

Esso Highlands Limited

PNG LNG Project

Environmental Impact Statement









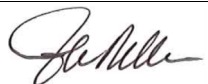
Table of Contents



January 2009
CR 1284_9_vI

Prepared by:
Coffey Natural Systems Pty Ltd ABN 61 005 041 878
126 Trenerry Crescent Abbotsford VIC 3067 Australia
T (+61) (3) 9418 0600 F (+61) (3) 9418 0650
coffey.com

PGGP-EN-SRENV-000001-001

Rev #	Rev Date	Description	Prepared By	Endorsed	Approver
A	Nov 08	Issued for Internal Review	 Carmel Coyne Coffey Natural Systems	 Steven Whisker ExxonMobil	 John Rullman ExxonMobil
B	Jan 09	Reissued for Internal Review	 Carmel Coyne Coffey Natural Systems	 Steven Whisker ExxonMobil	 John Rullman ExxonMobil
0	Jan 09	Issued for Use	 Carmel Coyne Coffey Natural Systems	 Steven Whisker ExxonMobil	 John Rullman ExxonMobil

CONTENTS

1. INTRODUCTION	1-1
1.1 Background	1-1
1.1.1 Liquefied Natural Gas	1-1
1.1.2 Prior Petroleum Developments and Proposals	1-4
1.2 Overview of the Development Proposal	1-5
1.2.1 Project Description	1-5
1.2.2 Project Development Schedule and Project Phases	1-8
1.2.3 Current Status of the Project	1-8
1.2.4 Project Objectives	1-11
1.2.5 Project Impacts	1-11
1.2.6 Project Staffing	1-14
1.3 PNG LNG Project Co-Venturers	1-15
1.3.1 Co-venturers of the PNG LNG Project	1-15
1.3.2 Company Profiles	1-16
1.4 This EIS	1-19
1.4.1 EIS Statutory Context	1-19
1.4.2 EIS Report Structure	1-19
1.4.3 Obtaining a Copy of the EIS	1-22
2. PRODUCING THE GAS	2-1
2.1 Introduction	2-1
2.2 Description of the Gas Resource	2-3
2.2.1 Geology and Reservoirs	2-3
2.2.2 Production Forecast	2-6
2.2.3 Fields, Wells and Gathering Systems	2-8
2.3 Description of the Gas Processing Facilities	2-18
2.3.1 Hides Gas Conditioning Plant	2-19
2.3.2 Juha Production Facility	2-23
2.3.3 Gobe Production Facility	2-25
2.3.4 Kutubu Central Processing Facility	2-26
2.3.5 Agogo Production Facility	2-28
2.4 Common Construction Activities	2-31
2.4.1 Preconstruction Survey	2-31
2.4.2 Surveying	2-32
2.4.3 Archaeological Clearance	2-32
2.4.4 Erosion Control	2-32
2.4.5 Equipment Mobilisation	2-33
2.4.6 Vegetation Clearing	2-33
2.4.7 Grading and Foundation Excavation	2-33
2.4.8 Site Clean-up and Rehabilitation	2-34
2.4.9 Construction Environmental Safeguards	2-35
2.5 Drilling the Wells and Constructing the Gathering Systems	2-35

2.5.1	Preparation of Wellpads	2-35
2.5.2	Water Supply	2-39
2.5.3	Equipment	2-39
2.5.4	Drilling Method for New Wells	2-39
2.5.5	Recompletion of Hides 1 and Hides 4	2-41
2.5.6	Disposal of Cuttings	2-41
2.5.7	Gathering Systems	2-42
2.6	Constructing the Processing Facilities	2-42
2.6.1	Site Preparation at the Hides Gas Conditioning Plant	2-42
2.6.2	Construction of the Hides Gas Conditioning Plant	2-43
2.6.3	Construction of the Juha Production Facility	2-45
2.6.4	Construction of the Associated Facilities	2-45
2.7	Operating and Maintaining the Processing Facilities	2-46
2.7.1	Operating and Maintaining the Hides Gas Conditioning Plant	2-46
2.7.2	Operating and Maintaining the Juha Production Facility	2-53
2.7.3	Operating and Maintaining the Wells and Gathering Systems	2-54
2.7.4	Operating and Maintaining the Camps	2-54
2.8	Safety and Security	2-54
2.8.1	General	2-54
2.8.2	Site Layout	2-55
2.8.3	Site Security	2-55
2.8.4	Fire-Detection and Firewater Systems	2-55
2.8.5	Gas Detection	2-56
2.8.6	Plant Emergency Shutdown Systems and Alarms	2-56
2.8.7	Gathering System Safety Shutdown Valves	2-57
2.9	Environmental Management	2-57
2.10	Decommissioning the Production Facilities	2-58
3.	TRANSPORTING THE GAS	3-1
3.1	Overview	3-1
3.2	Pipeline Design Criteria	3-3
3.3	Pipeline Descriptions and Routes	3-5
3.3.1	Pipeline Routing Standards	3-5
3.3.2	LNG Project Gas Pipeline	3-6
3.3.3	Hides–Kutubu Condensate Pipeline	3-9
3.3.4	Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline	3-9
3.3.5	Associated Oil Field Gas Pipelines	3-10
3.3.6	Common Onshore Pipeline Permanent Infrastructure	3-10
3.4	Constructing the Onshore Pipelines	3-15
3.4.1	Right of Way Design Criteria and Standards	3-15
3.4.2	Construction Environmental Safeguards	3-18
3.4.3	Onshore Pipeline Construction Activities	3-19
3.4.4	Special Construction	3-26
3.4.5	ROW Reinstatement and Rehabilitation	3-35
3.4.6	Pipeline Cleaning, Gauging and Testing	3-37

3.5	Constructing the Common Onshore Pipeline Infrastructure	3-41
3.5.1	Cathodic Protection	3-41
3.5.2	Valve Stations	3-41
3.5.3	Scraper Station	3-41
3.6	Constructing the Offshore Pipeline	3-41
3.6.1	Construction Timing	3-42
3.6.2	Omati River Landfall Construction	3-42
3.6.3	Offshore Pipeline Installation	3-42
3.6.4	Caution Bay Landfall Construction	3-49
3.6.5	Precommissioning Activities	3-53
3.6.6	Clean-up and Regeneration of Landfall Sites	3-53
3.6.7	Offshore Construction Crew and Accommodation	3-54
3.7	Operating the Pipelines	3-54
3.7.1	Monitoring and Control	3-54
3.7.2	Inspection and Maintenance	3-54
3.8	Decommissioning the Pipelines	3-55
3.8.1	Onshore Pipelines and Spines	3-55
3.8.2	Offshore Pipeline	3-55
4.	PRODUCING AND EXPORTING THE LNG	4-1
4.1	Overview	4-1
4.2	Description of the LNG Facilities	4-2
4.2.1	Proposed Site and General Arrangement	4-2
4.2.2	LNG Plant	4-8
4.2.3	LNG Plant Utilities	4-16
4.2.4	LNG Plant Offsites	4-22
4.2.5	LNG Plant Future Development	4-27
4.3	Description of the LNG Jetty and Materials Offloading Facility	4-27
4.3.1	LNG Export Berth	4-30
4.3.2	Condensate Export Berth	4-32
4.3.3	Materials Offloading Facility	4-32
4.3.4	Mooring Structures and Mooring Load Monitoring System	4-33
4.3.5	Marine Operations and Metocean Monitoring System	4-33
4.3.6	Navigation Aids and Pilot Station	4-33
4.3.7	Tug Berthing	4-33
4.4	Description of the LNG Facilities Site Supporting Infrastructure	4-35
4.4.1	Permanent Operations Camp	4-35
4.4.2	Permanent Turnaround Camp	4-35
4.4.3	Utilities for Permanent Camps	4-36
4.4.4	Telecommunications	4-36
4.4.5	Plant Support Buildings	4-37
4.5	Construction Overview	4-37
4.5.1	Scheduling and Sequencing	4-37
4.5.2	Construction Workforce	4-37
4.5.3	Transport, Shipping and Laydown	4-37
4.5.4	Safeguards	4-38
4.5.5	Training	4-39

4.6	Constructing the Initial Infrastructure	4-39
4.6.1	Site Preparation	4-39
4.6.2	Constructing or Upgrading Roads	4-43
4.6.3	Constructing the Causeway and the Materials Offloading Facility	4-43
4.6.4	Constructing the Temporary Construction Camp	4-45
4.6.5	Constructing the Foundations for Major Infrastructure Items	4-47
4.7	Constructing the LNG Plant	4-47
4.8	Constructing the LNG Plant Utilities and Offsites	4-48
4.8.1	LNG Storage Tanks and Loading System and Boil-off Gas System	4-50
4.8.2	Condensate Storage and Loading System	4-50
4.8.3	Flare Systems	4-50
4.8.4	Utilities	4-52
4.9	Constructing the LNG Jetty	4-52
4.9.1	Causeway Construction	4-52
4.9.2	LNG Jetty Construction	4-52
4.9.3	Export Berth Construction	4-52
4.9.4	Jetty Road and Auxiliaries	4-53
4.9.5	Shipping Access Channel Construction and Turning Basin	4-54
4.10	Constructing the LNG Facilities Site Supporting Infrastructure	4-54
4.11	Operating and Maintaining the LNG Facilities	4-54
4.11.1	Management of Environmental, Safety and Social Issues	4-54
4.11.2	Staffing	4-55
4.11.3	Commissioning	4-55
4.11.4	Control Centre	4-56
4.11.5	Maintenance	4-56
4.12	Operating and Maintaining the Marine Facilities	4-56
4.12.1	Staffing	4-56
4.12.2	Materials Offloading Facility Operations	4-57
4.12.3	LNG Jetty Operations	4-57
4.12.4	Marine Exclusion Zone	4-59
4.13	Decommissioning	4-60
4.13.1	LNG Facilities	4-60
4.13.2	Marine Facilities	4-60
5.	PROJECT LOGISTICS	5-1
5.1	Logistics Strategy	5-3
5.1.1	Overview of Logistics Routes	5-3
5.1.2	Overview of Logistics Loads	5-4
5.2	Logistics Infrastructure	5-4
5.2.1	Access via Water	5-4
5.2.2	Access via Air	5-7
5.2.3	Access via Land	5-11
5.2.4	Accommodation, Laydown Areas and Fuel Depots	5-21
5.3	Constructing or Upgrading the Logistics Infrastructure	5-25
5.3.1	General	5-25

5.3.2	Kopi Wharf	5-25
5.3.3	Upstream Pioneer and Construction Camps and Laydown Areas	5-26
5.3.4	Roadways and Bridges	5-26
5.4	Environmental Safeguards	5-29
5.5	Decommissioning the Logistics Infrastructure	5-29
6.	PIPELINE AND FACILITIES LOCATION CONTEXT	6-1
6.1	Routing Process	6-1
6.1.1	Routing Constraints and Criteria	6-1
6.1.2	Evolution of the Route	6-3
6.2	PNG LNG Project Pipeline Routes: Broad Scale	6-4
6.2.1	Section A: Juha Production Facility to Hides Gas Conditioning Plant	6-5
6.2.2	Section B: Hides Gas Field to Kutubu Central Processing Facility	6-5
6.2.3	Section C: Kutubu Central Processing Facility to Omati River Mouth	6-9
6.2.4	Section D: Omati River Landfall to LNG Facilities Site Landfall	6-12
6.3	PNG LNG Project Pipeline Routes: Fine Scale	6-13
6.4	PNG LNG Project Proposed Pipelines: Travelogue	6-13
6.4.1	Juha Gas Field to Hides Gas Conditioning Plant	6-13
6.4.2	Hides Gas Field to Hides Gas Conditioning Plant	6-17
6.4.3	Hides to Moro	6-19
6.4.4	Moro to Omati River Landfall	6-26
6.4.5	Omati River Landfall to the LNG Facilities Site	6-39
6.5	Associated Facilities	6-45
6.5.1	Segment 26: Agogo Gas Pipeline	6-45
6.5.2	Segment 27: Kutubu Gas Pipeline	6-45
6.5.3	Segment 28: South East Hedinia Spine	6-45
6.5.4	Segment 29: Gobe Gas Pipeline	6-46
7.	PROJECT SUBSTANTIATION (ALTERNATIVES ANALYSIS)	7-1
7.1	PNG Government Directive	7-1
7.2	Economic Benefits to Papua New Guinea	7-1
7.3	No-Project Option	7-2
7.3.1	Government and Landowners	7-2
7.3.2	Local Aspirations Disappointed	7-2
7.3.3	Other Benefits Foregone	7-3
7.3.4	Social Impacts Avoided	7-3
7.3.5	Macro-economic Impacts Avoided	7-3
7.3.6	Environmental Impacts Avoided	7-3
7.3.7	Strategic Consequences of the No-Project Option	7-4
7.4	Gas Commercialisation Options	7-5
7.4.1	LNG	7-5
7.4.2	Other Gas Commercialisation Options	7-6
7.5	LNG Facilities Location Options	7-7

7.5.1	North Coast versus South Coast	7-7
7.5.2	South Coast Options	7-7
7.6	Pipeline Route Options	7-12
7.7	LNG Plant Infrastructure Options	7-12
7.7.1	LNG Jetty Length	7-12
7.7.2	Marine Facilities Location	7-12
7.7.3	LNG Project Gas Pipeline Caution Bay Landfall	7-14
7.7.4	Materials Offloading Facility	7-14
7.7.5	Tug Permanent Moorage	7-20
7.8	LNG Plant Component Options	7-20
7.8.1	Power Generation	7-22
7.8.2	LNG Tanks	7-22
7.8.3	Refrigeration Circuit Compressors	7-23
7.8.4	Low NOx	7-24
7.8.5	Acid Gas Treatment	7-24
7.8.6	Mercury Removal	7-24
7.8.7	Cooling Medium	7-24
7.9	Reservoir Carbon Dioxide	7-25
7.10	Construction Options	7-26
7.10.1	Hides Gas Field Development	7-26
7.10.2	Spoil Management	7-36
8.	LEGAL, ADMINISTRATIVE AND PLANNING FRAMEWORK	8-1
8.1	National Goals and Directives	8-1
8.2	PNG Legislation	8-1
8.2.1	<i>Oil and Gas Act 1998</i>	8-1
8.2.2	<i>Environment Act 2000</i>	8-3
8.2.3	Statutory Planning Context for Project Facilities	8-7
8.2.4	Project Urban Planning Requirements: Office and Residential	8-10
8.2.5	Other PNG Legislation and Regulations	8-11
8.2.6	Summary of Project Approvals	8-13
8.3	International Conventions and Guidelines	8-13
8.3.1	International Environmental Agreements	8-13
8.3.2	Equator Principles	8-18
9.	STAKEHOLDER ENGAGEMENT	9-1
9.1	Overview	9-1
9.2	Consultation Requirements	9-1
9.2.1	PNG <i>Environment Act 2000</i>	9-1
9.2.2	PNG <i>Oil and Gas Act 1998</i>	9-2
9.2.3	International Standards	9-2
9.2.4	Operator Policies	9-3
9.3	Stakeholders	9-3
9.4	Stakeholder Engagement Program	9-5
9.4.1	History	9-5
9.4.2	Program Goals of the EIS Stakeholder Engagement	9-6

9.4.3	Approach and Methods of the EIS Stakeholder Engagement	9-6
9.4.4	Community Relations Management Resources	9-8
9.5	EIS and Related Activities Stakeholder Engagement Schedule	9-13
9.6	Documentation of Stakeholder Engagement	9-14
9.7	Consultation Topics and Feedback to Date	9-15
9.7.1	PNG State Government Officials	9-15
9.7.2	Research Organisations and Industry Groups	9-17
9.7.3	Landowners and Local Communities	9-17
9.8	Continuing Stakeholder Engagement	9-23
9.8.1	Public Consultation and Disclosure Plan	9-23
9.8.2	Grievance Mechanism	9-25
10.	RECEIVING ONSHORE ENVIRONMENT: UPSTREAM FACILITIES AND ONSHORE PIPELINES	10-1
10.1	Introduction and Terms	10-1
10.1.1	Study Area	10-1
10.1.2	'Baseline' and 'Monitoring'	10-2
10.2	Physical Environment	10-2
10.2.1	Location and Geomorphology	10-2
10.2.2	Landforms	10-5
10.2.3	Tectonic Setting and Regional Seismicity	10-10
10.2.4	Geology and Hydrogeology	10-12
10.2.5	Soils	10-16
10.2.6	Climate	10-18
10.2.7	River Systems and Hydrology	10-23
10.2.8	Water Quality	10-30
10.2.9	Noise	10-38
10.2.10	Air Quality	10-39
10.3	Terrestrial Biological Environment	10-40
10.3.1	Data Sources	10-40
10.3.2	Bioregions	10-40
10.3.3	Vegetation and Flora	10-43
10.3.4	Terrestrial Fauna	10-57
10.3.5	Conservation Areas	10-73
10.3.6	Conservation Status of Flora and Fauna	10-75
10.3.7	Noteworthy Areas of Terrestrial Biodiversity	10-81
10.4	Aquatic Biological Environment	10-86
10.4.1	Data Sources	10-86
10.4.2	Aquatic Habitats	10-87
10.4.3	Aquatic Flora	10-89
10.4.4	Fish Fauna	10-91
10.4.5	Aquatic Macroinvertebrate Fauna	10-98
10.4.6	Other Aquatic Fauna	10-99
10.4.7	Implications	10-102
10.5	Terrestrial and Aquatic Resources	10-102
10.5.1	Terrestrial Resource Use	10-102

10.5.2	Aquatic Resource Use	10-114
10.6	Implications for Upstream Facilities Planning, Design and Management	10-123
10.6.1	Natural Environment	10-123
10.6.2	Noise and Air Quality	10-124
11.	RECEIVING MARINE ENVIRONMENT: OFFSHORE PIPELINE	11-1
11.1	Introduction	11-1
11.2	Physical Environment	11-1
11.2.1	Proposed Route	11-1
11.2.2	Physiography	11-2
11.2.3	Climate	11-2
11.2.4	Oceanography	11-4
11.2.5	Water Quality	11-5
11.2.6	Underwater Noise	11-8
11.3	Biological Environment	11-8
11.3.1	Habitats and Seafloor Characteristics	11-8
11.3.2	Marine Fauna	11-10
11.4	Resource and Shipping Use	11-13
11.4.1	Commercial Fisheries	11-13
11.4.2	Subsistence Fisheries	11-18
11.4.3	Shipping Routes	11-19
11.4.4	Kumul Marine Terminal	11-21
11.5	Implications for Offshore Facilities Planning, Design and Management	11-21
12.	RECEIVING ONSHORE ENVIRONMENT: LNG FACILITIES	12-1
12.1	Introduction	12-1
12.2	Physical Environment	12-4
12.2.1	Geomorphology	12-4
12.2.2	Landforms	12-5
12.2.3	Tectonic Setting and Regional Seismicity	12-8
12.2.4	Geology and Hydrogeology	12-8
12.2.5	Soils	12-10
12.2.6	Climate	12-12
12.2.7	River Systems and Hydrology	12-16
12.2.8	Bed Sediment Characterisation	12-21
12.2.9	Water Quality	12-21
12.2.10	Noise	12-25
12.2.11	Air Quality	12-29
12.2.12	Visual and Landscape	12-31
12.3	Terrestrial Biological Environment	12-35
12.3.1	Survey Methods and Limitations	12-35
12.3.2	Vegetation and Flora	12-40
12.3.3	Terrestrial Fauna	12-44
12.3.4	Conclusion	12-50
12.4	Aquatic Biological Environment	12-50
12.4.1	Data Sources	12-51
12.4.2	Aquatic Habitats	12-51

12.4.3	Aquatic Flora	12-55
12.4.4	Fish Fauna	12-55
12.4.5	Macroinvertebrate Fauna	12-58
12.4.6	Other Aquatic Fauna	12-60
12.5	Terrestrial and Aquatic Resource Use	12-61
12.5.1	Terrestrial Resource Use	12-61
12.5.2	Aquatic Resource Use	12-61
12.6	Implications for Upstream Facilities Planning, Design and Management	12-62
13.	RECEIVING MARINE ENVIRONMENT: MARINE FACILITIES	13-1
13.1	Introduction	13-1
13.2	Physical Environment	13-2
13.2.1	Physiography	13-2
13.2.2	Climate	13-2
13.2.3	Oceanography	13-6
13.2.4	Water and Sediment Quality	13-10
13.3	Biological Environment	13-13
13.3.1	Nearshore Habitats Including Intertidal Mangroves	13-14
13.3.2	Coral Reefs and Seafloor Characteristics	13-17
13.3.3	Fish and Other Marine Fauna	13-24
13.4	Resource and Shipping Use	13-30
13.4.1	Subsistence Fisheries	13-32
13.4.2	Boat Traffic	13-35
13.4.3	Mangrove Resource Use	13-35
13.5	Implications for Upstream Facilities Planning, Design and Management	13-37
14.	CULTURAL HERITAGE ENVIRONMENT: UPSTREAM FACILITIES AND PIPELINES	14-1
14.1	Introduction	14-1
14.2	Investigations	14-1
14.3	Cultural and Historical Context	14-2
14.3.1	Juha to Hides	14-2
14.3.2	Hides to Kutubu	14-5
14.3.3	Kutubu to Kaiam	14-6
14.3.4	Kaiam to Goaribari Island	14-7
14.4	Important Cultural Heritage Sites	14-8
14.4.1	Juha to Hides	14-8
14.4.2	Hides to Kutubu	14-11
14.4.3	Kutubu to Kaiam	14-14
14.4.4	Kaiam to Goaribari Island	14-17
14.5	Implications for Project Planning, Design and Management	14-21
15.	SOCIO-ECONOMIC ENVIRONMENT: UPSTREAM FACILITIES AND PIPELINES	15-1
15.1	Introduction	15-1
15.2	Methods and Sources of Information	15-1

15.3	Upstream Project Impact Area	15-5
15.4	Study Area Cultural Groups	15-7
15.5	Social Organisation	15-8
15.6	Health	15-14
	15.6.1 Infrastructure and Service Delivery	15-14
	15.6.2 Principal Health Challenges in the Upstream Project Impact Area	15-15
	15.6.3 Morbidity and Mortality Profiles in the Upstream Project Impact Area	15-16
	15.6.4 Disease Control Issues	15-18
15.7	Education	15-20
	15.7.1 School System	15-22
	15.7.2 Educational Level and Enrolment	15-22
15.8	Agriculture, Fishing and Hunting	15-29
	15.8.1 Agriculture	15-29
	15.8.2 Fishing	15-31
	15.8.3 Forestry	15-31
	15.8.4 Commercial Activities	15-31
	15.8.5 Markets	15-32
	15.8.6 Resettlement	15-34
15.9	Transportation and Communication	15-34
	15.9.1 Roads	15-34
	15.9.2 Air Services	15-36
	15.9.3 Communications	15-36
15.10	Upstream Project Impact Area Economic Activity	15-36
	15.10.1 Local Businesses	15-36
	15.10.2 Personal Income	15-37
15.11	Government	15-38
	15.11.1 National Government	15-38
	15.11.2 Provincial Government	15-42
	15.11.3 Local-level Governments	15-42
15.12	Oil and Gas Governance	15-44
	15.12.1 Expenditure Implementation Committee	15-45
	15.12.2 Benefits Sharing Agreement	15-45
15.13	Gender and Women's Issues	15-46
16.	CULTURAL HERITAGE ENVIRONMENT: LNG AND MARINE FACILITIES	16-1
	16.1 Introduction	16-1
	16.2 Data Sources	16-1
	16.3 Cultural and Historical Context	16-1
	16.4 LNG Facilities Site: Cultural Heritage Sites	16-6
	16.4.1 Ethnographically Known Villages	16-7
	16.4.2 Burial Sites	16-7
	16.4.3 Sacred Sites and Traditional Story Sites	16-9
	16.4.4 Archaeological Sites	16-9
	16.5 Marine Facilities Site: Cultural Heritage Sites	16-11
	16.5.1 Submerged Stilt Villages	16-14

16.5.2	Traditional Story Sites	16-15
16.5.3	<i>Lagatoi</i> Wrecks	16-15
16.5.4	World War II Sites	16-15
16.5.5	Telegraph Cable	16-17
16.6	Implications for Project Planning, Design and Management	16-19
17.	SOCIO-ECONOMIC ENVIRONMENT: LNG FACILITIES	17-1
17.1	Introduction	17-1
17.2	Methods and Sources of Information	17-1
17.3	LNG Facilities Project Impact Area Description	17-3
17.4	LNG Facilities Cultural Groups	17-3
17.5	Social Organisation	17-5
17.6	Health	17-7
17.7	Education	17-12
17.8	Agriculture, Fishing and Subsistence	17-14
17.9	Transport and Communications	17-16
17.9.1	Road Survey Method	17-16
17.9.2	Road Survey Results	17-16
17.9.3	Road Condition	17-16
17.9.4	Analysis of Traffic Movements by Vehicle Type	17-18
17.10	Economic Activity	17-18
17.11	Government and Governance	17-22
18.	ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: UPSTREAM FACILITIES AND ONSHORE PIPELINES	18-1
18.1	General Approach	18-1
18.1.1	Impact Significance	18-1
18.1.2	Types of Impacts	18-2
18.1.3	Matrix Components	18-2
18.1.4	Impact Significance Matrix	18-3
18.2	Landform and Soils	18-3
18.2.1	Issues to be Addressed	18-4
18.2.2	Mitigation and Management Measures	18-6
18.2.3	Regeneration Potential Context	18-10
18.2.4	Residual Impact Assessment	18-20
18.3	Groundwater	18-24
18.3.1	Issues to be Addressed	18-24
18.3.2	Mitigation and Management Measures	18-24
18.3.3	Residual Impact Assessment	18-25
18.4	Water Resources and Hydrology	18-27
18.4.1	Definitions and General Approach	18-27
18.4.2	Issues to be Addressed	18-29
18.4.3	Mitigation and Management Measures	18-33
18.4.4	Residual Impact Assessment	18-37
18.5	Water Quality	18-44
18.5.1	Water Quality Criteria	18-44
18.5.2	Issues to be Addressed	18-46

18.5.3	Mitigation and Management Measures	18-47
18.5.4	Residual Impact Assessment	18-51
18.6	Aquatic Ecology	18-55
18.6.1	Residual Impact Assessment Criteria	18-55
18.6.2	Issues to be Addressed	18-56
18.6.3	Mitigation and Management Measures	18-57
18.6.4	Residual Impact Assessment	18-58
18.7	Biodiversity	18-63
18.7.1	Residual Impact Assessment Criteria	18-63
18.7.2	Issues to be Addressed	18-65
18.7.3	Mitigation and Management Measures	18-66
18.7.4	Residual Impact Assessment	18-78
18.8	Air Quality	18-102
18.8.1	Impact Assessment Criteria	18-102
18.8.2	Issues to be Addressed	18-103
18.8.3	Mitigation and Management Measures	18-105
18.8.4	Residual Impact Assessment	18-105
18.9	Noise	18-108
18.9.1	Impact Assessment Criteria	18-108
18.9.2	Issues to be Addressed	18-110
18.9.3	Mitigation and Management Measures	18-113
18.9.4	Residual Impact Assessment	18-114
19.	ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: OFFSHORE PIPELINE	19-1
19.1	General Approach	19-1
19.1.1	Types of Impacts	19-1
19.1.2	Matrix Components	19-2
19.1.3	Assessment of Significance	19-3
19.2	Seafloor Habitats	19-3
19.2.1	Issues to be Addressed	19-3
19.2.2	Mitigation and Management Measures	19-4
19.2.3	Residual Impact Assessment	19-4
19.3	Sea Water Quality and Hydrology	19-5
19.3.1	Issues to be Addressed	19-5
19.3.2	Mitigation and Management Measures	19-7
19.3.3	Residual Impact Assessment	19-10
19.4	Marine Fauna	19-13
19.4.1	Issues to be Addressed	19-13
19.4.2	Mitigation and Management Measures	19-15
19.4.3	Residual Impact Assessment	19-16
19.5	Marine Fisheries	19-19
19.5.1	Issues to be Addressed	19-19
19.5.2	Mitigation and Management Measures	19-20
19.5.3	Residual Impact Assessment	19-21
19.6	Marine Traffic	19-23
19.6.1	Issues to be Addressed	19-23

19.6.2	Mitigation and Management Measures	19-23
19.6.3	Residual Impact Assessment	19-24
19.7	Quarantine	19-24
19.7.1	Issues to be Addressed	19-24
19.7.2	Mitigation and Management Measures	19-25
19.7.3	Residual Impact Assessment	19-25
20.	ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: LNG FACILITIES	20-1
20.1	Environmental Assessment Method	20-1
20.1.1	General Approach to Assessment	20-1
20.1.2	Types of Impacts	20-1
20.1.3	Matrix Components	20-2
20.1.4	Impact Significance Matrix	20-2
20.2	Soils and Landforms	20-2
20.2.1	Issues to be Addressed	20-3
20.2.2	Mitigation and Management Measures	20-5
20.2.3	Residual Impact Assessment	20-6
20.3	Groundwater	20-7
20.3.1	Issues to be Addressed	20-7
20.3.2	Mitigation and Management Measures	20-7
20.3.3	Residual Impact Assessment	20-8
20.4	Hydrology and Sediment Transport	20-9
20.4.1	Definitions and General Approach	20-10
20.4.2	Issues to be Addressed	20-10
20.4.3	Mitigation and Management Measures	20-13
20.4.4	Residual Impact Assessment	20-14
20.5	Water Quality	20-15
20.5.1	Water Quality Criteria	20-15
20.5.2	Issues to be Addressed	20-17
20.5.3	Mitigation and Management Measures	20-18
20.5.4	Residual Impact Assessment	20-18
20.6	Aquatic Ecology	20-19
20.6.1	Issues to be Addressed	20-21
20.6.2	Mitigation and Management Measures	20-21
20.6.3	Residual Impact Assessment	20-22
20.7	Terrestrial Biodiversity	20-23
20.7.1	Definitions and Approach	20-24
20.7.2	Issues to be Addressed	20-26
20.7.3	Mitigation and Management Measures	20-27
20.7.4	Residual Impact Assessment	20-31
20.7.5	Conclusions	20-38
20.8	Air Quality	20-38
20.8.1	Impact Assessment Criteria	20-38
20.8.2	Issues to be Addressed	20-39
20.8.3	Mitigation and Management Measures	20-40
20.8.4	Residual Impact Assessment	20-41

20.9	Noise	20-47
20.9.1	Impact Assessment Criteria	20-48
20.9.2	Issues to be Addressed	20-48
20.9.3	Mitigation and Management Measures	20-50
20.9.4	Residual Impact Assessment	20-51
20.10	Visual	20-54
20.10.1	Issues to be Addressed	20-54
20.10.2	Mitigation and Management Measures	20-56
20.10.3	Residual Impact Assessment	20-58
21.	ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: MARINE FACILITIES	21-1
21.1	General Approach	21-1
21.1.1	Impact Significance	21-1
21.1.2	Types of Impacts	21-1
21.1.3	Matrix Components	21-2
21.1.4	Assessment of Significance	21-3
21.2	Physical Coastal Processes and Sediment Transport	21-4
21.2.1	Issues to be Addressed	21-4
21.2.2	Mitigation and Management Measures	21-4
21.2.3	Residual Impact Assessment	21-5
21.3	Sea Water Quality	21-5
21.3.1	Issues to be Addressed	21-5
21.3.2	Mitigation and Management Measures	21-7
21.3.3	Residual Impact Assessment	21-11
21.4	Coral Reef, Seagrass and Mangrove Habitats	21-18
21.4.1	Issues to be Addressed	21-18
21.4.2	Mitigation and Management Measures	21-19
21.4.3	Residual Impact Assessment	21-20
21.5	Marine Fish and Other Marine Fauna	21-20
21.5.1	Issues to be Addressed	21-20
21.5.2	Mitigation and Management Measures	21-21
21.5.3	Residual Impact Assessment	21-22
21.6	Subsistence Fisheries and Marine Traffic	21-24
21.6.1	Issues to be Addressed	21-24
21.6.2	Mitigation and Management Measures	21-24
21.6.3	Residual Impact Assessment	21-25
21.7	Mangrove Resource Utilisation	21-27
21.7.1	Issues to be Addressed	21-27
21.7.2	Mitigation and Management Measures	21-27
21.7.3	Residual Impact Assessment	21-28
21.8	Quarantine	21-28
21.8.1	Issues to be Addressed	21-28
21.8.2	Mitigation and Management Measures	21-28
21.8.3	Residual Impact Assessment	21-29

22.	PROJECT-WIDE CULTURAL HERITAGE IMPACTS AND MITIGATION MEASURES	22-1
22.1	Impact Assessment Approach	22-1
22.1.1	Assessment of Significance	22-1
22.1.2	Impact Matrix	22-2
22.2	Issues to be Addressed	22-2
22.2.1	Damage to or Destruction of Cultural Heritage Sites	22-2
22.2.2	Disconnection of Communities from Cultural Heritage Sites and Loss of Sites from Oral Tradition	22-3
22.3	Mitigation and Management Measures	22-3
22.3.1	Damage to or Loss of Cultural Heritage Sites	22-4
22.3.2	Disconnection of Communities from Cultural Heritage Sites and Loss of Sites from Oral Tradition	22-5
22.3.3	Site Specific Mitigation and Management Measures	22-5
22.4	Residual Impacts	22-10
23.	PROJECT-WIDE SOCIO-ECONOMIC IMPACTS AND MITIGATION MEASURES	23-1
23.1	Introduction	23-1
23.2	Assessment Approach	23-1
23.3	Social Cultural Context Considerations	23-1
23.4	Major Social Challenges	23-2
23.4.1	The Benefit Sharing Agreement	23-2
23.4.2	Involuntary Resettlement	23-3
23.5	Host Community Support for the Project	23-3
23.6	Future Economic Benefits	23-5
23.6.1	Beneficiaries	23-5
23.6.2	Benefit Streams	23-5
23.6.3	Without–PNG LNG Project Case	23-7
23.6.4	With–PNG LNG Project Case	23-10
23.6.5	Opportunities and Risks	23-17
23.7	Health	23-18
23.7.1	Context and Development Needs	23-18
23.7.2	Negative Aspects of the Existing Situation	23-20
23.7.3	Without–PNG LNG Project Case	23-20
23.7.4	With–PNG LNG Project Case	23-20
23.8	Education	23-21
23.8.1	Context and Development Needs	23-21
23.8.2	Negative Aspects of the Existing Situation	23-22
23.8.3	Without–PNG LNG Project Case	23-22
23.8.4	With–PNG LNG Project Case	23-23
23.9	Agriculture, Fisheries, Forestry and Subsistence	23-23
23.9.1	Context and Development Needs	23-23
23.9.2	Negative Aspects of the Existing Situation	23-24
23.9.3	Without–PNG LNG Project Case	23-25
23.9.4	With–PNG LNG Project Case	23-25
23.10	Transport and Communications	23-30
23.10.1	Context and Development Needs	23-30

23.10.2	Negative Impacts	23-30
23.10.3	Without–PNG LNG Project Case	23-31
23.10.4	With–PNG LNG Project Case	23-31
23.11	Community Issues	23-33
23.11.1	Project Landowner Identification and the Benefit Sharing Agreement	23-33
23.11.2	Local Business Development and Participation	23-34
23.11.3	Government Capacity and Alignment	23-36
23.11.4	Project Developer and Community Interface	23-37
23.11.5	Women’s Issues	23-37
23.11.6	Vulnerable Populations	23-38
23.11.7	Consumerism	23-38
23.11.8	Migration, Law and Order	23-39
23.11.9	Post-project Sustainability	23-40
23.11.10	Concluding Remarks on Community Issues	23-41
24.	CUMULATIVE AND ASSOCIATED IMPACTS	24-1
24.1	Definitions and Objectives	24-1
24.2	Cumulative Impacts Upstream: Oil and Gas	24-1
24.2.1	Existing Oil and Gas Developments	24-1
24.2.2	Future Developments	24-2
24.3	Cumulative Impacts Upstream: Project and Government Roads	24-3
24.3.1	Forestry	24-4
24.3.2	Food Agriculture	24-5
24.3.3	Biofuels	24-7
24.3.4	Fisheries	24-7
24.3.5	Tourism	24-8
24.3.6	Mining	24-8
24.3.7	Population Growth and Mobility	24-8
24.3.8	Cumulative Impacts Upstream Summary	24-10
24.4	Cumulative Impacts Downstream	24-12
24.4.1	Squatter Settlement	24-12
24.4.2	Habitat and Biodiversity Impacts of Squatting	24-13
24.4.3	Cultural Heritage Impacts of Squatting	24-13
24.4.4	Air Quality	24-13
24.5	Macro-economic Impacts	24-14
24.6	Associated Impacts	24-15
24.7	Project Impacts in Customer Countries	24-15
25.	WASTE MANAGEMENT	25-1
25.1	Relevant Legislation, Guidelines and Policies	25-1
25.1.1	PNG Legislation	25-1
25.1.2	International Conventions and Agreements	25-2
25.1.3	International Finance Corporation Guidelines for Waste Management	25-3
25.1.4	US EPA Standards	25-7
25.1.5	ExxonMobil Waste Management Studies and Standards	25-7
25.1.6	Project Objectives	25-8

25.2	Waste Types	25-9
25.2.1	Construction	25-9
25.2.2	Drilling	25-10
25.2.3	Operations	25-11
25.3	Waste Quantities	25-12
25.4	Waste Management Areas	25-14
25.4.1	Waste Management Area Infrastructure: Upstream	25-16
25.4.2	Waste Management Area Infrastructure: LNG Facilities	25-18
26.	GREENHOUSE GASES AND CLIMATE CHANGE	26-1
26.1	PNG Context	26-1
26.2	Greenhouse Gas Assessment	26-1
26.2.1	Methods of Assessment	26-1
26.2.2	Nature of Greenhouse Gases Included	26-3
26.2.3	Fuel Gas Emission Factors	26-3
26.2.4	Emission Sources	26-4
26.3	Greenhouse Gas Emissions	26-6
26.3.1	Emissions from Project Construction	26-6
26.3.2	Emissions from Upstream Facilities Operations	26-6
26.3.3	Emissions from LNG Facilities Site	26-7
26.3.4	Total Project Greenhouse Gas Emissions	26-10
26.3.5	PNG Total Emissions Context	26-10
26.4	Benchmarking of Greenhouse Gas Emissions	26-12
26.4.1	Comparison with Other Fossil Fuels	26-12
26.4.2	Direct and Indirect Emissions	26-12
26.4.3	Other LNG Developments	26-12
26.5	Project Design	26-15
26.6	Residual Assessment	26-15
27.	ENVIRONMENTAL HAZARD ASSESSMENT	27-1
27.1	Introduction	27-1
27.2	Legislative Framework and Guidelines	27-1
27.2.1	PNG Legislation	27-1
27.2.2	World Bank	27-1
27.3	Project Risk Management Approach and Design Criteria	27-2
27.3.1	ExxonMobil Environment Policy and Risk Management Framework	27-2
27.3.2	ExxonMobil Environmental Standards	27-3
27.3.3	ExxonMobil Philosophies	27-3
27.3.4	Technical Standards and Design Codes	27-3
27.3.5	ExxonMobil Development Company Risk Management Plan	27-4
27.4	Potential Environmental Hazards and Mitigation Measures	27-5
27.4.1	Upstream Hazard Summary	27-5
27.4.2	LNG and Marine Facilities Hazard Summary	27-10
27.4.3	General Mitigation Measures	27-11
27.5	Further Assessment	27-14

28.	ENVIRONMENTAL IMPACT SUMMARY TABLE	28-1
28.1	Environmental Impacts	28-1
28.2	Cultural Heritage Impacts	28-9
29.	SUMMARY OF MITIGATION AND MANAGEMENT COMMITMENTS	29-1
30.	ENVIRONMENTAL MANAGEMENT, MONITORING AND REPORTING	30-1
30.1	Introduction	30-1
30.2	Environmental Management System Overview	30-1
30.2.1	Operations Integrity Management System	30-1
30.3	Management Plan Framework	30-2
30.3.1	Environmental Management Plans	30-2
30.3.2	Social Management Plans	30-7
30.3.3	Health, Safety and Security Management Plans	30-7
30.4	Organisational Structure and Reporting	30-7
30.4.1	Overview of the Environmental and Social Management Organisation	30-7
30.4.2	Responsibilities	30-9
30.5	Policy, Legislation, Guidelines and Standards	30-9
30.5.1	Engineering Design and Management Principles	30-9
30.5.2	Mitigation Measures	30-10
30.6	Monitoring and Reporting	30-10
30.6.1	Monitoring Criteria	30-11
30.6.2	Quality Assurance and Control Procedures	30-14
30.6.3	Feedback and Improvement	30-14
30.6.4	Further Environmental, Cultural Heritage and Social Studies	30-14
31.	GLOSSARY AND ABBREVIATIONS	31-1
32.	BIBLIOGRAPHY	32-1
32.1	Publications	32-1
32.2	Standards	32-13
32.3	Personal Communications	32-14
33.	STUDY TEAM	33-1
33.1	PNG LNG Project	33-1
33.1.1	ExxonMobil	33-1
33.1.2	Esso Highlands Limited	33-1
33.2	Consultants to the PNG LNG Project	33-1
33.2.1	Coffey Natural Systems	33-1
33.2.2	Biodiversity Consultants	33-4
33.2.3	Cultural Heritage Consultants	33-4
33.2.4	Social Studies Consultants	33-5
33.2.5	Specialist Consultants	33-5
33.2.6	Other Project Consultants	33-6

Figures

1.1	Locality map of proposed PNG LNG Project facilities and pipelines	1-2
1.2	Project overview: new and existing facilities and pipelines	1-6
1.3	Indicative project development schedule	1-9
1.4	PNG LNG Project gas supply	1-10
1.5	ExxonMobil's Environment Policy	1-12
1.6	Guide to the EIS	1-21
2.1	Locality map of upstream onshore components	2-2
2.2	Schematic of regional geology and hydrocarbon reservoir elements	2-5
2.3	Juha, Hides and Angore fields locality map	2-9
2.4	Agogo Production Facility, Kutubu Central Processing Facility, Gobe Production Facility and South East Hedinia gas field locality map	2-10
2.5	Indicative layout of the Hides Gas Conditioning Plant, Hides Industrial Area, operations camp, construction camp and laydown areas	2-20
2.6	Indicative layout of the Juha Production Facility	2-24
2.7	Typical drilling rig site layout	2-37
2.8	Typical site layouts for a single and double well	2-38
2.9	Schematic for well design at Hides	2-40
2.10	Layout of the Hides Gas Conditioning Plant during early construction earthworks	2-44
2.11	Simplified process flow diagram for Hides Gas Conditioning Plant and Juha Production Facility	2-47
3.1	PNG LNG Project Pipelines	3-2
3.2	Indicative Kopi scraper station layout	3-11
3.3	Typical ROW cross-section	3-16
3.4	Typical onshore pipeline construction sequence	3-21
3.5	Pipeline watercourse crossing	3-29
3.6	Pipeline watercourse crossing erosion and sediment control and rehabilitation	3-30
3.7	Stages of horizontal directional drilling construction	3-32
3.8	Typical horizontal directional drilling construction site	3-33
3.9	Fault crossing points	3-36
3.10	Omati River onshore-pull landfall construction method	3-43
3.11	Typical anchored laybarge, associated pipe supply vessel and anchor layout	3-45
3.12	Typical mechanical cutter and its trench profiles	3-50
3.13	Typical plough and its trench profile	3-51
3.14	Typical jetting machine and its trench profile, and an artist's impression of a jetting machine in use	3-52
4.1	Proposed LNG Facilities site layout	4-4
4.2	LNG Facilities fencing and exclusion zones	4-7
4.3	Simplified process flow diagram of the LNG Plant	4-9
4.4	Block diagram of the LNG Plant utilities and offsites	4-17
4.5	Block diagram of the site power distribution system	4-20
4.6	Integrated LNG Jetty and Materials Offloading Facility causeway (indicative orientation)	4-28

4.7	Materials Offloading Facility and LNG, condensate and tug berths	4-29
4.8	Notional navigation channel and turning basins	4-34
4.9	Materials Offloading Facility and LNG Jetty construction	4-44
4.10	Indicative temporary facilities and laydown areas	4-46
4.11	LNG process equipment setting	4-49
4.12	LNG storage tank construction	4-51
5.1	Ports, logistics routes and laydown facilities	5-2
5.2	Indicative project barge route to Kopi Shore Base	5-6
5.3	Existing facilities and indicative layout of new facilities at Kopi Shore Base	5-8
5.4	Construction camps, laydown areas and helipads	5-12
5.5	Roads, access tracks and bridges (upstream)	5-13
5.6	Quarries	5-24
6.1	Alternative pipeline alignments	6-6
6.2	Options for pipeline alignment for Homa to Idauwi, Wage Creek and Moro to Ai'io River	6-8
6.3	Kikori River crossing to Omati River Landfall options	6-11
6.4	Travelogue - map 1	6-14
6.5	Travelogue - map 2	6-20
6.6	The Honeanda Complex	6-21
6.7	Travelogue - map 3	6-23
6.8	Travelogue - map 4	6-27
6.9	Travelogue - map 5	6-30
6.10	Travelogue - map 6	6-34
6.11	Travelogue - map 7	6-35
6.12	Travelogue - map 8	6-36
6.13	Travelogue - map 9	6-39
6.14	Travelogue - map 10	6-43
6.15	Travelogue - map 11	6-44
7.1	LNG Facilities alternatives	7-9
7.2	Pipeline landfall and marine facilities location options	7-13
7.3	Initially proposed and shortened Materials Offloading Facility layout	7-16
7.4	Tidal and wind-driven currents with and without a causeway in Caution Bay	7-17
7.5	Brine output mixing zones and marine habitats for the initially proposed Materials Offloading Facility location	7-21
7.6	Reducing the landform and associated impacts of the Hides Ridge ROW and access track	7-35
8.1	EIA process under the <i>Environment Act 2000</i>	8-5
8.2	Lease boundaries	8-9
8.3	Licences required	8-16
9.1	Villages presented to as part of the project's roadshows (2007, 2008)	9-24
10.1	Digital elevation model: Juha to Kutubu	10-3
10.2	Digital elevation model: Kutubu to Omati River Landfall	10-4

10.3	Landforms of the upstream project area	10-6
10.4	Geohazards study regional tectonic map	10-11
10.5	Earthquakes in the vicinity of Papua New Guinea (1900 to 2008)	10-13
10.6	Geology and lithology of the upstream project area	10-14
10.7	Soil orders of the upstream project area	10-17
10.8	Mean monthly rainfall at Tari, Lake Kutubu and Kikori	10-20
10.9	Drainage in the upstream project area (north)	10-24
10.10	Drainage in the upstream project area (south)	10-25
10.11	Bioregions of the upstream project area	10-42
10.12	Distributions of broad vegetation groups within the upstream project area	10-50
10.13	Forestry concessions in the highlands and the gulf region	10-108
11.1	Offshore pipeline route, bathymetry and marine pipeline survey sampling locations	11-3
11.2	Oceanic circulation in the Gulf of Papua	11-6
11.3	Tropical rock lobster migration paths through the Gulf of Papua	11-14
11.4	Gulf of Papua Prawn Fishery vessel monitoring data (2007) and seasonal closure boundaries	11-17
11.5	Key ports within the Gulf of Papua	11-20
12.1	Villages and river catchments at LNG Facilities and surrounds	12-2
12.2	Landforms of the LNG Facilities site and surrounds	12-6
12.3	Lithology and geology of the LNG Facilities site and surrounds	12-9
12.4	LNG Facilities soil sampling sites	12-11
12.5	Hydrology, sediment and groundwater sampling sites and catchment boundaries	12-17
12.6	Catchment areas and aquatic fauna sampling locations	12-23
12.7	Sensitive receptors potentially affected by noise and air emissions	12-26
12.8	Satellite imagery depicting local visual setting	12-33
12.9	Landscape character units	12-34
12.10	Vegetation and habitat regional context	12-37
12.11	Terrestrial Biodiversity Study Area and habitat classification	12-38
12.12	Fauna survey transects (April 2008)	12-39
12.13	The Vaihua River Ecosystem Complex and habitats	12-45
13.1	Caution Bay	13-3
13.2	Detailed bathymetry of Caution Bay	13-4
13.3	Tidal and wind-driven currents	13-8
13.4	Incidence of upwelling and correlation with southeast trade winds	13-9
13.5	Marine survey locations	13-11
13.6	Marine habitat map	13-15
13.7	Percentage of coral reef fish observations	13-25
13.8	Density and biomass of coral reef fish families in December 2007	13-26
13.9	Density and biomass of coral reef fish families in April 2008	13-27
13.10	Marine macrobenthic infauna abundance	13-31
13.11	Fishing zones in Caution Bay	13-36
14.1	Survey corridors investigated for cultural heritage in 2005 and 2008	14-3

14.2	Territory of language groups within the upstream cultural heritage survey divisions	14-4
14.3	Cultural heritage sites between Juha and Hides	14-9
14.4	Cultural heritage sites and 2008 survey corridors between Hides and Angore	14-12
14.5	Cultural heritage sites near the Hides Gas Conditioning Plant site	14-13
14.6	Cultural heritage sites and 2008 survey corridors between Hides and Kutubu	14-15
14.7	Cultural heritage sites and 2008 survey corridor between Kutubu and Kaiam	14-16
14.8	Cultural heritage sites and 2008 survey corridor between Kaiam and Goaribari Island	14-18
15.1	Territory of the ethnic groups within the upstream project impact area	15-9
15.2	Population estimate of ethnic groups within the upstream project impact area	15-10
15.3	Distribution of health facilities in the upstream project impact area	15-17
15.4	Reported HIV and AIDS infection cases in Papua New Guinea	15-21
15.5	PNG education system	15-23
15.6	Project impact area higher education profiles	15-26
15.7	Distribution of educational institutions across the upstream project impact area	15-27
15.8	Illiteracy rates identified in the project impact area from 2005 to 2008	15-28
15.9	Comparison 2005 and 2007 tertiary sponsorship by gender	15-30
15.10	PIA perceptions of decline in hunted species	15-33
15.11	Travel profiles 2005 to 2008	15-35
15.12	Expenditure patterns SIA 1998, 2001 and 2005	15-39
15.13	Expenditure patterns: greenfield and brownfield comparisons	15-40
15.14	Comparative trade store purchases SIA 2001 and 2005	15-41
15.15	Provincial and local-level government structure	15-43
16.1	LNG and marine facilities cultural heritage sites	16-2
16.2	19 th century Koita and Western Motu settlements and land extent	16-5
16.3	Overview of sites recorded during the cultural heritage surveys in the area surrounding the LNG and marine facilities	16-8
17.1	LNG Facilities regional location	17-4
17.2	Cultural groups affected by the project	17-6
17.3	Distribution of health facilities in the vicinity of the LNG Facilities site	17-9
17.4	Educational establishments in the vicinity of the LNG Facilities site	17-13
17.5	LNG Facilities site and environs road network	17-17
17.6	Percentage distribution of traffic users	17-19
17.7	Communal benefits wish-list for SIA 2005-8	17-21
18.1	Terrain types (water resources impact assessment): Kutubu–Hides–Juha	18-30
18.2	Terrain types (water resources impact assessment): Kutubu–Kopi–Omati	18-31
18.3	Kutubu Project water and quality comparison: upstream vs downstream of pipeline river crossings	18-40
18.4	Forestry concessions and roads	18-89
18.5	Lake Kutubu Wildlife Management Area	18-96
18.6	Predicted maximum 1-hour and annual average ground-level concentrations of NO ₂ due to emissions from the Hides Gas Conditioning Plant during operations (µg/m ³)	18-105
18.7	Graphical display of typical noise indices	18-107

18.8	Predicted noise contours for the construction of the Hides Gas Conditioning Plant facilities	18-114
20.1	Distribution of potential acid sulfate soils within the LNG Facilities site	20-4
20.2	Predicted annual and daily TSP concentrations, worst case scenario	20-43
20.3	Predicted annual and daily PM ₁₀ concentrations, worst case scenario	20-44
20.4	Predicted annual and hourly NO ₂ concentrations, worst case scenario	20-46
20.5	Construction noise contours	20-52
20.6	Operations noise contours	20-55
20.7	Viewpoint location map: all viewpoints	20-57
20.8	LNG Facilities viewpoint simulations	20-61
21.1	Brine output mixing zones and marine habitats	21-10
21.2	Modelling of sediment plumes from dredging	21-12
21.3	Turbid plume generated at the spoil disposal site	21-14
21.4	LNG Facilities exclusion zones	21-26
23.1	SIA household survey Q.G4 – project support	23-4
23.2	SIA household survey Q. G7 – positive project impact	23-6
23.3	Future projected gross oil project royalties to existing landowners	23-9
23.4	Future projected gross provincial and local-level government oil benefits	23-11
23.5	Projected comparative stakeholder benefits from oil projects 2008 to 2022	23-12
23.6	Provincial governments' benefits: oil vs LNG	23-15
23.7	SIA village survey Q. I – perceived development needs	23-19
23.8	SIA household survey Q. A1 – positive response to in-migration	23-28
23.9	SIA household survey Q. I5 – social issues affecting personal/family life	23-29
23.10	Multiple residence and licence benefit claims	23-35
25.1	Hides, Gobe and Kopi waste management areas	25-17
26.1	PNG CO ₂ emissions from fossil fuel combustion (1980 to 2005)	26-2
26.2	PNG LNG Project estimated annual emissions	26-11
26.3	Emissions benchmarking of fossil fuels	26-13
26.4	Emissions benchmarking of LNG facilities	26-14
30.1	Preliminary management plan framework	30-3
30.2	Indicative operations management plan hierarchy	30-4
30.3	Indicative environmental and social management team organisational chart	30-8
33.1	PNG LNG Project EIS Management Schematic	33-2

Tables

1.1	Estimated number of peak full-time equivalent positions required for Phase 1 construction	1-15
1.2	Estimated number of employees required for operations	1-15
1.3	Co-venturers of the PNG LNG Project and their interest in the PNG LNG Project	1-16
2.1	Estimated stream-day gas quantities by field (kSm ³ /hr)	2-6

2.2	Estimated stream-day condensate quantities by field (kSm ³ /d)	2-7
2.3	Total resource contribution by field over 30 years and over 40 years	2-8
2.4	Wellpads and wells proposed for the PNG LNG Project	2-12
2.5	Hides gathering system design data	2-15
2.6	Angore gathering system design data	2-17
2.7	Juha gathering system design data	2-18
2.8	Hides area electrical load summary	2-49
2.9	Security design basis summary	2-55
3.1	Summary of pipeline preliminary design parameters	3-4
3.2	Concrete coating thickness	3-8
3.3	Preliminary design criteria for the pipeline ROW	3-15
4.1	LNG Facilities electrical power base load, growth and contingency estimates	4-18
4.2	LNG carrier dimensions	4-31
4.3	Materials Offloading Facility vessel specifications	4-33
4.4	Current freight estimates	4-38
4.5	Operations environmental safety limits	4-59
5.1	Indicative logistics routes and their proposed loads	5-4
5.2	Roadway and bridge terminology	5-14
5.3	Preliminary design criteria for roadways	5-14
5.4	Truck movements during upstream construction	5-17
5.5	Preliminary summary of proposed new and upgraded roadways	5-20
5.6	Proposed construction camps, laydown areas and fuel depots	5-21
6.1	Pipeline route selection criteria	6-1
6.2	Factors for the route west of Homa	6-7
6.3	Moro to the Ai'io River route factors	6-10
6.4	Kikori River crossing to Omati River Landfall route factors	6-10
7.1	LNG Facilities site selection constraints	7-11
7.2	Modelled hydrodynamic effects of the 2-km-long combined LNG Jetty/Materials Offloading Facility causeway	7-18
7.3	Summary of results for the three causeway options	7-19
7.4	Single- and double-containment LNG tanks	7-22
7.5	Comparison of existing and PNG LNG Project Hides gas field wells and gathering systems	7-28
7.6	Hides gathering system (Hides Wellpads A to E only) construction methods summary	7-34
7.7	Spoil management options	7-36
8.1	Notification of Level 3 Activities to DEC Under Provisions of the Environment Act (Prescribed Activities) Regulation 2002	8-3
8.2	Notification of Level 2 Activities to DEC Under Provisions of the Environment Act (Prescribed Activities) Regulation 2002	8-4
8.3	Other environmental legislation and regulations	8-11
8.4	Government approvals for full project implementation (licences)	8-14
8.5	Government approvals for full project implementation (other)	8-15

8.6	Relevant international agreements to which PNG is a signatory	8-17
9.1	Methods of stakeholder consultation	9-6
9.2	EIS consultation schedule	9-13
9.3	Meetings with PNG state government officials and NGOs	9-15
9.4	Villages and number of participants – 2007 and 2008 roadshows	9-17
9.5	Summary of environmental and social issues raised through local community engagement	9-19
10.1	Meteorological data for the upstream project area	10-21
10.2	Water quality of the Baia River and Karius Ridge area	10-31
10.3	Water quality of streams in the Juha area	10-33
10.4	General water quality of upstream project area rivers in the Kikori River catchment	10-35
10.5	Summary of ambient and background noise levels at Hides village	10-39
10.6	Bioregions of the upstream project area	10-41
10.7	Groupings of FIMS vegetation types used in EIS analysis	10-46
10.8	Number of non-volant mammal species in the bioregions of the upstream project area	10-59
10.9	Endemicity of non-volant mammals in the bioregions of the upstream project area	10-61
10.10	Number of bat species in the bioregions of the upstream project area	10-63
10.11	Endemicity of bird species in the bioregions of the upstream project area	10-67
10.12	Number of reptile species in the bioregions of the upstream project area	10-69
10.13	Number of amphibian species in the bioregions of the upstream project area	10-71
10.14	WWF areas of biological significance in the upstream project area	10-75
10.15	Flora species of conservation significance in the upstream project area	10-76
10.16	Non-volant mammal species of conservation significance in the upstream project area	10-76
10.17	Bat species of conservation significance in the upstream project area	10-77
10.18	Bird species of conservation significance in the upstream project area	10-78
10.19	Reptile species of conservation significance in the upstream project area	10-80
10.20	Amphibian species of conservation significance in the upstream project area	10-81
10.21	Fish fauna of the highlands region of the upstream project area	10-92
10.22	Fish fauna of Lake Kutubu and preferred habitat types	10-94
10.23	Fish fauna of the Kikori River catchment included in the IUCN Red List	10-96
10.24	Comparison of total fish fauna and endemism in the major river systems of Papua New Guinea	10-97
10.25	Freshwater turtles of the Kikori River system	10-100
11.1	Summary of vessels that berthed at the Port of Port Moresby during 2005 and 2006	11-19
12.1	Air temperature statistics for Port Moresby	12-14
12.2	Rainfall statistics for Port Moresby	12-14
12.3	Mean monthly evaporation recorded at Port Moresby	12-15
12.4	Summary of the analysis of MesoLAPS and AWS data	12-15
12.5	Quality of surface waters sampled on the LNG Facilities site and environs	12-22
12.6	Comparison of water quality results against guidelines	12-24

12.7	Summary of ambient and background noise levels	12-28
12.8	Operator-attended ambient noise environment	12-28
12.9	Transects, habitat and fauna survey effort	12-36
12.10	Non-volant mammals recorded in 2008 and potentially in study area	12-47
12.11	IUCN-listed bat species potentially occurring at the study area	12-48
12.12	IUCN-listed and nationally protected bird species observed or possibly occurring at the study area	12-49
12.13	Fish species recorded in estuarine and freshwater habitats	12-55
12.14	Decapod crustaceans recorded in the estuarine and freshwater habitats.	12-59
12.15	Macroinvertebrate families recorded	12-60
13.1	Summary of the peak wind, wave, sea level and current conditions generated in Caution Bay by the passage of a theoretical 990 hPa tropical storm and Tropical Cyclone Guba	13-10
13.2	Summary of general water quality results	13-12
13.3	Sedimentation rates within Caution Bay	13-12
13.4	Coral reef community composition based on the 6-m coral visual census ^{1,2}	13-19
13.5	Fish density and biomass estimates	13-24
13.6	Observed use of reefs and mangroves between Boera and Papa	13-33
14.1	Scope of assessment conducted for the upstream cultural heritage characterisation from 2005 to 2008	14-1
15.1	Studies undertaken in the upstream project impact area during 2005 to 2008	15-2
15.2	Principal causes of morbidity and mortality in the project impact area	15-16
15.3	Outpatient ailments in Juha (PRL-2) area	15-19
15.4	School systems before the 1991 education reform	15-22
15.5	Formal education and literacy levels	15-22
15.6	University of Papua New Guinea Waigani campus 2006/07 enrolment statistics	15-24
15.7	Tertiary education sponsorship 2007	15-25
15.8	Average livestock per household	15-32
15.9	Proportion (%) of households surveyed reporting specific income sources	15-37
15.10	Local-level government status in Southern Highlands and Gulf province project areas	15-44
15.11	Beneficiaries and benefit stream flows	15-44
15.12	Huli women's associations	15-47
17.1	Previous studies undertaken in the vicinity of the proposed LNG Facilities site	17-1
17.2	LNG Facilities site area potable water supply status	17-8
17.3	Comparative education statistics for villages in the LNG Facilities site project impact area (2007)	17-14
17.4	Responses to questions about reef and mangrove use	17-15
17.5	Operating public motor vehicles in the LNG Facilities site environs	17-18
17.6	LNG Facilities site project impact area villages trade stalls status summary	17-20
17.7	SIA baseline comparison for stated income sources (1997–2008)	17-20
18.1	Matrix of significance	18-3
18.2	Observed regeneration on soil-dominated disturbed surfaces	18-11
18.3	Observed regeneration on limestone-dominated disturbed surfaces	18-12

18.4	Types of impacts and associated regeneration potential	18-19
18.5	Magnitude of impact – soils	18-21
18.6	Sensitivity of resource/receptor – soils	18-21
18.7	Magnitude of impact: groundwater	18-26
18.8	Sensitivity of resource/receptor: groundwater	18-26
18.9	Aquatic impact assessment: spatial scales	18-28
18.10	Aquatic impact assessment: temporal scales	18-28
18.11	Specific impact criteria: water resources and hydrology	18-29
18.12	Hydrotest water volumes	18-37
18.13	Pipeline ROW sedimentation into the Bakari, Maruba and Mandali river catchments	18-39
18.14	Study assessment impact criteria: total suspended sediment (TSS)	18-43
18.15	Prescribed water quality criteria	18-43
18.16	Emissions, effluent and waste levels from onshore oil and gas development	18-48
18.17	Specific impact criteria: aquatic biological community structure	18-54
18.18	Magnitude of impact: biodiversity	18-62
18.19	Sensitivity of resource/receptor: biodiversity	18-63
18.20	Relevance of impacts during construction and operations	18-63
18.21	Proposed mitigation and management measures in relation to biodiversity impacts	18-65
18.22	Estimated habitat losses produced by the upstream component of the project	18-76
18.23	Estimated habitat losses within BVGs produced by the upstream component of the project	18-77
18.24	Estimated habitat losses (ha) from the 12 bioregions	18-79
18.25	Residual impacts on listed species	18-99
18.26	Project air quality assessment criteria	18-101
18.27	Magnitude of impact – noise	18-112
18.28	Sensitivity of resource/receptor – noise	18-112
19.1	Magnitude of impact categories and descriptions – offshore pipeline	19-2
19.2	Sensitivity of resource/receptor categories and descriptions – offshore pipeline	19-3
19.3	Hydrotest water source and disposal options – offshore	19-9
19.4	Aquatic toxicity data for Bactron B1150	19-12
20.1	Impact magnitude and significance: water resources and hydrology	20-10
20.2	Areas of disturbance that will occur in the Vaihua River catchment during construction	20-11
20.3	Areas of disturbance that will occur in the North Vaihua River catchment during construction	20-12
20.4	Aquatic impact assessment: spatial scales	20-16
20.5	Magnitude of impact categories and descriptions: LNG Facilities site	20-20
20.6	Sensitivity or value of resource or receptor categories and descriptions: LNG Facilities site	20-20
20.7	Impact magnitude categories	20-25
20.8	Criteria for the value (sensitivity) of conservation assets at the LNG Facility site	20-26
20.9	Direct and indirect potential biodiversity impacts of the LNG Facility and associated infrastructure	20-27

20.10	Terrestrial biodiversity mitigation and management factors for the LNG Facility and associated infrastructure	20-28
20.11	Impact analysis for habitats and the Vaihua River Ecosystem Complex (VREC)	20-32
20.12	Habitat losses in site and regional context	20-33
20.13	Habitat losses within the Vaihua River Ecosystem Complex	20-35
20.14	Predicted highest concentration of emissions of carriers, tankers and tugs	20-47
20.15	Predicted construction noise levels (dB(A))	20-51
20.16	Predicted operations noise levels (dB(A))	20-53
20.17	Quantitative assessment of sensitive sites	20-59
20.18	Qualitative assessment of viewer response to visual change	20-59
21.1	Magnitude of impact categories and descriptions: marine facilities	21-2
21.2	Sensitivity of resource or receptor categories and descriptions: marine facilities	21-3
22.1	Upstream mitigation measures for cultural heritage sites	22-7
22.2	LNG and marine facilities mitigation measures for cultural heritage sites	22-9
23.1	Benefits summary to local stakeholders at December 2006	23-7
23.2	PNG stakeholder benefit streams	23-13
23.3	Percentage of respondents growing cash crops (catchment-wide averages)	23-24
23.4	Average livestock per households surveyed	23-24
23.5	Entitlement matrix	23-26
24.1	Existing and predicted additional forest clearance in the project area	24-11
25.1	Waste types that will be generated during upstream and LNG Facilities site construction	25-10
25.2	Additional waste types that will be generated during operation of the upstream facilities and the LNG Facilities site	25-11
25.3	Upstream construction and operations waste generated, estimated quantities and disposal methods	25-13
25.4	Waste management infrastructure	25-15
25.5	Waste haulage distances for upstream construction waste	25-16
26.1	Gas combustion emission factors	26-4
26.2	Emissions summary for construction	26-6
26.3	Emission summary for upstream facilities	26-7
26.4	LNG Facilities emissions	26-7
26.5	Benchmarking global LNG facilities	26-9
26.6	Shipping emissions	26-10
26.7	Project emissions	26-10
28.1	LNG Facilities site impact summary	28-2
28.2	Upstream project area impact summary	28-4
28.3	Marine facilities and offshore pipeline impact summary	28-8
28.4	Potential impacts to aspects of cultural heritage	28-11
29.1	LNG Facilities mitigation and management commitments	29-2
29.2	Upstream mitigation and management commitments	29-6
29.3	Marine mitigation and management commitments	29-25

29.4	Cultural heritage mitigation and management commitments	29-28
30.1	Water quality criteria	30-11
30.2	Emissions, effluent and waste levels from onshore oil and gas development	30-12
30.3	Air quality criteria	30-13
30.4	Preliminary list of environmental and cultural heritage studies	30-14

Plates

2.1	Hides Gas to Electricity Plant (background) and Porgera Power Plant (foreground)	2-14
2.2	Gobe Production Facility	2-14
2.3	Kutubu Central Processing Facility	2-14
2.4	Agogo Production Facility	2-29
2.5	Typical drill site (at Kutubu)	2-29
3.1	Typical pipeline marker sign	3-14
3.2	Example of a pipeline watercourse crossing with a shoo-fly road	3-14
3.3	Example of a pipeline laying spread	3-14
3.4	Example of a laydown area	3-22
3.5	Roadway or ROW grading, showing topsoil stockpiles at the right	3-22
3.6	Example of pipe bending	3-22
3.7	Example of pipeline spread stringing and welding pipe	3-25
3.8	Example of a pipeline watercourse crossing	3-25
3.9	Typical horizontal directional drilling rig	3-25
3.10	Example of horizontal directional drilling	3-34
3.11	Example of a pipeline swamp crossing	3-34
3.12	Example of timber riprap installation across a marsh area	3-34
3.13	Example of a reinstated ROW	3-38
3.14	Typical anchor-handling tug	3-38
3.15	Typical general supply vessel	3-38
3.16	Typical pipe supply vessel, showing pipe sections on deck and a pipe section being transferred to the pipelaying vessel by crane	3-47
3.17	Typical survey vessel	3-47
3.18	Natural revegetation near the Omati River Landfall	3-47
4.1	Night view of SEGAS LNG facility in Egypt	4-11
4.2	Close-up of SEGAS LNG facility in Egypt	4-11
4.3	A process pipe rack 70% completed	4-11
4.4	Typical pre-assembled pipe rack	4-12
4.5	LNG jetty at Tangguh LNG	4-12
4.6	Barge-mounted desalination plant	4-12
4.7	Amine absorber being unloaded	4-58
4.8	A cryogenic heat exchanger being unloaded	4-58
5.1	Typical large Highlands Highway bridge	5-16

5.2	Typical small Highlands Highway bridge	5-16
5.3	Typical sealed section of the Highlands Highway	5-16
6.1	Unbroken low-altitude, medium-crowned forest on the route from Juha to the Hides Gas Conditioning Plant	6-15
6.2	Stream disappearing into a sinkhole at Juha North survey area	6-15
6.3	Landslides in the Baia River area	6-15
6.4	Swampland and settlement in the South Karius survey area	6-17
6.5	Typical wellpad location on karst	6-17
6.6	Hides Ridge lower-montane, small-crowned forest with <i>Nothofagus</i>	6-17
6.7	Hides Ridge very small-crowned forest with <i>Nothofagus</i>	6-18
6.8	Swamps associated with sinkholes	6-18
6.9	Landscape between the road and the Tagari River proposed for the Hides Gas Conditioning Plant	6-18
6.10	Possible site of the Benaria River crossing	6-24
6.11	The Mubi River	6-24
6.12	Little-disturbed forest in the upper catchment of Wage Creek	6-24
6.13	The northern end of Lake Kutubu	6-25
6.14	Swamp forest complexes at Lake Kutubu	6-25
6.15	The crude oil export pipeline ROW in karst near the Kutubu Central Processing Facility	6-25
6.16	The crude oil export pipeline ROW and access road near the Iwa Range	6-28
6.17	Small-crowned forest in polygonal karst terrain in the Ai'io River valley	6-28
6.18	Manu village in the Ai'io River valley	6-28
6.19	Polygonal karst terrain clothed in small-crowned forest in the eastern Ai'io River valley	6-31
6.20	Kantobo village on the Mubi River	6-31
6.21	Flooding of the existing crude oil export pipeline ROW	6-31
6.22	Pipeline ROW descent to the Mubi River crossing	6-32
6.23	Approximate site of Mubi River crossing	6-32
6.24	Medium-crowned lowland hill forest along the northern bank of the Kikori River downstream of the Mubi River confluence with the existing crude oil export pipeline in foreground	6-32
6.25	Road intersections near Gobe Airstrip	6-37
6.26	Kaiam ferry crossing on the Kikori River	6-37
6.27	Small rugged karst terrain south of Veiru Creek	6-37
6.28	Landfall on the Omati River	6-40
6.29	Nypa palms and reeds in the Omati River	6-40
9.1	Project Awareness and Environmental Inception Report Roadshow presentation to DEC and other government officials	9-9
9.2	Lea Lea Project Awareness and Environmental Inception Report Roadshow presentation (November 2007)	9-9
9.3	Kaiam Project Awareness and Environmental Inception Report Roadshow presentation (November 2007)	9-9

9.4	Goare Project Awareness and Environmental Inception Report Roadshow presentation (November 2007)	9-10
9.5	Papa Project Awareness and Environmental Inception Report Roadshow presentation (November 2007)	9-10
9.6	Juni Project Awareness and Environmental Inception Report Roadshow presentation (November 2007)	9-10
9.7	Idauwi Project Awareness and Environmental Inception Report Roadshow presentation (November 2007)	9-11
9.8	Kikori Project Community Awareness and Mitigation Roadshow presentation (November 2008)	9-11
9.9	Boera Project Community Awareness and Mitigation Roadshow presentation (November 2008)	9-11
9.10	Yarale Project Community Awareness and Mitigation Roadshow presentation (November 2008)	9-12
10.1	Darai Plateau showing cockpit and cone karst countryside	10-8
10.2	Pinnacle and tower karst countryside	10-8
10.3	Emergence of subsurface waters from underground stream	10-8
10.4	Limestone pavement and thin root mat of fallen trees	10-19
10.5	Wind-thrown patches of forest	10-19
10.6	Example of the unstable banks of the Baia River	10-19
10.7	Example of active bank failure along the Tagari River	10-27
10.8	Hegigio Gorge	10-27
10.9	View of Lake Kutubu	10-27
10.10	Lichens and mosses on limestone pavement	10-44
10.11	Significant slumping in the middle Hegigio River	10-44
10.12	The Karius Range with steep scrub-covered sides	10-44
10.13	Epiphytes in lower montane small-crowned forest with <i>Nothofagus</i>	10-52
10.14	The Ai'io River swamp forest complexes	10-52
10.15	<i>Arenga</i> sp. and <i>Galubia</i> sp. palms typical of less inundated areas	10-52
10.16	<i>Melodinus forbesii</i> found on Hides Ridge	10-58
10.17	<i>Agalymyia formosa</i> found on Hides Ridge	10-58
10.18	Plush-coated ringtail	10-58
10.19	Mountain cuscus	10-60
10.20	Megachiropteran bat <i>Nystimene aello</i>	10-60
10.21	Megachiropteran bat <i>Paranyctimene</i> sp.	10-62
10.22	Microchiropteran bat <i>Rhinolophus euryotis</i>	10-62
10.23	Microchiropteran bat <i>Aselliscus tricupidatus</i>	10-64
10.24	Superb fruit-dove	10-64
10.25	Rufous-backed honeyeater	10-64
10.26	Garnet robin	10-68
10.27	The gecko <i>Cyrtodactylus</i> sp.	10-68
10.28	The agamid <i>Hypsilurus modestus</i>	10-68
10.29	Boelen's python (<i>Morelia boeleni</i>)	10-70

10.30	The ranid frog <i>Rana cf. grisea</i>	10-70
10.31	Tree frog laying eggs on a leaf above a sinkhole swamp	10-70
10.32	Tree frog eggs on leaf where tadpoles will hatch and drop into a sinkhole swamp below	10-72
10.33	An undescribed species of microhylid <i>Albericus</i>	10-72
10.34	The tree frog <i>Litoria cf. arfakiana</i>	10-72
10.35	The torrent frog <i>Litoria wollastoni</i>	10-74
10.36	A <i>Nyctimistes</i> sp. tree frog with road-map eyelids typical of the genus	10-74
10.37	Hides Wellpad E, site of the existing Hides 1 well	10-74
10.38	Sinkhole swamp on Hides Ridge	10-84
10.39	The Maruba River near Homa	10-84
10.40	Riverine habitat (Baia River mainstream)	10-84
10.41	Baia River clear water stream habitat	10-88
10.42	Standing groundwater sinkhole habitat	10-88
10.43	Blind cave gudgeon (<i>Oxyeleotris caeca</i>)	10-88
10.44	Pig-nosed turtle (<i>Carettochelys insculpta</i>)	10-101
10.45	New Guinea freshwater crocodile (<i>Crocodylus novaeguineae</i>) at Baia River	10-101
10.46	Typical garden in the highlands	10-101
10.47	Juvenile pigs	10-105
10.48	Juvenile cassowary	10-105
10.49	Disused logging roads built by Turama Forest Industries in Gulf Province	10-105
10.50	Log barge, Kikori River	10-111
10.51	Sirebi logging camp, Kikori River	10-111
10.52	Loading logs at Paia Inlet, Gulf Province	10-111
10.53	Forest traversed by the Juha–Hides route	10-112
10.54	Lowland forests in the Juha area	10-112
10.55	Rugged terrain in the vicinity of the Juha–Hides route	10-112
10.56	Emergent klinkii pine in the Hides area	10-113
10.57	Steep polygonal karst terrain in the Kutubu–Poroma proposed concession	10-113
10.58	Lake Mabuli	10-113
10.59	Subsistence catch of Kutubu tandans and fimbriate gudgeons from Lake Kutubu	10-119
10.60	Fisherman holding a barramundi caught in the Omati–Kikori delta	10-119
10.61	Pig-nosed turtle eggs collected in the Omati–Kikori delta	10-122
10.62	Captured pig-nosed turtles	10-122
11.1	Turbid outflow from the Omati–Kikori delta	11-7
11.2	Forest debris in the Gulf of Papua near the Omati–Kikori delta	11-7
11.3	Video footage showing high levels of suspended sediment near the Omati River mouth	11-7
11.4	Shark in prawn trawl catch	11-11
11.5	Ray in prawn trawl catch	11-11
11.6	Olive ridley turtle in prawn trawl catch	11-11
11.7	Green turtle in prawn trawl catch	11-12

11.8	Sea snakes in prawn trawl catch	11-12
11.9	Dolphins observed during the marine pipeline survey	11-12
11.10	Gulf of Papua Prawn Fishery trawler in Port Moresby	11-16
11.11	Canoes getting trash fish from a prawn trawler	11-16
12.1	Grasslands on the LNG Facilities site	12-3
12.2	Mangroves at the LNG Facilities site	12-3
12.3	Backwater at the LNG Facilities site	12-3
12.4	Saltflat, beach and dune, and mangrove, typical of Coastal Papa System (northern end of study area)	12-7
12.5	Grassland with streamside open woodland	12-7
12.6	Savanna on hilly terrain	12-7
12.7	Black cracking clays (vertisols) on the site	12-13
12.8	The mouth of the Vaihua River	12-13
12.9	Remnant pool of the Vaihua River	12-13
12.10	Upper reaches of the Vaihua River	12-19
12.11	Flowing reach of Karuka Creek	12-19
12.12	Noise and air quality monitoring equipment at Metago Bible College	12-19
12.13	Grassland and open woodland extending east from Lea Lea Road	12-43
12.14	Riparian forest along the Vaihua River	12-43
12.15	Mangroves and subcoastal wetlands/mudflats around the Vaihua River	12-43
12.16	Mangrove along the Vaihua River	12-46
12.17	Eastern tributary of Karuka Creek (dry season)	12-46
12.18	Western tributary of Karuka Creek (dry season)	12-46
12.19	Mudflat inundated after a night's heavy rain	12-53
12.20	Mudflat and grassland inundated after a night's heavy rain	12-53
12.21	Evidence of mangrove wood harvesting in Vaihua River	12-53
12.22	Gill netting to sample fishes	12-57
12.23	Fyke-net recovery at high tide	12-57
13.1	Automatic weather station near Caution Bay coast	13-5
13.2	Dominant fringing-coast mangrove (<i>Rhizophora stylosa</i>)	13-5
13.3	Aerial roots of a grey mangrove patch (<i>Avicennia marina</i>)	13-5
13.4	Small patches of sandy beach along the southern coast of Caution Bay	13-16
13.5	Supratidal mudflats / saltflats	13-16
13.6	<i>Enhalus acoroides</i> , <i>Syringodium isoetifolium</i> , and <i>Cymodocea</i> spp. seagrass	13-16
13.7	Coral rubble on an offshore bommie in Caution Bay	13-18
13.8	Dead coral and rubble	13-18
13.9	Reef top dominated by brown algae (<i>Sargassum</i> spp.)	13-18
13.10	Sea urchins (<i>Diadema</i> spp.) in Caution Bay	13-21
13.11	Fish abundance on <i>Pavona clavus</i> bommie	13-21
13.12	Coral structure of <i>Pavona clavus</i> bommie	13-21
13.13	Coral diversity and cover at Vari Vari Island	13-23
13.14	Schooling damselfish at Idihi Island	13-23

13.15	Cryptic damselfish on a digitate <i>Acropora</i> coral	13-23
13.16	Butterflyfish feeding on encrusting algae	13-29
13.17	Dolphins in Caution Bay	13-29
13.18	Fresh catch of tuna in Boera village	13-29
15.1	Longhouse at Siabi showing 'menstrual confinement' structure	15-11
15.2	The late Kula from Gesesu; an eminent and widely known curer	15-11
15.3	Collecting mud crabs at Goaribari Island	15-11
16.1	<i>Lagatoi</i> on Port Moresby Harbour	16-4
16.2	Pottery being manufactured at Porebada	16-4
16.3	Motu ceramic pot types	16-4
16.4	Stream outlet at Davage, where Edai Siabo's first <i>lagatoi</i> was built	16-10
16.5	Dugout canoe under construction at Davage	16-10
16.6	Memorial commemorating Reverend Lawes and the first church, Boera	16-10
16.7	1944 Boera battery: number 1 gun	16-12
16.8	2008 Boera battery: gun pit number 2	16-12
16.9	World War II artillery projectiles held at Boera village	16-12
16.10	Artillery projectile head discovered in the LNG Facility site area. Armour piercing head and fuse was intact, indicating the projectile was live	16-13
16.11	Pottery rim from the north side of the intertidal zone at Konekaru Beach	16-13
16.12	Stone core artefact from the intertidal zone at Konekaru Beach	16-13
16.13	Location of first <i>lagatoi</i> landing and stone anchor site, Boera (marked by arrow)	16-16
16.14	First <i>lagatoi</i> landing and stone anchor site, showing stone anchor at low tide near Boera village	16-16
16.15	Instrument panel and aluminium skin from Japanese Zero fighter at Lea Lea	16-16
16.16	October 1943 Boera Point, New Guinea: drums with the marine telegraph cable attached being towed to shore	16-18
17.1	Lea Lea water track	17-10
17.2	Fetching water at Lea Lea	17-10
17.3	Five-day summary water usage in Porebada	17-10
17.4	Latrines in Boera	17-11
17.5	Market trade stall, Boera village	17-11
18.1	Regeneration of Kutubu to Kopi access way with cut and fill on ridge descending into Ai'io River	18-13
18.2	Regeneration of the crude oil export pipeline ROW 8 km east of Kutubu	18-14
18.3	Regeneration around Ai'io valve station	18-15
18.4	Regeneration of the crude oil export pipeline ROW approaching Mubi valve station	18-16
18.5	Regeneration on limestone rubble at major ROW excavation in Mubi River karst terrain	18-17
18.6	Example of poor regeneration on limestone pavement	18-18
18.7	Example of poor regeneration on limestone rubble (Moran Road, May 2005)	18-18
24.1	Sirebi log yard on the Sirebi River	24-6
24.2	Small-scale logging impact	24-6

Boxes

10.1	Notes on existing and proposed forest management areas on the PNG LNG Project area	10-110
28.1	Example cultural heritage impact matrix	28-10

Appendices

UPSTREAM AND OFFSHORE PIPELINE

- 1 Biodiversity Impact Assessment
- 2 Aquatic Fauna Impact Assessment
- 3 Resource Use Survey of the Omati–Kikori Delta
- 4 Hydrology and Sediment Transport Impact Assessment
- 5 Water and Sediment Quality Impact Assessment
- 6 Groundwater Impact Assessment
- 7 Forestry Impact Assessment
- 8 Soils and Rehabilitation Impact Assessment
- 9 Air Quality Impact Assessment
- 10 Noise Impact Assessment
- 11 Offshore Impact Assessment

LNG AND MARINE FACILITIES

- 12 Biodiversity Impact Assessment
- 13 Aquatic Fauna Impact Assessment
- 14 Hydrology and Sediment Transport Impact Assessment
- 15 Water and Sediment Quality Baseline Impact Assessment
- 16 Groundwater Impact Assessment
- 17 Soils and Rehabilitation Impact Assessment
- 18 Air Quality Impact Assessment
- 19 Noise Impact Assessment
- 20 Visual Impact Assessment
- 21 Road User Survey
- 22 Hydrodynamic Modelling
- 23 Nearshore Marine Impact Assessment
- 24 Resource Use Survey of Caution Bay

PROJECT-WIDE

- 25 Greenhouse Impact Assessment
- 26 Social Impact Assessment (including cultural heritage)

Attachments

- 1 LNG Safety
- 2 Cross-reference of DEC Guidelines and Requirements to EIS Sections
- 3 Technical Codes and Standards
- 4 Potentially Applicable Legislation
- 5 Hazard Identification Summary
- 6 ExxonMobil Operations Integrity Management System