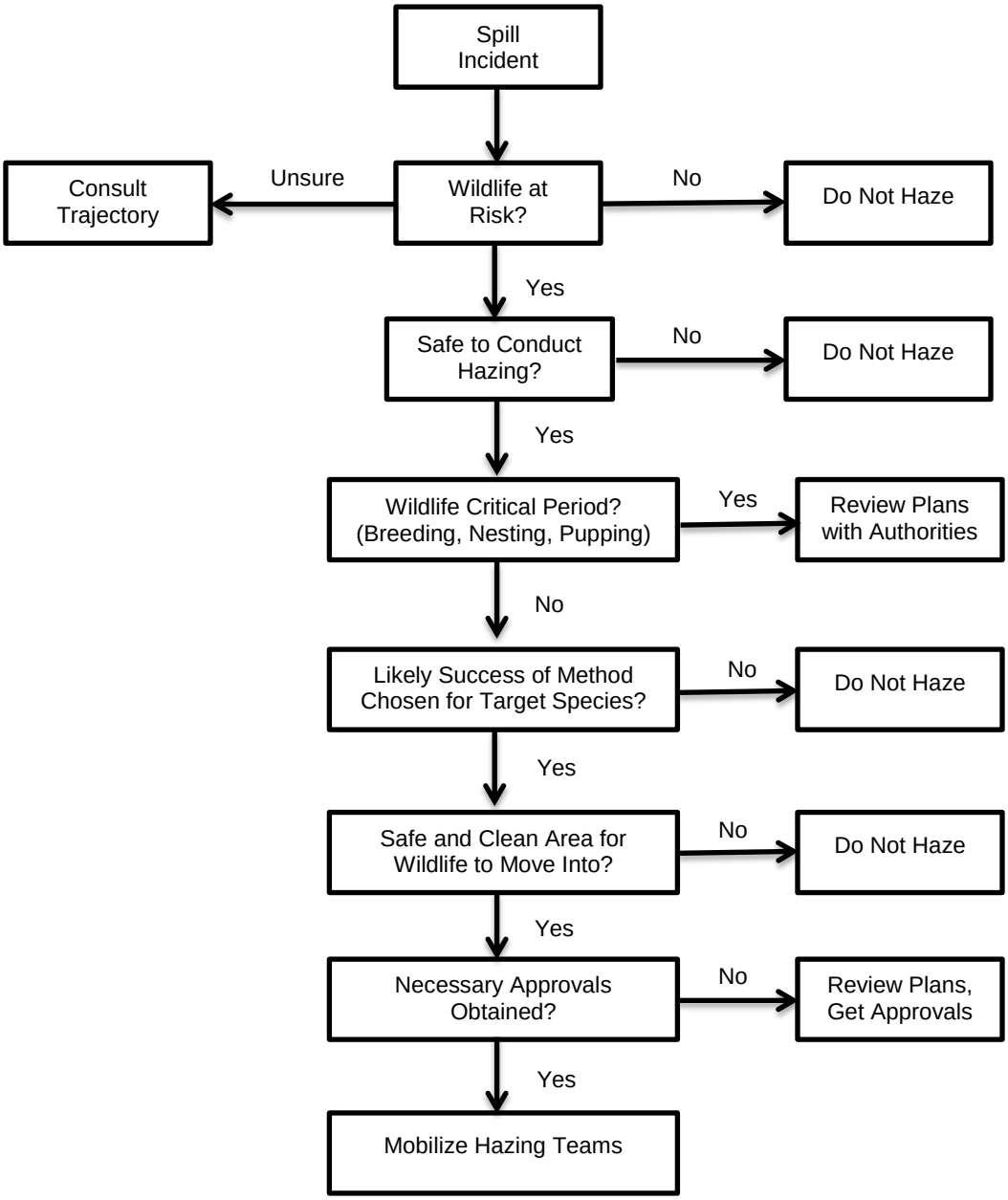


Figure 5-1: Hazing Decision Tree

5.2 Deterrence Methods and Equipment

Deterrent operations should include both visual and auditory techniques. Some petroleum products are highly flammable during the first few hours after a spill, due to high concentrations of volatile oil fractions. Techniques with potential to induce sparks should be avoided in these situations. The effects of sound emitting devices on humans, in terms or irritation and noise, especially at night, will influence whether or not some hazing methods will be acceptable.

5.2.1 Gas-Operated Cannons

Gas-operated cannons should only be used by trained personnel. The cannons produce a loud shotgun-like noise when discharged. Blasts are emitted at adjustable time intervals from less than one minute to as much as 30 minutes. If multiple cannons are used in an area, stagger the firing intervals. Cannons should be elevated at a 45 degree angle and preferably aimed downwind to increase effectiveness. Propane cannons are more effective for migrating and hunted species that associate danger with loud noises.

5.2.2 Pyrotechnics

Pyrotechnic devices disturb wildlife by producing a whistling noise, explosion, and/or flash of light. Types include shotgun-launched projectiles (crackers), fireworks, and a variety of pistol-launched projectiles. Pyrotechnic devices are potentially dangerous and should only be used by trained personnel. Safety goggles and ear protection should be worn by operators. When using these devices, care must be taken not to ignite spilled oil or vegetation.

5.2.3 Aircraft

Aircraft are often effective for deterring birds and terrestrial mammals because of the combination of loud noise and rapid approach from above. Because of their maneuverability and noise, helicopters are probably more effective than fixed-wing aircraft.

5.2.4 UAVs

Unmanned Aerial Vehicles (UAVs) operate similarly to manned aircraft, but may be able to operate at lower altitudes. Typically they operate in conjunction with ground or boat based personnel. UAVs can be used to scare off birds in flight. UAVs should be operated by trained personnel and must be approved by the Aviation Branch and appropriate government authorities.

5.2.5 Boats

Air boats or boats propelled by outboard motors can be used to haze wildlife and marine mammals. Small, noisy, shallow draft boats have been reported to be particularly effective. Boats can be used in combination with other hazing methods (i.e., UAVs, pyrotechnics).

5.2.6 All-Terrain Vehicles (ATVs)

ATVs are moderately effective for hazing many species of wildlife. Human presence reinforces the effects of the noise and rapid movement of the vehicle.

5.2.7 Air Horns

Air horns can be used to deter wildlife. Since habituation may be rapid, it is recommended that air horns be used in combination with other deterrent methods or devices.

5.2.8 Electronic Sound Generators

Sound generators broadcast loud, intermittent electronically synthesized sounds. The units can be adjusted to the most effective range of sound patterns for the target species. Sound generators can be positioned on land, mounted on boats, or housed within floats in water. When a sound generator is deployed within a drifting slick, the potential of scaring birds directly into the oil-contaminated water is reduced.

5.2.9 Balloons

All-weather helium balloons are considered effective if frequently refilled and moved. They can be suspended from land or from floating objects in water (e.g., spill booms). They should not be located near trees or other objects that could cause puncturing.

5.2.10 Human Effigies and Predator Models

Human effigies (scarecrows) and raptor models may be effective if they appear lifelike, have motion, are moved frequently, and are used in combination with loud sounds or recorded distress calls.

Additional hazing techniques are available. The recommendation to haze will be guided by site-specific and species-specific factors present at the time of the spill, and availability of proven hazing techniques.

6 Capture and Transport of Oiled Wildlife

6.1 Objective

The sooner oiled wildlife can be captured and treated the better their chances for survival. It is helpful to plot and number oiled wildlife on maps and charts to identify search and recovery patterns. Reconnaissance surveys for oiled wildlife may occur in offshore and near-shore waters, shorelines in oiled areas, in addition to areas that could potentially be oiled. Reconnaissance surveys may also be conducted at nearby feeding and nesting areas to detect oiled wildlife that may have moved away from oiled areas. The objectives of a reconnaissance survey are to 1) evaluate the number, species, and locations of wildlife potentially affected by an oil spill and 2) determine the feasibility to rescue oiled wildlife.

Local experts can provide information regarding special site considerations (i.e., nesting grounds, cultural or historic sites) and oiled species prioritization for capture. An effort should be made to avoid capturing birds, or other animals, that are not impacted by the spill, unless otherwise authorized.

Wildlife capture operations should only be conducted when weather conditions permit. Captured wildlife may be aggressive and should be regarded as potentially dangerous. Only trained individuals should undertake the capture and treatment of oiled wildlife.

6.2 Capture

A capture team consists of two or more individuals wearing appropriate protective clothing. Capture strategies should be discussed before any attempt to capture oiled wildlife. Safety of individuals is not to be compromised for the objective of capture.

A variety of methods can be used to capture wildlife:

- Dip nets, throw nets, or mist nets can be used for small birds and mammals;
- Seine nets and net guns can be used for larger birds or turtles;
- Capture poles can also be used.

Oiled birds can be approached using boats, but it is best to allow them to reach the shore if possible. Oiled wildlife should be approached carefully so as not to further stress the animal.

Appropriate handling techniques are based on the size and species of the animal. Field personnel should be properly trained before attempting to handle oiled wildlife.

Dead wildlife should also be collected to prevent other wildlife from becoming oiled as they attempt to eat the carcasses. Each carcass should be labelled, numbered, and documented on the appropriate form.

6.3 Transport

Oiled wildlife should be transported in well ventilated containers of sufficient size for the species captured. Some species may be placed 2 or 3 to a container. Containers should be placed in an area separate from the operator of the transport vehicle to protect the operator from inhaling vapors. Temperature should be maintained at an adequate level to prevent hypothermia or overheating.

7 Stabilization, Rehabilitation, and Husbandry

7.1 Introduction

If an oiled animal is hypothermic, dehydrated, sick, or injured, it may not survive the stress of being washed. Stabilization increases an oiled animal’s chances for a successful rehabilitation and release.

7.2 Stabilization

A stabilization center will serve as a collection site for all oiled wildlife collected by the wildlife search teams. A field stabilization group will provide initial care in the field prior to transportation to the rehabilitation facility. Stabilization can include warming or cooling of oiled animals to stabilize body temperature, preliminary examinations and initial cleaning, and providing fluids and nutrition.

7.3 Rehabilitation

A suitable facility must have a large open space that can easily be reconfigured to accommodate the changing needs of the wildlife rehabilitation process. Contracted wildlife

specialists and/or agency representatives should be consulted regarding facility requirements for optimum rehabilitation. The following are equipment and facility considerations:

- Location with respect to location of spill;
- Anticipated number of animals;
- Types and numbers of species;
- Season / weather;
- Hot and cold water capacity;
- Electric and lighting;
- HVAC systems (good air handling necessary);
- Communications;
- Noise control;
- Waste management issues (collection and storage);
- Appropriate holding pens (species dependent).

Each wildlife rehabilitation facility must have a Site Safety Plan in place prior to start-up. The Site Safety Plan must include checklists for measures to avoid physical, chemical, and biological hazards, safe animal handling procedures, and other emergency procedures and contact numbers.

Buildings of Opportunity

It may be possible to secure an appropriate building for oiled wildlife rehabilitation that is normally used for some other purpose but can be quickly transformed into a suitable facility. Examples may include warehouses, fairgrounds, community centers, etc. To utilize this option will require considerable planning and contracts with building owners, suppliers and tradesmen to ensure that the facility can be up and running within hours when needed, and is able to provide the required space, water, heating and ventilation necessary to meet the goals of the wildlife plan (IPIECA, 2014).

Mobile facilities

Mobile facilities are comprised of modules (trailers, containers, tents, etc.) that can be easily transported and set up wherever they are needed. Infrastructure needs may vary, and potential settings could, for example, range from a large warehouse space with water and utilities to a level field or the deck of a barge or large ship. Such facilities may be used for field operations or all phases of rehabilitation. A wide variety of examples of mobile units exist that are intended for use as specific components or as a complete oiled wildlife rehabilitation facility (IPIECA, 2014).

8 Wildlife Release Considerations

The goal in rehabilitating oiled wildlife is the release of healthy animals back into their natural environment. Release of rehabilitated wildlife requires planning in advance. Consultation with local wildlife experts, government agencies, and Incident Command is necessary to determine appropriate release sites and disposition of animals that cannot be released. Timely release is

important to prevent or reduce occurrence of secondary problems associated with captivity. For wildlife that cannot be released, the options are euthanasia or placement in a long-term facility.

To be released, wildlife must exhibit:

- Normal behavior;
- Normal body weight;
- Waterproof (particularly in seabirds);
- Normal blood values and physical exam;
- Normal feeding.

Release sites should:

- Be free of oil contamination and not at risk of re-contamination;
- Same general geographic area or habitat of capture;
- Minimal human disturbance;
- Appropriate seasonal range for species (important for long rehabilitations);
- Safe for response personnel.

If post-release monitoring is necessary, wildlife should be tagged or banded prior to release to aid visual observation.

9 Record Keeping

Record keeping is an important part of a wildlife rehabilitation program. Records are essential for evaluating the effectiveness of treatments and whether the rehabilitation efforts were successful. In addition records are used to determine a spill's impact on wildlife. Records are usually divided into the following types:

- Field Survey and Wildlife Collection:
  - Document species collected, numbers, condition, location, etc.;
- Chain-of-Custody:
  - Used to track transport and transfer of all collected animals;
- Admission and Examination:
  - Record of admission to rehab center, initial assessments, etc.;
- Treatment:
  - Tracks treatment of individual animals, feeding, behavior, etc.;
- Necrospy:
  - For use by veterinarian for determining cause of death.

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Appendix A – Habitats

Coastal and Marine Habitats

Several habitat types are present in the network of plains and low hills that comprise Guyana's coast, including mangroves, salt to brackish lagoons, brackish herbaceous swamps, swamp woods and swamp forests. The swamps are an important source of freshwater to mangroves and other flora and fauna. The coastal mangroves are vital to Guyana's biodiversity, physical security, and economy. Guyana has relatively few beaches, but the beaches that do occur are critically important nesting habitats for sea turtles.

Guyana's continental shelf occupies an area of 48,665 sq. km. The average width of the continental shelf is 112.6 km (NDS, 1997). The shelf is widest near the Suriname and Venezuela borders, and slightly narrower near the center, north of Georgetown. The entire continental shelf, continental slope, and the adjoining portion of the abyssal plain (including the Sorubim and Liza Areas of Interest) are part of the North Brazil Large Marine Ecosystem (LME). The North Brazil LME is an oceanic habitat unit that extends from the Caribbean Sea south to the Parnaiba River in Brazil. Marine benthic biological resources offshore of Guyana are poorly studied, but do not include the matrix of shallow coral reefs and seagrass meadows that are characteristic of coastal tropical Atlantic environments elsewhere. This is due to the highly turbid conditions offshore of Guyana, which do not permit the growth of warm water corals, since they rely on symbiotic photosynthetic algae for nourishment (ERM, 2016).The substrate is generally composed almost entirely of mud and silt deposited by the North Brazil Current.

Mangroves

Mangroves are important ecosystems to security of the biodiversity of the entire Guiana Shield region. They occupy over 81,000 hectares of Guyana's coast but the distribution of mangroves along the coast is highly dynamic, and subject to rapid change. Six of Guyana's ten geopolitical regions have mangroves but approximately 75% of the country's mangroves are concentrated in the Barima-Waini and Pomeroon-Supenaam regions.

There are currently three species of mangrove in Guyana: *Rhizophora mangle* (Red mangrove), *Avicennia germinans* (Black mangrove), and *Laguncularia racemosa* (White mangrove). Many invertebrates live either on or in close proximity to mangrove roots and substrate and include snails, barnacles, tunicates, mollusks, polychaete worms, oligochaete worms, shrimps, crabs, sponges, jellyfishes, amphipods and isopods. These small organisms provide forage for birds, mammals, reptiles, amphibians, fish, crabs, and shrimp.

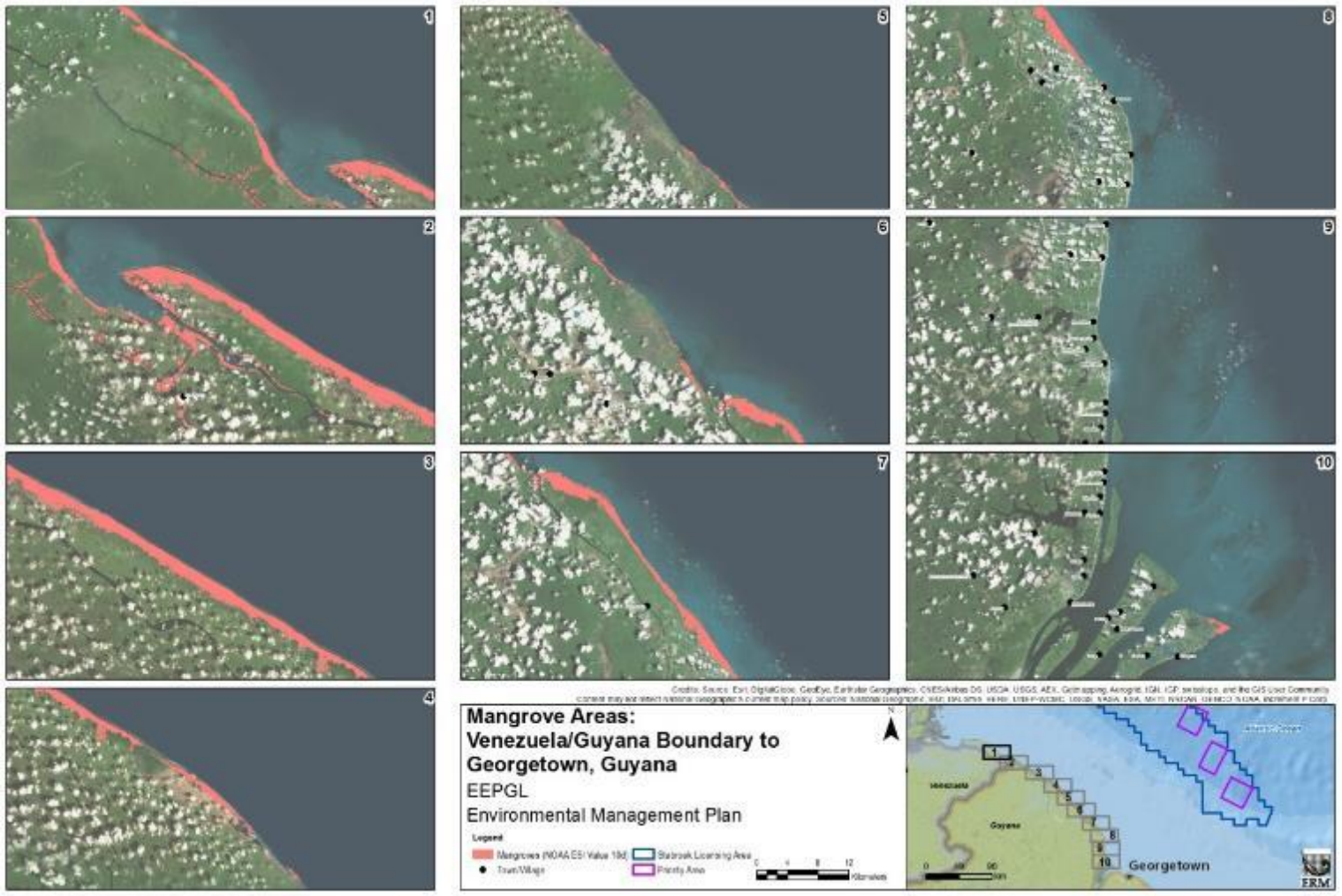


Figure A-1: Guyana's Mangrove Distribution (Georgetown west to Venezuelan Border)

Mud Banks

The 1,500 km-long coast of South America between the Amazon and Orinoco River mouths is the world's muddiest coastline. Mud banks extend approximately 20 to 40 km offshore to a depth of 20m, and are located seaward of the mangrove swamps that fringe much of the coastline. The mud banks are rich in invertebrate fauna, including plankton and micro-plankton assemblages, algae mats (diatoms), and benthic communities of Nematodes (worms), Tanaidacea (crustaceans), and Foraminifera (amoeboid protists). These small organisms provide habitat for fish species, post-larval and juvenile shrimps, and crabs, and numerous resident and migratory shore birds.

Shell Beach

Shell Beach is a protected area on Guyana's coast that could potentially be impacted by a spill. It accounts for 200,000 ha or approximately 11% of Guyana's total protected area. Figure A-2 provides a detailed map of Shell Beach and the surrounding area. It is located in northwestern Guyana and extends for almost 140km between the Waini, Baramani, and Moruka Rivers and the Atlantic Ocean. Shell Beach is a dynamic area and constantly changes due to the competing effects of erosion and deposition along the shorefront. Seventy percent of the area is forested; the rest is made up of mostly swamp (28.8%), and sandy beaches (1.2%). Shell Beach supports numerous species of plants including coconut, papaya, and palm trees.

Shell Beach is not the only portion of Guyana's coast that contains mangroves; mangroves are a prominent feature along much of northwest Guyana's coastline. They are ecologically important, and are a critical natural component of Guyana's coastal defense network, protecting the low-lying inland areas of the coast from sea-level rise and saltwater intrusion during storm events.

Shell Beach is best known as a marine turtle nesting site. The composition of the substrate at Shell Beach, its geographical location and the low human impact makes it an ideal nesting site for sea turtles. Most nesting beaches in Guyana are used by only one or two species of sea turtle but four species of sea turtle (Leatherback, Hawksbill, Olive Ridley, and Green Turtle) found in Guyana nest at Shell Beach (Pritchard, 2001).

In addition to the sea turtles there are also at least four other species of turtles present within the protected area including the yellow-foot tortoise (*Geochelone denticulate*), scorpion mud turtle (*Kinosternon scorpioides*), giant river turtle (*Podocnemis expansa*) and mata mata (*Chelus fimbriata*).

The Shell Beach area is also home to several species of mammals, including howler monkeys (*Alouatta* spp.), jaguars (*Panthera* spp.), and manatees (*Trichechus* sp.) (ERM, 2016). Amerindian groups also inhabit the Shell Beach area and are concentrated along the areas of Almond Beach, Father's Beach, and Assakata (ERM, 2016).

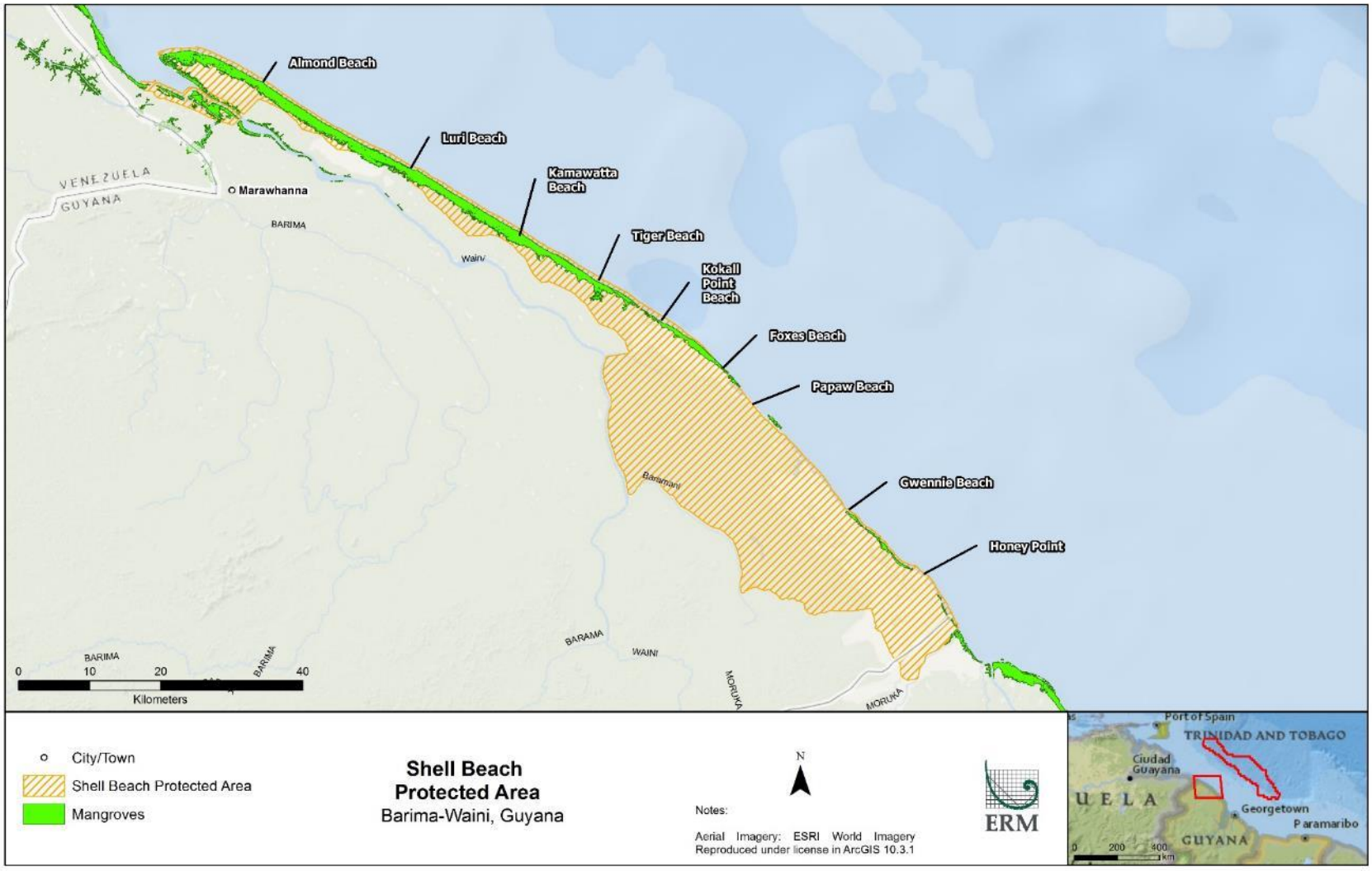


Figure A-2: Shell Beach Protected Area

Appendix B – Bird Species

Birds are by far one of the most diverse classes in the animal kingdom, owing their success to several adaptations over the course of evolution. Birds comprise of over 8600 species distributed among 27 orders.

Of the 27 orders, 20 are found in Guyana. Of these, 9 are shore birds. Both migrant and native shore bird species occupy important ecological niches, serve as important biological control agents and act as dispersers. Because of their importance in the ecosystem and their declining population numbers, the conservation and or protection of some species is vital for the promotion of a healthy and long living ecosystem.

Of the thirty-two families of waterfowl identified, twelve (12) are found along the coast of Guyana. Many of these bird species migrate from the Northern, Western and Eastern United States for the winter season. Millions of shorebirds make the annual 2000-mile journey from North America to winter in South America. Migratory routes of shorebirds follow three main flyways: Shorebirds appearing on the coast of Guyana utilize the Atlantic and Central Flyways for their migration (see Figure B-1). These migratory paths are influenced by winds and geography.

The beaches on the coast of South America provide the ideal wetland conditions for waterfowl. The wetlands on the South American coast provide mangrove forests for shelter and breeding, and mudflats, sandy beaches and open fishing areas for foraging. Shorebirds are found mainly on the seashore between the low and high water marks feeding on a variety of small invertebrates, clams, snails, larvae and insects. Due to the diversity of food supplies in the same wetland, large mixed flocks of shorebirds are usually observed.

Coastal bird populations consist of ibises, egrets, herons, gulls and other seashore species. Oceanic species such as frigatebirds and albatrosses spend most of their time at sea and are less common along the coast. Migratory seabirds occur in Guyana on a seasonal basis. Guyana's coastal mangroves are noted for being wintering grounds for migratory birds including austral and Nearctic migratory species. Austral migrants breed in temperate South America during the summer, but spend the remainder of the year in the tropics. Nearctic migrants migrate in the other direction, breeding in North America during summer and overwintering in tropical South America. Both groups spend winter in Guyana, which creates a peak in migratory waterbird abundance in Guyana from early October to late March. See Table B-1 for some common seabird species. All of the 30 species of seabirds known to occur in Guyana are currently listed on the IUCN Red List as LC (with the exception of Leach's Storm Petrel – VU), which means that the population status of the species does not meet the IUCN criteria for a threatened or NT designation (IUCN, 2016)

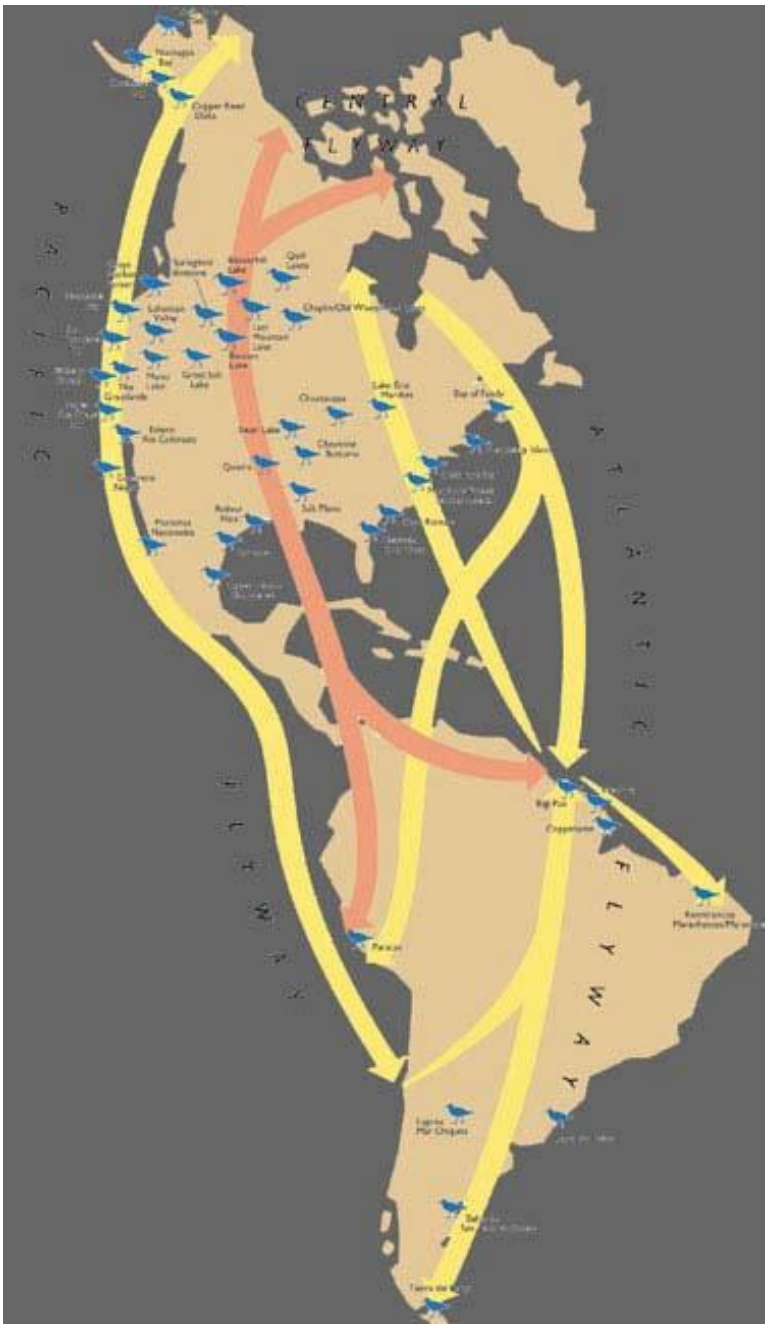


Figure B-1: Migratory Routes of Shorebirds

Migratory routes of shorebirds follow three main flyways: The Atlantic Flyway, The Pacific Flyway and The Central Flyway.

Table B-1: Common Seabird Species Known to Occur in Guyana

Common Name	Scientific Name
Magnificent Frigatebird	*Fregata magnificens*
Brown Booby	*Sula leucogaster*
Masked Booby	*Sula dactylatra*
Red-footed Booby	*Sula sula*
White-tailed Tropicbird	*Phaethon lepturus*
Leach's Storm-petrel	*Oceanodroma leucorhoa*
Audubon's Shearwater	*Puffinus lherminieri*
Wilson's Storm-petrel	*Oceanites oceanicus*
Cory's Shearwater	*Calonectris diomedea*
Barolo Shearwater	*Puffinus baroli*
Great Shearwater	*Ardenna gravis*
Arctic Jaeger [c]	*Stercorarius parasiticus*
Pomarine Jaeger	*Stercorarius pomarinus*
Parasitic Jaeger	*Stercorarius parasiticus*
South Polar Skua	*Stercorarius maccormicki*
Great Skua	*Catharacta skua*
Least Tern	*Sternula antillarum*
Royal Tern	*Sterna maxima*
Black Tern	*Chlidonias niger*
Common Tern	*Sterna hirundo*
Bridled Tern	*Onychoprion anaethetus*
Sooty Tern	*Onychoprion fuscatus*
Sandwich Tern	*Thalasseus sandvicensis*
Roseate Tern	*Sterna dougalli*
Brown Noddy	*Anous stolidus*
Gull Billed-tern	*Gelochelidon nilotica*
Northern Gannet	*Morus bassanus*
Laughing Gull	*Larus atricilla*
Brown Pelican	*Pelecanus occidentalis*
Neotropic Cormorant	*Phalacrocorax brasilianus*

Of the species observed in the Stabroek Block during the EEPGL seismic surveys, the most commonly observed species (in descending order of number of sightings (i.e., frequency of occurrence) were the Masked Booby (*Sula dactylatra*), Magnificent Frigatebird (*Fregata magnificens*), and Brown Booby *(Sula leucogaster*) (ERM, 2016; RPS, 2016).

Important Bird Areas (outside of the Stabroek Area of Operation)

Three Marine IBAs of global or regional importance to seabirds have been designated in neighboring countries: St. Giles Islands and Little Tobago, both located off the northeastern tip of Tobago, and Isla de Aves in Venezuela (Lentino and Esclasans, 2009; Birdlife International 2016b; Devenish et al., 2009). Figure B-2 depicts the location of these IBAs relative to the Stabroek Block.

St. Giles Islands IBA: includes one main island and several surrounding rock outcrops that support globally important numbers of breeding Red-billed Tropicbird (*Phaethon aethereus*) and regionally important numbers of breeding Audubon's Shearwater (*Puffinus lherminieri*), Magnificent Frigatebird (*Fregata magnificens*), Masked Booby (*Sula dactylatra*), and Red-footed Booby (*S. sula*). Other seabirds such as Brown Booby (*S. leucogaster*) and Brown Noddy (*Anous stolidus*) also breed there (White, 2008; Devenish et al., 2009).

Little Tobago IBA: supports globally important breeding populations of Red-billed Tropicbird and Laughing Gull (*Larus atricilla*), and regionally important breeding populations of Audubon's Shearwater, Brown Booby, Red-footed Booby, and Bridled Tern (White, 2008; Devenish et al., 2009).

Field surveys conducted as part of the coastal mapping of Trinidad and Tobago documented large colonies of seabirds at both St. Giles Island and Little Tobago, as well as along the northeastern cliffs of Tobago, from Corvo Point to Pedro Point (ERM, 2016).

The Isla de Aves IBA: in Venezuela supports the largest breeding colony of Brown Noddy known from the Caribbean (5,509 pairs), as well as the principal breeding colony of Sooty Tern (*Sterna fuscata*) in Venezuela (12,182 pairs) (Lentino and Esclasans, 2009).



Figure B-2: IBAs with Importance to Seabirds Relative to Stabroek Block

Appendix C – Marine Mammals

The equatorial waters of Guyana are home to several species of marine mammals. There have been no comprehensive studies on marine mammals offshore Guyana, but regional studies and bycatch reports provide some insight into the composition and distribution of the marine mammal community in the vicinity of the Project. Marine mammals whose distributions overlap with Guyana's Exclusive Economic Zone (EEZ) are listed in Table C-1.

Marine mammals are highly migratory and should be able to avoid a spill should one occur. The greatest danger to marine mammals is from collisions with vessels during operations. Marine mammals not directly impacted from a spill may also be impacted indirectly through food-chain related impacts.

The data from a 2012 Suriname survey strongly suggest that toothed whales (including dolphins, porpoises, pilot whales, and sperm whales) are more common offshore of Suriname than the baleen whales (including Bryde's and sei whales). The species with the highest abundance index was the melon-headed whale, while the lowest was the Bryde's whale. The most frequently sighted species was the spinner dolphin, and the least frequently sighted was the sei whale (Boer, 2012). The highest number of strandings reported were for sperm whales, and the lowest number were for sei whales (Boer, 2012). The 2012 Suriname study was conducted at similar depths and distances offshore as the Sorubim and Liza Areas of Interest, so such species could occupy similar ranges within the Project lead areas as well.

The West Indian manatee has been documented in the region, but is either now considered to be locally extinct or extremely rare and would not be expected to be encountered in coastal waters adjacent to the POA (ERM, 2016). However, the manatee may be encountered in nearshore and riverine settings.

Table C-1: Marine Mammals with Ranges that include Waters Offshore Guyana

Common name	***Scientific name***
Sei whale	*Balaenoptera borealis (EN)*
Bryde's whale *	*Balaenoptera brydei*
Blue whale	*Balaenoptera musculus (EN)*
Fin whale	*Balaenoptera physalu (EN)*
Short beaked common dolphin	*Delphinus delphis (LC)*
Minke whale	*Balaenoptera acutorostrata (LC)*
North Atlantic right whale	*Eubalaena glacialis (EN)*
Pygmy killer whale	*Feresa attenuate*
Short-finned pilot whale *	*Globicephala macrorhynchus*
Rissos dolphin *	*Grampus griseus (LC)*
Pygmy sperm whale	*Kogia breviceps*
Dwarf sperm whale	*Kogia simus*
Frasers dolphin *	*Lagenodelphis hosei (LC)*
Humpback whale	*Megaptera novaeangliae (LC)*
Blainvilles beaked whale	*Mesoplodon densirostris*
Gervais beaked whale	*Mesoplodon europaeus*
Trues beaked whale	*Mesoplodon mirus*
Melon-headed whale *	*Peponocephala electra (LC)*
Sperm whale *	*Physeter macrocephalus (VU)*
False killer whale	*Pseudorca crassidens*
Tucuxi	*Sotalia fluviatilis*
Pantropical spotted dolphin *	*Stenella attenuate (LC)*
Clymene dolphin	*Stenella clymene*
Striped dolphin	*Stenella coeruleoalba (LC)*
Rough-toothed dolphin	*Steno bredanensis (LC)*
Spinner dolphin *	*Stenella longirostris*
West Indian manatee	*Trichechus manatus*

LC = Least Concerned VU = Vulnerable EN = Endangered

Note: species marked with an asterisk (*) were confirmed sighted during EEPGL activities since 2014.

Appendix D – Marine Reptiles

Five sea turtle species are found in the wider Caribbean, all of which occur in Guyanese waters. Four of these species: green turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and Olive Ridley turtle (*Lepidochelys olivacea*) nest on Guyana's beaches. Loggerhead turtles (*Caretta caretta*) also occur offshore Guyana but rarely come ashore. The primary nesting site for all these species is Shell Beach, located on the northwestern coast of Guyana. The exact location of secondary nesting sites changes due to coastal erosion which creates and destroys nesting areas continuously, but they are generally distributed along the northwest coast between the Pomeroon and the Waini river estuaries. Leatherback turtles are the most common species on the nesting beaches, while nesting green and hawksbill turtles are less common. Olive Ridley turtle populations have declined in recent times, but remain stable.

According to the Center for Rural Empowerment and the Environment (CREE), the primary nesting season for the leatherback, green, and olive ridley turtles in Guyana (Shell Beach) occurs during the cover of darkness from March to August (CREE, 2014). Hawksbill turtles nest primarily on Almond Beach in the northwest corner of the Shell Beach Protected Area. Large populations of the green and leatherback turtles are located in the Guianas (Suriname and French Guiana), while smaller nesting areas are located from northwestern Guyana (Shell Beach) to Venezuela and into the Caribbean Sea (which includes the Netherland, Lesser, and Greater Antilles); the Gulf of Mexico (Central America); and Atlantic Ocean (the Bahamas; and the southern coast of the United States) (Piniak, 2011).

The hawksbill turtles' range is primarily in the Caribbean Sea with small nesting areas in the Guianas and in eastern Brazil. The olive-ridley turtles primarily nest along the French Guiana coast with small nesting areas along the northeastern coast of Venezuela to the Suriname and in eastern Brazil (Piniak, 2011).

The primary threats to sea turtles are poaching of eggs and adults, intentional and accidental fishing, and habitat disturbance and degradation due to marine pollution, coastal zone development, shore erosion, lighting and debris. Population monitoring and conservation activities are limited, primarily due to the logistical challenges associated with the remoteness of primary nesting sites. Most marine turtle species are believed to move out of Guyanese waters as juveniles (Piniak, 2011).

Table D-1: Marine Reptiles with Ranges that include Waters Offshore Guyana

Common name	Scientific name	Nest
Green turtle	*Chelonia mydas*	*Shell Beach*
Leatherback turtle	*Dermochelys coriacea*	*Shell Beach*
Hawksbill turtle	*Eretmochelys imbricata*	*Almond Beach*
Olive Ridley turtle	*Lepidochelys olivacea*	*Shell Beach*
Loggerhead turtles	*Caretta caretta*	*Rare*

Appendix E – Marine Finfish

Most of what is known about the marine finfish off the coast of Guyana is through commercial fishing. Approximately 80 species of fish can be found in Guyanese waters (ERM, 2016), of which about 30 are ranked by the IUCN. The inshore finfish community is dominated by drums, croakers, and marine catfishes, and includes other species such as snooks and tarpon. Offshore, the community is dominated by migratory pelagic species such as tuna, jacks, groupers and mackerals. Several species of shark are also present.

Table E-1: Marine Finfish Offshore Guyana on IUCN Redlist

Common name	Scientific name	Species Status
Spotted Eagle Ray	*Aetobatus narinari*	*NT*
Common Thresher Shark	*Alopias vulpinus*	*VU*
Foureyed Flounder	*Ancylopsetta kumperae*	*DD*
Blackbelly Skate	*Breviraja nigriventralis*	*DD*
Blacknose Shark	*Carcharhinus acronotus*	*NT*
Spinner Shark	*Carcharhinus brevipinna*	*NT*
Silky Shark	*Carcharhinus falciformis*	*NT*
Bull Shark	*Carcharhinus leucas*	*NT*
Blacktip Shark	*Carcharhinus limbatus*	*NT*
Oceanic Whitetip Shark	*Carcharhinus longimanus*	*VU*
Dusky Shark	*Carcharhinus obscurus*	*VU*
Caribbean Reef Shark	*Carcharhinus perezi*	*NT*
Smalltail Shark	*Carcharhinus porosus*	*DD*
Night Shark	*Carcharhinus signatus*	*VU*
Frilled Shark	*Chlamydoselachus anguineus*	*NT*
Hookskate	*Dactylobatus clarkii*	*DD*
Southern Stingray	*Dasyatis americana*	*DD*
Sharpsnout Stingray	*Dasyatis geijskesi*	*NT*
Sickelfish Grouper	*Dermatolepis inermis*	*NT*
Atlantic Goliath Grouper	*Epinephelus itajara*	*CE*
Red Grouper	*Epinephelus morio*	*NT*
Nassau Grouper	*Epinephelus striatus*	*EN*
Tiger Shark	*Galeocerda cuvier*	*NT*
Nurse Shark	*Ginglymostoma cirratum*	*DD*
Albacore Tuna	*Thunnus alalunga*	*NT*
Yellowfin Tuna	*Thunnus albacares*	*NT*
Bigeye Tuna	*Thunnus obesus*	*VU*
Atlantic Bluefin Tuna	*Thunnus thynnus*	*EN*
Scalloped Hammerhead	*Sphyrna lewini*	*EN*
Squat-headed Hammerhead	*Sphyrna mokarran*	*EN*
Smalleye Hammerhead	*Sphyrna tudes*	*VU*

NT = Near Threatened VU = Vulnerable EN = Endangered CE = Critically Endangered DD = Data Deficient

Appendix F – Marine Fisheries

There are four main types of marine fisheries in Guyana (MOA, 2013) that can be defined by the species targeted, gear types used, and the depth of water where the fishery takes place. Table F-1 summarizes the characteristics of these fisheries.

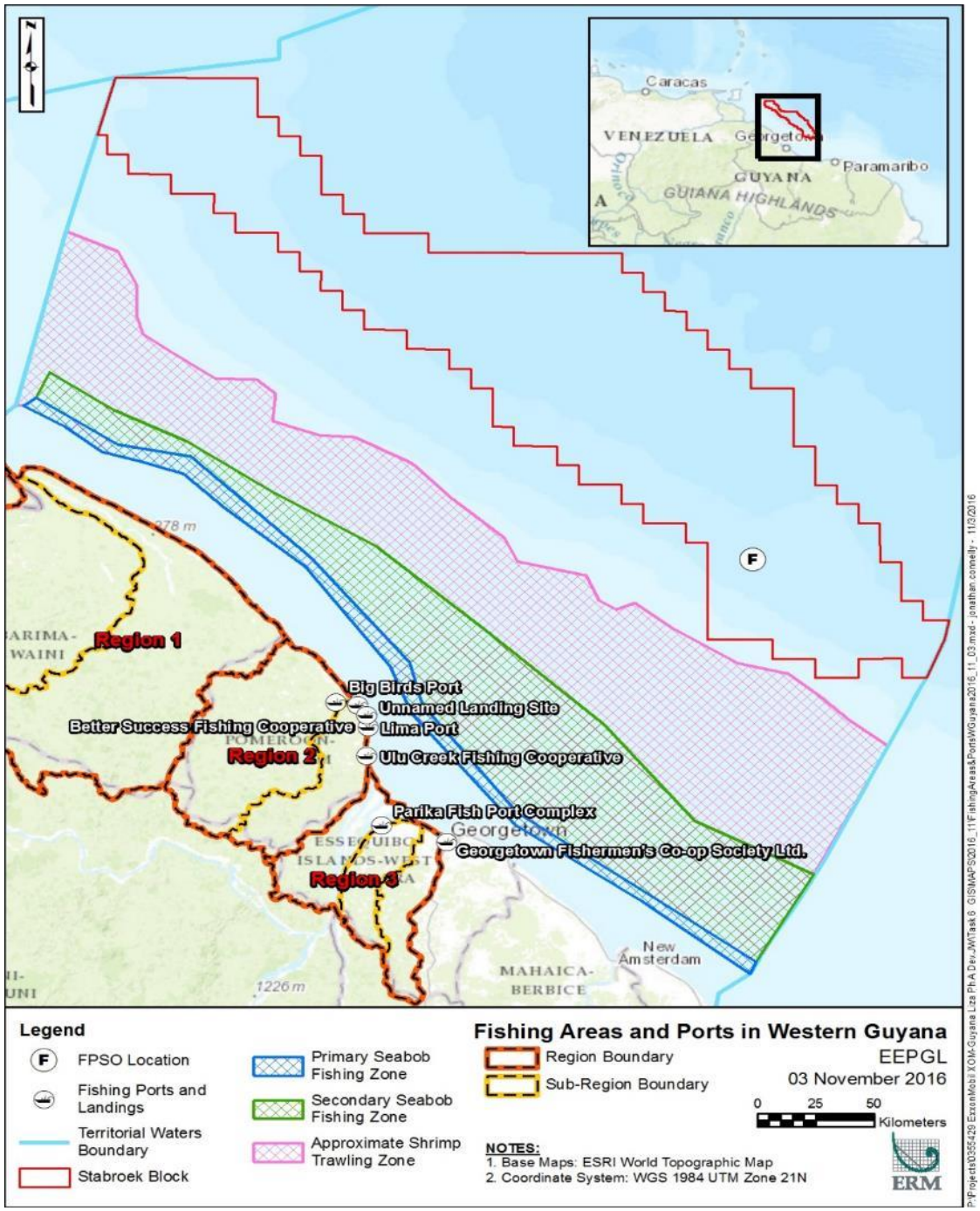
Table F-1: Primary Characteristics of Marine Fisheries in Guyana

Type of Fishery	Species	Gear	Depth
Industrial	Seabob, shrimps, and prawns	Trawls	Primarily between 13-16 m, but can occur from 0-75 m
Semi-industrial	Red snapper and vermillion snapper	Fish traps and lines	Edge of continental shelf
Artisanal	Mixed finfish and shrimp	Gillnets, seines, and others	0–18 m
Shark	Various	Trawls, gillnets, and hook and line	Throughout the continental shelf waters

The industrial seabob shrimp sector, as well as the artisanal finfish sector, are important commercial fisheries for Guyana that intersect the POA (see Figure F-1).

Guyana's marine finfish community exemplifies the ecological connectivity among the mangroves, estuaries, and offshore zones, because many fish species are dependent on different habitats at specific life stages or occur in more than one habitat type. Several species that occur in the inshore and offshore zones as adults are dependent on coastal mangroves as juveniles, particularly drums, croakers, and snappers. Catfishes occur in the mangroves, estuaries, and oceanic waters as adults (ERM, 2016). As a result, impacts in these areas may also have an impact on the fishery.

The Guyana Fisheries Department (a division of the Guyana Ministry of Agriculture), should be consulted on any potential impacts of an unplanned release.



** NOTE: Map does not represent a depiction of the maritime boundary lines of Guyana*

Figure F-1: Fishing Zones and Ports

Appendix G – Wildlife Branch Guidance

In the early hours of a spill response it is important to quickly estimate the scale of the event (relative to potential animal impacts) as best as possible and order the equipment and personnel. Estimating size and ordering resources should be the first priority as it will take some time to mobilize and deploy resources.

Wildlife Branch Objectives:

- Develop a Wildlife Plan for inclusion in the Incident Action Plan (IAP);
- Identify and mobilize equipment/facilities;
- Identify and mobilize personnel and support;
- Complete notifications: internal and external (phone list);
- Maintain communication: internal and external.

Staffing/Positions (depending on response level):

- Branch Director (BD):
  - Leads Wildlife Branch, develops incident specific wildlife plan;
- Deputy Branch Director (DBD):
  - Backup to the Director, compiles wildlife plan info, manages wildlife branch deadlines;
- Wildlife Reconnaissance Group Supervisor (WRGS):
  - Develops land, water, air reconnaissance plans;
  - Coordinates activities with Land, Water, and Air Operations;
- Bird Recovery and Rehabilitation Group Supervisor (BRRGS):
  - Coordinates bird handling issues, protocols, and hazing activities;
- Marine Mammal Recovery and Rehabilitation Group Supervisor (MMRRGS):
  - Develops and coordinates capture, handling, and rehabilitation of marine mammals;
  - Develop and coordinate efforts for handling marine reptiles;
- Wildlife Volunteer Coordinator (VC):
  - If necessary, will coordinate training, use, and deployment of volunteers for wildlife collection and rehab activities;
- Liaison (L):
  - Will coordinate communication between Environmental Unit in Planning, JIC, etc., and the Wildlife Branch in Operations;
  - Assist in maintaining communication with government agencies, NGOs, and other involved parties;
- IAP software specialist:
  - Enter forms into the IAP;
  - Assist in getting maps and updating the Common Operating Picture (COP);

- Documentation tracker (for larger events).

Initial steps (complete these in this order and on Day 1 when possible):

- Notify Command (as appropriate) that Wildlife Branch is up and running and making plans:
  - Notify Operations Section Chief;
  - Notify Environmental Unit;
  - Notify interested agencies, parties, or organizations.
- Begin Unit Log (ICS 214).
- Identify Branch staff and assignments. Use the list of positions and tasks above to identify tasks and who will be doing them. Remember, the number of personnel expands and contracts as appropriate to the event so it may be one person doing everything or there may be a full contingent of staff. (Provide an organization chart (ICS 207) and contact information to resources).
- Estimate equipment (facility) and personnel needed based on the estimated number and type of animals anticipated. Lean toward over responding as it's easier to send resources back than not have resources when needed.
- Identify deployment locations for equipment and personnel. Equipment locations need to be available for a long enough time to handle entire (anticipated) response AND rehabilitation to avoid having to move during the process.
- Develop reconnaissance plan or "animal location" needs (on Day 1 this will be a very brief plan, if one at all). Coordinate with EU and Flight Operations, etc.
- Develop search and collection and transportation plans (Day 1 there may not be formal plans, Day 2 will). Identify search areas, number of crews, support needs, etc. (ICS 204 and ICS 204a).
- Develop a wildlife rehabilitation plan.
- Begin drafting the Wildlife Plan for inclusion in the IAP. Templates are on the RRT Sharepoint page.
- Provide an Oiled Wildlife Statement to the JIC, listing phone numbers for reporting oiled wildlife and warning the public to stay away from oiled wildlife. A template is available on the RRT Sharepoint page.