20. ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES: LNG FACILITIES

This chapter discusses the potential onshore environmental impacts and mitigation measures associated with the construction and operation of the LNG Facilities site and the access road to the site (referred to collectively herein as ‘the LNG Facilities site’ and shown in Figure 4.1). The impacts and mitigations associated with the marine facilities (the LNG Jetty and the Materials Offloading Facility) are discussed in Chapter 21, Environmental Impacts and Mitigation Measures: Marine Facilities.

The LNG Facilities site is located on the shores of Caution Bay approximately 20 km northwest of Port Moresby at the mouth of the Vaihua River. Grasslands currently dominate the site vegetation. The site was previously developed as a sisal plantation and later as pasture for livestock production. In addition, the location was a firing range for the Allied armed forces during World War II. For more information pertaining to the existing and historical conditions at the site, see Chapter 12, Receiving Onshore Environment: LNG Facilities.

20.1 Environmental Assessment Method

20.1.1 General Approach to Assessment

The general approach and method that this EIS uses to assess environmental impact significance is described in Section 18.1.1, Impact Significance.

Definitions of the types of impacts (direct, indirect and cumulative), magnitude of impacts and sensitivity of the resource/receptor in the onshore environment of the LNG Facilities site are described in the sections below.

20.1.2 Types of Impacts

20.1.2.1 Direct and Indirect Impacts

Direct impacts are generally those impacts occurring either within the project footprint (such as clearing of vegetation) or as a direct consequence of a project activity (such as a waste discharge).

Indirect impacts are those arising from project facilities or activities, but with a degree of separation in time or space (for example the spread of weeds). They are, by their nature, hard to predict except in broad terms.

20.1.2.2 Cumulative and Associated Impacts

A step further removed are impacts arising from actions of third parties, which the presence of the project may enable or assist. Chapter 24, Cumulative and Associated Impacts, characterises these impacts as scenarios based on informed assumptions about the influence that the project may have on what other people may or may not do.

20.1.3 Matrix Components

The significance of the potential impacts associated with the construction and operation of the onshore LNG Facilities site and infrastructure have been derived from the analysis of:

- The amount and type of change, including the timing, scale, size and duration and likelihood of the impact (magnitude).
- The sensitivity of the environment to change, including its capacity to accommodate the kinds of changes the project may bring about (sensitivity of resource/receptor).

20.1.3.1 Impact Magnitude

The magnitude of an impact reflects:

- The intensity or severity of the impact.
- How long the impact will last.
- Over what spatial extent the impact will be felt.

20.1.3.2 Sensitivity of the Affected Receptor

The sensitivity of the environmental receptor will reflect:

- Its formal status, whether by statutory or attributed conservation status, land use zoning or environmental quality standard.
- Its vulnerability to material damage or loss by the impact in question.
- Its iconic or symbolic importance to cultural value systems.

20.1.3.3 Criteria

Where the impact potential warrants, the individual impact sub-sections (i.e., Sections 20.2, Soils and Landforms to 20.10, Visual) will include issue-specific impact magnitude and resource/receptor sensitivity criteria from very high to minimal. These, in turn, provide the two axes of the impact significance matrix.

20.1.4 Impact Significance Matrix

The matrix in Table 18.1, assigns significance to each combination of the impact magnitude and receptor sensitivity rankings. It assumes that the stated mitigation and management measures will have been implemented.

20.2 Soils and Landforms

This section summarises the findings and assessments presented in the soils impact assessment report (Appendix 17, Soils and Rehabilitation Impact Assessment) as it pertains to significant landform types that will be disturbed. It describes the potential issues associated with the construction and operation of the LNG Plant and Materials Offloading Facilities, the proposed mitigation and management measures and discusses the residual environmental impacts of project construction and operations activities relating to soils that help determine landform characteristics.

The sensitivity of landforms *per se* to disturbance is largely aesthetic and so this section makes a qualitative assessment of landform impacts based on susceptibilities of areas concerned and magnitude and duration of works. The residual impact assessment criteria for soils and landforms are set out in Section 20.2.3, in accordance with the environmental assessment method described in Section 20.1.

The earthworks, which change soils and landforms, have consequences for other aspects of the environment, notably Section 20.4, Hydrology and Sediment Transport, Section 20.5, Water Quality, Section 20.7, Terrestrial Habitat and Section 20.10, Visuals).

Unplanned events, such as fuel or chemical spills in uncontained areas, are addressed in Chapter 27, Environmental Hazard Assessment.

20.2.1 Issues to be Addressed

20.2.1.1 Construction

Landform and soil impacts will occur primarily where new ground disturbances occur, as a result of excavation and placement of fill from earthworks and the subsequent deposition of material from active construction sites and areas under regrowth.

The dominant landforms (see Figure 12.2 and Section 12.2.1, Geomorphology, Section 12.2.2.3, The Fairfax System and Section 12.2.5, Soils) involved in the construction of the LNG Facilities site are:

- A seaward swamp with mangroves.
- A beach ridge.
- A back swamp.
- Clay plains.

The soil issues of these landforms are discussed below.

Acid Sulfate Soils

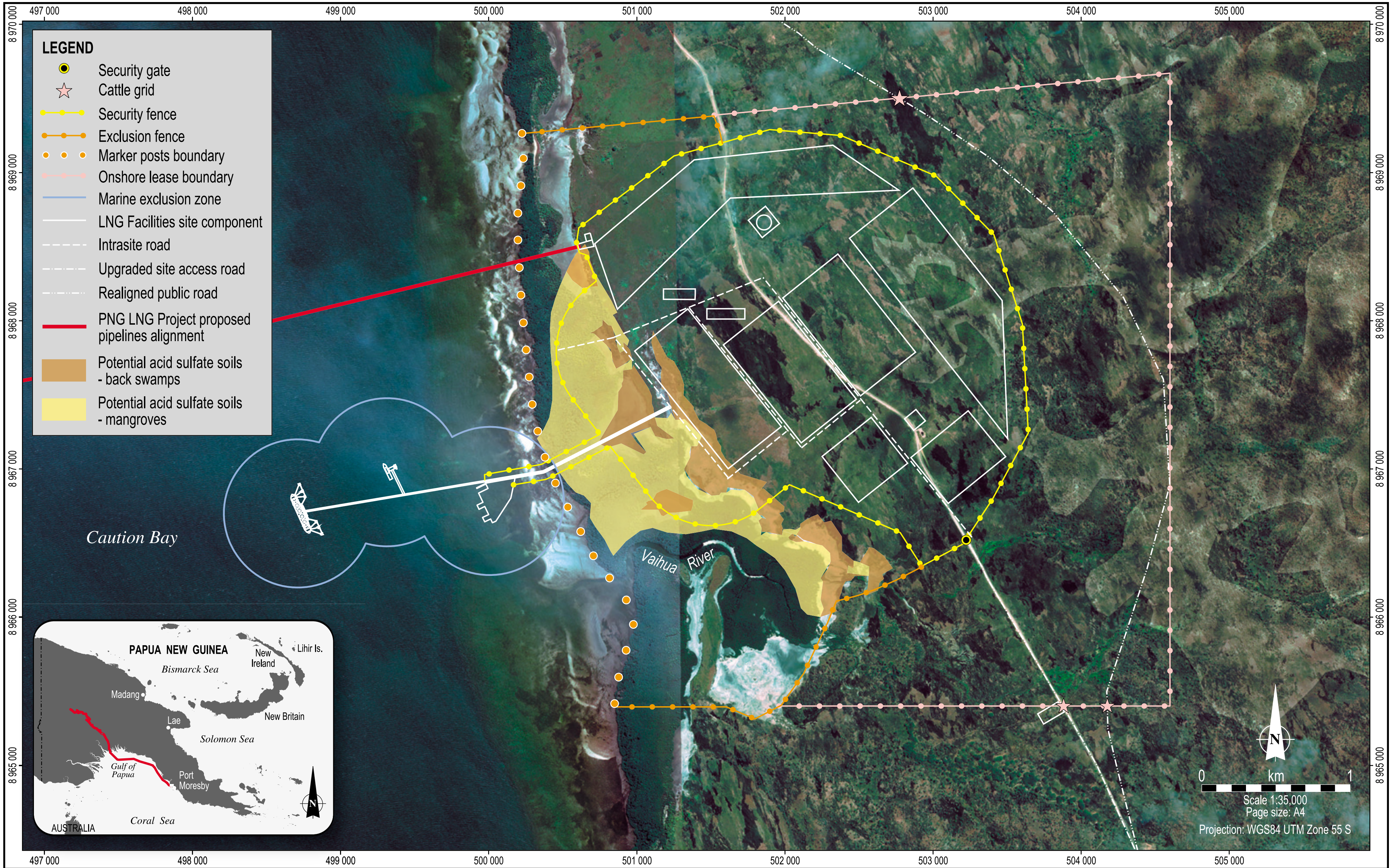
Acid sulfate soils are commonly associated with mangroves and low-lying coastal landforms. Undisturbed, saturated soils of tidal plains are recharged with each high tide and maintain an oxygen-free environment, with traces of acid neutralised by the overlying seawater.

When the soils are excavated and allowed to drain, the acid sulfate soil is exposed to oxygen in the air and the sulfate oxidises to sulfuric acid. Subsequent exposure to water (for example, rain) yields a toxic acid solution, which can affect aquatic life, and attack the concrete and steel of engineered structures and equipment. These soils may also have poor load-bearing capacity.

The location of acid sulfate soils within the LNG Facilities site is shown in Figure 20.1. Approximately 100 ha of potential acid sulfate soils will be disturbed during construction.

Black Cracking Clays

Black cracking clay soils are uniformly textured soils with a high clay content and very low permeability, and are subject to shrinking and cracking on a seasonal cycle associated with wetting and drying. These soils have a high sodium content (sodic soils) that causes them to swell when wet and disperse and, as a result, are prone to erosion if exposed. Black cracking clays are



Source: Soils data from Howard Rogers, 2008
Note: Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG

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File Name: 1284_09_F20.01_GIS_HB

Esso Highlands Limited

PNG LNG Project

Distribution of potential acid sulfate soils within the LNG Facilities site

Figure No: 20.1

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present inland from the swamp areas across most of the LNG Facilities site.

Vegetation Loss and Reduced Recovery Resulting from Soil Horizon Mixing

The mixing of the organic topsoil layer with infertile and poorly structured subsoils after earthworks has the potential to impede vegetation regrowth and increase erosion potential.

20.2.1.2 Operations

Once construction earthworks are complete, the disturbed soils will stabilise progressively and revegetate. Monitoring is required to confirm that this is occurring and to direct remedial action if progress is unsatisfactory.

20.2.2 Mitigation and Management Measures

The following mitigation and management measures for landforms and soils will be applied during both construction and operations.

Acid Sulfate Soils

The soils disturbed with acid sulfate potential will be managed via acid sulfate soil management plan to be prepared in the water management plan and implemented prior to construction [M28]. The management plan may include the following measures:

- Surveying areas likely to contain acid sulfate soils to identify the scale and intensity of treatment (if any) that may be required in areas to be disturbed during construction.
- Stockpiling such soils in a bunded area with an acid-resistant liner to prevent the release of runoff.
- Mixing of such soil with a neutralising agent (such as lime) that inhibits oxidation and increases pH.
- Keeping disturbed soil dry, thereby eliminating the risk of formation of a sulfuric acid solution.
- Reburial.

These measures represent established practice for earthworks in acid sulfate soil environments (see also Dear et al., 2002).

Black Cracking Clays

Black cracking clays may be disturbed during project construction. Appropriate management measures [M18] will be adopted to minimise erosion and dispersion from these soils including further soil characterisation tests as part of the project’s reclamation plan.

Vegetation Loss and Reduced Recovery Resulting from Soil Horizon Mixing

Vegetation recovery can be encouraged by the separate stripping and storage of topsoil and subsoils (as appropriate) and the subsequent reinstatement of displaced materials in an approximation of the pre-disturbance soil profile. The sediment and erosion control measures of the construction phase will remain in place until they are no longer required [M12].

Where areas have been disturbed during construction, efforts will be made to reinstate the former landforms. Post-construction revegetation and overall rehabilitation of erosion-prone areas will receive particular attention [M18].

Additional measures for the management of topsoil at the site are described in Section 20.5, Water Quality and Section 20.7, Terrestrial Biodiversity.

20.2.3 Residual Impact Assessment

The residual impact assessment process referred to in Section 20.1, General Approach to Assessment, has been tailored to suit soils and landform.

The physical alteration of soils and landform will be long term in nature but perceptions of impacts will fade with time. There is therefore little that a more complex temporal classification of residual landform impacts can add.

For residual soil impacts, the temporal classification of residual impacts is as follows: short term (pre-vegetation re-establishment), medium term (post-vegetation re-establishment) and long term (regeneration). The spatial scale for impacts on landforms and soils is limited to the areas directly covered by and adjacent to the operational area and site boundary (see Figure 4.2).

Criteria for the magnitude of impact and sensitivity of resource or receptor are given in Tables 18.5 and 18.6 respectively (see Section 18.2.4, Residual Impact Assessment). The matrix of significance used is shown in Table 18.1 (see Section 18.1.4, Impact Significance Matrix).

20.2.3.1 Construction

Acid Sulfate Soils

The objective of the management plan for acid sulfate soils will be to contain fugitive acidic solutions from work areas in the seaward and back swamp landforms (see Figure 20.1). Disturbance during construction will be localised and temporary. Therefore the significance of the residual impact should be minor (magnitude low, sensitivity high).

Black Cracking Clays

Additional soil tests will determine appropriate management measures to minimise erosion and dispersion of black cracking clays during construction and subsequent revegetation of the disturbed clays. Implementation of these measures will result in residual impacts being of minor significance (magnitude low, sensitivity high).

Vegetation Loss and Reduced Recovery Resulting from Soil Horizon Mixing

The relatively small earthwork volumes in flat terrain equate to a medium impact magnitude on soils and, with proper soil management, vegetation should recover on completed works areas within the medium term. The significance of the residual impact thereafter should be minimal (magnitude minimal, sensitivity low).

20.2.3.2 Operations

Bulk earthworks are not proposed during operations therefore, land disturbance should be infrequent and localised. Therefore residual impacts to soils will be minimal.

20.3 Groundwater

This section summarises the findings and assessments presented in the Groundwater Impact Assessment specialist report undertaken for the LNG Facilities site (Appendix 16, Groundwater Impact Assessment), and addresses the principal issues (Section 20.3.1), proposed mitigation and management measures (Section 20.3.2), and discusses residual environmental impacts of project construction and operations relating to groundwater resources at the LNG Facilities site and surrounding area (Section 20.3.3).

The groundwater resources in the area are closely associated with the coastal environment, flowing from inland to the coast, and provide a primary water source for neighbouring villages (Section 12.2.4.2, Hydrogeology).

20.3.1 Issues to be Addressed

The main groundwater issues arising during construction and operations of the LNG Facilities site relate to water quality and include:

- Potential contamination from fuels, lubrication oils and chemicals due to the transport, storage, and handling of these materials during construction.
- Potential contamination from hydrocarbon product, fuels, lubricating oils and chemicals due to the transport, storage and handling of these materials during operations.
- Potential contamination associated with the operation of feed gas processing and reticulation systems for processing and transferring feed and treated gas and condensate around the LNG plant should some form of damage occur to pipework, processing units or transfer vessels. Contamination may also occur during the dehydration, mercury removal and fractionation processes (see Section 4.2.2, LNG Plant and Appendix 16, Groundwater Impact Assessment for a description of the processing and reticulation systems). Potential contaminants of concern include heavier volatile organic compounds (VOCs) in liquid form such as benzene, xylene and toluene, and heavy metals such as mercury and require appropriate management through the process stream.
- Potential contamination from the operation of offsite and utility systems alongside the LNG Plant (see Section 4.2.3, LNG Plant Utilities, and Appendix 16, Groundwater Impact Assessment). Potential contaminants of concern are hydrocarbon residues (from the hot oil and fuel gas systems), brine (from the demineralised water system), hazardous and dangerous chemicals (from effluent, flare and vent, drain, stormwater and diesel storage and delivery systems) and biological, pharmaceutical and nutrients (from the sewage system).

There will not be groundwater supply issues associated with construction and operations at the LNG Facilities site. Water supply for the project will not be sourced from groundwater because of the potential impacts to the groundwater balance in the area. It is proposed that the required water supply for the project will be sourced from seawater desalinisation by reverse osmosis (see Section 4.2.3.5, Water Systems).

20.3.2 Mitigation and Management Measures

The protection of groundwater from pollution depends on sound design, operating principles and methods, and the spill response plan that the project will develop prior to construction.

Measures concerned with the protection of soils and surface water quality and management will also help to protect groundwater resources and these are addressed in Section 20.2, Soils and Landforms, and Section 20.5, Water Quality.

The following mitigation and management measures will be implemented to ameliorate the impacts identified in Section 20.3.1, Issues to be Addressed, for both construction and operations:

- Vehicles and machinery will be maintained to a high level of safety with respect to leaks [M25].
- Fuel, lubricating oils and chemicals required during construction will be stored in appropriately designed and sized designated containment areas [M26].
- A spill response plan appropriate to the project phase will be developed and include staff training at induction to inform workers of their responsibilities under the plan [M27].
- Wastewaters from the plant and associated facilities (including construction and operations camps) will be appropriately managed in accordance with the wastewater management plan that will be developed the site (Section 4.2.4.5, Wastewater Treatment Systems) [M29].
- Waste management plans will be developed and implemented during construction and operations of the project (Section 25.1.5.2, Waste Management Plans) [M29].
- Biological, pharmaceutical and medical wastes will be treated and disposed of using appropriate technologies, which will be detailed in waste management plans (Section 25.1.5.2, Waste Management Plans) [M29].
- Suitable containment will be provided for all parts of the plant area where hazardous or dangerous goods (e.g., fuel, lubricating oils and chemicals) are stored or used [M30].
- A groundwater monitoring network will be installed within the LNG Facilities site and on the downstream hydraulic gradient side of potentially contaminating/impacting activities (e.g., the landfill site). The network will be designed to alert the operator to the need for remedial action to contain a leak or spill [M31].

20.3.3 Residual Impact Assessment

Table 18.7 outlines the categories and definitions of magnitude of potential impacts to groundwater. The sensitivity of resource/receptor is considered to be high for the entire site as groundwater from the project area flows to sensitive environments of the coastal fringe and the watertable provides a water supply for nearby villages. This groundwater impact assessment uses the matrix of significance provided in Table 18.1 and also considers a qualitative assessment of the scale of risk to groundwater resources by project activities (Appendix 16, Groundwater Impact Assessment).

Two important naturally occurring constraints to groundwater contamination exist within the physical environment, which are considered in this assessment. These include:

- A layer of low permeability clayey sediments overlaying the alluvial aquifers containing the groundwater. These sediments are between 5 and 10 m thick (see Section 12.2.4.2, Hydrogeology) and would restrict the percolation of any released contaminant-laden waters to the watertable and bind most potential contaminants during infiltration.

- Upward hydraulic gradients reportedly exist within the coastal plain shallow groundwater system which will act to restrict infiltration and mixing of any contaminant laden soil water to the upper section of the watertable that occurs within the shallow clayey profile.

20.3.3.1 Construction

Residual impacts of minor spillages after mitigations (e.g., implementation of fuel-handling procedures, secondary containment bunds and emergency spill response and clean-up) at the site scale or further afield are predicted to be minimal (magnitude minimal, sensitivity high) in both the short and long term, as the volumes of liquids likely to be involved will be small and cleaned up immediately.

Procedures involved in managing major accidental spillages will be set out in the spill response plan to be developed by the project prior to construction. Discussion of the potential major project hazards and project hazard design mitigations measures is given in Chapter 27, Environmental Hazard Assessment.

20.3.3.2 Operations

Provided the project facilities are designed, constructed and operated to industry good practice, in particular the site landfill facility, then the impacts on groundwater are predicted to be minor.

Feed Gas Processing and Reticulation Systems

The residual impacts of spillages after mitigations from feed gas processing and reticulation systems are expected to be minor (magnitude low, sensitivity high) in both the short and long term as amounts are small and releases will occur to paved and drained catchments, and in the case of the mercury absorber and the fractionation unit, mercury and hydrocarbon condensate are within a closed process circuit. Spill response plans will also be in place for immediate action.

Utility and Offsite Systems

The residual impacts of spillages after mitigations from utility and offsite systems are expected to be minor (magnitude low, sensitivity high) in both the short and long term as effluents and residues will be handled in accordance with appropriate standards and specific waste management plans will be in place to ensure proper containment.

Storage Facilities

Potential impacts from condensate storage tanks and transfer systems are considered moderate (magnitude medium, sensitivity high) because of the volumes of liquids that could potentially be released.

20.4 Hydrology and Sediment Transport

This section summarises the findings and assessments presented in the Sediment Transport and Hydrology specialist report (Appendix 14, Hydrology and Sediment Transport Impact Assessment), defines terms and describes the general approach to the assessment (Section 20.4.1), principal issues (Section 20.4.2), mitigation and management measures (Section 20.4.3), and assesses the residual environmental impacts (Section 20.4.4) of project construction and operations on hydrological processes and sediment transportation.

Streams within and adjacent to the project area are shown in Figure 12.5 (see Section 12.2.7.1, Vaihua River), along with stream catchment boundaries and hydrological and sediment (both streambed and stream bank) sampling sites.

20.4.1 Definitions and General Approach

The hydrological and sediment transport parameters that may be affected by construction and operations of the project are water yield, stream flow and bed material load.

Resource sensitivity has not been considered in the assessment of hydrology and sediment transport as these are not dependent on resource sensitivity (Appendix 14, Hydrology and Sediment Transport Impact Assessment). Instead, impact criteria were developed against which impact significance can be determined. Table 20.1 sets out specific impact magnitude criteria for water yield, stream flow and bed material load and corresponding significance for each impact.

Table 20.1 Impact magnitude and significance: water resources and hydrology

Issue	Impact Magnitude	Impact Significance
Water yield	Basically unchanged water yields (less than 10% deviation); indistinguishable from the predisturbance range of surface runoff and/or groundwater flows.	Minimal
	Deviations in water yields between 10% and 25% of the predisturbance range.	Minor
	Deviations in water yields between 25% and 50% of the predisturbance range.	Moderate
	Deviations in water yields greater than 50% of the predisturbance range.	Major
Stream flow duration	Basically unchanged (less than 10% deviation).	Minimal
	Between 10% and 25% of the predisturbance range.	Minor
	Between 25% and 50% of the predisturbance range.	Moderate
	Greater than 50% of the predisturbance range.	Major
Bed material load	Less than 10% of the predisturbance range; basically indistinguishable from the predisturbance range, such that the receiving watercourse can transport all delivered coarse sediments downstream.	Minimal
	Between 10% and 25% of the predisturbance range.	Minor
	Between 25% and 50% of the predisturbance range.	Moderate
	Bed sediment loading greater than 50% of the predisturbance range.	Major

20.4.2 Issues to be Addressed

The proposed early works and construction program for the LNG Facilities site and the work on Lea Lea Road are described in Chapter 4, Producing and Exporting the LNG, and Chapter 5, Project Logistics, respectively. Construction of these components of the project will potentially impact on hydrological processes and sediment transport in a number of ways as described below. Activities during construction will be limited to three[1] catchments: Vaihua River, North Vaihua River and Karuka Creek (see Figure 12.5).

20.4.2.1 Vaihua River and North Vaihua River Catchments

Table 20.2 lists the areas of disturbance during construction and final project land use within the Vaihua River catchment. Habitats that will be disturbed in this catchment are principally savanna grassland and, to a lesser extent, riparian savanna woodland.

Table 20.2 Areas of disturbance that will occur in the Vaihua River catchment during construction

LNG Facilities Site Component	Land Area Disturbed Directly by Construction (ha)
2.4-km section of the Lea Lea Road realignment	2.5
1.1-km widening of access road (existing Lea Lea Road) within the site	1.4
2.6-km widening of access road (existing Lea Lea Road) outside the site*	3.2
Part of construction camp (eastern section)	10.5
Permanent living and support facilities	20.0
Support buildings	15.7
Helipad	1.0
Total	**54.3**
Rounded total	**54**

*From the main security gate to the start of the Lea Lea Road realignment approaching from Port Moresby.

The bulk of the LNG Facilities site will be constructed in the relatively small coastal catchment of the North Vaihua River. Table 20.3 details estimated areas by habitat type that will be disturbed during construction activities and, the final land use.

[1] Appendix 14, Hydrology and Sediment Transport Impact Assessment, considered an additional catchment, namely Vaihua Tributary Catchment. As this catchment drains to the Vaihua River prior to the Vaihua River meeting the ocean, the Vaihua Tributary Catchment has been incorporated into the Vaihua River Catchment in this chapter. All impacts associated with the Vaihua Tributary Catchment are therefore discussed in the relevant Vaihua River Catchment sections of this chapter.

Table 20.3 Areas of disturbance that will occur in the North Vaihua River catchment during construction

Habitat Affected by LNG Facilities Project Component	Land Area Disturbed Directly by Construction (ha)
Grasslands	
LNG storage tanks	31.4
Condensate storage tanks	16.6
LNG train(s)	39.6
LNG train(s) (future)	39.6
Part of temporary construction and turnaround camps	53.1
Spoil areas and landfills	61.1
Security fence road	0.6
Main plant-site roads	3.3
Minor plant-site roads*	2.0
Part of LNG Jetty/Materials Offloading Facility causeway	2.1
Part of PNG Project Gas Pipeline easement	3.6
Subtotal	*252.9*
Mangroves	
Part of LNG Jetty/Materials Offloading Facility causeway	4.3
Part of PNG Project Gas Pipeline easement	0.5
Subtotal	*4.8*
Subcoastal Wetlands (Mud or Saltflats)	
Part of LNG Jetty/Materials Offloading Facility causeway	5.2
Part of PNG Project Gas Pipeline easement	0.8
Subtotal	*6.0*
Rounded total	**264**

*Preliminary estimate.

Land disturbance during construction activities and subsequent operations within the Vaihua River and North Vaihua River catchments has the potential to cause the following impacts:

- Changes to surface hydrology, in particular increased runoff volumes into the rivers due to removal of vegetation, landscaping and an increase in area of hard surfaces.
- Increased in-channel water velocities due to increased runoff.
- Erosion (and the formation of gullies) of exposed land surfaces, resulting in an increased delivery of sediment to channels and elevated total suspended solids (TSS) within rivers.
- Elevated TSS in remnant pools (i.e., pools of water that become isolated during the dry season) of receiving watercourses.
- Streambed sedimentation, including in-filling of remnant pools.

- Changes to downstream stream velocities, sediment delivery and duration of flows as a result of diversion of existing channels required to drain the LNG Facilities site. These changes may modify the sediment delivery to the North Vaihua River and greater Vaihua River estuaries, thereby impacting coastal mangroves that rely on delivery of this sediment for survival.

The post-construction hydrological and sediment-related issues arising from the presence of the causeway are discussed in Chapter 21, Environmental Impacts and Mitigation Measures: Marine Facilities.

20.4.2.2 Karuka Creek Catchment

Construction within the Karuka Creek catchment is limited to a 5-km-long section of the proposed realignment of Lea Lea Road to the east the LNG Facilities site. The road realignment follows relatively flat ground in the upper subcatchments of five western tributaries of Karuka Creek.

Impacts during construction may include:

- Erosion and formation of gullies of exposed land surfaces and subsequent increased delivery of sediment to Karuka Creek with associated increases in TSS concentrations.
- Elevated TSS concentrations in remnant pools.

During operations, impacts of the road within the Karuka Creek catchment may result in altered streamflows and continuing soil erosion, particularly if there is insufficient drainage during construction and if appropriate revegetation and soil stabilisation does not occur.

20.4.3 Mitigation and Management Measures

20.4.3.1 Construction

During construction, the following measures will be implemented to mitigate potential impacts to the existing hydrological and sediment transport regime in the three potentially affected catchments:

- Clearing of riparian vegetation will be limited to the amount necessary to undertake construction activities in a safe manner. Construction personnel will be prevented from entering areas outside of project-related activities to minimise damage to vegetation. [M4]
- At new or improved road crossings, maintain connectivity of wet season flow in watercourses, avoiding the creation of high-velocity 'chutes' or step-down cascades in order to enable fish migration. [M22]
- As far as practicable, disturbed areas will be reinstated to former landforms and revegetation of exposed areas will occur as soon as practicable once construction activities are completed in any particular location. Areas prone to erosion will receive particular attention. [M18]
- All watercourse crossings, diversions and culverts will be designed to accommodate expected streamflows. Similarly, the drainage system within the LNG Facilities site will be designed to minimise changes to flow regimes and sediment transport of existing creeks including any works on the North Vaihua River tributaries and Karuka Creek. [M19]

Specific design details will be developed in the form of construction environmental management plans for contractors to implement during construction. Adherence to management plans will form part of the contractual obligations and will be monitored under the proposed environmental management, monitoring and reporting program outlined in Chapter 30, Environmental Management, Monitoring and Reporting.

20.4.3.2 Operations

During operations, the integrity of the floodplain of the North Vaihua River and downstream coastal wetlands and mangroves will be monitored to determine whether sediment delivery from areas disturbed by construction areas is similar to preconstruction conditions.

If monitoring indicates the need, measures over and above those of the construction phase to be developed will be implemented. Post-construction revegetation and overall rehabilitation of erosion-prone areas, especially at river crossings and riparian areas, will assist in mitigating impacts to sediment transport.

20.4.4 Residual Impact Assessment

20.4.4.1 Construction

Vaihua River and North Vaihua River Catchments

Modifications to drainage systems during construction will be undertaken in such a way as to have similar hydraulic characteristics as the pre-existing natural drainage. They will, therefore, be able to support similar streamflows and sediment transport regimes.

In the North Vaihua River catchment, where the majority of construction activities will occur, the area is predominantly flat and drainage systems will be designed to have minimal effect on the overall water availability downstream.

Surfaces that will be modified during construction (see Tables 20.2 and 20.3) are expected to have similar rainfall runoff characteristics as existing surfaces (Appendix 14, Hydrology and Sediment Transport Impact Assessment). Therefore, based on the assessment criteria outlined in Table 20.1, the significance of residual impacts to water yields and stream flow durations for the Vaihua River are assessed as minimal.

Due to the level of construction activity occurring in the North Vaihua River catchment, the significance of residual impacts to water yields and stream flow durations within this catchment are expected to be minor (Appendix 14, Hydrology and Sediment Transport Impact Assessment).

Hydrological modelling undertaken (see Appendix 14, Hydrology and Sediment Transport Impact Assessment) to determine impacts on existing stream sediment loading regimes due to construction activities indicate that:

- At site VS2 on the Vaihua River (see Figure 12.5):
  - A bank-full flow (occurring on average every two years) can currently transport at least 23,000 t/d of sediment. Construction activities would contribute an additional 688 t/d of sediment to the river, equivalent to 3% of total capacity.
  - A bank-full flow would result in a maximum suspended sediment concentration of 5,000 mg/L. Construction activities would result in suspended sediment increasing by 266 mg/L, i.e., an increase of approximately 5%.

- During the first year of construction, stream sediment loading in the main channel of the North Vaihua River catchment is expected to increase by between 10 and 30%.

Based on the modelling results and criteria in Table 20.1, the significance of residual impacts on the Vaihua River catchment sediment loading are expected to be minimal while the significance of residual impacts on the North Vaihua River catchment sediment loading are estimated to be minor.

Karuka Creek Catchment

While no modelling of impacts to sediment loading in Karuka Creek was undertaken, an impact assessment (Appendix 14, Hydrology and Sediment Transport Impact Assessment) determined that the significance of impacts of water yield, stream flow duration and bed material load (based on criteria set out in Table 20.1 and taking into consideration the mitigation strategies described in Section 20.4.3, Mitigation and Management Measures) would be minimal.

In the year following construction, most of the construction areas will have been rehabilitated and watercourses stabilised, such that further sediment delivery to watercourses will have been greatly attenuated.

20.4.4.2 Operations

The connectivity of catchment and estuarine flows established during construction to continue existing conditions will require maintenance during operations. Small areas of erosion arising after intense storms will require remediation but, in general, the significance of residual impacts will, for the most part, be minimal (Table 20.1 and Appendix 14, Hydrology and Sediment Transport Impact Assessment).

20.5 Water Quality

This section summarises the findings presented in the surface water specialist study (Appendix 15, Water and Sediment Quality Baseline Impact Assessment) and presents the water quality assessment criteria (Section 20.5.1), issues to be addressed (Section 20.5.2), mitigation and management measures (Section 20.5.3) and the residual impacts (Section 20.5.4) of construction and operations of the LNG Facilities site.

Figure 12.5 shows the drainage features discussed in this section.

20.5.1 Water Quality Criteria

20.5.1.1 Residual Impact Assessment Criteria

Definitions of the spatial and temporal scales of impacts on freshwater aquatic environments give a specific meaning to statements about the degree of an impact. For aquatic impacts, these definitions are common to the discussion of water quality (this section) and aquatic ecology (Section 20.6, Aquatic Ecology).

Residual impacts on freshwater and estuarine aquatic environments in the project area have been evaluated at three spatial (Table 20.4) and temporal scales (see Table 18.10).

Table 20.4 Aquatic impact assessment: spatial scales

Spatial Scale	Description
Site scale	Immediate watercourse within 2 km downstream of a project impact location.
Local scale	Extending between 2 km and 10 km downstream a project impact location and generally includes the main three catchments: Vaihua River, North Vaihua River and Karuka Creek (see Figure 12.5).
Regional scale	Extending more than 10 km downstream from a project impact location.

Note: No classification of spatial scales for standing waters, swamps or floodplain off-channel waterbodies are presented, as residual impacts are assessed on an individual standing waterbody basis, which, in effect, is a 'site scale' in itself.

During construction, water quality will be most affected by fugitive fine sediments after rainfall, with increases in total suspended sediment (TSS) concentrations in flowing watercourses. Operationally-defined criteria are necessary to undertake an assessment of nominal changes in the concentrations of TSS (see Table 18.14). These criteria have an empirical basis in observed impacts of elevated TSS and enable the assessment of residual impacts on aquatic ecology in Section 20.7, Terrestrial Biodiversity, to be made. These criteria do not apply to non-flowing watercourses, such as swamps and wetlands.

Specific impact criteria for other water quality variables have not been set given that aquatic impacts will be dominated by the effect of fugitive sediments and the discharges of other contaminants will be low and generally controlled by effluent standards and good operating practice and PNG's receiving water quality regulations.

20.5.1.2 Receiving Water Quality Criteria

In Papua New Guinea, discharge to receiving waters must not lower the water quality of the receiving environs below the Prescribed Water Quality Criteria of Schedule 1 of the *Environment Act 2000* (see Table 18.15).

Under the act, an environment (waste discharge) permit must be granted prior to any waste discharge occurring. When granted, the permit will contain a number of conditions, one of which is the need to comply with prescribed water quality guidelines at the downstream limit of a site-specific mixing zone[2] that is applied at the time the permit is granted.

As part of conditions of approval, the project will be required to monitor against the water quality criteria as set out in the Prescribed Water Quality Criteria of Schedule 1. Where this schedule does not set criteria for particular contaminants, alternate international standards may be applied such as:

- IFC (2007e) effluent guidelines for stormwater drainage (see Table 18.16).
- ANZECC/ARMCANZ (2000) guidelines for phosphorus and nitrogen.

[2] A mixing zone is the body of water into which waste is discharged and where the prescribed water quality guidelines are required to be met and beneficial values need not be protected. The downstream end of the mixing zone is called the compliance point.

20.5.2 Issues to be Addressed

20.5.2.1 Construction

The proposed construction program for the LNG Facilities site is described in Chapter 4, Producing and Exporting the LNG. Project construction will take place across three catchments; North Vaihua River, Vaihua River, and Karuka Creek (for the road diversion only) (see Figure 12.5).

As described in Chapter 12, Receiving Onshore Environment: LNG Facilities, baseline water and sediment quality results show that the concentrations of most contaminants were below detection limits and were not of ecological risk. Some isolated exceedences of the *Environmental Act 2000*, ANZECC/ARMCANZ (2000) and IFC (2007a) water quality guidelines were detected, and concentrations of some metals (arsenic and nickel) exceeded low-level interim sediment quality guidelines (ANZECC/ARMCANZ, 2000).

Construction activities could cause additional or greater exceedences of these guidelines. The principal issues potentially affecting water and sediment quality during construction at the LNG Facilities site are summarised below.

Sediment Loading

Construction activities will disturb soils and create fugitive sediment as follows:

- 264 ha of the North Vaihua River catchment will be disturbed, which represents 48% of the total catchment area of 550 ha (see Table 20.3 for the source of change).
- Disturbance to 54 ha of the Vaihua River catchment will occur, representing less than 2.8% of the total catchment area of 1,950 ha (see Table 20.2 for the source of change).
- Within the Karuka Creek catchment, 5 ha will be disturbed, which is 0.2% of the total catchment area of 2,325 ha.

Release of Metals and Nutrients

Construction-disturbed soils exposed to rainfall runoff or to surface water or groundwater in excavations may release dissolved and particulate-associated metals and nutrients.

Acid Drainage

Issues associated with acid sulfate soils are addressed in Section 20.2, Soils and Landforms.

Discharge of Wastewaters

Wastewaters, including treated domestic wastewater, water used to hydrotest the LNG tanks and brine from desalination processes, will be disposed of in Caution Bay and are therefore addressed in Section 21.3, Sea Water Quality.

20.5.2.2 Operations

The principle water quality issues during operations relate to the disposal of wastewaters, including treated domestic wastewater and brine from desalination processes. As these will be discharged in Caution Bay, this issue is addressed in Section 21.3, Sea Water Quality.

Runoff from the LNG Facilities site could potentially contain contaminants and will require capture and treatment prior to discharge to the environment. As this treated water will also be disposed of in Caution Bay, this issue is addressed in Section 21.3, Sea Water Quality.

20.5.3 Mitigation and Management Measures

Construction contractors will be required to comply with commitments and obligations set out in this EIS and operationally defined in the construction environmental management plans (see Chapter 30.3.1.4, Contractor Environmental Management Plan Guidelines and Expectations). This will include sediment and erosion control procedures within a water management plan that limits the mobilisation and dispersion of sediment into freshwater and estuarine environments by implementing the following measures:

- Restricting riparian clearing to the width required to safely accommodate roads and watercourse crossings [M4].
- Limiting ground disturbance and vegetation clearing for the LNG Facilities site, camps and laydown areas to the area within the security fence [M5].
- Prohibiting works from exceeding the design disturbance width and enforcing boundaries through use of security fencing [M6].
- Promptly revegetating areas no longer required for construction or support services where practicable [M7].
- Using silt curtains and other industry good practice management controls as appropriate when working in mangroves, particularly near the seaward extent [M24].
- Encouraging regeneration to natural conditions for vegetation communities, wetland substrates and savanna as close as possible, through seed collection and/or use of topsoil as a seed resource [M11]. The plan would also address the stripping, storage and salvage of topsoil where applicable [M12].

Surface water on site will include water stored in retention ponds, grey water and process water (such as water from hydrostatic testing). Retention ponds will be constructed with liners and monitoring systems will be implemented to monitor water levels to prevent overflow or uncontrolled releases (see Section 4.2.4.5, Wastewater Treatment Systems).

20.5.4 Residual Impact Assessment

20.5.4.1 Sediment Loading

The bulk of the construction for the LNG Facilities site will be carried out in the small coastal catchment of the North Vaihua River. Section 20.4.4, Residual Impact Assessment, discusses residual impacts of sediment loading on the Vaihua River, North Vaihua River and Karuka Creek catchments.

The residual impact significance on water quality as it relates to subcoastal wetlands and mangrove swamps, which occur at the regional scale, are assessed in the short and longer term as minimal, due to the naturally elevated TSS concentrations in these coastal and subcoastal waters brought about by tidal flushing of mangrove swamp bed sediments.

In the year following construction, most of the disturbed areas and the formalised drainage system will have been revegetated or stabilised, such that further fine sediment delivery to watercourses will have been greatly attenuated.

20.5.4.2 Release of Metals

Appendix 15, Water and Sediment Quality Baseline Impact Assessment, indicates that most background metal concentrations in the surface water sampled were at or below their analytical detection and reporting limits, which is typical for a former cattle property with no history of industrial development and no naturally mineralised geological units.

The dominant black cracking clay soils of the LNG Facilities site and environs have low concentrations of metals of environmental concern, such as zinc (1.1 mg/kg), copper (2.9 mg/kg) and boron (0.77 mg/kg), which is also reflected in the low metal concentrations observed in surface waters. Therefore, the significance of residual impacts are assessed as minimal in the short and long term.

20.5.4.3 Release of Nutrients

The principal soil type to be disturbed by construction in the North Vaihua River catchment is black cracking clay soils, which have a total phosphorus content of 96 mg/kg (Appendix 17, Soils and Rehabilitation Impact Assessment); this phosphorus content is low when compared with the world crustal average of 1,050 mg/kg. Significant increases in soluble phosphorus concentrations are not anticipated in the water column of the North Vaihua River, owing to the low concentrations of extractable phosphorus (range 7 to 8 mg/kg) present in the dominant black cracking clay soils of the LNG Facilities site (Appendix 17, Soils and Rehabilitation Impact Assessment).

Overall, nutrient levels are indicative of slightly disturbed conditions and erosion control procedures will substantially reduce the impacts of the project on the existing conditions. Therefore, the significance of residual impacts of increased nutrient concentrations on watercourses of the project area are assessed in the short and longer term as minimal at the site scale or greater.

20.6 Aquatic Ecology

This section draws on the baseline characterisation information in Chapter 12, Receiving Onshore Environment: LNG Facilities and draws on the Aquatic Fauna Impact Assessment (Appendix 13, Aquatic Fauna Impact Assessment). Potential issues associated with the construction and operations of the LNG Facilities site are described in Section 20.6.1, the measures that will be implemented to mitigate these issues provided in Section 20.6.2, and the residual impacts, assuming successful implementation of these measures are set out in Section 20.6.3.

The criteria for assessment the magnitude of impacts to aquatic ecology are given in Table 20.5 and aquatic fauna sampling sites are shown in Figure 12.6.

The sensitivity of the resource or receptor that may be impacted was determined from the existing environment information (see Chapter 12, Receiving Onshore Environment: LNG Facilities) and classified into categories based on Table 20.6.

Table 20.5 Magnitude of impact categories and descriptions: LNG Facilities site

Category	Description
Very High	Effect likely to have a large and widespread impact on population, community or ecosystem survival and health, possibly even leading to extinction or system collapse. The impact extends greater than 25 km from the centre of the facility. Recovery would not be possible.
High	Effect that will have an impact on a population, community or ecosystem, which impedes survival, health, or on aesthetic value. The impact extends beyond 10 km but less than 25 km. Recovery, if possible, is long term and may take up to 25 years.
Medium	Effect will be detectable at the local scale but not severe. The impact occurs within and beyond the boundary of the facility but less than 10 km in radius. Recovery is likely to take up to 7 years.
Low	Effect may be medium term and is detectable but is small and highly unlikely to have any material impact. Impact is limited in scale, affecting the immediate area of the project area. Within or at the edges of the boundary of the facility. Recovery is short-term, up to 3 years.
Minimal	Effect is temporary and unlikely to be detectable and within the boundaries of the facility.

Table 20.6 Sensitivity or value of resource or receptor categories and descriptions: LNG Facilities site

Category	Description
Very High	A population of internationally important species or a site supporting such a species. A rare, threatened or vulnerable habitat or species and/or a breeding ground or feeding area that is critical to the survival of such species.
High	A population of nationally important species or a site supporting such a species. A sustainable area of priority habitat.
Medium	A population of regionally important species or a site supporting such a species. Site supports 1% or more of regional population.
Low	Sites or populations that enrich the local area.
Minimal	No ecological value or sensitivity. A resource that does not have the access reduced to a receptor in quality, quantity or time.

Residual impact significance on aquatic fauna has been based on the magnitude of impact and sensitivity of resource or receptor, as shown in Tables 20.5 and 20.6 respectively. The matrix of significance used in this assessment is provided in Table 18.1.

20.6.1 Issues to be Addressed

20.6.1.1 Construction

Construction will take place across three catchments: Vaihua River, North Vaihua River and Karuka Creek (see Figure 12.6). As discussed in Section 12.4, Aquatic Biological Environment, during the dry season freshwater input to the estuaries of these watercourses is minimal and the estuaries exist as coastal tidal inlets. At these times, the freshwater habitats consist of isolated pools in otherwise dry riverbeds and consequently, the fauna in these habitats is less diverse than in the estuarine habitats where a total of 30 species of fish and 5 species of macro-invertebrates (including the mud crab) were recorded.

During the wet season, the flow between the freshwater catchments and estuaries is restored. The aquatic species found at, or in, the vicinity of the LNG Facilities site are widespread throughout southern Papua New Guinea and no rare or threatened species were observed.

Construction of the LNG Facilities site has the potential to affect aquatic habitats, such as remnant pools (during the dry season), flowing watercourses (during the wet season), coastal wetlands, and estuaries. In particular, adverse impacts to hydrology, water quality and habitat connectivity (as discussed in sections 20.4, Hydrology and Sediment Transport and 20.5, Water Quality) may impact on aquatic habitats.

These changes have implications for the ability of aquatic fauna to survive conditions of changed physical habitat and water quality, and the ability to move throughout the catchment area or beyond.

In addition, issues include the potential impacts of introductions of noxious weeds, pests and pathogens due to project-related activities, and the impacts of competition on the resident species from any introduced species.

20.6.1.2 Operations

Potential impacts to aquatic ecology decrease rapidly once operations begin as disturbed areas stabilise and the construction-related impacts to hydrology, sedimentation and water quality diminish.

A potential issue is the requirement to maintain the nearshore current and coastal processes at the Vaihua River estuary, which is discussed in Section 21.2, Physical Coastal Processes and Sediment Transport. If these processes are not maintained then aquatic ecology may suffer.

20.6.2 Mitigation and Management Measures

20.6.2.1 Construction

Mitigation measures designed to avoid or ameliorate the impacts of construction on water quality and hydrology are also designed to mitigate the associated impacts on aquatic ecology (in terms of maintenance of habitat quality and connectivity). These are described in Section 20.4, Hydrology and Sediment Transport, and Section 20.5, Water Quality.

Additional mitigation measures to protect aquatic flora and fauna from accidental introductions of exotic pests will include the establishment and enforcement of a pest and weed management procedures in the ecology, natural habitat and biodiversity management plan for the LNG Facilities site. These procedures will be aimed at identifying foreign and invasive weed and exotic pest threats (see Chapters 29, Summary of Mitigation and Management Commitments and 30, Environmental Management, Monitoring and Reporting). The plan will include procedures to prohibit project personnel and contractors from establishing any gardens and from introducing, keeping or transporting any plants, seeds or animals (including fish) within the site security fence. This plan will include such provisions as worker education to assist in recognition and eradication of pest species and other measures specific to the LNG Facilities site [M1, M2, M8].

There will be a general prohibition against the disturbance or harassment of wildlife, hunting of fauna, gathering of plants or bush foods, collection of firewood or possession of wildlife products by project workers or contractors. This prohibition will be enforced while undertaking all activities associated with the project, such as travelling in project vehicles and residing in project field accommodation [M9].

The above mitigation measures will be implemented in the form of a construction environmental management plan and the effectiveness of these measures will be monitored (see Chapter 30, Environmental Management, Monitoring and Reporting).

20.6.2.2 Operations

The mitigations previously discussed in Section 20.2, Soils and Landforms, Section 20.4, Hydrology and Sediment Transport and Section 20.5, Water Quality, will also be effective in mitigating the potential affects to aquatic flora and fauna during operations.

20.6.3 Residual Impact Assessment

The residual impact assessment process referred to in Section 20.1, Environmental Assessment Method, has been tailored to allow for the assessment of impacts on aquatic fauna as described at the start of this section.

20.6.3.1 Construction

The area of construction-related impact represents about 48% of the North Vaihua River catchment, less than 2.8% of the Vaihua River catchment area, and less than 0.2% of the Karuka Creek catchment. Despite the larger proportion of the North Vaihua catchment affected, it contains only two main drainage channels and a number of small tributaries with very small, flat subcatchments. Bulk earthworks will be minimal and control of fugitive sediment managed by an erosion and sediment control management plan, designed to limit the mobilisation and dispersion of sediment into freshwater and estuarine environments; and also to avoid the creation of barriers to fish movement.

Furthermore:

- Aquatic plants, mangrove fish, prawns and other macroinvertebrates are tolerant of naturally turbid waters, which they encounter regularly within the mangroves as a result of tidal flushing and wave action.
- No species of restricted distribution or endangered status was observed or reported to be present.

- For much of the year (during the dry season) the freshwater creeks are dry and the aquatic environment is predominantly marine and tidal; and not affected by the construction issues considered here.
- Onshore and offshore movements of marine and estuarine fish into the mangroves either side of the causeway will remain uninterrupted (see Section 21.2, Physical Coastal Processes and Sediment Transport).
- The Vaihua River catchment is small, so the extent of potential impacts is effectively limited to the local scale (or medium magnitude of impact category) at worst.

On this basis and with the mitigation measures in place, the magnitude of impact is minimal (as defined in Table 20.5) and the sensitivity low (see Table 20.6). Therefore the significance of the overall impact is minimal (based on the assessment criteria in Table 18.1).

20.6.3.2 Operations

During operations, the definitions in Table 20.5 of the magnitude of impact remain as minimal. Similarly, the criteria in Table 20.6 define the sensitivity as low. Using the definitions in Table 18.1, the significance of the overall impact of operations on the aquatic ecology is assessed as minimal.

20.7 Terrestrial Biodiversity

This assessment of the impacts on terrestrial biodiversity at the LNG Facilities site is based on:

- Appendix 12, Biodiversity Impact Assessment.
- A detailed characterisation of site biodiversity values, which are summarised in Section 12.3, Terrestrial Biological Environment.
- A detailed analysis of the potential impacts on terrestrial biodiversity associated with construction and operation of the LNG Facilities site, including:
  - The value and sensitivity of habitats, special areas, flora and fauna.
  - The potential biodiversity impacts of individual components of the LNG Facilities site.
  - Impact mitigation recommendations.
  - The significance of direct and indirect impacts on habitats, special areas and sensitive species before and after mitigation.

Indirect but unquantifiable impacts to biodiversity outside the fence of the LNG Facilities site are likely due to in-migration and the associated impacts arising from new housing, agriculture, hunting, timber cutting and introduced plants, animals and pathogens. Nevertheless, the extent and location of these impacts is speculative, as is their significance in the context of regional biodiversity. These issues are discussed in Section 24.4, Cumulative Impacts Downstream.

The survey limitations mentioned in Section 12.3.1, Survey Methods and Limitations require the discussion of habitat and species not necessarily observed but potentially present.

20.7.1 Definitions and Approach

The assessment follows the method applied to the upstream components of the project (see Section 18.1, General Approach). Specifically, the level of impact significance is derived from a matrix of:

- The magnitude of the impact, a function of its scale, duration and extent.
- The value or sensitivity of the receptor (e.g., species or habitat) to change.

Table 20.7 presents impact magnitude criteria in three categories:

- Habitat impacts (clearing).
- Population impacts.
- Other ecological impacts, being impacts that degrade habitat or reduce population viability (for example barrier effects, fire, exotic species and contamination).

Table 20.8 presents receptor sensitivity for the sites and species of the LNG Facilities site project area.

Table 20.7 Impact magnitude categories

Magnitude of Impact	Habitat	Other Ecological Effects (Barrier Effects, Contamination, Exotics, etc.)	Populations
Very High	Large impact on substrates and habitats that will be permanent and reduce ecosystem survival and health over large areas within the local contextual region (i.e., LCR), possibly even leading to system collapse. Recovery, if possible, is likely to take more than 25 years.	Impact may be widespread affecting more than 10% of the local contextual region (i.e., LCR) and up to national scale.	Populations will be lost from impact site and losses may cause extinctions within the local region. Loss of ≥ 20% of national population.
High	Substrates will be lost and replacement or treatment may be difficult or impossible. If replaced there is a strong possibility that succession may not lead to original habitats and there is a reasonable chance of long-term reduction in site capacity to support original habitat. Hydrology and/or tidal flows significantly interrupted resulting in long-term degradation of wetland ecosystem functioning. Loss and/or degradation of habitat extends more than 1 km beyond impact site. Habitat regeneration may take up to 25 years after substrate treatment or replacement. Loss of habitat may affect 5% to 10% of the habitat's range within the local region.	Impact is regional affecting 5% to 10% of local region.	Impacts will involve local loss of population (i.e., within the LNG Facility site) for at least 25 years or recolonisation may never occur. Any losses of local population likely to significantly reduce likelihood of species persisting in the local region. Loss of 5% to 20% of national population.
Medium	Substrates will be lost and replacement or treatment will be necessary to initiate successions or rehabilitate ecosystem functioning. However, there is unlikely to be any long-term reduction in site capacity to support original habitat. Hydrology and/or tidal flows significantly interrupted resulting in medium-term degradation of wetland ecosystem functioning. Loss of and/or degradation of habitat extends up to 500 m beyond impact site. Habitat regeneration will be slowed and good tree cover may take up to 12 years after substrate treatment. Loss of habitat may affect up to 5% of the habitat's range within the local region.	Impact is regional affecting up to 5% of local region or detectable up to 10 km from impact site.	Impacts will involve local loss of population for up to 7 years or recolonisation may never occur. However, loss of the local population highly unlikely to affect persistence of the species within the local region. Loss of up to 5% of national population.
Low	Substrates may be disturbed or lost but habitat can readily recover on remaining/replaced substrate with slowing of successions by 1 to 3 years at most. Generally only a short-term (1 to 3 years) reduction in site capacity to support original habitat. Substrate disturbance results in minor, short-term disruption of tidal and/or freshwater flows within wetland systems. Impacts restricted to immediate vicinity of impact site. Habitat regeneration capable of starting within 1 to 3 years.	Affects immediate surrounds from impact and detectable up to 2 km from impact site.	Impacts likely to involve loss of a portion of the local population that will reduce the chances of long-term survival in remaining habitat around the project component and species may be temporarily lost. Recolonisation will be rapid and occur within 3 years after development of successions to the stage of canopy closure.
Minimal	Deleterious impacts unlikely to be detectable on habitats.	Not detectable without major research effort.	Species populations may lose a few individuals or home ranges may retract but there is unlikely to be any long-term lowering of the viability of local populations.
Positive	Change is likely to benefit the species community or ecosystem. This will be detectable by rapid assessment program surveys pre- and post-impact showing increase in abundance and/or occurrence of species at sites they did not occur in before.		

Table 20.8 Criteria for the value (sensitivity) of conservation assets at the LNG Facility site

Category	Sites and/or Habitats	Species
Very High	• An internationally designated site. • A designated national protected area, e.g., wildlife management area. • A large area of little disturbed, intact habitat(s) that provides ecosystem services important in maintaining national or global biodiversity. • An area with some very high category species or a high concentration of high category species. • Site supports 20% or more of a national population of any species.	A population of internationally important species in IUCN category Critically Endangered.
High	• A sustainable area of priority habitat identified by the World Wildlife Fund. • A large area of little disturbed, intact habitat(s) that provides ecosystem services important in maintaining regional biodiversity. • A high diversity area with a moderate concentration of high category species and/or a high concentration of medium category species. • Site supports up to 20% of national population of any species. • Habitat of peculiar sensitivity that is hard to restore or regenerate.	A population of internationally important species in IUCN categories Endangered or Vulnerable.
Medium	• A local reserve. • A substantial area of intact habitat(s) with few invasive species and/or that provides ecosystem services important in maintaining local biodiversity. • An area with moderate diversity, some high category species and/or a moderate concentration of medium category species. • Site supports up to 5% of national population of any species.	A population of a species in IUCN category Near Threatened and/or classified as P under PNG legislation.
Low	• Sites that enrich the local area. • A low to moderate diversity area with no very high or high category species and a low concentration of medium and low category species.	A population of a species in IUCN category Data Deficient and/or classified as R under PNG legislation.
Minimal	• No significant ecological value.	A population of a species in IUCN category Least Concern or is unclassified and is not listed under PNG legislation.

20.7.2 Issues to be Addressed

Impacts discussed in Appendix 12, Biodiversity Impact Assessment, are grouped here into twelve categories of direct impacts and six categories of indirect impacts. Table 20.9 relates these impacts to habitat and flora and fauna, and to the construction and operations phases of the project. These are separated according to direct and indirect impacts, as defined in Section 20.1, Environmental Assessment Method.

Table 20.9 Direct and indirect potential biodiversity impacts of the LNG Facility and associated infrastructure

Impact Type	Construction		Operations	
	Habitat and Flora	Fauna	Habitat and Flora	Fauna
Direct Impacts				
Habitat loss	X	X		
Edge effects	X	X	I	
Barrier effects	X	X	A	A
Physical damage and disturbance to caves		X		
Fauna falling into trenches, drains, pits, etc.		X		C
Erosion, movement of soil and spoil	X		A	
Changes to hydrology	X		I	I
Materials handling, disposal and pollution	X	X	C	C
Dust	X	X	C	C
Noise, lights and other disturbance to fauna		X		C
Traffic		X		C
Loss of breeding and display grounds		X		
Indirect Impacts				
Fire	X	X	C	C
Dieback	X		I	
Invasive species – weeds and plant pathogens	X		I	
Invasive species – fauna	X	X	I	I
Hunting		X		C
Collection of flora	X		C	

X = impact mainly during this activity; A = impact ameliorating with time; C = impact continuing but at a reduced level; I = impact possibly increasing with time.

20.7.3 Mitigation and Management Measures

Table 20.10 summarises the proposed biodiversity mitigation and management measures by issue and the project phase to which they are relevant.

Table 20.10 Terrestrial biodiversity mitigation and management factors for the LNG Facility and associated infrastructure

Proposed Mitigation or Management Measure	Biodiversity Element			Project Activity		Direct Impacts										Indirect Impacts				
	Habitat	Flora	Fauna	Construction	Operation	Habitat Loss	Edge Effects	Barrier Effects	Erosion and Spoil	Hydrology	Pollution	Dust	Disturbance	Traffic	Loss of Display Area	Fire	Dieback	Exotic Weeds and Pathogens	Exotic Fauna	Hunting and Collecting Flora
Limit ground disturbance and vegetation clearing to areas within the security fence. Prohibit works from exceeding the design disturbance width and enforce boundaries through use of security fencing. Where practicable, revegetate promptly areas no longer required for construction or support services [M5, M6, M7].	X	X	X	X		X	X	X	X	X					X					
As far as practicable, limit clearing of riparian vegetation. Construction work boundaries will be indicated by tape or similar methods [M4].	X	X	X	X		X			X	X										
Develop a reclamation plan that would include as a priority the regeneration of natural vegetation communities, wetland substrates and savanna as close to natural levels as possible through seed collection and/or use of topsoil as a seed resource [M11].	X	X	X	X		X	X	X		X										
Conduct a preconstruction survey for sandalwood and other listed species and develop a management procedures in the event listed species are discovered [M13].	X	X	X	X																
Where tree removal is necessary for road construction, limit damage to surrounding habitats by felling trees away from existing stands where practicable taking into account the value and safety of the areas where the trees are being felled into [M14].	X	X	X	X	X	X	X		X	X										
Inspect trees prior to felling to locate any IUCN-listed bat species' colonies. If any are located, use controlled felling methods to allow colony to relocate [M16].			X	X	X	X							X							
Limit the scraping of standing tree trunks by machinery as far as practicable [M15].	X	X	X	X	X	X	X													
Where practicable strip and salvage topsoil. Where salvaged, protect topsoil from loss or degradation. Use topsoil in reclamation management plan [M12].	X	X	X	X		X			X											

Table 20.10 Terrestrial biodiversity mitigation and management factors for the LNG Facility and associated infrastructure (cont'd)

Proposed Mitigation or Management Measure	Biodiversity Element			Project Activity		Direct Impacts										Indirect Impacts				
	Habitat	Flora	Fauna	Construction	Operation	Habitat Loss	Edge Effects	Barrier Effects	Erosion and Spoil	Hydrology	Pollution	Dust	Disturbance	Traffic	Loss of Display Area	Fire	Dieback	Exotic Weeds and Pathogens	Exotic Fauna	Hunting and Collecting Flora
Use cleared vegetation where practicable for dust control and revegetation [M17].		X	X	X	X	X			X			X						X		
Establish and enforce sediment and erosion control measures, as part of a water management plan, that limits the mobilisation and dispersion of sediment into freshwater and estuarine environments particularly in relation to site preparation earthworks watercourse diversions, site drainage design and road crossings [M23].	X	X	X	X		X			X	X										
Develop and implement an acid sulfate soil management plan within a project wide water management plan [M28].	X	X	X	X	X				X	X	X									
Maintain existing marine along-shore sediment transport patterns in the vicinity of the Vaihua River mouth [M223].	X	X	X	X	X	X				X							X			
Provide suitable containment wherever hazardous or dangerous goods are stored or used [M30].	X	X	X	X	X	X					X						X			
Establish spill response plan appropriate to the project phase and train staff in their responsibilities under the plan [M27].	X	X	X	X	X	X					X						X			
Develop air emissions management plan, including dust management procedures, for the LNG Facilities site including project roads [M42].	X	X	X	X		X						X					X			
Prohibit disturbance/harassment of wildlife, hunting of fauna, gathering of plants or bush foods, collection of firewood or possession of wildlife products by project workers or contractors while working, travelling in project vehicles, and residing in project field accommodation. Implement appropriate inductions and education to encourage staff to comply with regulations [M9].	X	X	X	X	X	X							X							X
During operations prohibit staff from disturbing migratory species and associated habitats, especially along perimeter fence adjacent to saltflat habitat [M8].			X	X	X								X							

Table 20.10 Terrestrial biodiversity mitigation and management factors for the LNG Facility and associated infrastructure (cont'd)

	Biodiversity Element			Project Activity		Direct Impacts										Indirect Impacts				
Proposed Mitigation or Management Measure	**Habitat**	**Flora**	**Fauna**	**Construction**	**Operation**	**Habitat Loss**	**Edge Effects**	**Barrier Effects**	**Erosion and Spoil**	**Hydrology**	**Pollution**	**Dust**	**Disturbance**	**Traffic**	**Loss of Display Area**	**Fire**	**Dieback**	**Exotic Weeds and Pathogens**	**Exotic Fauna**	**Hunting and Collecting Flora**
Establish a blasting management plan (for both the terrestrial and marine environments) considering ANZECC Guidelines (1990), or similar and in consultation with local communities [M35].			X	X									X							
Establish and enforce speed limit for project traffic on all roads. Liaise with government agencies and local villages with regard to general road safety and traffic regulation [M36].			X	X	X									X						
Limit machinery and vehicle movements to defined works areas and designated project roads. (Note that anywhere within the security fence will be accessible during construction) [M10].			X	X	X								X	X						
Undertake community consultation regarding the use of burning in the vicinity of the LNG Facilities site [M21].	X	X	X	X	X	X										X	X			
Establish and enforce project-wide quarantine management procedures within the ecology, natural habitat and biodiversity management plan. This would include inspection of equipment, machinery and consumables such as pipe and imported rock [M1].	X	X	X	X	X	X											X	X	X	
Establish and enforce pest and weed management procedures within the ecology, natural habitat and biodiversity management plan for the LNG Facilities site including procedures to prohibit project workers or contractors from establishing any gardens, introducing, keeping or transporting any plants, seeds or animals (including fish) within the perimeter fence. This plan would include provisions such as worker education to assist in recognition and eradication of pest species and measures specific to the LNG Facilities site [M2].	X	X	X	X	X	X											X	X	X	
At new or improved road crossings, in order to maintain connectivity of wet season flow in watercourses and enable fish migration, avoid using step-down cascades or high-velocity 'chutes' [M22].	X		X	X		X		X												
Where practicable, locate perimeter fence and other facilities to the landward side of the saltflats and wetlands [M3].	X		X	X		X	X	X	X	X			X							
Conduct community consultation regarding fishing, mud crab and mangrove wood collection and how the project will minimise impacts to these activities [M20].		X	X	X	X															X

20.7.4 Residual Impact Assessment

20.7.4.1 Significance of Impacts on Habitats and Special Areas

Table 20.11 sets out the value or sensitivity of individual habitats and special areas (see Section 12.3, Terrestrial Biological Environment, Figure 12.11 and Appendix 12, Biodiversity Impact Assessment) and assesses the significance of direct and indirect impacts before and after mitigation.

The value of each habitat type at the LNG Facilities site is determined mainly by the extent of similar habitat in the local region. For purposes of this assessment, 'local region' has been defined as some 229,000 ha of coastal lowland extending for 113 km (measured as a straight line) along the coast from Suckling Point (55 km northwest of the LNG Facilities site) to the coastal village of Gaire No. 1 (33 km southeast of Port Moresby and 58 km southeast of the LNG Facility site). The inland boundary of the local region follows approximately the 250-m contour.

Table 20.12 shows the habitat losses for each project component and the proportion that this represents of each habitat type in the LNG Facilities site and local region.

Sub-coastal Wetlands/Flats

The original layout of the LNG Facilities site would have cleared a total of 23.9 ha of mangrove and wetlands. This is based on design layout at the time of the biodiversity study (Appendix 12, Biodiversity Impact Assessment). Subsequent relocations of the LNG storage tanks has reduced the cleared area to 4.2 ha of mangroves and 7 ha of wetland/saltflat, which is less than that considered in this assessment.

The main direct threats to the wetlands are pollution and changes to hydrology. Standard industry controls on materials and waste management should be sufficient in themselves to address the former. However, in order to maintain the drainage and water circulation patterns, on which the wetlands and mangroves depend, the design of the jetty and causeway earthworks requires specific measures. These may need to be backed up by the post-construction removal of accumulations of sediment (see Section 21.3.3.2, Operations).

Using the criteria set out in Tables 20.7 and 20.8, these measures are predicted to reduce the significance of residual direct impacts to minor (magnitude low, significance medium).

The introduction of exotic weeds and pathogens represents the greatest potential indirect impact and would, without mitigation, represent a threat of moderate significance. Application of the pest and weed control measures will be implemented at the point of origin of imported materials and normal quarantine procedures will be employed when materials arrive at the LNG Facilities site and during construction.

Based on the assessment criteria described in Tables 20.7 and 20.8, the adoption of these measures and regular monitoring and eradication of outbreaks, are predicted to reduce the significance of these residual indirect impacts to minor (magnitude low, significance medium).

Table 20.11 Impact analysis for habitats and the Vaihua River Ecosystem Complex (VREC)

Habitat	Value[1]	Direct impacts[2]							Indirect Impacts[2]				Impact Significance Before Mitigation[3]		Impact Significance After Mitigation[3]	
		Total Habitat Loss	Edge Effects	Barrier Effects	Erosion & Spoil	Hydrology	Pollution	Dust	Fire	Dieback	Exotic Fauna, Weeds & Pathogens	Collecting Plant Material	Direct	Indirect	Direct	Indirect
Wetlands/Flats	3	M	N	L	M	H	H	L	N	N	H	N	Moderate	Moderate	Minor	Minor
Mangroves	3	M	L	M	M	H	H	L	L	M	VH	L	Moderate	Major	Minor	Minor
Savanna	2	L	N	N	L	N	L	L	L	M	VH	L	Minor	Major	Minor	Minor
Grassland	4	M	N	N	L	N	L	L	L	N	H	N	Minor	Minor	Minor	Minimal
Open Woodland	3	L	N	N	L	N	L	L	L	L	H	L	Minor	Moderate	Minor	Minor
Gallery Forest	3	N	N	N	N	M	M	L	L	L	H	L	Minor	Moderate	Minor	Minor
VREC	2	M	L	L	M	H	H	L	L	M	VH	L	Moderate	Major	Minor	Minor

[1] The value of habitats/special areas follows the system outlined in Table 20.8: 1 – Very High Value; 2 – High Value; 3 – Medium Value; 4 – Low Value.

[2] The magnitude of direct and indirect impacts follows the system outlined in Table 20.7: VH – Very High; 2: H – High; M – Medium; L – Low; N – Minimal.

[3] The impact significance matrix is shown in Table 18.1. The categories are: major, moderate, minor, minimal and positive.

Table 20.12 Habitat losses in site and regional context

Study Area Components	Total Area of Habitat Loss (ha)	Grassland (Low Value)/ Open woodland (Moderate Value)			Savanna (High Value)			Mangroves (Moderate Value)		Wetlands or Flats (Moderate Value)		Mangroves and Wetlands
		Total (ha)	%SA[1]	%LCR[2]	Total (ha)	%SA[1]	%LCR[2]	Total (ha)	%SA[1]	Total (ha)	%SA[1]	%LCR[2, 3]
LNG Facilities site	687.4	588.7	37.9	3.6	8.0	0.3	<0.1	13.2	5.1	9.5	7.9	<0.1
Pipeline ROW	1.3	0.1	<0.1	<0.1	0	-	-	0.5	0.2	0.7	0.6	<0.1
Roads												
• Private - Lea Lea Road upgrade	6.4	6.4	0.4	<0.1	0	-	-	0	-	0	-	-
• New public	5.8	5.3	0.3	<0.1	0.5	<0.1	<0.1	0	-	0	-	-
Total maximum	700.9	600.5	38.7	<3.7	8.5	<0.4	<0.1	13.7	5.3	10.2	8.5	<0.1

[1] Proportion of habitat lost from the study area.

[2] Proportion of habitat lost from the local contextual region.

[3] The area of mangroves and wetlands lost from the study area were combined to calculate percentage losses from the local regional context, since these habitats are combined under FIMS vegetation types.

Mangroves

The causeway across the mangrove fringe will cause clearance and barrier effects. The area cleared is 13.7 ha, which is 5.3% of the mangroves that occur on the LNG Facilities site and 0.1% of their occurrence in the local region. The mangroves have been assessed as of medium value and sensitivity (reflecting ongoing cutting for firewood), the direct impact as medium magnitude and the residual impact significance as minor.

The main direct threats to the mangroves and the subcoastal wetlands/flats are pollution and changes to hydrology, with high impact potential if unmitigated. Similarly, standard pollution and waste management controls and specific measures to maintain the hydrological regime will reduce the significance of direct impacts to minor (magnitude low, significance medium).

The introduction of exotic weeds and pathogens represents the greatest potential indirect impact and would, without mitigation, represent a high impact. This issue requires application of pest and weed control measures at the point of origin of imported materials and normal quarantine procedures at the LNG Facilities site. The adoption of these measures and regular monitoring and eradication of outbreaks are predicted to reduce the residual indirect impact significance to minor (magnitude low, sensitivity medium).

Savanna

The remnant savanna has a long history of disturbance and the area of remnants to be cleared is 8 ha, a small proportion of the total area within the LNG Facilities site. With application of environmental management plans for pollution control and site rehabilitation measures, the significance of the residual direct impacts on savanna is assessed as minimal (magnitude minimal, sensitivity high).

As is the case for mangroves, the premitigation threat to remnant savanna from the indirect impacts of weeds and pathogens is very high, which mitigation measures should lower to a residual impact of moderate significance (magnitude low, sensitivity high).

Grassland

The grassland component is assessed as being of low value and direct and indirect project impacts as of minor and minimal significance respectively after application of monitoring and eradication measures to control weeds and pathogens (magnitude low, sensitivity low).

Open Woodland

Open woodland has been mapped with grassland within a single vegetation class, because their ecology and floristic components are similar and boundaries are indistinct and because they share a largely common fauna (Appendix 12, Biodiversity Impact Assessment).

The medium value of the remnants of open woodland reflects extensive disturbance by timber cutting and fire. For reasons given above, the area to be cleared has not been estimated but it represents a small proportion of the mapped area of grassland and open woodland combined**.** With normal pollution control and site rehabilitation measures, the significance of residual direct impacts on open woodland should be minor (magnitude low, sensitivity medium).

The unmitigated potential indirect impacts of exotic weeds and pathogens represent a potentially high impact. Standard hygiene, monitoring and eradication measures, fire control and an end to harvesting of plant material within the LNG Facilities site should combine to reduce the significance of the residual indirect impacts on open woodland to minor (magnitude low, sensitivity high).

Gallery Forest

Gallery forest will not be directly affected, but there is an area 250 m downstream of where Lea Lea Road crosses the Vaihua River that is susceptible to the direct impacts of changes to hydrology and sedimentation from upstream construction activities.

These short-term and localised direct impacts are assessed to be moderate, but normal erosion and sedimentation controls should reduce the residual direct impact to minor significance (magnitude low, sensitivity medium).

Application of the weed, pest and pathogen management plans and monitoring will be required to reduce the high potential impact of weeds and pathogens to minor residual indirect impact significance (magnitude low, sensitivity high).

Special Area: the Vaihua River Ecosystem Complex

Table 20.13 shows the areas to be cleared of grassland, open woodland, mangrove and wetland/mudflat habitats within the Vaihua River Ecosystem Complex. These figures are conservative and do not include relocations of the LNG storage tanks that reduces the areas of mangrove and wetland affected to 4.2 and 7.0 ha respectively.

Table 20.13 Habitat losses within the Vaihua River Ecosystem Complex

Project Component	Total		Grassland/ Open Woodland		Mangroves		Wetlands/Mudflats	
	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%
LNG Plant footprint area	39.4	10.5	19.8	24.1	4.3	1.6	15.3	12.6
Jetty	0.9	0.2	0.8	1.0	-	-	0.1	0.1
Security fence	2.2	0.6	0.3	0.3	1.8	1.2	0.1	0.1
Total maximum	**42.5**	**11.3**	**20.9**	**25.4**	**6.1**	**2.8**	**15.5**	**12.8**

Total and proportional area losses, and losses per habitat, incurred within the Vaihua River Ecosystem Complex through clearing for various components of the construction and operation of the LNG Facilities site. The proportion (%) of the total area and the area of each habitat that will be lost is also shown.

Appendix 12, Biodiversity Impact Assessment, has assessed the Vaihua River Ecosystem Complex as a high-value local special area. It potentially faces a moderately significant impact from the unmitigated direct impacts of changes to hydrology and pollution on the mangrove and wetland habitats of the Vaihua River Ecosystem Complex. Unmitigated indirect impacts of weeds and pathogens are assessed as a major potential impact.

However, the application of the measures set out above for mitigating potential impacts on the specific constituent habitats of the Vaihua River Ecosystem Complex are expected to reduce the significance of both direct and indirect impacts to minor.

20.7.4.2 Significance of Impacts on Listed Species

The habitat of the LNG Facilities site is either highly disturbed or fragmented and, in either case, subject to the pressures of proximate and active subsistence communities, who hunt and gather. Listed species were not observed and their existence in such a disturbed area is improbable. However, those that could conceivably be present have been singled out for discussion, and the taxa discussed below include those IUCN-listed species (Threatened, Near Threatened or Data Deficient) and species protected (P) under the PNG *Fauna (Protection and Control) Act 1966* already recorded or that may occur at the LNG Facilities site.

Plants

The sandalwood (*Santalum macgregorii*) (Endangered) is a parasitic species of open savanna vegetation and savanna gully forest and has been exploited for its scented wood for more than a century. Now, few mature trees or virgin stands remain. In the Port Moresby area, sandalwood has not been seen since the 1970s and is likely to be locally extinct, especially in light of current population pressures.

Mammals

The giant bandicoot (Data Deficient) is a poorly known species recorded only in the lowlands of Papua New Guinea, including the Port Moresby area. This largest of all bandicoots is targeted by hunters and dogs, and the habitat has been disturbed by clearing and burning. There have been no recent records from the area, and it is unlikely to be present at the LNG Facilities site.

The New Guinean planigale (Vulnerable) is a small marsupial carnivore known from few specimens (approximately 30), most of which (more than 90%) were collected from the Port Moresby area, including Waigani Swamp, some 18 km to the east of the LNG Facilities site. The ecology of this species is poorly known, although it has sometimes been found in rock-strewn areas and it appears somewhat tolerant of human-modified habitats. It is possible that a population persists at the LNG Facilities site, where potential habitat includes savanna-covered hills in the site's south and east and the low, rocky ridges that line the broadest areas of saltflats, wetlands and mangroves in the southeast of the Vaihua River Ecosystem Complex.

None of these potential habitat areas is planned to be cleared, but individuals of the New Guinean planigale could be either directly affected by falling into open trenches, drains, pits, etc., or indirectly, via the introduction of exotic flora and fauna.

The canefield rat (Near Threatened) occurs in savanna grassland in New Guinea and northern Australia. There are numerous records from the Port Moresby area, and it is likely to occur in suitable habitat at the LNG Facilities site. Project infrastructure will result in the loss of potential habitat in the site's northwest. However, if present, the species will persist in large areas of suitable habitat throughout the unaffected remainder of the site (and indeed in the local region).

The New Guinea big-eared bat (Critically Endangered) (*P. imogene*) has not been recorded for over 100 years and is probably extinct. As doubtful as it may be, if *P. imogene* were present on site, then it would most likely reside in the savanna and woodland. Although minimal areas of woodland and savanna are to be cleared, the loss of individual trees containing colonies of this very rare species could result in a major direct impact on regional and national populations. Direct impacts should be low if mitigations relating to clearing potential bat habitat (see Chapter 29, Summary of Mitigation and Management Commitments; Chapter 30, Environmental Management, Monitoring and Reporting; and Appendix 12, Biodiversity Impact Assessment) are followed.

Six additional IUCN-listed bat species may occur in habitats present at the LNG Facilities site.

Watt's pipistrelle (Near Threatened) is likely to favour mangroves as foraging habitat on site, and has been recorded roosting in houses and feeding around villages. Some habitat used by this species may be lost to the jetty/causeway. However, if these small bats do occur, then they are also likely to be present in other woodland habitats and in other, larger areas of mangroves north of the LNG Facilities site around Galley Reach.

Troughton's sheathtail-bat (Vulnerable), yellow-bellied sheathtail-bat (Near Threatened), greater long-eared bat (Vulnerable), Papuan pipistrelle (Near Threatened) and the big-eared mastiff-bat (Vulnerable) are all species that may occur in savanna and/or woodland areas on site. Little or no impact is expected upon foraging habitat nor, if the tree clearance protocol suggested for *P. imogene* is followed, on colonies in tree roosts.

The presence of the remaining 11 listed bat species occurring at the LNG Facilities site is only a possibility if there are cave roosts or suitable forest foraging habitats are present. Neither of these critical habitat requirements has yet to be identified on site.

Birds

The osprey (Protected) is an uncommon, specialist marine fish-eater with a global distribution. A single osprey was observed hunting near the mouth of the Vaihua River during the April 2008 survey. Impacts will be minimised by the measures proposed to maintain coastal habitat and prohibit hunting by staff and contractors.

The great, intermediate and little egrets (Protected) are all protected under the PNG *Fauna (Protection and Control) Act 1966*. All three species are commonly observed in wetlands near Port Moresby (Mackay, 1970), and all were recorded at the LNG Facility site in April 2008.

The beach thick-knee (Near Threatened) is a widely though sparsely distributed shorebird of sandy beaches, tidal mudflats, reefs and mangroves. It is rarely recorded in the Port Moresby area and although the LNG Facility site includes suitable foraging habitat, the small and frequently disturbed beach is not suitable for breeding.

In addition to resident waterbirds, a variety of migratory Paleoarctic shorebirds have been recorded at the wetlands on site, and the black-tailed godwit (Near Threatened) and Asian dowitcher (Near Threatened) may also occur. Both are found most commonly along coastal mudflats, and both have been recorded in wetlands near Port Moresby.

The black-necked stork (Near Threatened) inhabits wetlands, intertidal mudflats and flooded grassy plains from India to Australia. In New Guinea it is restricted to the Trans-Fly region, though there is an unconfirmed record from the Port Moresby area. This species is unlikely to occur at the LNG Facilities site.

The Tahiti petrel (Near Threatened) and Heinroth's shearwater (Vulnerable**)** are pelagic seabirds. Neither is believed to breed on the mainland of New Guinea nor on the islands. The Tahiti petrel is occasionally recorded off New Guinea's south coast, including near Port Moresby, and both may occur near the LNG Facilities site from time to time. The project should have no impact upon these species.

All birds-of-paradise are protected under the PNG *Fauna (Protection and Control) Act 1966*. The LNG Facilities site lies within the range of five species that utilise habitats present on site. The glossy-mantled manucode is the most likely to occur, being found in gallery forest in savanna, heavy savanna and mangroves (Coates, 1990; Frith & Beehler, 1998). Though less common, the trumpet manucode is also known from gallery forest in Port Moresby savannas. The magnificent riflebird, king and raggiana birds-of-paradise are tropical forest species occasionally recorded in other forest habitats. These species are more likely to be hunted than manucodes, and they are less likely to favour the habitats on site. Their presence cannot be ruled out, though the area is unlikely to support permanent populations.

Reptiles and Amphibians

No IUCN-listed or nationally protected terrestrial reptiles or amphibians have been recorded or are likely to occur at the LNG Facilities site.

20.7.5 Conclusions

Construction and operation of the LNG Facility are expected to present a low overall impact to local biodiversity values if the appropriate mitigation and management procedures are adopted. These procedures are now standard industry practice: quarantine, weed and plant pathogen hygiene, maintenance of critical hydrological processes, minimising vegetation clearance, erosion and sediment control, and prohibitions of burning and poaching. The project’s environmental management plans (see Chapter 30, Environmental Management, Monitoring and Reporting) will give specific effect to these measures for each component of the project.

The listed species of plants and animals, which could or do occur on the site, appear unlikely to be adversely affected by the construction and operation of the PNG LNG Project: the project’s footprint will fall almost entirely on land cleared (and since abandoned) for cattle grazing, the loss of the least disturbed habitats is a small proportion of their local occurrence and a very small proportion of their regional occurrence, and some existing threatening process (such as hunting and burning) will be eliminated within the security fence of the LNG Facilities site.

20.8 Air Quality

This section presents impact assessment criteria (Section 20.8.1), addresses the principal issues (Section 20.8.2), proposed mitigation and management measures (Section 20.8.3) and residual environmental impacts (Section 20.8.4) of the project related to construction and operations phase air quality impacts. This section summarises Appendix 18, Air Quality Impact Assessment, which presents a detailed analysis of the project’s air quality impacts.

20.8.1 Impact Assessment Criteria

Papua New Guinea has no formal air quality guidelines, and so the project has followed the approach suggested by the World Bank (World Bank, 1998 and 1999). The project’s air quality assessment criteria incorporate World Bank, World Health Organisation (WHO) (WHO, 1987, 2000, 2005b) and the Texas Natural Resources Conservation Commission (TNRCC) guidelines

(TNRCC, 2008), as shown in Table 18.26. The project air quality targets are consistent with, but slightly more stringent than the concentrations currently used by the US EPA for PM_{10}.

The TNRCC guidelines have been used in the assessment in the absence of PNG standards to address the volatile organic compounds (VOCs) benzene, toluene, ethylbenzene and xylene (referred to as BTEX compounds) which are of particular interest from the point of human health. While the World Bank Pollution Prevention and Abatement Handbook (World Bank, 1998) specifies emission limits for VOCs, it does not provide guidance as to the acceptable ambient exposure to VOCs. Additionally, the WHO guidelines (WHO, 1987 and 2000) discuss the impacts of exposure to BTEX compounds in terms of risk assessment, they do not recommend an acceptable concentration and associated averaging time.

Instead of adopting a risk-based approach to assessing BTEX exposure, it is more appropriate to assess the potential affects of exposure via a screening approach. The TNRCC guidelines allow such an approach to be undertaken via effects screening levels that are used to evaluate the potential for effects to occur as a result of exposure to airborne BTEX (Appendix 18, Air Quality Impact Assessment). Effects screening levels are not ambient air quality standards and do not necessarily indicate a problem if they are exceeded, rather they are designed to trigger a more in-depth review should an exceedence occur.

The guidelines for air quality are designed to protect human health, flora and fauna and other aspects of the environment.

For the purposes of assessing the impacts of emissions from shipping, the focus has been confined to LNG Jetty activities during operations. This will capture the worst-case impacts for land-based and sea-based receptors. Existing air quality information is provided in Section 12.2.11, Air Quality.

20.8.2 Issues to be Addressed

20.8.2.1 Construction

Construction activities related to the PNG LNG Project are described in detail in Chapter 2, Producing the Gas, Chapter 3, Transporting the Gas and Chapter 5, Project Logistics. Activities that affect air quality include earthworks as part of construction of the temporary and permanent accommodation camps and later associated with the preparation of the site for the LNG train(s) and associated tanks, flares, roads and other infrastructure, together with exhaust emissions from construction vehicles and earthmoving equipment and the high temperature waste incinerator.

These sources will temporarily increase the local concentrations of airborne particulate matter and certain gases, including nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), VOCs and welding fumes.

Air quality impacts of construction, in particular dust emissions, will depend on seasonal conditions at the time the work is undertaken. Airborne particulate matter in dust can affect human health, particularly as PM_{10}. Total suspended particulates (TSP) and dust deposition are more likely to have an aesthetic and amenity impact.

20.8.2.2 Operations

LNG Facilities Site

During operations, emissions will occur from gas-fired equipment and will largely involve emissions of NO_x, and VOCs (i.e., BTEX). These emissions will occur over the life of the project.

During operations, the LNG Plant will not be a significant source of particulate matter or of SO_2; therefore no modelling of these was undertaken, although they are considered in the assessment of shipping emissions.

The type of wastes incinerated in the high temperature waste incinerator will be controlled through the project environmental management plan.

LNG Carriers, Condensate Tankers and Tugs

LNG carriers and condensate tankers, as well as the tugs that will be used to assist these vessels, will be sources of NO_2, SO_2 and particulate matter (PM_{10}).

Cumulative Impacts of the LNG Facilities and Shipping

Given onshore winds, emissions of NO_2, SO_2 and PM_{10} from LNG carriers, condensate tankers and tugs could carry emissions from shipping across the LNG Facilities site, resulting in cumulative impacts inland and downwind of the LNG Facilities site.

20.8.3 Mitigation and Management Measures

20.8.3.1 Construction

Construction phase atmospheric emissions will be managed as follows:

- Incorporate dust management procedures within the air emissions management plan for the LNG Facilities site including project roads [M42].
- Speed limits on site will be controlled via posted speed limit signs and vehicles will be confined to marked trafficable areas, which will be maintained in a damp (not using saline water) and compacted condition to enhance safety and manage and minimise dust emissions [M34].
- Water carts will be used to keep trafficked surfaces damp when conditions are dry, i.e., when generation of dust is more likely [M34].
- Construction vehicles and equipment will be maintained in order to reduce exhaust emissions [M33].
- Where practicable, diesel-powered equipment will use low-sulfur diesel fuel [M44].
- Place spoil into low, rounded stockpiles to limit erosion and dust effects [M32].

20.8.3.2 Operations

Emissions to air from operation of the LNG Plant and associated facilities will be mitigated through engineered solutions that will be incorporated into the design and operations (see Chapter 4, Producing and Exporting the LNG) as follows:

- Turbine generators will use dry, low-emissions technology to maintain NO_X and CO concentrations at less than 25 ppm [M49].
- A 'smokeless' flare design will apply to normal operation [M37].
- Low NO_X turbines will be used in the LNG Plant [M43].
- BTEX emissions from acid gas removal will be treated by thermal destruction or industry good practice [M46].
- Valves, pipes and tanks will be regularly inspected and maintained to reduce fugitive VOCs emissions [M47].

The modelling assessment of operations emissions (see Appendix 18, Air Quality Impact Assessment) has focused on assessing the impacts of emissions of NO_x, PM_{10}, BTEX and SO_2 from fixed plant on shore and the emissions of NO_x, SO_2 and PM_{10} from shipping. The type of wastes incinerated will be controlled through the project environmental management plan.

20.8.4 Residual Impact Assessment

This impact assessment, including Appendix 18, Air Quality Impact Assessment, has found that project air quality criteria (see Table 18.26 in Section 18.8.1, Impact Assessment Criteria) will be met.

The intention of the fenced buffer zone (perimeter fence) around the LNG Facilities site's plant security fence is to provide a margin of confidence that the guideline values will be met at any dwelling that may be built in the future.

Activities, both during construction and operations, that are likely to result in significant emissions were assessed by means of an atmospheric dispersion model (Appendix 18, Air Quality Impact Assessment) as follows:

- TSP and PM_{10} during construction.
- Emissions of NO_2 and SO_2 from the LNG Facilities site during operations.
- Emissions of NO_2 and SO_2 and PM_{10} from shipping during operations.
- The combined impacts of NO_2 and SO_2 from the LNG Facilities site and shipping during operations.

20.8.4.1 Construction

The total area within the LNG Facilities site to be disturbed during earthworks is approximately 448 ha. As it is unrealistic to assume that work would occur on all 448 ha simultaneously, a conservative estimate was adopted for dispersion modelling whereby it was assumed that half of the 448 ha of land is exposed and is being worked on under the busiest phase in the construction. This has been done to account for the fact that certain construction activities would be completed or be left in a condition where dust emissions are minimal before other works are commenced. The adoption of these assumptions provides a more realistic, but still conservative approach to the assessment under the busiest phase in construction.

Vehicle and plant exhaust emissions will be localised in effect, transient and generally spread out along project roads, access tracks and within the construction site area.

Dispersion modelling undertaken for the worst-case, 24-hour TSP concentration due to emissions from construction predict that at the most sensitive receptor (be it a village, individual dwelling, school or other building used regularly by the surrounding community) a maximum ground-level concentration of 130 $\mu g/m^3$ will occur (see Figure 20.2).

This is below the lower end of the project air quality target range of 150 to 230 $\mu g/m^3$ (see Table 18.26 in Section 18.8.1, Impact Assessment Criteria). Therefore a TSP background concentration of 20 to 100 $\mu g/m^3$ would need to occur before the criterion was exceeded.

Modelling of annual average TSP concentrations due to emissions from the construction work at the most affected sensitive receptor predict a maximum concentration of 38 $\mu g/m^3$ compared with the WHO criterion of 60 to 90 $\mu g/m^3$ (see Figure 20.2). This would allow background concentrations of 22 to 52 $\mu g/m^3$ to occur before the criterion was exceeded. It is unlikely that naturally occurring annual average TSP concentration would reach 52 $\mu g/m^3$ anywhere on or near the project area (Appendix 18, Air Quality Impact Assessment).

Dispersion modelling undertaken for worst-case, 24-hour PM_{10} concentration due to emissions from the construction work predict that at the most affected sensitive receptor, PM_{10} will not exceed 65 $\mu g/m^3$ (see Figure 20.3). This is below the project target of 150 $\mu g/m^3$ (see Table 18.26) and would require a background concentration of 85 $\mu g/m^3$ to occur before the criterion was exceeded.

Modelling of the annual average PM_{10} concentration due to emissions from the construction work predict a maximum concentration of 19 $\mu g/m^3$ at the most affected sensitive receptor (see Figure 20.3). This is below the project target (see Table 18.26) and would not be exceeded until a background concentration of 51 $\mu g/m^3$ occurred.

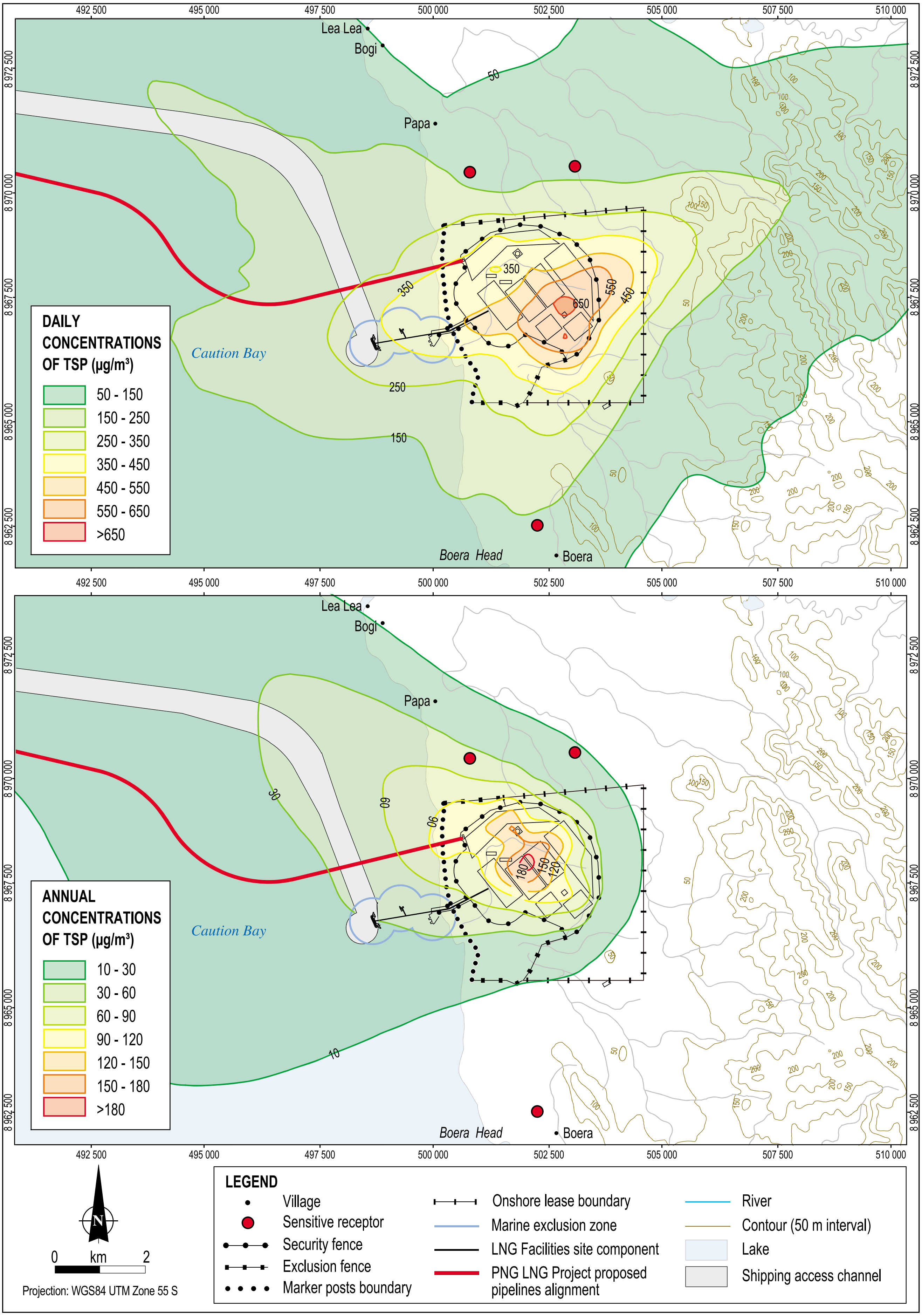
Based on a site inspection and review of existing land use (Appendix 18, Air Quality Impact Assessment), the annual average PM_{10} concentration at the LNG Facilities site is unlikely to exceed 20 $\mu g/m^3$.

The construction phase of the project is expected to meet all relevant air quality assessment criteria set out in Table 18.26. Therefore no impacts to air quality are predicted to occur at sensitive receptor during construction.

20.8.4.2 Operations

LNG Facilities Site

Dispersion modelling was undertaken to predict the impacts of emissions of NO_2 and BTEX from operations of aero-derivative turbines used in the LNG Plant.



Source: Air quality data from Holmes Air Sciences, 2008.

PNG LNG	Date: 26.09.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F20.02_GIS_HB	Esso Highlands Limited PNG LNG Project	Predicted annual and daily TSP concentrations, worst case scenario	Figure No: 20.2

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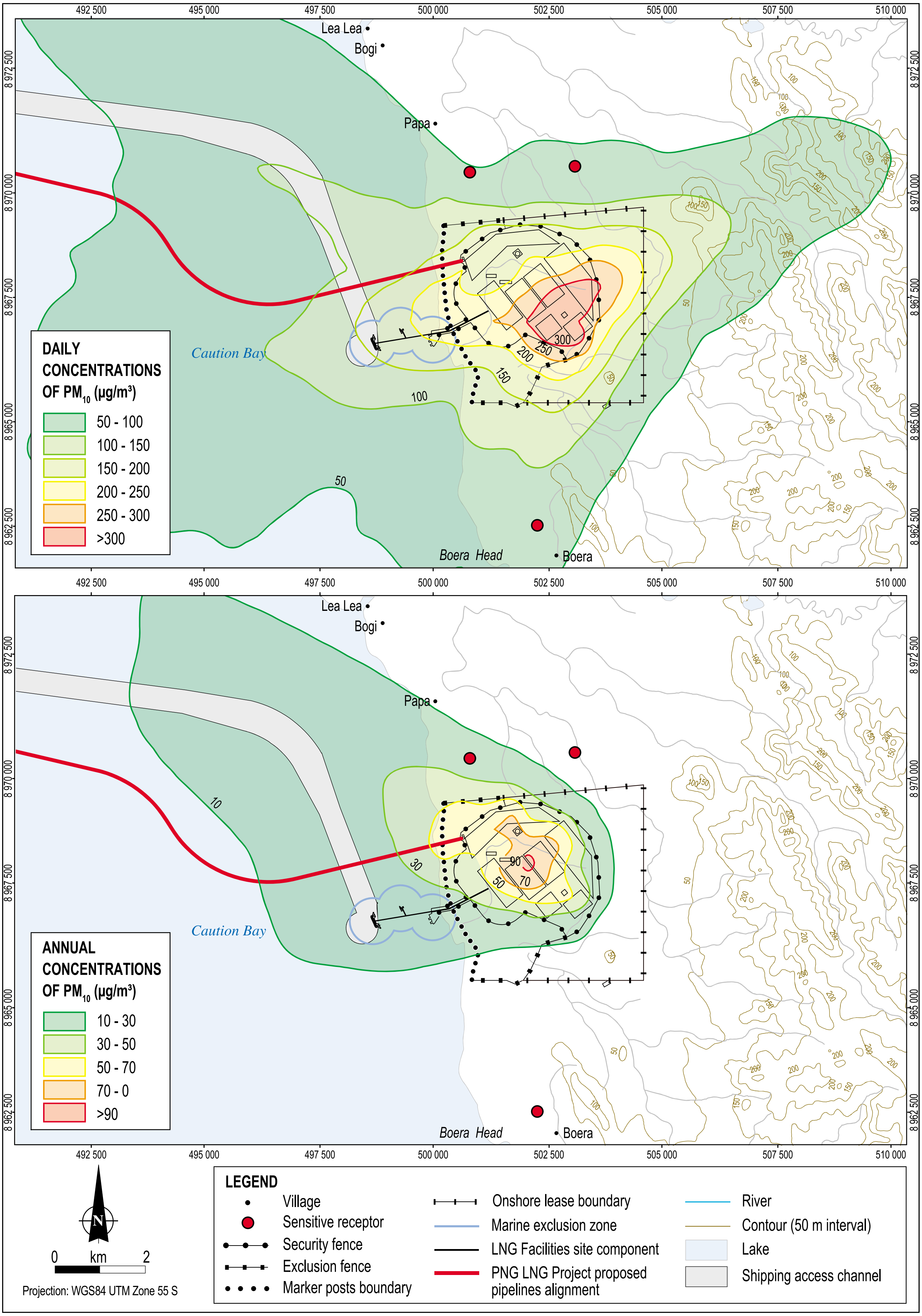

Source: Air quality data from Holmes Air Sciences, 2008.

PNG LNG	Date: 26.09.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F20.03_GIS_HB	**Esso Highlands Limited** **PNG LNG Project**	**Predicted annual and daily PM_{10} concentrations, worst case scenario**	Figure No: **20.3**

PGGP-EN-SRENV-000001-**001**
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The LNG Plant will not be a significant source of particulate matter or of SO_2 and so no modelling of these emissions was undertaken (although they were modelled when emissions from shipping are assessed and are described below).

Modelling predicts that emissions from the LNG Facility will not exceed the assessment criteria as summarised below.

Modelling predicts that the 1-hour average NO_2 concentration at the LNG Facilities site perimeter boundary will slightly exceed 20 µg/m^3 along the northern perimeter (Figure 20.4). At the nearest sensitive receptor concentrations will not exceed 15 µg/m^3. NO_2 concentrations at both locations are an order of magnitude lower than the project NO_2 assessment criteria of 200 µg/m^3 (see Table 18.26).

The highest annual average NO_2 concentration predicted by the dispersion model to occur at:

- The site perimeter boundary is slightly over 1.8 µg/m^3 at the northeastern corner.
- The nearest sensitive receptor is 1.4 µg/m^3.

Both of these predicted concentrations are well under the project NO_2 criteria of 40 µg/m^3.

Dispersion modelling for 1-hour average benzene concentrations predict that at the LNG Facilities site perimeter concentrations do not exceed the project assessment criteria of 170 µg/m^3 (see Appendix 18, Air Quality Impact Assessment and Table 18.26).

Similarly, modelling shows that the highest annual average benzene concentration predicted at the nearest sensitive receptor is well below the project assessment criteria of 4.5 µg/m^3.

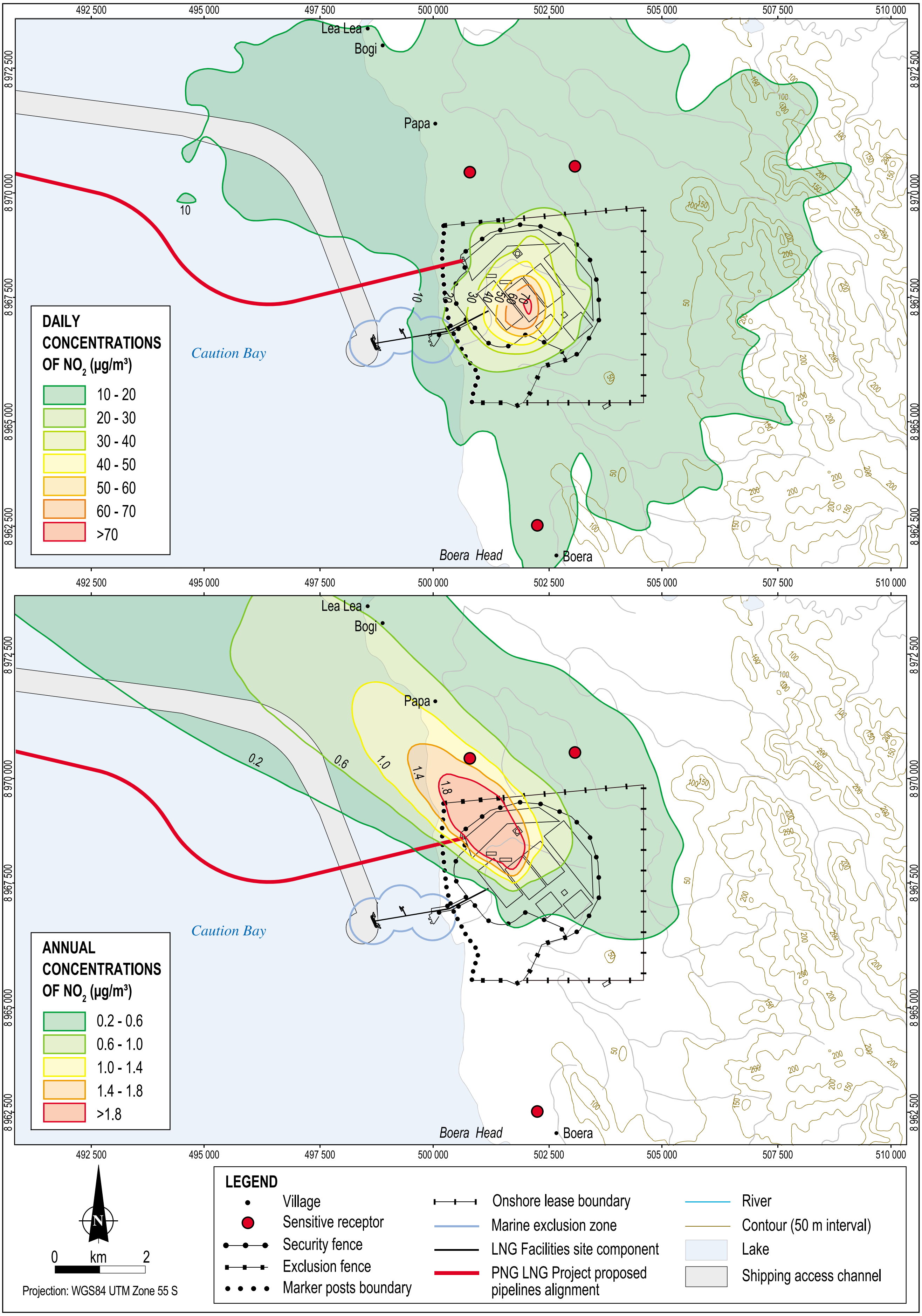
As benzene has the most stringent concentration criteria of the BTEX compounds and meets project assessment criteria, the other BTEX compound criteria will also be met.

Based on the impact assessment, which included air quality dispersion modelling, no impacts are predicted to occur at sensitive receptor during operation of the LNG Facilities.

LNG Carriers, Condensate Tankers and Tugs

LNG carriers, condensate tankers and the tugs that will be used to assist the carriers will be sources of NO_2, SO_2 and particulate matter (PM_{10}). For the purposes of modelling impacts, a conservative scenario of one carrier and four tugs operating in the vicinity of the wharf has been adopted. The highest modelled concentrations of emissions predicted to occur under these conditions at the nearest sensitive receptors are shown in Table 20.14. The cumulative impact of operations at the LNG Facilities site has also been included.

Overall, modelling shows that sensitive receptors located onshore which are outside of the LNG Facilities site will not experience exceedences of any of the assessment criteria for NO_2, SO_2 or PM_{10} during loading of LNG carriers, including taking the cumulative impacts of air quality into account (Appendix 18, Air Quality Impact Assessment). However some areas within Caution Bay in the immediate area around the LNG Jetty are predicted to exceed the project assessment criteria for SO_2.



Source: Air quality data from Holmes Air Sciences, 2008.

PNG LNG	Date: 26.09.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F20.04_GIS_HB	Esso Highlands Limited PNG LNG Project	Predicted annual and hourly NO_2 concentrations, worst case scenario
			Figure No: 20.4

The area where exceedences may occur around the LNG Jetty during LNG loading activities will be the subject of a 500-m-wide exclusion zone (Section 4.12.4, Marine Exclusion Zone). The significance of impact is assessed as minor (magnitude low, sensitivity high). The minor impact significance value is expected to be maintained by effective patrol of the 500-m-wide exclusion zone around the jetty during LNG loading operations.

Table 20.14 Predicted highest concentration of emissions of carriers, tankers and tugs

Emission		Nearest Sensitive Receptor	Predicted Concentration
NO_2	Maximum 1-hour average	Papa village	110 μg/m^3
		Boera village	100 μg/m^3
	Annual	Papa village	1.5 μg/m^3
		Boera village	<0.1 μg/m^3
SO_2	Maximum 1-hour average	Papa village	200 μg/m^3
		Boera village	200 μg/m^3
	Annual	Papa village	<1 μg/m^3
		Boera village	<1 μg/m^3
PM_{10}	24-hour average	Papa village	1 μg/m^3
		Boera village	<1 μg/m^3
	Annual	Papa village	<0.1 μg/m^3
		Boera village	<0.1 μg/m^3

20.9 Noise

This section presents noise impact assessment criteria (Section 20.9.1), addresses the principal issues (Section 20.9.2), proposed mitigation and management measures (Section 20.9.3) and residual environmental noise impacts of project construction and operations (Section 20.9.4).

Sound is a fundamental sense used to perceive the environment. Noise is typically described as an unfavourable sound. The assessment of sound is primarily based on human response values such as hearing damage and potential health affects such as stress. The overall level of a sound is usually expressed in terms of decibels (dB(A)), which is measured using the ’A-weighting’ filter incorporated in sound level meters. These filters have a frequency response corresponding approximately to that of human hearing. Humans are most sensitive to sounds at mid frequencies (typically 500 Hz to 4,000 Hz) and less sensitive at lower and higher frequencies. The level of a sound in dB(A) is considered a good measure of the loudness of that sound.

A change of up to 3 dB(A) in the level of a sound is difficult for most people to detect, whilst a 3 dB(A) to 5 dB(A) change corresponds to a small but noticeable change in loudness. A 10 dB(A) change corresponds to an approximate doubling or halving in loudness.

Existing ambient and background noise levels at nearby sensitive receptors to the LNG Facilities site and the process of surveying these noise levels are described in Section 12.2.10, Noise.

20.9.1 Impact Assessment Criteria

There are no formal policies or guidelines for environmental noise in Papua New Guinea, and so project noise criteria have been established as described in Section 18.9.1, Impact Assessment Criteria.

Based on these noise criteria and guidelines, noise levels relevant for assessment of potential impacts for construction and operations at the LNG Facilities site are:

- Noise targets at the onshore lease boundary of 55 dB(A) L_{eq} between 7 a.m. and 10 p.m. and 45 dB(A) L_{eq} from 10 p.m. to 7 a.m. The pre-existing background noise criterion at the boundary are not relevant, as currently the area adjacent to the lease boundary fence is uninhabited and, should people choose to move closer to the facility, the background noise of the area would already be dominated by the facility.
- Single events (traffic pass-bys on roads etc.) have no daytime criteria suggested but 60 dB(A) L_{max} would be a reasonable design goal Appendix 19, Noise Impact Assessment. Single events are primarily concerned with sleep disturbance at night and the recommended night (10 p.m. to 7 a.m.) noise criterion is 45 dB(A).

The above criteria are the same as those adopted for the Juha Production Facility and the Hides Gas Conditioning Plant.

20.9.2 Issues to be Addressed

20.9.2.1 Construction

It is anticipated that construction of the LNG Facilities site will take approximately four years. The main sources of project noise will be as follows:

LNG Facilities Site

Noise will be generated at the LNG Facilities site by:

- Site preparation and earthmoving: heavy construction vehicles and equipment such as bulldozers, scrapers, front-end loaders, backhoes, graders, rollers, dump trucks and water carts.
- Materials Offloading Facility and LNG Jetty causeway: heavy construction equipment such as excavators, bulldozers, dump trucks, graders, rollers and concrete trucks. Sheet piling will be required for the final section of the causeway.
- Civil works and plant fabrication: concrete and asphalt batch plants, installation of foundation structures and paved areas within the LNG Facilities site will require equipment such as piling, heavy rollers, dump trucks, concrete trucks, generator sets and steel reinforcement fabrication hand tools such as grinders and welders.
- Haul roads between Materials Offloading Facility and LNG Plant: installation of heavy haul and access roads will require equipment such as rollers, dump trucks, concrete trucks and asphalt laying equipment.
- Construction of the LNG Facilities will include activities such as receiving and transporting large plant items from the Materials Offloading Facility to the LNG Facilities site, which will

typically require equipment such as tugs and barges, offloading crawler cranes and heavy transport equipment. Onsite steel fabrication and pipe erection will typically require equipment such as tower cranes, grinders, welders, generator sets, air compressors and tools. Erection and assembly of plant items will require equipment such as tower cranes, forklifts, generator sets, air compressors and tools.

- Construction of the LNG Jetty trestle will typically require equipment such as pile driving and crawler cranes.

In addition to routine construction noise from earthworks, facilities and infrastructure installation, there may be temporary elevations in the noise profile from blasting. The blasting events may occur at irregular intervals.

Public Road Realignment and Project Traffic

The upgrade and realignment of the Lea Lea Road around the LNG Facilities site and upgrades to sections of the existing public road from Port Moresby to the LNG Facilities site will typically require equipment such as front-end loaders, backhoes, graders, rollers, dump trucks and water carts. This work will be of relatively short duration and generally occur only during the daytime. It is possible that some increased traffic noise impacts may be experienced by settlements in the vicinity of the Baruni Junction resulting from project traffic and transport between Port Moresby and the site (see Figure 17.5).

Construction details of the LNG Facilities site are provided in Chapter 4, Producing and Exporting the LNG. Comprehensive lists of construction equipment and associated sound power levels are provided in Appendix 19, Noise Impact Assessment.

20.9.2.2 Operations

It is anticipated that the operational life of the facility will be 30 years and that the LNG Plant will run 24 hours a day, 7 days a week. Noise will be generated from all operating components of the facility, as well as from vehicles and personnel. These levels will be within adopted limits in accordance with guidelines and criteria. In the event of an operation upset, alarms and emergency venting and flaring will generate significant sound levels, which may temporarily impact the surrounding environment.

The main noise sources are located within the LNG Plant and utilities areas, the LNG Jetty and the flare area. The operational duty cycles of each item of equipment are wide-ranging and difficult to approximate at this early stage. Accordingly, a 'typical' worst-case scenario with all equipment operating has been adopted for the model as described in Appendix 19, Noise Impact Assessment.

Shipping

LNG loading will take approximately between 8 and 10 hours, during which only minimal noise-producing equipment will be operating such as pumps and tanker auxiliary power generators. For the purposes of predicting noise emissions from shipping operations a maximum activity case was assumed. The scenario includes a single LNG tanker shortly after departing the LNG Jetty with up to four tugs assisting the vessels departure. A further vessel docked at the condensate berth was also included.

A list of shipping equipment and associated sound power levels are provided in Appendix 19, Noise Impact Assessment.

20.9.3 Mitigation and Management Measures

The project will adhere to specific criteria for construction and operations that are aligned to the intent of the IFC and WHO Guidelines on Environmental Noise Management (see Section 20.8.1, Impact Assessment Criteria). At project facility sites, the perimeter boundary noise limit will be 55 dB(A) L_{eq} during the day period and 45 dB(A) L_{eq} during the night from noise sourced from the construction and operation of the facilities to protect the amenity of landowners [M35].

An onshore lease boundary fence will be constructed around the onshore lease area of the LNG Facilities site (Portion 2456). A security fence will also be constructed around the LNG Facilities site components to contain the operations. Approximately 1,000 ha of land between the onshore lease boundary fence and the security fence will serve as a noise buffer between the plant and neighbouring receptors.

The IFC guideline noise limits will apply to both construction and operations phases of the project. This approach considers the proximity of any dwellings to the facility, with consideration of the potential for local communities building new residences at the project perimeter boundary fence lines. Consideration of the pre-existing background noise level is not deemed necessary as currently the area adjacent to the proposed onshore lease boundary fence is uninhabited and should people choose to move closer to the facility the background noise of the area would already be dominated by the facility. The IFC guideline limits at the perimeter boundary provides an appropriate level of noise amenity for any newly developed community close to the facility and will protect them against adverse impacts.

Additional noise control criteria relevant to the management of noise from aspects such as project traffic, on site blasting and pile driving that will be considered in the preparation of the project construction and operations environmental management plans are discussed in Section 6 of Appendix 19, Noise Impact Assessment. Specific noise mitigation measures that will be implemented to achieve the project-adopted noise limits (Section 20.9.1, Impact Assessment Criteria) during construction and operations are outlined below.

20.9.3.1 Construction

During construction, achievement of project noise guidelines will be accomplished using a combination of sound planning and scheduling of construction activities and engineered controls such as silencers, barriers, enclosures and laggings on project equipment. The project will also implement the following noise mitigation measures:

- Maintain construction vehicles and equipment in order to limit emissions.
- Establish a blasting management plan (for both the terrestrial and marine environments) considering ANZECC guidelines (ANZECC, 1990), or similar and in consultation with local communities [M35].

Behavioural controls will also be implemented in and around the site to minimise traffic noise. These controls will include enforced speed limits and community and employee awareness training.

20.9.3.2 Operations

Mitigation of operational noise will be similar to the construction mitigation measures. Operational upsets may result in sudden, intrusive noise to the area surrounding the LNG Facilities site. These events will be reduced as much as reasonably practicable while maintaining the safety of the employees, community and environment with engineered controls such as pressure sensitive devices and emergency venting and flaring.

20.9.4 Residual Impact Assessment

The residual impact assessment process (Section 20.1.1, General Approach to Assessment) adopts noise-specific categories and definitions of magnitude of impact, and of sensitivity of resource/receptor (Tables 18.27 and 18.28 respectively). These, in turn, provide the two axes of the matrix of significance (see Table 18.1).

20.9.4.1 Construction

Site Activities

Construction noise levels have been predicted for the three scenarios representing a ‘typical’ worst-case activity with all equipment operating. The predicted LA_{eq} noise level has been predicted for ‘neutral’ and ‘adverse’ meteorologically enhanced conditions at the four nearest sensitive community receptors of Papa, Boera and Lea Lea villages and Metago Bible College and are summarised in Table 20.15.

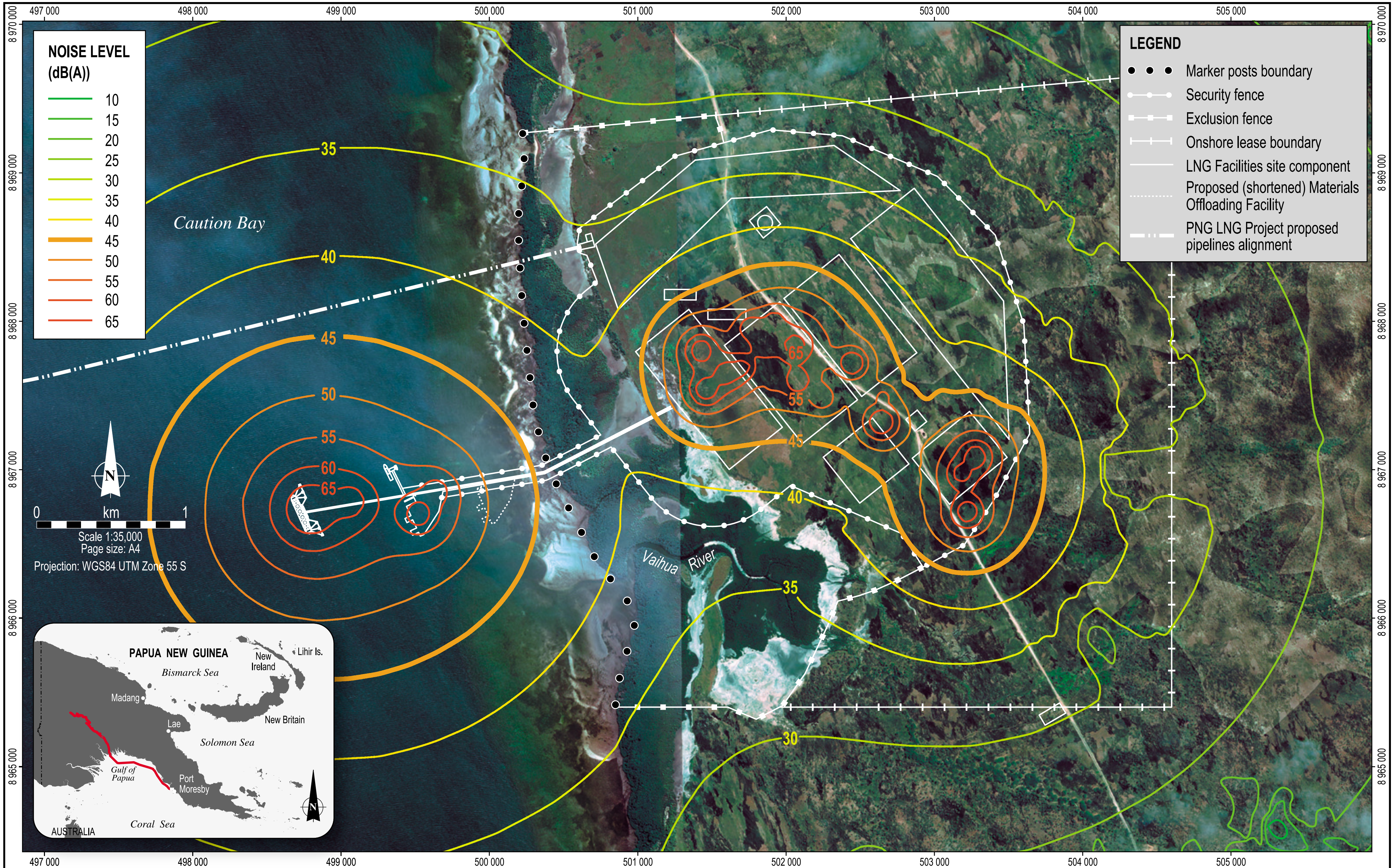
Table 20.15 Predicted construction noise levels (dB(A))

Location of Most Affected Receptor	Project Noise		Site Preparation		Civil Works		Construction of LNG Facilities Site, Utilities and LNG Jetty	
	Day	Night	Neutral	Adverse	Neutral	Adverse	Neutral	Adverse
Papa	55	45	27	33	26	32	21	27
Metago Bible College	55	45	26	33	24	30	21	27
Boera	55	45	19	25	12	18	16	21
Lea Lea	55	45	18	24	11	16	13	18

The predicted construction noise levels show compliance with noise criteria under all conditions during the day and night period. Furthermore, construction noise is likely to be inaudible above the existing ambient background noise level (ranging from an average of 48 to 63 dB(A) at the most affected receptors), particularly during the night period.

Noise contours predicted as typical for ‘worst case’ conditions during construction are shown in Figure 20.5. The 45 and 55 dB(A) limits lie comfortably within the confines of the LNG Facility site boundary.

Using the assessment of significance matrix (see Table 18.1), the sensitivity of the resource or receptor is assessed as high (Table 18.28); the magnitude of impact is assessed as low and hence the overall significance of the potential impact is assessed as minor.



Source: Noise contours data from Heggies, 2008.
Note: Modelling based on initially proposed Materials Offloading Facility location.
Layout is indicative only.
Final placement of all components are contingent upon pending soil and geological data.
Pipeline approximates the proposed alignments based on engineering data provided up to 14 June 2008.

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Construction noise contours

Figure No: 20.5

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Blasting

Sufficient information is not available to model the noise impacts associated with blasting. Regardless, the project will comply with the relevant sections of ANZECC Guidelines (1990) and Australian Standards AS 2187.2: 1993, and blasting management procedures will be developed in consultation with the local communities in the area (sensitive noise receptors) prior to the commencement of works.

Traffic and Transport

The Lea Lea Road will be the primary traffic and transport route used to access the site and will carry more traffic during both project construction and operations. The route is sufficiently far from the villages of Boera (approximately 2.5 km) and Porebada (approximately 2.7 km) to mitigate road noise. The Napa Napa Road section of the route passes through residential communities closer to Port Moresby, where communities are located near the road. Road traffic generated during construction may result in noise increases of approximately 1 to 2 dB(A), resulting in levels that would be considered generally acceptable at most communities. However, the village of Baruni (see Figure 17.5), which has a minimal setback distance (i.e., 15 to 20 m), currently experiences relatively high levels of traffic resulting in existing day and night noise levels of 64 dB(A) and 55 dB(A) respectively that may already be considered high. Project construction traffic through Baruni has the potential to increase current noise levels that are already above criteria.

Using the assessment of significance matrix, the sensitivity of the resource or receptor is assessed as high; the magnitude of impact is assessed as medium; and hence the overall significance (see Table 18.1) of the potential impact is assessed as moderate, except for the people living close to the road in the village of Baruni, where the significance of the impact may be high.

The upgraded road conditions between Baruni village and Baruni Junction will assist in improving safety and may alleviate potential noise impacts related to increased traffic associated with project development. The project's grievance mechanism (see Chapter 23, Project-wide Socio-economic and Cultural Impacts and Mitigation Measures) will be used to monitor and manage community issues during project construction and operations.

20.9.4.2 Operations

Operations noise levels for the LNG Facilities site and shipping have been predicted for 'neutral' and 'adverse' meteorological conditions at the four nearest sensitive community receptors of Papa, Boera and Lea Lea villages and Metago Bible College and are summarised in Table 20.16.

Table 20.16 Predicted operations noise levels (dB(A))

Location of Most Affected Receptor	Proposed Project Noise Limit		LNG Processing and Utilities		Shipping		Flare		Cumulative	
	Day	Night	Neutral	Adverse	Neutral	Adverse	Neutral	Adverse	Neutral	Adverse
Papa	55	45	29	33	28	34	35	35	37	39
Metago Bible College	55	45	29	33	18	23	33	34	35	37

Table 20.16 Predicted operations noise levels (dB(A)) (cont'd)

Location of Most Affected Receptor	Proposed Project Noise Limit		LNG Processing and Utilities		Shipping		Flare		Cumulative	
	Day	Night	Neutral	Adverse	Neutral	Adverse	Neutral	Adverse	Neutral	Adverse
Boera	55	45	25	30	21	25	10	13	27	31
Lea Lea	55	45	25	30	22	26	11	13	27	32

The predicted noise levels show that proposed operational noise targets will be met at the perimeter boundary of the LNG Facilities site and noise levels will be well below noise targets at the nearest village receptors under all conditions during the day and night period.

Evaluation of the cumulative level of noise from all three noise generating operational aspects, i.e., the LNG Facilities site, shipping and flare, show that, should all occur simultaneously, the noise target would still be met.

Noise contours predicted as typical for 'worst case' conditions during operations are shown in Figure 20.6. The 45 and 55 dB(A) limits lie comfortably within the confines of the LNG Facility site boundary.

Using the assessment of significance matrix (see Table 18.1), the sensitivity of the resource or receptor is assessed as high, the magnitude of impact is assessed as low and hence the overall significance of the potential impact is assessed as minor.

20.10 Visual

This section is based on and summarises Appendix 20, Visual Impact Assessment. It addresses the principal visual issues (Section 20.10.1), proposed mitigation and management measures (Section 20.10.2) and residual visual impacts of project construction and operations (Section 20.10.3).

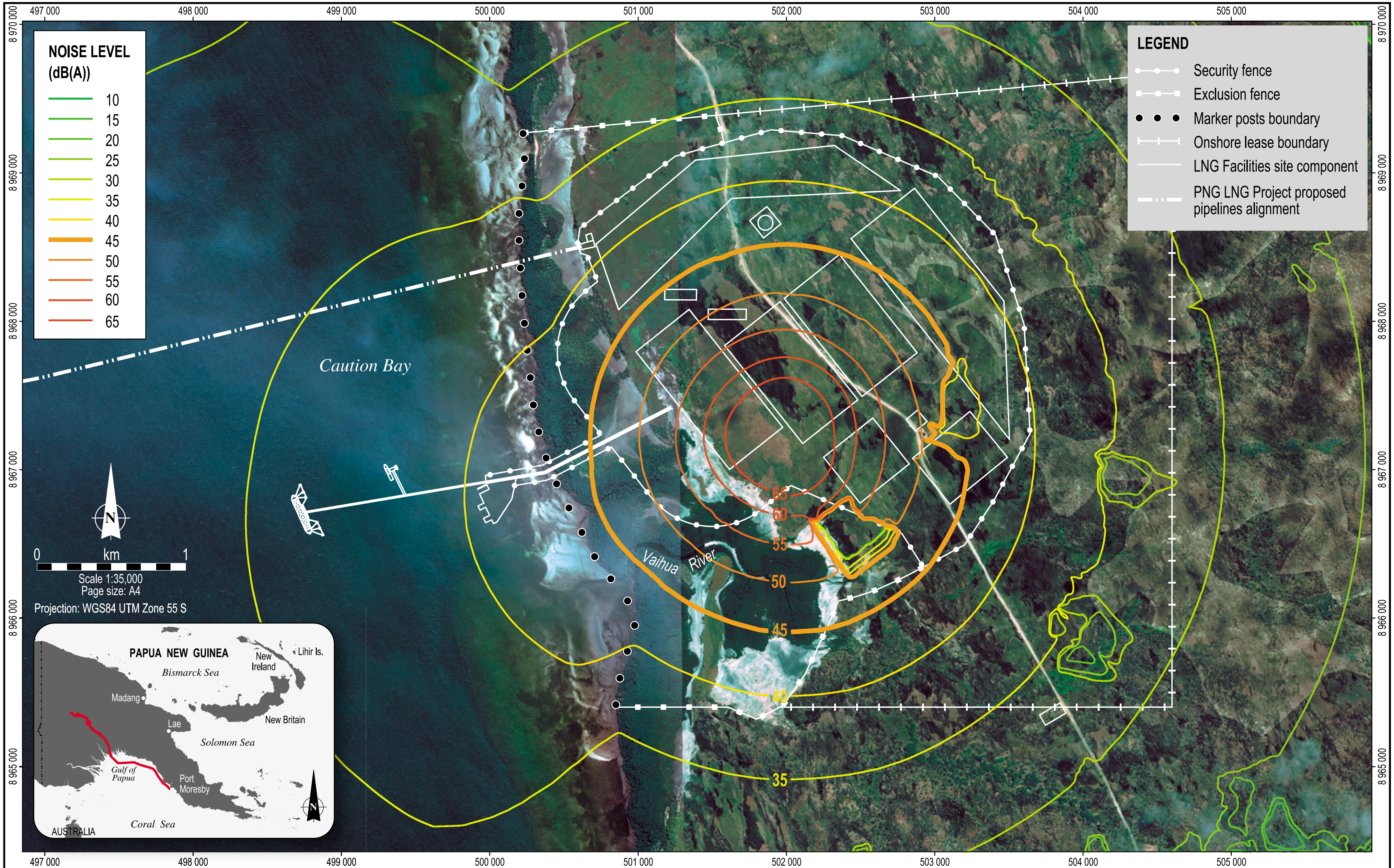
A detailed characterisation of the existing visual aspects of the LNG Facilities site is provided in Section 12.2.12, Visual and Landscape.

The assessment method varies from the method applied to the upstream components of the project (see Section 18.1, General Approach). While the degree to which a development of the scale of the proposed LNG Facilities site is visible from certain vantage points can be quantified in terms of distance to the receptor viewpoint, the degree to which viewers from surrounding sensitive viewpoints will be impacted is influenced by an individual's perceptions. Qualitative assessments are therefore given of the perceptual responses of viewers to visual change caused by the proposed developments.

20.10.1 Issues to be Addressed

Quantitative and qualitative assessment of landscape and visual impacts has been undertaken for the following settings:

- Regional (more than 5 km from the project area).



Source: Noise contours data from Heggies, 2008.

Note:

Layout is indicative only.

Final placement of all components is contingent on pending soil and geological data.

Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG

Date: 13.11.2008

MXD: PNG_LNG_Project_GIS.mxd

File Name: 1284_09_F20.06_GIS_HB

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PNG LNG Project

Operations noise contours

Figure No: **20.6**

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- Subregional (1 km to 5 km from the project area).
- Local (within 1 km of the project area).

Ten viewpoints were selected (five regional, three subregional and two local) within the viewshed or zone of visual influence identified for the project for both the quantitative and qualitative assessment. The location of these viewpoints is given in Figure 20.7.

20.10.1.1 Construction

During the estimated 49-month period of construction at the LNG Facilities site, the potential level of reduced aesthetics will increase as the extent of the work increases. The most immediate impact will result from site clearing and grading. As taller components are constructed or installed, the extent of area from which the development can be seen will increase (see Figure 4.1).

20.10.1.2 Operations

The LNG Facilities are expected to have an operational life of 30 years; therefore, the visual impact of the LNG Facilities and associated shipping traffic can be considered permanent.

The proposed LNG Facilities include the following major components, which will impact on the landscape and visual amenity of the surrounding area:

- Gas pipeline shore crossing.
- Operations camp and turnaround camp.
- LNG Plant and utilities.
- Gas flare.
- LNG storage tanks.
- LNG Jetty, export terminal and Materials Offloading Facility.
- LNG carriers and tugs.

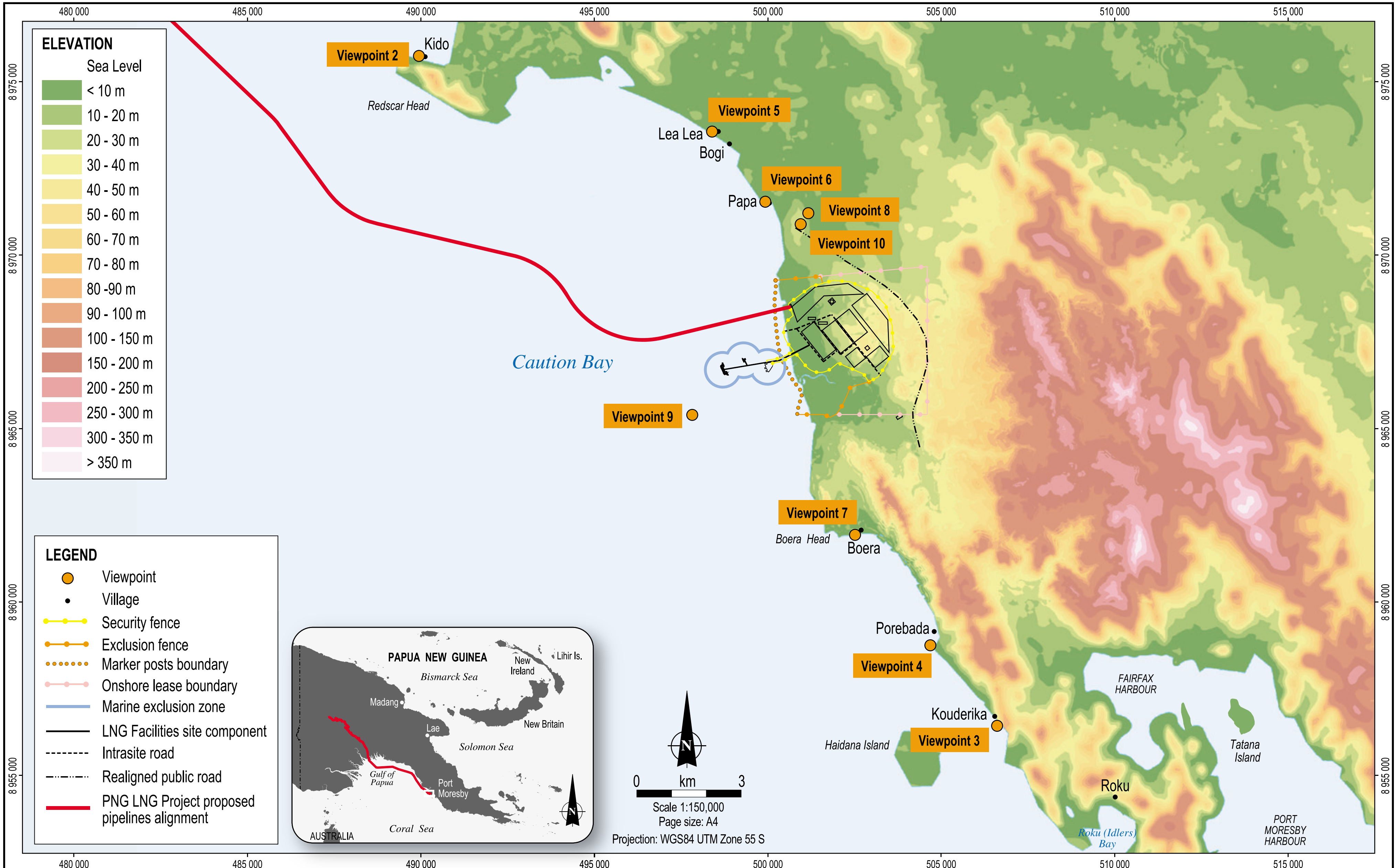
Chapter 4, Producing and Exporting the LNG, and Section 3.3.4.2, Pipeline Route and Crossings, provide detailed descriptions of these components.

The LNG Plant, camps and LNG Jetty will operate 24 hours a day, 365 days a year and thus will be illuminated for both security and occupational health and safety reasons. Flaring of gas from the facility will be an infrequent event, but should it occur at night will be highly visible. Given the lack of other significant lighting in the area, this night lighting may be visually intrusive.

20.10.2 Mitigation and Management Measures

20.10.2.1 Construction

Local communities will be consulted during construction to provide information and receive any concerns that can be acted upon. Their visual amenity may be protected by the erection of visual screening, such as vegetation or bunding. However, such screening will not be installed where it would impede safety or security requirements. Visual screening is most effective when employed at the site perimeter. However, given the security requirement for views along the site perimeter fence to be maintained, any amelioration treatment would be offset from the fence to maintain a clear visual corridor [M40].



Source: DEM and viewpoints data from EDAW, 2008.
Note:
Layout is indicative only.
Final placement of all components is contingent on pending soil and geological data.
Pipelines approximate the proposed alignment based on engineering data provided up to 1 October 2008.

PNG LNG

Date: 28.10.2008
MXD: PNG_LNG_Project_GIS.mxd
File Name: 1284_09_F20.07_GIS_HB

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PNG LNG Project

Viewpoint location map: all viewpoints

Figure No: 20.7

PGGP-EN-SRENV-000001-001
Rev0

Where practicable, construction staff will conduct routine maintenance and housekeeping of debris and construction materials across the construction site will be undertaken to manage the aesthetic value of the construction area. Stockpiled soils and overburden that are to be maintained on site for significant periods will be rounded to stabilise them and to improve the aesthetics of their appearance [M32].

20.10.2.2 Operations

During operations, community visual amenity may be dealt with via visual screening, such as vegetation or bunding. Earth mounding (bunding) is an effective short-term mitigation measure, as it blocks views as soon as it is completed and the raw, earth-coloured appearance of mounding is very quickly replaced by the green of germinating cover plants, particularly in tropical locations [M39].

As a mitigation measure, the LNG Facilities site will have infrastructure located according to safe constructability and operational requirements [M38]. However, any massing or grouping of components of the development will reduce the extent of ameliorative screening required and also reduce the extent of the area from which they will be seen.

The primary sensitive viewing locations of the LNG Facilities site will be from the land, therefore buildings will be of a colour that is visually compatible with the surrounding landscape, for example, olive or mid-greens that are compatible with both the wet season greens and the dry season straw-green or yellow [M39].

The visual impact of taller elements, such as tanks and flare stacks, will be dependent on material colour selection to mitigate their visual impact.

The perimeter and internal components of the LNG Facilities site and around the site perimeters must be well illuminated for both security and occupational health and safety reasons. Where practicable, treatments such as shrouds will be used, and fixed lighting will be shielded to reduce the potential for light spill [M41].

In the case of the LNG Jetty and Materials Offloading Facility, the visual impact will be mitigated by its proposed slender, low-profile design.

20.10.3 Residual Impact Assessment

Visual impact was qualitatively assessed based on the sensitivity level of a viewer. Results of the quantitative assessment are given in Table 20.17 and the locations noted in Figure 20.7. The results of the quantitative assessment will not be altered by implementation of the proposed mitigation measures, as the measures proposed do not limit the horizontal or vertical view of the development.

Table 20.17 Quantitative assessment of sensitive sites

Viewpoint	View Shed	Horizontal Distance from Viewer (km)	Horizontal Potential Visual Prominence	Vertical Potential Visual Prominence
Viewpoint 1 Port Moresby	Regional	21.0	No impact	No impact
Viewpoint 2 Kido	Regional	12.0	No impact	No impact
Viewpoint 3 Kouderika	Regional	9.2	No impact	No impact
Viewpoint 4 Porebada	Regional	6.1	No impact	No impact
Viewpoint 5 Lea Lea	Regional	6.0	Potentially noticeable	Potentially noticeable
Viewpoint 6 Papa	Subregional	3.8	Potentially noticeable	Potentially noticeable
Viewpoint 7 Boera	Subregional	2.4	No impact	No impact
Viewpoint 8 Papa School	Subregional	2.4	Potentially dominant	Potentially noticeable
Viewpoint 9 Intertidal zone	Local	Less than 1	Potentially dominant	Potentially dominant
Viewpoint 10 Realigned Lea Lea Road	Local	Less than 1	Potentially dominant	Potentially dominant

Results of the qualitative assessment of the perceptual responses of viewers to visual change caused by the proposed developments are given in Table 20.18 and locations noted in Figure 20.7 along with the associated residual visual impacts after implementation of the proposed mitigation measures.

Table 20.18 Qualitative assessment of viewer response to visual change

Viewpoint	Premitigation Visual Impact	Residual Impact
Viewpoint 1 Port Moresby	None, as the site will not be visible from this location.	None, as the site will not be visible from this location.
Viewpoint 2 Kido	None for the village centre, as the site will not be visible from this location. Views may be possible through vegetation from high points to the southeast of the village. The potential visual impact of these views will be low.	None for the village centre, as the site will not be visible from this location. Low for views of the LNG Jetty from the headland as mitigation options will be limited.
Viewpoint 3 Kouderika	None, as the site will not be visible from this location.	None, as the site will not be visible from this location.
Viewpoint 4 Porebada	None, as the site will not be visible from this location.	None, as the site will not be visible from this location.

Table 20.18 Qualitative assessment of viewer response to visual change (cont'd)

Viewpoint	Premitigation Visual Impact	Residual Impact
Viewpoint 5 Lea Lea	The key visible elements from this location will be the LNG Jetty and any attendant LNG carrier or condensate tanker. Impact will be moderate, as the visible elements will contrast with the existing character of the visual setting.	Moderate impact, as mitigation options for the LNG Jetty will be limited.
Viewpoint 6 Papa	The key visible elements from this location will be the LNG Jetty and any attendant LNG carrier or condensate tanker. Impact will be moderate to high, as the visible elements will contrast significantly with the existing character of the visual setting.	Moderate to high impact, as mitigation options for the LNG Jetty will be limited.
Viewpoint 7 Boera	None for the village centre, as topography blocks views to the site. However, views of the LNG Jetty will be possible through vegetation from high points to the north of the village. For such views, the visual impact will be high.	None for the village centre, as the site will not be visible from this location. High impact for views of the LNG Jetty from the headland as mitigation options will be limited.
Viewpoint 8 Papa School	Overlooking the site will be possible due to slight elevation and open landscape, allowing expansive and exposed views. The visual impact will be high due to the proximity of the site and the visual contrast between the LNG Facilities site and the existing setting.	Moderate to high impact, as perimeter planting will be effective at screening views of less elevated elements.
Viewpoint 9 Intertidal zone	The visual impact will be high due to the moderate sensitivity of users and the visually dominant appearance of the site, including the LNG Jetty, at this distance.	High impact, as mitigation options for the LNG Jetty will be limited.
Viewpoint 10 Realigned Lea Lea road	The visual impact will be moderate due to the low sensitivity of users and the visually dominant appearance of the facility at this distance.	Low to moderate impact, as foreground screening vegetation will be effective at mitigating views.

Figure 20.8 shows simulations of views of the post mitigation LNG Facilities site from viewpoints 8, 9 and 10.

A number of management and mitigation measure can be implemented to reduce visual impacts of the proposed LNG Facilities, but ultimately, the development will significantly change the landscape character of the local and sub regional setting. The residual impact that this will have on the relatively limited number of villages and people that will view it is very dependent on how these people perceive the development. By applying the impact assessment matrix in Section 18.1, General Approach, the magnitude of impact (see Table 18.1) is high. The sensitivity of resource or receptor is high; and hence the overall significance is moderate.

Source: Visualisations from EDAW, 2008.	PNG LNG	Job No: 1284	Esso Highlands Limited	LNG Facilities viewpoint simulations
		File Name: 1284_09_F20.08_HB	PNG LNG Project	Figure No: 20.8

PGGP-EN-SRENV-000001-**001**
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