Assessment and Impact Analysis of Terrestrial Biodiversity at the LNG Facilities Site, Central Province, Papua New Guinea

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ACRONYMS AND ABBREVIATIONS

AGRU	Acid gas removal unit
CEP	Construction Execution Plan
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CAN	Conservation Needs Assessment
CR	Critically Endangered (IUCN)
DD	Data Deficient (IUCN)
EAAF	East Asian-Australasian Flyway
EHL	Esso Highlands Limited
EMP	Environmental Management Plan
EN	Endangered (IUCN)
EPDB	Early Project Development Basis
Fauna Act	PNG Fauna (Protection & Control) Act 1966, 1978
FIMS	Forest Inventory Mapping System
G	Grasslands
GF	Gallery Forest
ha	Hectares
IUCN	International Union for Conservation of Nature and Natural Resources
KICDP	Kikori Integrated Conservation and Development Project
LCR	Local Contextual Region
LNG	Liquefied Natural Gas
MOF	Materials Offloading Facility
Mv	Mangroves
NT	Near Threatened (IUCN)
OC	Oceans and Coastal marine habitats
OW	Open Woodland
P	Protected under the PNG Fauna Act
PNG	Papua New Guinea Project
R	Species restricted for trade under the PNG Fauna Act because of International market demand and traditional utilisation within PNG
ROW	Right-of-Way
Sv	Savanna
UXO	Unexploded ordinance
VREC	Vahiua River Ecosystem Complex
VU	Vulnerable (IUCN)
W	Wetlands, mud-flats and salt-pans
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

1. The Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) aims to commercialise petroleum reserves from multiple gas fields (Kutubu, Agogo, Gobe, Moran, Hides, Juha and Angore) present in the Southern Highlands and Western Provinces of PNG. The project involves the production of gas and its transportation to an LNG Facility located on the coast approximately 20 km northwest of Port Moresby in the Gulf of Papua in PNG's Central Province.

2. As part of an impact assessment of the PNG LNG Project this report provides information on (a) the terrestrial biodiversity values (fauna and flora) present in the vicinity of the LNG Facilities site (Study Area), and (b) the magnitude of impacts on these values associated with development of the PNG LNG Project.

3. The baseline biodiversity survey was conducted between 12 and 21 April 2008. A preliminary assessment of the Study Area was conducted by six members of an extended biodiversity team on 12 April. Following this, three members remained to survey mammals, birds, reptiles and amphibians from April 13−21. Fauna were detected by both opportunistic methods and systematic techniques.

4. Logistic constraints limited survey time and access to some habitats. Consequently, characterisation of on site terrestrial biodiversity was achieved through a combination of field surveys and desktop assessments.

5. Habitats at the Study Area include grassland and open woodland (34.9%), savanna (56.5%), mangroves (5.9%), sub-coastal wetlands/mud flats (2.7%) and oceans and coastal marine habitats.

6. Terrestrial habitats on site have been subjected to a long history of intensive anthropogenic disturbances, including pastoral use, frequent burning, hunting and/or firewood collection. As a result, most habitats exhibit a substantially reduced environmental complexity and are rich in invasive species.

7. No nationally protected or IUCN-listed plant species were found. The only plant of conservation significance potentially present at the Study Area is the Endangered Sandalwood (*Santalum macgregorii*), a parasitic species found in savanna. However, this species has not been seen in the Moresby area since the 1970s and is probably locally extinct.

8. Three non-flying mammal species were directly recorded (Agile Wallaby, Grassland Melomys and House Mouse), and three additional species were recognized by local residents (Southern Common Cuscus, Cape York Rat, Black Rat). None are of conservation concern.

9. Additional non-flying mammals possibly occurring at the site include three IUCN-listed species, the New Guinean Planigale (Vulnerable – VU), Giant Bandicoot (Data Deficient – DD) and Dusky Field Rat (Near Threatened – NT). The New Guinean Planigale and Giant Bandicoot are also protected under PNG law (P).

10. A desktop assessment was used to generate a list of bat species potentially occurring in the area. During the 12 April site assessment three major bat habitat types were identified: cleared pastureland, mangroves and savanna/woodland.

11. 23 bat species may occur at the Study Area, including seven IUCN-listed species: the Critically Endangered (CR) New Guinea Big-eared Bat, Troughton's Sheathtail-bat (VU), Greater Long-eared Bat (VU), Big-eared Mastiff-bat (VU), Yellow-bellied Sheathtail-bat (NT), Papuan Pipistrelle (NT) and Watt's Pipistrelle (NT).

12. An additional 33 species that may occur require caves for diurnal roost sites or rainforest as primary foraging habitat. These critical habitat requirements have not been identified at the Study Area. They include four Vulnerable and seven Near Threatened species.

13. The New Guinea Big-eared Bat may be extinct, although if present it would reside in the savannas of the LNG Facility site. A tree clearance protocol was suggested in the event that a colony of this or other IUCN-listed bat species may be present in any woodland trees that need to be felled. This protocol will mitigate any impacts upon listed bat species.

14. A total of 70 bird species was recorded during the survey, including four nationally protected species: Osprey, Little Egret, Intermediate Egret and Great Egret. No IUCN-listed bird species were recorded. The highest number of species was recorded in savanna (23), other open woodland formations (26), mangroves (21) and wetlands (18).

15. Bird endemism was low (three species) and a high proportion of migratory species was recorded: 16 species (22.9 %) occur in New Guinea only as non-breeding migrants, and 14 species (20%) have resident populations augmented by seasonal migrants. Most wholly migratory birds occur in wetlands (11 species) or coastal marine habitats (3 species).

16. The Study Area includes habitat suitable for another 198 bird species known from the region, including six IUCN-listed species (Heinroth's Shearwater – VU, Black-tailed Godwit – NT, Asian Dowitcher – NT, Beach Thick-knee – NT, Black-necked Stork – NT, Tahiti Petrel – NT) and five species protected under PNG law.

17. A total of three frog and eight reptile species were documented at the Study Area. All except one of these are common in the savanna habitats of southern Papua New Guinea, and no species of conservation concern are expected to occur.

18. The small skink *Cryptoblepharus yulensis* is a recently described species known from four sites around Port Moresby, Yule Island, and a single, unknown site in Western Province. It probably has a broad distribution along coastal areas of southern Papua New Guinea.

19. No dangerously venomous snakes were encountered but Taipans (*Oxyuranus scutellatus canni*) occur throughout the region and the grassland habitats of the LNG Facility site provide suitable habitat for this species so they are highly likely to occur on site. Papuan Black Snakes (*Pseudechis papuanus*) are rare in the area but their presence cannot be discounted.

20. The mangrove systems along Vaihua River, although heavily disturbed, provide suitable habitat for the widespread homalopsine snakes *Fordonia leucobalia* and *Myron richardsoni* and for the Mangrove Monitor, *Varanus indicus*. The possibility of saltwater crocodiles (*Crocodylus porosus*) occurring in these mangroves cannot be entirely discounted and appropriate caution should be used when traversing these mangroves habitats.

21. Species richness recorded in 2008 was low across all taxa. This was likely the result of (a) restrictions in survey time and accessibility, and (b) low overall biodiversity due to highly modified habitats that are likely to support only a portion of the faunal communities that may originally have been present.

22. Although subject to firewood collection and other harvesting pressures, mangroves and sub-coastal wetlands comprise among the Study Area's most intact habitats. They also support a distinct fauna that includes a number of mangrove endemics and a wide variety of resident and migratory waterbirds. Eighteen wetland bird species were recorded in these habitats, including three nationally protected species and 10 migratory Palearctic shorebirds. Possible additional species include three Near Threatened waterbirds, one Near Threatened bat and 12 nationally listed species.

23. Mangroves and sub-coastal wetlands are well represented in surrounding areas; The 261 ha of these habitats found on site represents 1.5% of their total extent within the local region.

24. Although heavily modified by long-term human activity, savanna at the Study Area may support up to nine IUCN-listed mammals, seven of which are bats. More than 6% of savanna within the local region occurs at the Study Area.

25. Grassland and open woodland at the Study Area amount to nearly 9.5% of the grassland-dominated habitats present throughout the local region. No IUCN-listed species were found in these habitats during the survey. Five Threatened and four Near Threatened species may occur in open woodland habitats, all of which are more likely to occur in the more densely wooded savanna. The Canefield Rat (NT) is the only IUCN-listed species expected to occur in grassland. No nationally protected (P) species are expected to occur in grassland or open woodland.

26. Impacts discussed include habitat loss, edge and barrier effects, erosion, changes to hydrology, pollution, disturbance, fire, invasive species and hunting.

27. It is estimated a total of approximately 700.9 ha will be cleared for project development, of which 85.7% will be grassland and open woodland habitat. Most of the habitat lost from this vegetation class will be open grassland, assessed to be of low biodiversity value, rather than the marginally higher value woodland habitats.

28. Other habitat losses include 10.2 ha of sub-coastal wetlands and 13.7 ha of mangroves. Proportionally these losses represent 8.5% of the Study Area's wetlands and 5.2% of the site's mangroves. In a regional context these losses amount to less than 0.1% of the mangrove and sub-coastal wetland habitats present in the local region.

29. Additional major direct threats associated with project development include pollution, changes to hydrology and erosion. After mitigation direct impacts to species and habitats are predicted to be minimal or low.

30. The greatest potential impacts may arise indirectly from the introduction of exotic fauna, weeds and pathogens. Adoption of stringent and hygienic importation, control and monitoring procedures is predicted to reduce these threats to a low or minimal level.

PART I

Terrestrial Biodiversity Characterisation

1. INTRODUCTION

1.1 Project Overview

The Papua New Guinea Liquefied Natural Gas (PNG LNG) Project involves the development of a number of gas fields and facilities in a series of development phases to produce liquefied natural gas (LNG) for export. The development will also produce condensate. The development of the Hides, Angore, and Juha gas fields and blowdown of the gas caps at the existing Kutubu, Agogo and Gobe oil fields will supply the gas resources. An extensive onshore and offshore pipeline network will enable transportation of the gas to a new LNG Plant near Port Moresby and stabilised condensate to the existing oil processing and storage, and offloading facilities at the Kutubu Central Processing Facility and Kumul Marine Terminal respectively. Small amounts of condensate are also produced at the LNG Facilities site.

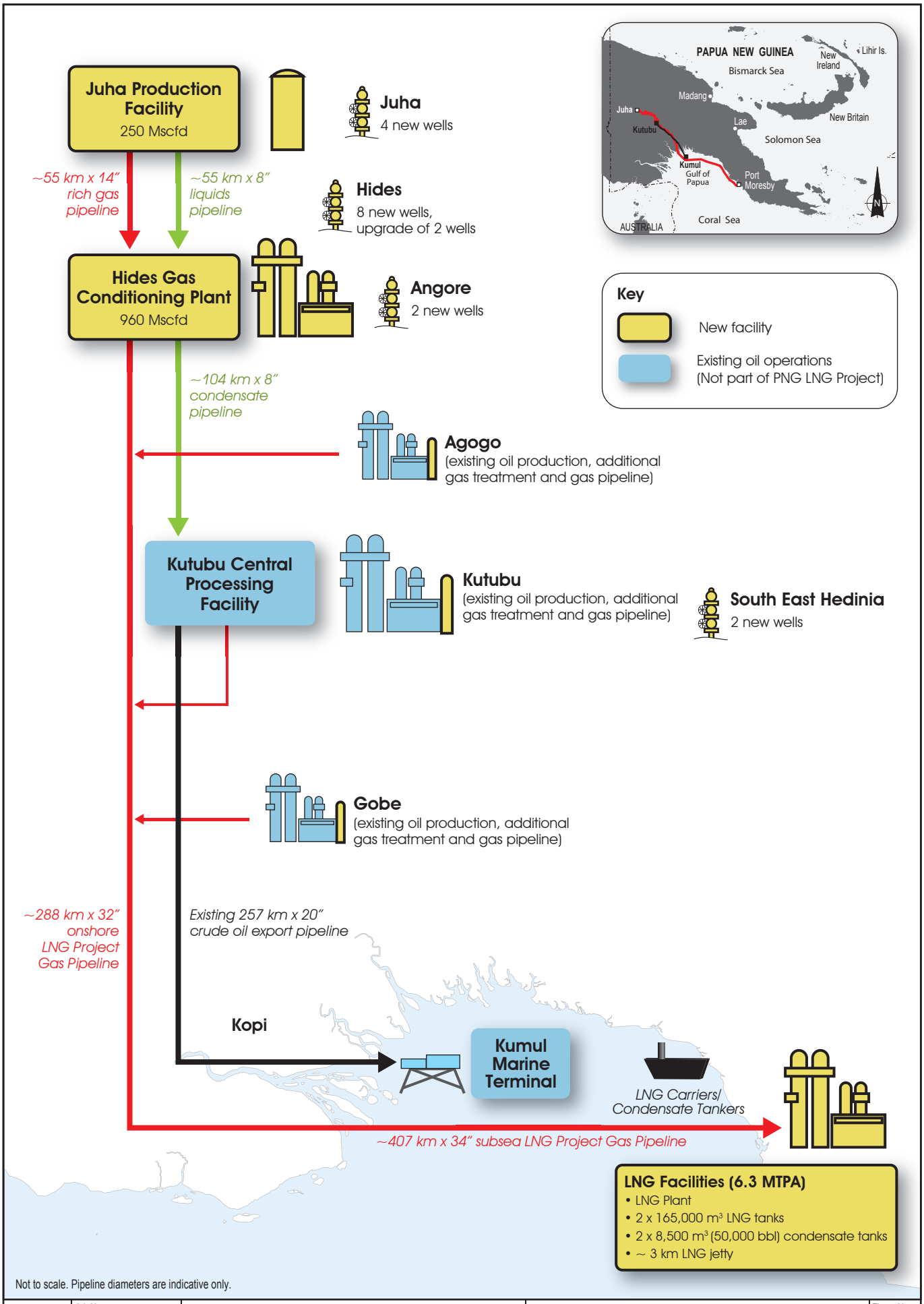
Esso Highlands Limited (Esso), a Papua New Guinea subsidiary of the Exxon Mobil Corporation (ExxonMobil), is the operator of the PNG LNG Project. The PNG LNG Project will be developed in five phases over a period of 10 years to ensure reliability and consistent quality of supply of LNG for over the 30 year life of the project.

A list of the proposed developments is provided below, and **Figure 1** shows a schematic of facilities and pipelines:

1.2 Developments and Components

1.2.1 Upstream Development Components

- Hides gas field development:
  - Seven wellpads with a total of eight new wells and re-completion of two existing wells.
  - Hides gathering system including gas flowlines from new and re-completed Hides wells.
  - Hides spineline and mono-ethylene glycol (MEG) Pipeline in the same right of way (ROW).
  - Hides Gas Conditioning Plant.
  - Hides–Kutubu Condensate Pipeline in the same ROW as the LNG Project Gas Pipeline.
- Juha gas field development:
  - Three new wellpads with four new wells.
  - Juha gathering system including gas flowlines from new Juha wells.
  - Juha spinelines and MEG Pipeline in the same ROWs.
  - Juha Production Facility.
  - Juha–Hides pipelines right of way (ROW) containing three pipelines including Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline.



PNG LNG	Job No: 1284	Esso Highlands Limited	Project overview: new and existing	Figure No: 1
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- Angore gas field development:
  - Two new wellpads with two new wells.
  - Angore gathering system including gas flowlines from new Angore wells.
  - Angore spineline and Angore MEG Pipeline to Hides Gas Conditioning Plant, both in the same ROW.
- Gas from existing fields:
  - Gas treatment at the Agogo Production Facility and a new Agogo Gas Pipeline from the Agogo Production Facility to LNG Project Gas Pipeline.
  - Gas treatment at the Gobe Production Facility and a new Gobe Gas Pipeline from the Gobe Production Facility to LNG Project Gas Pipeline.
  - Gas treatment at the Kutubu Central Processing Facility and a new Kutubu Gas Pipeline from the Kutubu Central Processing Facility to the LNG Project Gas Pipeline.
  - South East Hedinia gas field development: one new wellpad and two new wells; new gathering system including gas flow lines from the South East Hedinia new wells to the Kutubu Central Processing Facility in the same ROW as the Kutubu Gas Pipeline.
- Kopi scraper station.
- LNG Project Gas Pipeline:
  - Onshore: from Hides Gas Conditioning Plant to Omati River Landfall.
  - Offshore: Omati River Landfall to Caution Bay Landfall.

1.2.2 LNG Facilities Development Components

- Onshore LNG Plant including gas processing and liquefaction trains, storage tanks, flare system and utilities.
- Marine facilities including jetty, LNG and condensate export berths, materials offloading facility and tug moorage.

1.2.3 Supporting Facilities and Infrastructure

In addition to the principal gas production, processing and transport, and LNG production and export facilities, the project will involve the following permanent infrastructure and facilities:

- New roads and upgrade of existing roads.
- New bridges and upgrade of existing bridges.
- Upgrade of two existing airfields (upstream at Komo and Tari).
- New helipads (multiple).
- New wharf and an upgrade of the existing Kopi roll-on, roll-off facility.
- Water supply systems and pipelines, wastewater and waste management facilities.
- Operations Camps (at Hides, Juha and Tari).

A series of temporary works and access roads will also be required during the construction phase, including:

- Construction camps (multiple).
- Material/pipe laydown areas.

1.3 Assessment and Impacts on Biodiversity at Caution Bay

Protection of the environment is listed as a key objective of the operating and control design of the PNG LNG Project (PNG LNG Project 2007).

As part of an impact assessment of the PNG LNG Project, this report outlines the terrestrial biodiversity values present in the vicinity of the LNG Plant at Caution Bay and the potential impacts associated with the construction and operation of the LNG Plant and associated infrastructure. Objectives of this study are to:

- Characterise the terrestrial biodiversity present in the vicinity of the LNG Plant.
- Evaluate the value/sensitivity of on site biodiversity values, including fauna, flora, habitats and special areas.
- Assess the potential impacts on these values resulting from development and operation of the LNG Plant and associated infrastructure.
- Develop recommendations designed to mitigate impacts on sensitive habitats, taxa and/or communities.

The following activities were undertaken to characterise on site terrestrial biodiversity:

1. Survey bird, mammal, herpetofauna (reptiles and amphibians) and vegetation communities present in the vicinity of the LNG Plant.
2. Determine the status of rare, threatened and/or protected species likely to be present, and report on their habitat requirements and the viability and importance of existing populations in a regional, national and global context.
3. Evaluate the value/sensitivity of habitats and rare, threatened and/or nationally listed species.

2. SITE DESCRIPTION

2.1 Location and Area Definitions

The LNG Plant will be situated on the coast at Caution Bay approximately 20 km northwest of Port Moresby between the coastal settlements of Boera and Papa **(Figure 2)**. The development site is centred on the industrial reserve Portion 152.

The focal area of interest, termed the Terrestrial Biodiversity Study Area (hereafter 'Study Area'), is defined as the ca. 4,450 hectare (ha) area covered by Portion 152 and its coastal extension across intertidal habitats including sub-coastal wetlands and mangroves **(Figures 2 and 3)**. The LNG Plant will be located in the northwest of the Study Area. **Figure 3** shows the major components of the LNG Plant and associated infrastructure and their location in relation to the Study Area boundary. The area enclosed within the security fence is hereafter referred to as the 'LNG Facilities site'.

2.2 Land Systems Classification

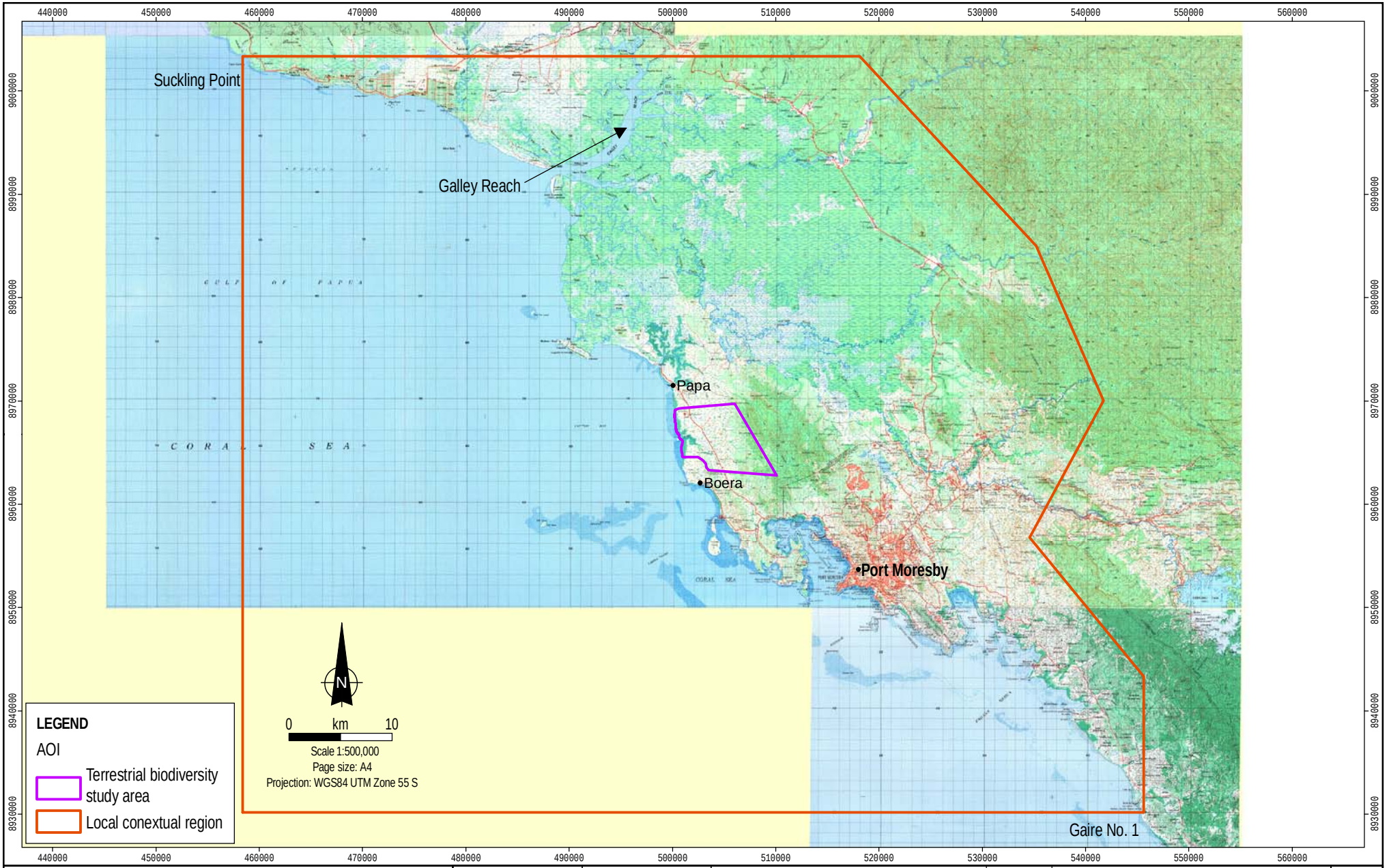
The Study Area consists of a series of coastal floodplains and low hills and is characterised by three distinct land systems as described in the CSIRO Land Research Series No. 14 for the Port Moresby − Kairuku area (Mabbutt *et al*. 1965).

- The coastal **Papa system** consists of tidal flats, salt-pans, estuarine mudflats, dunes and beach ridges on "grey clayey or sandy peats to brown sticky clays". It is vegetated with mangroves, other salt-tolerant communities and grassland.
- The **Boroko system** lies inland from the Papa system and comprises "alluvial plains with cracking grey soils and flood plains with olive silty clays". It is largely cleared.
- The **Fairfax system** covers the eastward (inland) and southern parts of the Study Area. It consists of low plateaus and hills with brown lithosols and undulating plains with brown clay soils, and is dominated by open eucalypt savanna with narrow strips of gallery forest along the seasonal waterways.

2.3 Habitat

These land systems follow closely the vegetation types that cover the Study Area as defined under the Forest Inventory Mapping System (FIMS). The FIMS delineated broad vegetation classes present across all of PNG based on interpretation of a nation-wide series of aerial photographs (average scale 1:110,000). The Study Area covers four FIMS vegetation types **(Figure 4)**. These are listed below together with definitions provided by Hammermaster and Saunders (1995).

- **Mangrove** – "All vegetation of the saline or brackish communities tidal zone. Ranges from forest over 30 m tall, to low halophytic herbs."
- **Grassland** – "Grasses, sedges, herbs and very low woody shrubs. Generally less than 3 m tall. Scattered trees may be present."
- **Savanna** – "Scattered to moderately dense layer of trees. Generally less than 6 m tall. A clearly visible ground layer of herbs and/or grasses."



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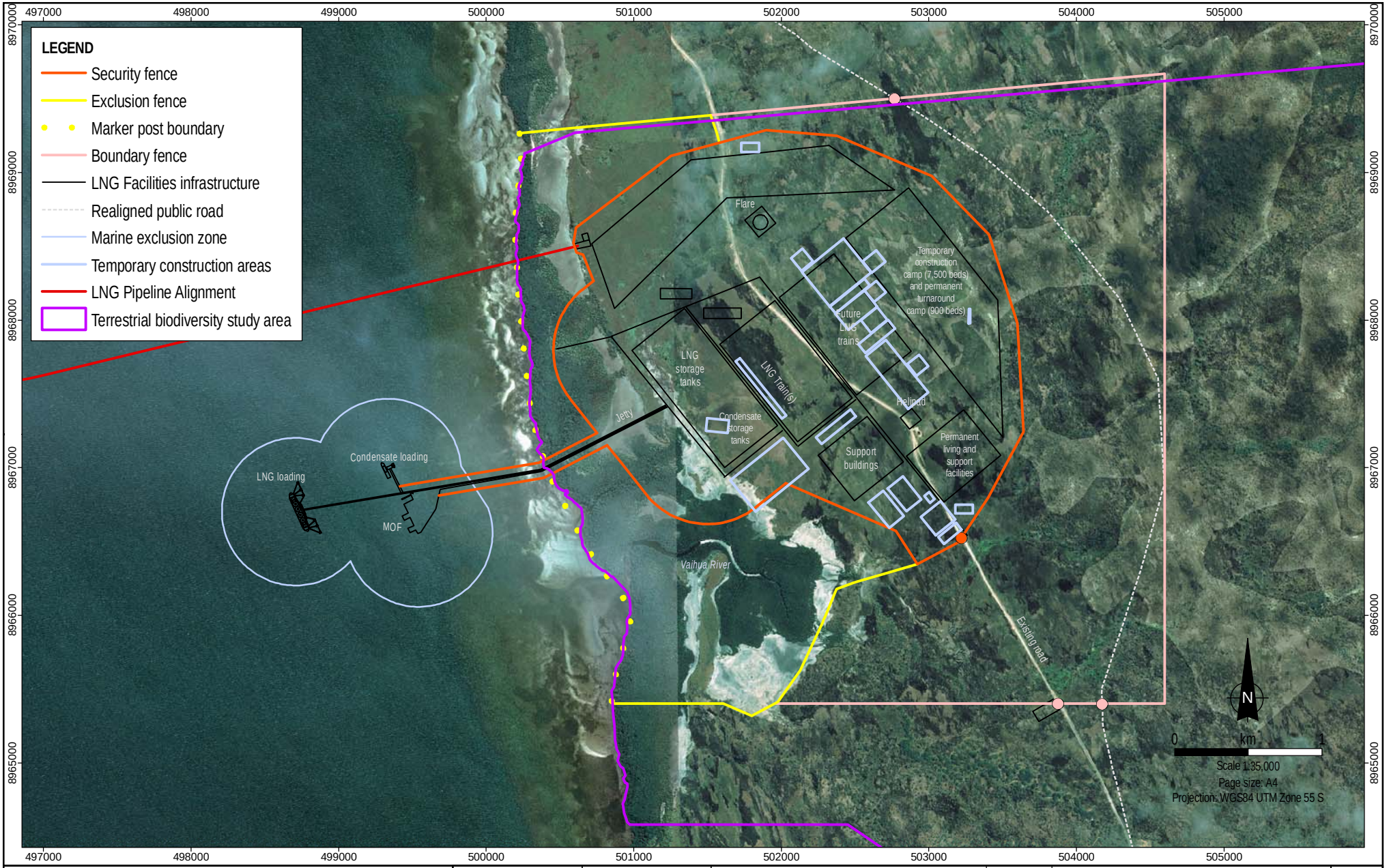
Topographic map of the Port Moresby area showing location of the terrestrial biodiversity study area and the local contextual region

Figure No: 2



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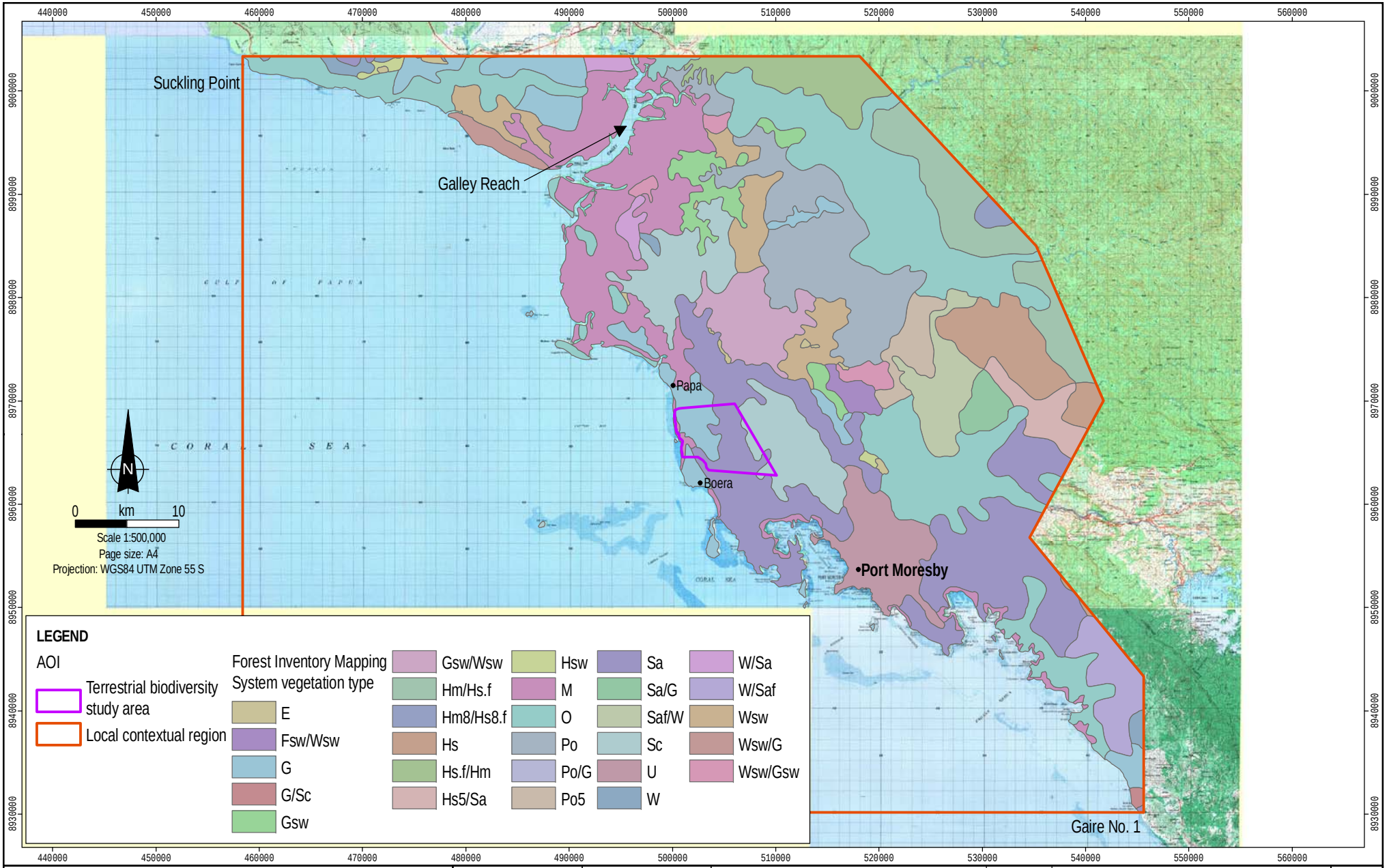
PNG LNG

Permanent and temporary components of the LNG Plant and associated infrastructure

Figure No: 3



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PNG LNG Project

PNG LNG

Forest Inventory Mapping System (FIMS) vegetation types present at the terrestrial biodiversity study area and throughout the local contextual region

Figure No: 4

- **Scrub** – “Dense shrubs with or without scattered low trees. Generally less than 6 m tall.”

‘Scrub’ vegetation is restricted to the larger hills in the extreme east of the Study Area. This habitat will not be influenced by development of the LNG Plant and associated facilities and was not assessed as part of this report.

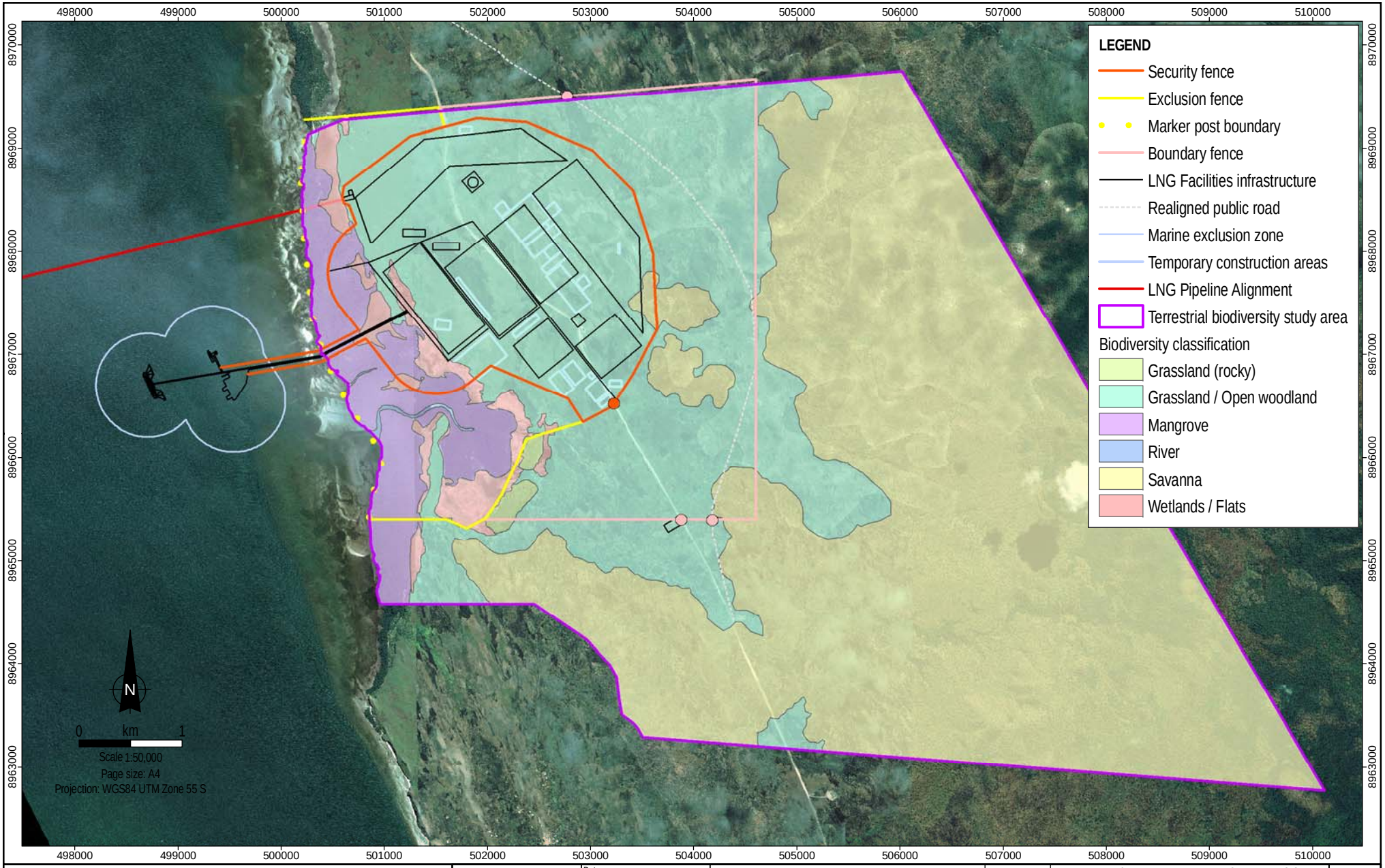
The remaining three vegetation classes can be further split into distinct habitats that occur at the Study Area.

- ‘Mangrove’ areas on site include:
  - Mangrove forest and scrub **(Plates 1−5)**.
  - A series of sub-coastal ephemeral wetlands, mud-flats and salt-pans **(Plates 1, 4−9)**.
- ‘Grassland’ on site includes:
  - Treeless expanses of grassland **(Plates 1, 10−13)**.
  - Various open woodland habitats, including areas with scattered trees and vegetation such as pandanus along natural drainage areas **(Plates 10, 13−16)**.
- ‘Savanna’ includes:
  - Eucalypt savanna woodland **(Plates 16−19)**.
  - Small areas of gallery forest along larger waterways such as the Vaihua River **(Plate 20)**.

Figure 5 shows the approximate distribution of habitats present at the Study Area. Boundaries of the FIMS vegetation types are inaccurate at this scale as they were developed largely without ground-truthing. Habitat distributions shown in **Figure 5** are based on a more accurate assessment of aerial imagery combined with on-the-ground assessments conducted during the April 2008 terrestrial biodiversity surveys. Four main vegetation types are shown: mangroves, wetlands/flats, savanna and combined grassland/open woodland communities.

The site consists predominantly of severely modified savanna and grassland habitats. Original, intact vegetation at the Study Area is largely restricted to mangroves, areas of *Melaleuca* woodland and the salt-pans that persist along the coast and the Vaihua River in the middle of the block. The mangroves are widest (approx. 600 m) along the Vaihua River and narrow to a break with a small beach just north of the northern boundary of the block. Other remnant vegetation includes areas of gallery forest that persist along the Vaihua River between the mangroves and Lea Lea Road and isolated pandanus and low trees on shallow drainage lines running into the Vaihua River.

Habitat at the Study Area has been heavily modified by human activities. Much of the site was cleared early in the twentieth century for agriculture on what was then the Fairfax Station. At present there are no active agricultural pursuits on the property, though local residents regularly hunt on the site, periodically burn the grasslands and savanna and collect other natural resources such as firewood from the mangroves. The site is traversed by numerous vehicle tracks and a main road that connects Port Moresby with Papa village in the north (Lea Lea Road). Fishing occurs along the coast.



	coffey natural systems	Date: 23.10.2008 MXD: PNG_LNG_Project_GIS File Name: 1284_IW_F012_GIS	Esso Highlands Limited PNG LNG Project	PNG LNG	Vegetation types present at the terrestrial biodiversity study area, as defined following the April 2008 biodiversity surveys, the LNG Facilities site and associated linear developments	Figure No: 5

According to the Papua New Guinea Conservation Needs Assessment published in 1993 (Synopsis Report, Swartzendruber 1993), the Study Area lies just to the south of the 'Central Province Dry Zone', an area of important terrestrial biodiversity composed of savanna and monsoon forest complex with wetlands that is threatened by development. This zone includes two large coastal mangrove systems, one centred on Galley Reach inlet situated approximately 26.5 km north-northwest of the Study Area, the other around the Angabanga River drainage behind Yule Island, 50 km northwest of Galley Reach and 24 km southeast of the provincial border.

3. CHARACTERISATION METHODS

A combination of field surveys and desktop assessments was used to characterise the biodiversity values present at the Study Area.

3.1 Survey Timing and Personnel

A preliminary assessment of the Study Area was conducted by all members of an extended biodiversity team on 12 April 2008. During this assessment the biodiversity team was driven the length of the site along the Lea Lea Road, stopping regularly to assess changes in habitat and other points of interest. Team members included Iain Woxvold (avifauna, co-ordinator), Francis Crome (vertebrate communities, vegetation), Stephen Richards (herpetofauna), Ted Mamu (mammals), Greg Richards (bats) and Wayne Takeuchi (botanist). Safety considerations restricted survey personnel to the bitumen on Lea Lea Road during this visit.

Following this initial assessment Iain Woxvold and Stephen Richards remained in the Port Moresby area to survey birds, reptiles and amphibians on site from April 13−20. Ted Mamu remained to survey mammals from April 13−21.

3.2 Vegetation

Information on the structure and condition of the vegetation communities and the plant species present at the Study Area was collated and prepared by Wayne Takeuchi following the visit on 12 April 2008.

3.3 Fauna

Data on mammals, birds, reptiles and amphibians were collected by direct field observations and during interviews with local residents. Data on fish and invertebrates were not collected as they are the subject of a separate specialist study.

3.3.1 Field Observations

3.3.1.1 General Methods

Field surveys were conducted along pre-prepared walking trails or by boat along the Vaihua River and tributary. Transects surveyed are shown in **Figure 6**. Details of the position, survey effort and habitats encountered during transect surveys are summarised in **Table 1**. Supplementary data were gathered opportunistically while driving or walking along the Lea Lea and Boera Roads during planning and induction phases.

Safety requirements restricted survey personnel to the tracks cleared of unexploded ordinance (UXO) and limited the timing of surveys to daylight hours.

3.3.1.2 Birds, Reptiles and Amphibians

Formal transect surveys of birds, reptiles and amphibians were conducted simultaneously by Iain Woxvold and Stephen Richards on April 17−20. A total of 19 hours was spent surveying avifauna and herpetofauna along transects (**Table 1**). Transects were walked slowly and all birds, reptiles and frogs encountered were identified by sight or sound. In addition to general observations herpetofauna were targeted by looking beneath logs and rocks.

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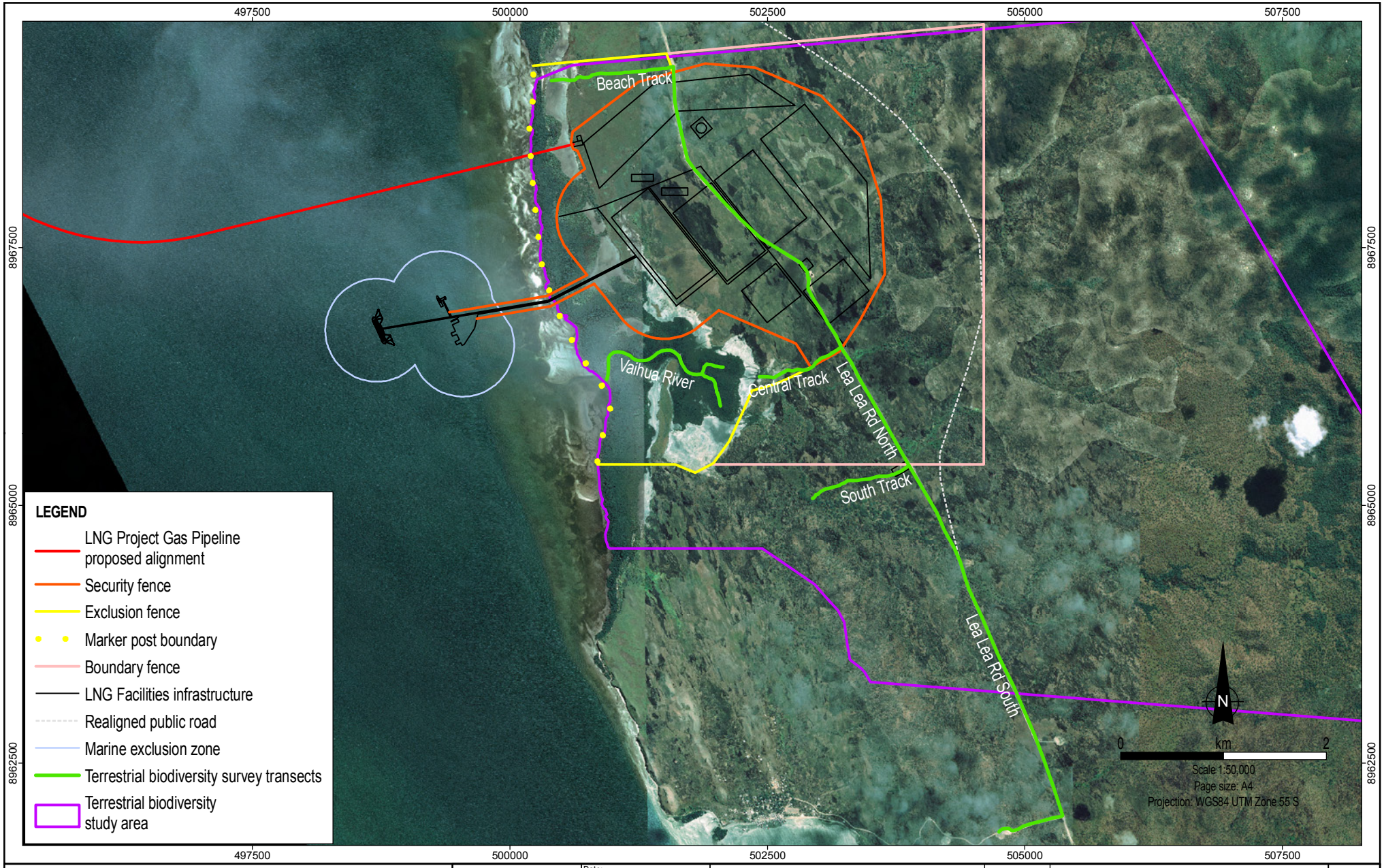
Table 1 Survey effort, coordinates and habitat encountered on each transect

Transect	Habitat	Start Coordinates	End Coordinates	Bird, Reptile and Amphibian Surveys				Mammal Surveys		
				Date	Time Start	Time Finish	Total Time (hrs)	Trap Dates	No. Traps	No. Trap Nights
Vaihua River	OC, Mv	501050°E 8966100°N	502235°E 8965803°N	April 17	0730	1100	3.5			
Lea Lea Rd North	G, OW	501598°E 8969210°N	503872°E 8965391°N	April 18	1000	1215	2.25			
Beach Track	G, OW, WS, Mv	501602°E 8969214°N	500515°E 8969218°N	April 18 April 19	1630 0720	1730 1035	1 3.25	April 18−21	25	3
Lea Lea Rd South	Sv, OW, GF, G	504748°E 8961829°N	503872°E 8965391°N	April 19	1430	1700	4.5			
South Track	Sv, OW, GF, G	503872°E 8965391°N	503082°E 8964958°N	April 20	0645	0930	2.75	April 18−21	25	3
Central Track	Sv, OW, GF, G, WS	503217°E 8966531°N	502485°E 8966108°N	April 20	1445	1630	1.75			
Total							**19**		**50**	**6**



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Esso Highlands Limited

PNG LNG Project

PNG LNG

Terrestrial biodiversity survey transects (April 2008)

Figure No: 6

3.3.1.3 Non-volant Mammals

Small mammals were systematically surveyed by walking transects and setting small Elliot traps along the Beach Track and South Track transects **(Figure 6)**. A total of 25 traps were set at least 10m apart along each transect on April 18−21 for a total of 150 trap nights (**Table 1**). All traps were baited with rolled oats with a mixture of peanut butter and honey.

All captured animals were identified in the field. Trapped individuals were marked on the ears to identify subsequent recaptures, and then released.

3.3.2 Village Interviews

Local landowners were interviewed about mammals they had seen or hunted in the area, and these were identified from pictures in Flannery (1995). The local language names were recorded in Motu language.

Local residents were not interviewed about birds or herpetofauna during the April 2008 surveys, though some information was collected previously by Francis Crome during a visit to the site between 21st and 26th of May 2007.

3.3.3 Desktop Assessments

The list of species generated during field surveys and village interviews represents a subset of the total fauna that utilise habitat at the Study Area. Consequently, desktop assessments were used to generate supplementary lists of species that have not yet been recorded within the project area but may be expected to occur in light of information regarding distribution and habitat preference. Those species whose ranges overlap with the Study Area and whose requirements include habitat present on the site (e.g. mangroves, savanna) were listed and an assessment made as to their likely occurrence.

Comprehensive lists of potential additional species were generated for birds and bats. Information on the distribution and natural history of birds within New Guinea and surrounding regions was obtained from Mackay (1970), Coates (1985, 1990), Beehler *et al*. (1986) and a number of primary sources.

No bats were recorded directly during the survey, so that information on species potentially occurring at the Study Area was collated and prepared entirely by Greg Richards following the preliminary assessment of habitats and condition of the site on 12 April 2008. Background information on bat fauna was obtained from several sources, including Flannery's (1995) book on New Guinea mammals, Bonaccorso's (1998) field guide, and reports from World Wide Fund for Nature (WWF) activities related to the Kikori Integrated Conservation and Development Project (KICDP). Field surveys conducted in 2005 and 2008 at faunal reference areas along the LNG pipeline provided extensive information about the ecology, particularly habitat utilisation, of the PNG bat fauna.

Lists generated for additional species of non-volant mammals and herpetofauna were non-exhaustive as the distribution and ecological requirements of most species is still relatively poorly understood. Rather, for these taxa the list of potential additional species focuses on those IUCN-listed (International Union for Conservation of Nature and Natural Resources) and nationally protected species that may be present.

3.4 Taxonomy and Identification

Mammal nomenclature (common and scientific names) used in this paper follows the taxonomy of Flannery (1995) with the exception of the *Melomys*/*Paramelomys* group which follows Menzies (1996). Nomenclature and family arrangements of birds follow the Sibley and Monroe system (Sibley and Monroe 1990, 1993a, b) for most species.

3.5 Conservation Status

The global conservation status of all species was taken from the 2007 IUCN Red List of Threatened Species (http://www.redlist.org/). IUCN categories rank the relative risk of individual taxa becoming extinct in the wild based on a set of standardised criteria.

National conservation status is given for species listed under the PNG *Fauna (Protection & Control) Act 1966, 1978* ('Fauna Act'). The Fauna Act lists 30 species as **Protected** and 30 as **Restricted**.

The definitions and classification codes for the various categories of global and national conservation status are presented in **Table 2**.

Table 2 Conservation classifications used in the PNG Fauna (Protection and Control) Act 1966, 1978 ('Fauna Act') and the IUCN Red List of Threatened Species

PNG Fauna (Protection and Control) Act*	
Protected (P)	Taxa declared protected.
Restricted (R)	Taxa not declared protected but restricted for trade because of International market demand and traditional utilisation within PNG.
IUCN	
Critically Endangered (CR)	A taxon is Critically Endangered when it is facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	A taxon is endangered when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium term future.
Lower Risk But Near Threatened (NT)	A taxon is Lower Risk when it has been evaluated, does not satisfy the criteria for any of the categories Critically Endangered, Endangered or Vulnerable. Near threatened taxa are close to qualifying for Vulnerable.
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. Such species are often extremely rare with few confirmed records.

* The listed species for the PNG *Fauna (Protection and Control) Act* have been under revision for some time. The present list is based on CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) rulings which control international trade in fauna and do not necessarily reflect conservation status in a country.

3.6 Limitations of the Present Study

Logistic constraints limited the biodiversity surveys of the Study Area to three days.

In addition to restricted sampling time, safety considerations limited surveys and travel to and from the site to daylight hours. Thus no surveys were conducted at night, the most profitable time for detection of amphibians and some mammals, or at dawn, the most profitable time for detecting birds.

Taken together, these logistic constraints severely limited the time available to survey most habitats present at the Study Area, and precluded direct assessment of some habitats altogether. Consequently, the desktop component of the assessment of the diversity and ecological requirements of fauna at the Study Area is greater than for the upstream component of the PNG LNG biodiversity report.

4. TERRESTRIAL BIODIVERSITY AT THE LNG FACILITY SITE

This section outlines results of the April 2008 terrestrial biodiversity surveys, including the number of species recorded or possibly occurring in the area and their conservation status. The status, ecology and sensitivity of nationally protected and IUCN-listed species known to occur or possibly occurring at the Study Area are discussed in more detail in section 10.1.

4.1 Vegetation

The majority of the Study Area consists primarily of a *Heteropogon-Dichanthium* grassland community. The co-dominant species (*Heteropogon contortus* and *Dichanthium superciliatum*) are characteristic elements of the fire disclimax in southern New Guinea (Hammermaster & Saunders 1995). Heyligers (1966, 1972) gives a detailed description of the occurrences around Port Moresby.

Although *Heteropogon* and *Dichanthium* are native to the southern region, the grassland at the Study Area has a speciose alien component represented by many noxious weeds. The adventives include, *inter alia*, *Alysicarpus vaginalis*, *Atylosia scarabaeoides*, *Clitorea ternatea*, *Panicum maximum*, *Passiflora foetida*, *Sida acuta*, and *Tridax procumbens*.

A palm-like gymnosperm from these weedy communities is often misidentified as the IUCN-Vulnerable *Cycas media* (e.g., in Heyligers 1966). Although formerly placed with *C. campestris* (Hill 1994), the Moresby cycads are currently referred to a broadly circumscribed *C. schummanniana* (Laubenfels & Adema 1998). Many cycads are regarded as taxa in need of protection because of excessive collecting for the ornamental trade. However the local cycads are not of conservation concern.

Within the grassland/open woodland complex a *Pandanus* sp. of uncertain affinity (section Maysops) forms localised clusters along the creeks and smaller drainage lines near the Lea Lea Road (**Plate 14**). *Albizzia procera* may also be present in that section.

The upland side of the Study Area has the general aspect of an impoverished savanna. However the tree densities are marginal even by woodland standards. *Eucalyptus alba* and *E. confertiflora* are the dominant phanerophytes on fire terrain around Moresby, and are probably also the species present in the tenement. At least within areas closest to the road, the only other trees observed were widely scattered individuals of the introduced Rain Tree (*Samanea saman*) (**Plate 15**) and what appears to be *Premna serratifolia* (based on inspection of sterile individuals).

The coastal vegetation is dominated by a mangrove zone as described in Percival and Womersley (1975). Mangrove communities are dominated by *Rhizophera* sp., and are also comprised of *Bruguiera* sp., *Sonneratia alba*, *Ceriops* sp. and *Avicennia* sp. (H. Rogers, pers. comm.; Coffey Natural Systems 2008).

No nationally protected or IUCN-listed plant species were found during the terrestrial biodiversity surveys. Possibly the only plant of conservation significance which may be present in the Study Area is the Endangered sandalwood *Santalum macgregorii*, a parasitic or semi-parasitic species found in open savanna vegetation and in savanna gully forest.

4.2 Fauna

Six distinct habitats were distinguished during the April 2008 survey to indicate habitat preferences of the fauna species present:

- Savanna (Sv).
- Gallery Forest (GF).
- Grasslands (G).
- Open Woodland habitats other than savanna (OW) – includes pandanus and other vegetation along drainage areas and areas of scattered trees in grassland.
- Wetlands, mud-flats and salt-pans and (W).
- Mangroves (Mv).
- Oceans and Coastal marine habitats (OC) – open waters off-shore from the site.

Impacts on marine biodiversity at the Study Area are the subject of a separate specialist report (Coffey Natural Systems 2008). Marine reptiles and mammals, such as turtles and dugongs, are therefore excluded from this report. However, ocean and coastal habitats are included here as a number of seabirds were observed during the survey.

All vertebrate fauna recorded at the LNG facility site in 2008 are listed in **Appendix 1** together with their degree of endemism, conservation status and the habitat they were recorded in. The residency/migratory status of birds is also listed.

Appendix 2 lists those additional species potentially occurring at the Study Area based on current knowledge of habitat preference and geographical distribution, together with their conservation status, habitat preferences and residency/migratory status (birds).

In the following text common English names are used unless a species does not have one. Scientific names can be found in Appendix 1 and 2. Scientific names are included alongside common names only where species do not occur in Appendix 1 or 2.

4.2.1 Non-volant Mammals

4.2.1.1 Species Recorded

Only three non-flying mammal species were directly recorded during the survey, the Agile Wallaby and two rodents, the Grassland Melomys and the introduced House Mouse, that were caught in small mammal traps. Both rodents were captured in grassland, and both were young lactating females (nuliparious). Three additional species were recognised by local residents, the Southern Common Cuscus, Cape York Rat and the introduced Black Rat (Appendix 1).

None of the six mammal species listed in Appendix 1 are of national or international conservation concern.

The trapping success rate was low during the survey (4%). Small ground-dwelling mammals may be uncommon due to the frequent burning of the grassland areas for hunting and for other land use purposes. There is very little refuge for these mammals during fire or periods of prolonged drought.

Gallery forest and savanna may support some larger mammals. Locals confirmed that they hunt for cuscus and wallabies in the inland forests. The Agile Wallaby sighted by Stephen Richards was observed in savanna near the Lea Lea Road in the southern half of the Study Area. Agile Wallabies and other larger mammals are often locally isolated and restricted to specific sites due to hunting pressure. Local residents indicated these mammals are locally rare near the LNG Facilities site and tend to inhabit the forests in hinterlands away from human settlements.

4.2.1.2 Additional Species

The non-volant mammals recorded thus far at the Study Area are a subset of a more diverse assemblage known from the Port Moresby area. Eight additional species not yet recorded but potentially occurring at the site are listed in Appendix 2. These include three IUCN-listed species, the New Guinean Planigale (VU), Giant Bandicoot (DD) and Dusky Field Rat (NT), two of which are also protected under the PNG Fauna Act (New Guinean Planigale, Giant Bandicoot).

4.2.2 Bats

During the Study Area inspection (12 April 2008) it was noted that three major bat habitat types were present on the site:

- Cleared pastureland with occasional shrubs and trees, dissected by ephemeral watercourses, particularly in areas earmarked for infrastructure development.
- Fringing mangroves along the coast.
- Open savanna woodland to the south and east.

The major portion of the site that had been cleared for agricultural purposes and designated for the LNG facility would not provide good foraging areas for bats.

Appendix 2 includes 23 species of bat from four families that may reasonably be expected to occur in the Study Area based on current knowledge of their ecology, distribution and the habitats present. Potentially occurring species include seven IUCN-listed taxa. Four of these are listed as Threatened, including the Critically Endangered New Guinea Big-eared Bat and three Vulnerable species (Troughton's Sheathtail-bat, Greater Long-eared Bat, Big-eared Mastiff-bat). A further three are Near Threatened (Yellow-bellied Sheathtail-bat, Papuan Pipistrelle, Watt's Pipistrelle).

An additional 33 species that may occur in the area require caves for diurnal roost sites or rainforest or its ecotones as primary foraging habitat. These are listed in **Appendix 3**. These have been omitted from Appendix 2 as their critical habitat requirements have not yet been identified at the Study Area. However, more thorough surveys may reveal the presence of these critical habitats on-site. For example, two ridges of what appear to be limestone run from Boera to the LNG Facilities site. They are mapped as cretaceous “chert, limestone, siltstone and tuff” in Mabbutt *et al*. (1965). There could be bat colonies in caves if these hills are indeed limestone. In addition, gallery forest persists along parts of the Vaihua River between Lea Lea Road and the coastal mangrove communities. The extent and condition of this habitat is yet to be determined and it may provide vital foraging habitat for a number of additional bat species.

In the absence of additional habitat data, species requiring rainforest and/or cave habitats have been listed separately in Appendix 3, together with their conservation status and critical habitat requirements. They include four Threatened (Vulnerable) and seven Near Threatened species.

Construction and operation of the LNG Plant is expected to impact minimally on the savanna habitats most likely to provide diurnal roosts for tree-dwelling bat fauna (Section 9.1.1.7), on gallery forest and other rainforest formations, and on the low hills and ridges in the south and east of the Study Area where caves may be present.

4.2.3 Birds

4.2.3.1 Totals

A total of 70 bird species from 30 families was recorded during the survey, including four species that are protected under the PNG Fauna Act: Osprey, Little Egret, Intermediate Egret and Great Egret (Appendix 1). No IUCN-listed bird species were recorded.

The species discovery curve for the bird survey at the Study Area is shown in **Figure 7**. The curve does not approach an asymptote towards the end of the survey period, indicating that the list of observed species is likely to be an underestimate. The reasons for this are discussed above (Section 3.6).

4.2.3.2 Resident and Migratory Species

Birds recorded at the Study Area in 2008 include 40 (57.1%) breeding resident species, 14 species (20%) with resident populations augmented by seasonal migrants and 16 species (22.9 %) that occur in New Guinea only as non-breeding migrants.

All species with both resident and migrant populations in PNG are of Australo-Papuan origin, with migrant populations arriving in New Guinea as non-breeding visitors from Australia. Eight of those recorded at the Study Area in 2008 are wetland species (Little, Intermediate and Great Egrets, Australian Ibis, Pacific Black Duck, Grey Teal, Little Black Cormorant and Masked Lapwing). Our survey was conducted during the dry season and there was no evidence of breeding by wetland birds. The remaining six (Brush Cuckoo, Forest Kingfisher, Rainbow bee-eater, Black-faced Cuckooshrike, Slender-billed Cicadabird and White-winged Triller) inhabit forest/woodland in the Port Moresby area. All are known to breed in the region with numbers augmented by non-breeding visitors from March/April to October (Mackay 1970; Beehler *et al*. 1986). It is unknown whether the individuals observed were resident breeders and/or early arrivals from Australia.

Of the 16 wholly migratory species recorded, 11 are wetland species, three are marine coastal seabirds (Common Tern and Little Tern, Lesser Frigatebird) and two are Australo-Papuan woodland species (Sacred Kingfisher, Tree Martin). The wetland migrants include 10 Arctic-breeding shorebird species (Scolopacidae, Charadriidae) that visit tidal and coastal mudflats during the austral summer (September–April) (Whimbrel, Far Eastern Curlew, Common Greenshank, Grey-tailed Tattler, Red-necked Stint, Sharp-tailed Sandpiper, Pacific Golden-Plover, Grey Plover, Mongolian Plover, Greater Sand Plover). These species were recorded in the extensive sub-coastal wetlands that lie behind the mangroves along most of the Study Area. This system of mangroves, salt-flats and ephemeral wetlands extends north out of the study site along the coast towards Papa village.

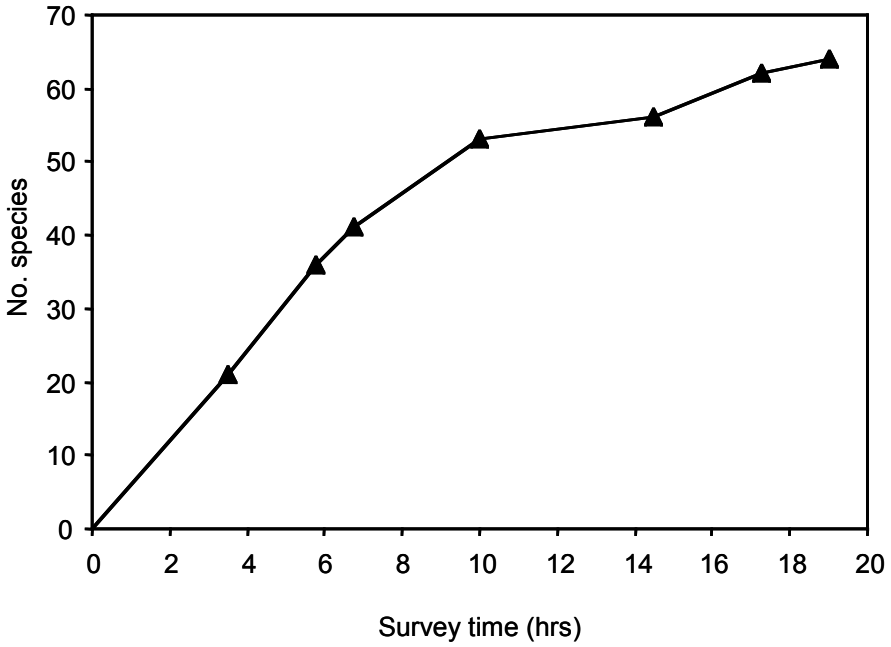


Figure 7 **Species discovery curve for the 2008 bird survey of the Terrestrial Biodiversity Study Area. Data include detection of species during active formal surveys (transects). Data from opportunistic observations excluded.**

The ecology of migratory shorebirds, their habits in the Port Moresby area and the potential importance of the wetlands near the LNG Facilities site are discussed further below (Section 8.2.1.4).

4.2.3.3 Endemism

Around 240 bird species are found only on New Guinea and its satellite islands. Most of these are residents of rainforest at various elevations. By contrast, the savanna and coastal plains vegetation that characterise much of the habitat around Port Moresby support a resident bird community that is much more Australian in character. Accordingly, and together with the high proportion of migratory species observed, only three New Guinea endemics were recorded during this survey (Papuan Marsh-Harrier, White-shouldered Fairywren, Brown Oriole). Moreover, the Papuan Marsh-Harrier has long been the subject of taxonomic debate, so that some authors include it as a race of the more widespread Eastern Marsh-Harrier (*Circus spilonotus*) or Australian Marsh-Harrier (*C. approximans*) (Ferguson-Lees and Christie 2005).

4.2.3.4 Habitat Preferences

Figure 8 shows the number of birds recorded in each habitat according to their residency/migratory status. The highest number of species was recorded in savanna (23), other open woodland formations (26), mangroves (21) and wetlands (18). Most species recorded in forest/woodland formations (savanna, open woodland, gallery forest and mangroves) and grasslands were breeding residents. Of these habitats the highest proportion of migratory species was recorded in mangroves.

The wetlands, coast and ocean supported a much higher proportion of migratory species.

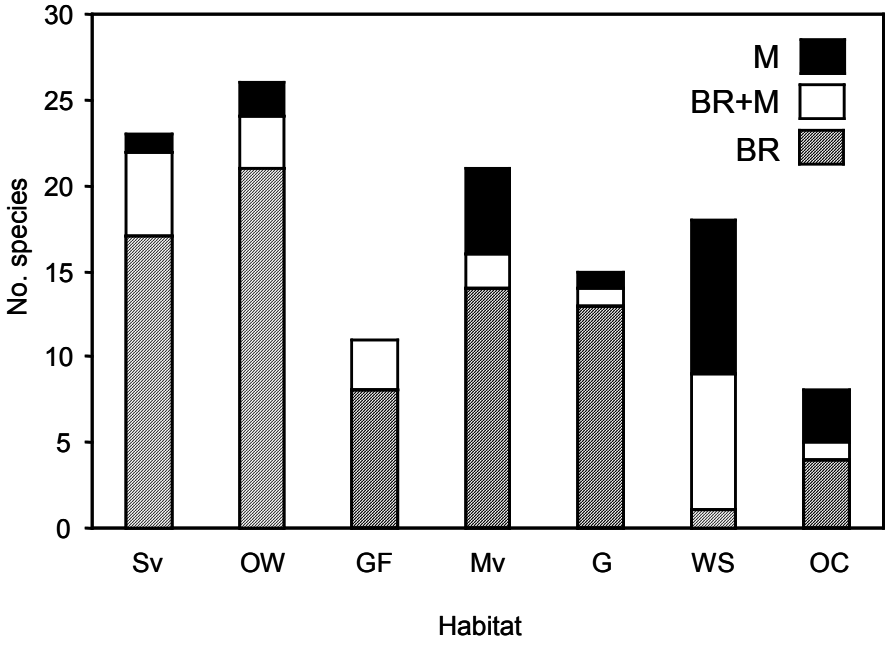


Figure 8 **The number of breeding resident birds (BR), migrants (M), and resident species with seasonal migrant populations (BR+M) recorded in different habitats (Sv – Savanna; OW – Open Woodland; GF – Gallery Forest; Mv – Mangrove; G – Grassland; WS – Wetlands and Saltpans; OC – Oceans and Coastal Marine).**

4.2.3.5 Additional Species

Excluding rare migrants, an additional 198 bird species that have not yet been recorded within the project area may be expected to occur in light of information regarding distribution and habitat preference. These species are listed in Appendix 2 together with their conservation status, residency/migratory status and habitat preferences.

Eleven species listed in Appendix 2 are of global or national conservation significance, with six listed by the IUCN as Vulnerable (Heinroth's Shearwater) or Near Threatened (Black-tailed Godwit, Asian Dowitcher, Beach Thick-knee, Black-necked Stork, Tahiti Petrel) and five species protected under the PNG Fauna Act (Glossy-mantled Manucode, Trumpet Manucode, Magnificent Riflebird, King Bird-of-paradise and Raggiana Bird-of-paradise).

134 species (67.7%) are New Guinea residents, 14 species (7.1%) have resident populations augmented by seasonal migrants and 50 (25.3%) occur in New Guinea only as non-breeding migrants.

Sixty-three species (31.8%) are primarily associated with rainforest habitats. These are listed as possibly occurring at the Study Area as they are occasionally recorded in adjacent disturbed habitats and in gallery forest. Forty-five species (22.7%) occur in open forest formations including savanna and/or agricultural areas and at least 10 (5.1%) commonly occur in mangroves. Nineteen (9.6%) are seabirds and 51 (25.8%) are predominantly wetland species.

4.2.4 Herpetofauna

4.2.4.1 Species Recorded

A total of three frog and nine reptile species was documented at the Study Area **(Appendix 1)**. All except one of these (*Cryptoblepharus yulensis*) are common species in the savanna habitats of southern Papua New Guinea. Reptiles were recorded in all habitats except gallery forest and oceans/coast, with the greatest number of species (n = 6) found in savanna. The two species of tree frog were recorded in grassland and open woodland habitats. Introduced Cane Toads were also found in savanna and wetlands.

The small skink *Cryptoblepharus yulensis* is a recently described species known from four sites around Port Moresby, Yule Island, and a single, unknown site in Western Province. It probably has a broad distribution along coastal areas of southern Papua New Guinea.

No reptile or amphibian species recorded at the Study Area are IUCN-listed and none are protected under the PNG Fauna Act.

4.2.4.2 Additional Species

The herpetofauna of the Study Area is a subset of the diverse savanna assemblage typical of the Port Moresby area. Additional time and trail access on the site, including nocturnal surveys, would undoubtedly have resulted in additional reptile and amphibian species being recorded.

Twelve additional terrestrial species not yet recorded but potentially occurring at the site are listed in Appendix 2. These include seven species that are listed as restricted trade under the PNG Fauna Act (R).

No dangerously venomous snakes were encountered but Taipans occur throughout the region and the grassland habitats of the Study Area provide suitable habitat for this species so they are highly likely to occur on site. Papuan Black Snakes are rare in the area but their presence cannot be discounted.

The mangrove systems along Vaihua River, although heavily disturbed, provide suitable habitat for the widespread homalopsine White-bellied and Richardson's Mangrove Snakes and for the Mangrove Monitor. Local residents have indicated that saltwater crocodiles do not occur at the Study Area. Nevertheless, the possibility of crocodiles occurring along the coast and in the mangroves cannot be entirely discounted and appropriate caution should be used when traversing these habitats.

Turtles are covered in the chapter on marine impacts (Coffey Natural Systems 2008).

Frog diversity on the site is certainly substantially higher than the total documented during this survey. However, no frogs of global conservation concern are known to occur in the general area, and no amphibians are protected under the PNG Fauna Act. No amphibians are listed in Appendix 2, which focuses on those herpetofauna of conservation concern.

5. BASELINE SURVEY CONCLUSIONS

A low diversity of terrestrial fauna was recorded at the Study Area in April 2008. Despite surveying a variety of distinct habitats, including mangroves, savanna, wetlands and grasslands, only three mammal species, 12 reptiles and amphibians and 62 bird species were directly encountered in terrestrial habitats (excluding oceanic birds). The low observed species richness was most likely the result of two factors:

- The severe restrictions in survey time and accessibility encountered during the survey.
- Low to moderate overall biodiversity values present at the Study Area.

Logistic constraints experienced during the survey restricted the ability of the biodiversity team to achieve an exhaustive first-hand account of the species present at the Study Area. These constraints are described above (Section 3.6). Additional time and greater access to a variety of habitats would undoubtedly have revealed additional species from all taxonomic groups. For example, had they been permitted, nocturnal, dawn and dusk surveys would have yielded numerous additional mammal, frog and bird species that almost certainly occur on site but remain undetected. Increased access to a range of habitats would also help determine the presence and extent of caves and gallery forest required as critical habitat by a large number of bat species, many of which are listed as Threatened or Near Threatened by the IUCN.

Despite these restrictions, results of the field surveys do suggest that the Study Area supports only low to moderate biodiversity value.

Overall species richness may be moderate, due largely to the wide range of habitats present on site, from marine through freshwater habitats to a variety of terrestrial habitats and vegetation types, including savanna, grasslands, gallery forest and streamside vegetation on alluvial flats and rocky hills and ridges. A series of sub-coastal wetlands may provide seasonal habitat for a wide variety of waterbirds, including some IUCN-listed migratory shorebird species.

Despite this diversity in habitat and substrate availability, much of the site is highly modified and likely to support only a portion of the faunal communities that may originally have been present. Low mammal trap rates and frog and reptile diversity documented during this survey reflect a substantial reduction in the site's environmental complexity resulting from prior intensive pastoral use and current disturbances including frequent burning and hunting.

No IUCN-listed species were recorded during the brief and restricted surveys although a number of Threatened and Near Threatened species may occur. Six nationally listed birds, including four protected species, were recorded in various habitats, and a number of additional nationally listed species may occur. No terrestrial reptiles or amphibians of conservation concern are expected to occur in the Study Area.

Information on the ecology, status and distribution of IUCN-listed and nationally listed species, together with their susceptibility to individual impacts, is discussed below in Section 12 (Significance of Impact on Listed Species). Section 11 (Significance of Impact on Habitats and Special Areas) describes those habitats present at the Study Area that are of importance to the site's terrestrial biodiversity and/or will be impacted by development of the LNG Plant and associated infrastructure. Descriptions include habitat ecology, biodiversity values, occurrence at the Study Area, local region and PNG.

PART II

Impact Analysis

6. LNG PLANT AND ASSOCIATED INFRASTRUCTURE

The potential impacts on terrestrial biodiversity associated with the construction and operation of the LNG Plant are discussed below.

Impact analysis was based on the project description provided in the Early Project Development Basis (PNG LNG Project 2007), the Construction Execution Plan (PNG LNG Concept Selection Project 2007a) and updates on project design provided by EHL engineers during the course of writing. In the following discussion references to the Early Project Development Basis will be abbreviated to EPDB with section and page numbers (e.g. EPDB 1:3).

Development of the LNG Plant and associated infrastructure will include both onshore and offshore works. High-pressure gas (at 7,500 kPag; 14° to 21°C) will be delivered along the LNG Project Gas Pipeline and reach the LNG Plant at the onshore pig receiver. The LNG Plant will be located onshore. After processing and storage, a causeway/jetty structure will carry the LNG loading line from the LNG storage tanks to an LNG carrier berth and loading facility offshore (EPDB 2:28) **(Figure 3)**.

6.1 LNG Plant Utilities and Offsites

In addition to LNG processing plants, including LNG processing trains, the LNG Plant will include various utilities and offsites. 'LNG Plant utilities' will include the hot oil system, utility and instrument air system, low-pressure and high-pressure fuel gas systems, power generation, power distribution system, service water system, nitrogen system, and cooling system. 'LNG Plant offsites' will include LNG and condensate storage and loading units, including LNG and Condensate storage tanks (2 x 160,000 m^3 LNG tanks and space for additional tanks), flare systems, acid gas incinerator, wastewater treatment system, fire-protection system, freshwater system (desalination plant), diesel system, and the refrigerant storage system.

Construction of these facilities will require temporary construction and permanent staff camps.

The LNG Plant will be constructed during Phase 1 of the PNG LNG Project and will be designed to incorporate expansions including an LNG CO_2 Upgrade during Phase 4 (EPDB 5:14). Infrastructure associated with these expansions may include additional processing plants and trains and a third LNG tank.

6.2 Marine Facilities

The LNG Plant's marine facilities, designed for the loading of LNG carriers ranging from 125,000 to 216,000 m^3, will include the LNG Jetty, LNG export berths (LNG, condensate, tug berths, crew boat berth) and the Materials Offloading Facility.

The LNG Plant's marine facilities, particularly the LNG jetty, will impact upon both marine and terrestrial environments. Potential impacts of the jetty on terrestrial habitats and biota are treated in this report.

6.3 Fencing and Roads

A 1,260 m security fence will surround the LNG Plant utilities and offsites and the LNG Jetty, defining the LNG Facilities site area **(Figure 3)**. Exclusion and Boundary fences will be

constructed along the Portion 2456 lease area boundary delineating the area under project control. Project developments outside the LNG Facilities site will also include the upgrading of a private road and the construction of a new public road linking Port Moresby and Papa.

7. ASSESSING IMPACTS

A predictive approach is necessary when assessing the impacts of development of the LNG Plant and associated infrastructure on terrestrial biodiversity at the Study Area. Impact assessments are based on both objective information and subjective, expert opinion. They rely heavily on a combination of the following types of information:

- Biodiversity data that has been gathered for the project.
- Existing data on local, regional and national biodiversity values.
- A general understanding of the ecology and dynamics of the species and habitats involved.
- Experience that has been gained from other resource development projects.

The following impact assessments are therefore based on the professional judgment and experience of specialists as well as empirical data gathered on-site.

The level of information available on the ecology and dynamics of individual species and habitats within PNG is highly variable; although the distribution and ecological requirements of some taxa are fairly well understood, little or virtually no information exists regarding the status, requirements and sensitivities of many others. Within this context, impact assessments need to be guided by a decision-making system that attempts to produce consistency across assessments.

The system used here is a modification of the system being developed by Coffey Natural Systems which has at its core the concept of **impact significance**. In this context the term 'significance' carries the common English meaning and should not be confused with classical statistical significance.

The level of significance is derived from a combination of two elements:

1. The **value or sensitivity of the receptor** (species or habitat) to change.
2. The **magnitude of impact** – measured as the amount and type of change, including scale, duration and likelihood of the occurrence.

7.1 The Value or Sensitivity of the Receptor

Criteria used to define receptor value/sensitivity for sites and species are listed in **Table 3**.

7.2 Magnitude of Impact

7.2.1 Magnitude Criteria

The magnitude of impact is defined for three categories of effects:

- Habitat impacts concern the impact of clearing on habitat.
- Population impacts refer to effects on populations, including disturbance, direct mortality and reduced breeding success.
- Other ecological effects refer to impacts that degrade habitat or reduce population viability e.g. barrier effects, fire, exotic species, contamination etc.

Categories and definitions of impact magnitude are described in **Table 4**.

7.2.2 Local Contextual Region (LCR)

Impact magnitude is measured partly in relation to its effect in a regional context (see **Table 4**). For the purposes of this report, a Local Contextual Region (LCR) has been defined in order to provide a regional context for habitat and population losses **(Figures 1 & 2)**. The LCR lies entirely within the Central Province and covers approximately 112.25 km of coastal lowlands (measured as a straight line) from Suckling Point south to Gaire No. 1. Suckling Point lies 30 km west of Galley Reach, 55 km northwest of the LNG Facilities site and 79.5 km northwest of Port Moresby. The coastal village of Gaire No. 1 lies some 32.7 km southeast of Port Moresby and 58 km southeast of the LNG Facilities site. The LCR covers a land area of 228,865 ha between the coast and an inland boundary that follows approximately the 250 m above sea level (asl) contour. It includes 26 FIMS vegetation types **(Figure 4)**. The FIMS vegetation types are described in **Appendix 4**.

7.3 Impact Significance

Combinations of impact magnitude and conservation asset value have been assigned impact significance levels of major, moderate, minor, negligible or positive as shown in **Table 5**.

Table 3 Criteria used to assess the value and/or sensitivity of conservation assets present at the Terrestrial Biodiversity Study Area

Value	Sites and/or Habitats	Species
Cat. 1 Very High Value	An internationally designated site. A designated national Protected Area e.g WMA. A large area of little disturbed, intact habitat/s that provides ecosystem services important in maintaining national or global biodiversity. An area with some Cat. 1 species or a high concentration of Cat. 2 species. Site supports 20% or more of a national population of any species.	A population of internationally important species in IUCN category Critically Endangered.
Cat. 2 High Value	A sustainable area of priority habitat identified by WWF. 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 Cat. 2 species and/or a high concentration of Cat. 3 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.
Cat. 3 Medium Value	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 Cat. 2 species and/or a moderate concentration of Cat. 3 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.
Cat. 4 Low Value	Sites that enrich the local area. A low to moderate diversity area with no Cat. 1 or 2 species and a low concentration of Cat. 3−4 species.	A population of a species in IUCN category Data Deficient and/or classified as R under PNG legislation.
Cat. 5 Least Value	No significant ecological value.	A population of a species in IUCN category Least Concern or is unclassified and is not listed under PNG legislation.

Table 4 Impact categories used in assessment

Magnitude of Impact	Habitat	Other ecological effects (barrier effects, contamination, exotics etc.)	Populations
VH Very High	Large impact on substrates and habitats that will be permanent and reduce ecosystem survival and health over large areas within the local 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 > 10% of the local 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.
H 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 5−10% of the habitat's range within the local region.	Impact is regional affecting 5−10% of local region.	Impacts will involve local loss of population (i.e. within the Study Area) 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 5−20% of national population.
M 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.
L Low	Substrates may be disturbed or lost but habitat can readily recover on remaining/replaced substrate with slowing of successions by 1-3 years at most. Generally only a short-term (1-3 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.	Effects 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.
N Negligible	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.
P Positive	Change is likely to benefit the species community or ecosystem. This will be detectable by RAP surveys pre and post impact showing increase in abundance and/or occurrence of species at sites they did not occur in before.		

Table 5 Impact significance matrix

Magnitude of Impact	Value/Sensitivity of Conservation Assets				
	Cat. 1	Cat. 2	Cat. 3	Cat. 4	Cat. 5
Very High	Major	Major	Major	Moderate	Minimal
High	Major	Moderate	Moderate	Low	Minimal
Medium	Moderate	Moderate	Low	Low	Minimal
Low	Moderate	Low	Low	Low	Minimal
Negligible	Minimal	Minimal	Minimal	Minimal	Minimal
Positive	Positive	Positive	Positive	Positive	Positive

8. RECEPTOR SENSITIVITY/VALUE

8.1 IUCN-listed and Nationally Protected Species

Sensitive species are defined as those species listed by the IUCN as Threatened, Near Threatened or Data Deficient, or listed under the PNG Fauna Act, and the value/sensitivity of individual species is calculated according to the formula shown in **Table 3**. The value/sensitivity of each listed species is given in **Table 12** along with the significance of various impacts. Information on the ecology, status and distribution of individual species, together with their susceptibility to individual impacts, is discussed below in section 12.

8.2 Focal Habitats

The following sections describe those habitats present at the Study Area that are of importance to the site's terrestrial biodiversity and/or will be impacted by development of the LNG Plant and associated infrastructure. Descriptions include habitat ecology, biodiversity values, occurrence at the Study Area, local region and PNG.

Table 6 lists the area of each habitat within the Study Area, focal area (Vaihua River Ecosystem Complex, see Section 8.3) and LCR, and the proportion of each habitats extent throughout the LCR that is located within the Study Area.

Table 7 summarises the biodiversity values identified and possibly occurring at each habitat or focal area within the Study Area. For each habitat/area the number of birds, mammals, reptiles and amphibians recorded or possibly occurring at the Study Area is listed, together with the number of IUCN-listed and nationally listed species recorded or possibly occurring on site.

Table 6 Areas (ha) of habitats present at the Terrestrial Biodiversity Study Area (TBSA), Vaihua River Ecosystem Complex and Local Contextual Region (LCR), and the proportion (%) of each habitat's range within the Local Region present at the Study Area (TBSA/LCR)

	Terrestrial Biodiversity Study Area (TBSA)	Vaihua River Ecosystem Complex	Local Contextual Region (LCR)[1]	TBSA/LCR (%)
Grassland/Open woodland	1553	82.2	16391	9.47
Savanna	2511	0	40640	6.17
Mangrove & Wetlands/Flats	382	230.9	25354	1.51
Mangrove	261	148.8	-	-
Wetlands/Flats	121	82.1	-	-
Total	**4446**	**376[3]**	**-**	**-**

[1] Areas of habitats within the LCR were calculated using the following Forest Inventory Mapping System (FIMS) vegetation types: Grassland/Open woodland (G – Grassland, G/Sc – Grassland/Scrub, Gsw – Swamp grassland); Savanna (Sa – Savanna, Saf/W – Savanna with gallery forest/Woodland); Mangrove & Wetlands/Flats (Mv – Mangrove).

[3] The total VREC area includes areas of river and submerged sand habitats not itemised in this table.

8.2.1 Sub-coastal Wetlands/Flats

8.2.1.1 Occurrence and Ecology at the LNG Facility Site

The Study Area includes an integrated system of sub-coastal wetlands that lie behind the mangroves along most of the site **(Figures 3 & 5; Plates 1, 4−9)**. The system of mangroves, salt-flats, mud-flats and wetlands extends north out of the study site along the coast towards Papa village. However, the vast proportion of this discrete area of habitat lies within the Study Area. Our brief assessment of the site indicates that this system of wetlands constitutes a potentially important site for waterfowl and migratory shorebirds.

The hydrological dynamics of this ecosystem have not been recorded in detail at the Study Area. However, the shifting character of these wetlands can be reasonably predicted based on limited observations and seasonality of the Port Moresby area.

Much of the wetlands may be almost permanently inundated during the wet season. In the dry season the wetlands appear to contract significantly, leaving large areas of salt-pan and mud-flats. Salt has been commercially harvested from these areas in the past. When dry these areas offer little in terms of biodiversity value. However, even during the dry season these areas offer some value as wetland habitat, with occasional flooding following heavy rains. **Plates 4−8** show photos taken near the Vaihua River during the April 2008 surveys, during the transition between the end of the monsoon season in March and the dry season. These areas were dry two days earlier and had filled following heavy overnight rains.

The shifting water level in these wetlands is regulated by both marine tidal and freshwater stream dynamics. In addition to lining the seaward edge of this extensive sub-coastal system, mangroves also occur along some parts of the inland (eastern) edge, such as along the course of the Vaihua River and its tributaries, indicating the presence of at least some saltwater in this area. Conversely, Cane Toad (*Bufo marinus*) larvae were abundant during the survey in these waterways as they traversed the salt and mud-flats. Although tolerant of a moderate degree of salinity, their presence also indicates the importance of freshwater flow into these areas.

Table 7 **For each of six habitat classes identified at the Study Area, (a) the number of birds, mammals, reptiles and amphibians recorded or possibly occurring on site, and (b) the number of IUCN-listed (Threatened and Near Threatened − NT) and nationally listed species (Protected – P; Restricted – R) recorded or possibly occurring on site. For each habitat, the total proportion of all species recorded or possibly occurring on site is also shown (% total)**

	Birds	Mammals	Reptiles	Amphibians	% Total	Threatened	NT	PNG (P)	PNG (R)
Recorded April 2008 (Appendix 1)									
Savanna	23	2	0	0	-	0	0	0	0
Gallery forest	11	2	0	0	-	0	0	0	0
Grassland & open woodland	32	3	5	3	-	0	0	0	2
Wetlands & flats	18	0	1	1	-	0	0	3	0
Mangroves	21	0	0	0	-	0	0	0	0
Oceans and coastal marine	8	0	0	0	-	0	0	2	0
Possibly occurring (Appendix 2)*									
Savanna	54	22	4	-	-	5	4	2	8
Gallery forest	103	21	8	-	-	4	3	5	9
Grassland & open woodland	98	25	4	-	-	5	4	0	9
Wetlands & flats	65	0	5	-	-	0	3	0	8
Mangroves	60	7	5	-	-	0	3	1	4
Oceans and coastal marine	39	0	1	-	-	1	5	0	3
Totals*									
Savanna	77	24	4	0	29.2	5	4	2	8
Gallery forest	114	23	8	0	40.3	4	3	5	9
Grassland & open woodland	130	28	9	3	47.2	5	4	0	11
Wetlands & flats	83	0	6	1	25.0	0	3	3	8
Mangroves	81	7	5	0	25.8	0	3	1	4
Oceans and coastal marine	47	0	1	0	13.3	1	5	2	3

* Note: These figures do not represent precise estimates. Unrecorded biodiversity values for birds and bats represent an upper limit and may vary by up to ≥25%. Unrecorded biodiversity values for non-volant mammals and reptiles focus on conservationally significant and culturally important taxa and are therefore underestimated.

8.2.1.2 Regional Context: Extent and Importance of Central Province Wetlands

Major coastal wetland sites including mud-flats, estuaries and mangroves are associated with PNG's larger river systems. The major wetland sites on the south coast occur along the Fly, Kikori and Purari River systems in western and central PNG. Smaller coastal wetland systems of biological importance are found in the southeast along the Kemp Welch River, which drains into Hood Bay ~95 km southeast of Port Moresby, and the Vanapa River/Brown River system which drains into Galley Reach 25−30 km north of the Study Area (Sekhran and Miller 1994).

The Vanapa/Brown drainage has been described as a "compact but important peninsular river system that drains into a significant mangrove system" (Sekhran and Miller 1994, p. 118). This area of mangroves and the inland portions of the Vanapa/Brown drainage comprise two distinct and important components of the region's total wetlands.

'Central Province Wetlands'

The PNG Conservation Needs Assessment (CNA), published in 1993 (Synopsis Report, Swartzendruber 1993), identified the inland freshwater component of the Vanapa/Brown drainage as the 'Central Province Wetlands':

"A series of wetlands lie northwest of Port Moresby; because of proximity to the capital these wetlands are under varying levels of exploitation and disturbance. They support large and diverse populations of waterfowl and other wetland birds. The area is particularly important as a dry season refuge for migrant waterfowl from Australia and as a staging area for Palearctic shorebirds on their way to and from wintering areas in Australia."

The Waigani Swamp, which includes a small number of shallow lakes near Port Moresby, is a part of the Central Province Wetlands. The Waigani Swamp is heavily modified and degraded and receives about 80% of Port Moresby's sewage, resulting in severe changes in the biotic communities present over the last few decades (Sekhran and Miller 1994). Nevertheless, it remains an important area for the region's waterfowl and shorebirds.

Lakes that form part of the Central province Wetlands lie just 5km north of the Study Area's north-eastern boundary and less than 10 km from the proposed site of the LNG Plant.

Galley Reach and the Vanapa/Brown System Mangroves

The 'Central Province Dry Zone' which lies just 10 km to the northwest of the Study Area constitutes an area of important terrestrial biodiversity that is threatened by development.

Some 40 km north of the Study Area the Vanapa/Brown River system drains into Galley Reach inlet and the second largest system of mangroves in PNG's Central Province. This area forms the southern part of the 'Central Province Dry Zone', a region of important terrestrial biodiversity as defined by the PNG CNA (Swartzendruber 1993). The mangrove system is bordered landward by an extensive series of sub-coastal wetlands similar to the habitat found at the Study Area. As with the Central Province Wetlands, the sub-coastal wetlands around Galley Reach also provide extensive habitat for the region's resident and migratory waterbirds.

Combining mangrove and sub-coastal wetlands/flats, the total area of these habitats present at the Study Area amounts to just over 1.5% of the mangrove and sub-coastal wetland areas present in the local region.[1]

8.2.1.3 Biodiversity Values at the Study Area

Eighteen wetland bird species were recorded at the Study Area during the April survey, including 3 nationally protected species and 10 migratory Palearctic shorebird species that breed in northern Asia and Siberia (**Appendix 1, Table 7**).

The timing of our survey coincides with a period of reduced migratory shorebird activity. At this time of year most shorebirds have typically left their southern hemisphere 'wintering' grounds to embark on the long journey to breeding areas in northern Asia and the Palearctic. The precise movements of many of these species and their various populations are still poorly known. However, many of the species recorded thus far at the Study Area may rely on New Guinea's coastal wetlands mostly as temporary stopover points during migration. Although individuals and groups of many species may remain in the area throughout the austral summer, their numbers typically swell during periods of migration to and from their wintering grounds in Australia (Mackay 1970; Coates 1985; Beehler *et al*. 1986). Although such visits may be brief, stopover points are of vital importance in helping migratory shorebirds satisfy their energy budgets during migration.

As with surrounding wetland areas, the Study Area may provide important habitat for migrating as well as resident shorebirds, including three Near Threatened species (**Table 7**).

The degree to which these and other waterbirds rely on the site's wetlands remains unknown and can only be determined with further research. Despite large areas of wetland habitat persisting in the local region to the north and east, the wetlands at the Study Area:

- Represent a substantial area of intact habitat that provides ecosystem services important in maintaining local biodiversity.
- Provides habitat potentially used by a moderate number of Near Threatened species.

Wetlands at the Study Area are therefore considered to be of **Moderate Value** (Cat. 3).

8.2.1.4 Taxon Focus – Migratory Shorebirds (Charadriidae, Scolopacidae)

Conservation Significance of Shorebirds – Populations and Trends in the East Asian-Australasian Flyway

The Study Area is situated in the southern half of the East Asian-Australasian Flyway (EAAF), along which more than 35 species of Arctic-breeding migratory shorebirds travel to reach regular non-breeding grounds in Australia and New Zealand (Geering *et al*. 2007). The EAAF holds the highest number of shorebird populations of any of the world's flyways (Gosbell and Clemens 2006). Large population declines have been recorded for numerous migratory shorebird species worldwide, and a disproportionate number of species in the EAAF have been classified as threatened and are under increasing pressure from habitat loss and degradation (IWSG 2003; Meltofte *et al*. 2004; Gosbell and Clemens 2006). In Australia, reporting rates have declined for several migratory shorebirds, including a number of species recorded during our brief survey of the Study Area, such as the Eastern Curlew, Sharp-tailed Sandpiper, Pacific Golden Plover,

[1] The FIMS vegetation classification system does not distinguish between areas of mangroves and sub-coastal wetlands/flats within the local region.

Lesser Sand Plover, Grey Plover and Grey-tailed Tattler (Barrett *et al*. 2003; Gosbell and Clemens 2006; Harding *et al*. 2007). Significant regional declines have been reported for a number of other species that may be expected to utilise wetlands near the LNG Facilities site, including the Bar-tailed Godwit, Terek and Curlew Sandpipers (Mackay 1970; Gosbell and Clemens 2006).

The Convention on the Conservation of Migratory Species of Wild Animals (1979) is included among the international conventions and treaties explicitly listed by Esso as applicable to the PNG LNG Project (PNG LNG Project 2007).

Shorebird Ecology

Shorebirds have the highest daily energy demands relative to body mass of any marine predator (Kersten and Piersma 1987; Finn 2007). The energy required for migration comes primarily from the large amounts of fat stored at wintering grounds and stopover points, particularly in the few weeks prior to departure (Battley and Rogers 2007; Finn 2007).

The daily foraging routine of shorebirds is dictated by the tides. At high tide, non-breeding birds generally roost in flocks at selected locations above the high water mark, moving off to feed in nearby intertidal flats as the tide recedes. Thus both suitable feeding and roosting habitats are required in close proximity in order to sustain shorebird populations. In a regional context, it is important that shorebirds have access to a number of roost sites within reasonable distance of one another, so that they can move to an alternative site if disturbed by people, predators (e.g. dogs) or adverse weather conditions (Peters and Otis 2007).

Threats to Shorebirds

Shorebird conservation is currently afforded high priority since a large proportion of species is in decline (Barrett *et al*. 2003; Meltofte *et al*. 2004; Gosbell and Clemens 2006) and continues to be threatened by a wide range of environmental changes and human-related activities, including:

- Coastal developments.
- Land reclamation (e.g. wetland drainage) or altered hydrological dynamics.
- Pollution.
- Disturbance from recreational and development activities.

Each of these processes has the potential to impact upon shorebird communities that utilise habitat near the LNG Facilities site. For example, numerous studies worldwide have demonstrated the capacity of human activity to seriously deplete local habitat quality and the carrying capacity of individual wetlands (Burton *et al*. 2002). Potent processes in this sense are not restricted to the direct alteration or loss of habitat per se, but also include temporary disturbances from traffic, recreation, construction work, etc. Even in intact habitats, increased disturbance from human-related activities may cause a reduction in habitat quality and can significantly affect the behaviour, mortality and breeding success of shorebirds (Harding *et al*. 2007; Tomkovich and Weston 2007).

The coastal areas northwest of Port Moresby are well populated and most natural habitats are subject to hunting and other forms of harvesting. For example, it is known that local residents regularly visit the Study Area's mangroves to collect firewood. These processes already impact all species of waterbirds and shorebirds that use the site.

8.2.2 Mangroves

8.2.2.1 Ecology

Mangrove forest (Mangal) is a specialised ecosystem that has evolved to survive in harsh coastal environments which experience frequent and extreme variations in water-level, temperature, salinity and oxygen availability. Mangrove forests occur throughout the world along tropical and subtropical coastlines and brackish estuaries and deltas, where evergreen trees and shrubs thrive in tidal mud- or sand-flats inundated daily with sea water. These flats are found mostly along bays, inlets and other stretches of shoreline that are protected from heavy waves.

Mangrove forests are often adjacent to any of several other habitats, including salt-flats with herbaceous and succulent plant forms, sandy beaches, freshwater swamp or terrestrial forest or scrub. Although the transition between these habitats is often very abrupt, more than half of the faunal species that may be present in mangrove forest may also occur in adjacent plant communities. Such species are termed mangrove associates.

Mangroves provide a range of physical and chemical services vital to maintaining ecosystem health. They are vital for coastal protection, water purification and for absorbing CO_2. Mangroves play an important role in trapping sediments, and protecting the shore-line from wave action. The fine, anoxic sediments that accumulate at the base of mangrove forest often act as a sink for a variety of heavy (trace) metals which are removed from the overlying seawater by colloidal particles in the sediments. In places where mangroves have been cleared for development, the disturbance of these underlying sediments may result in trace metal contamination of seawater and associated biota. Healthy mangrove forest may also prevent muds from becoming acidic on exposure to air and rainwater, which then have the potential to affect surrounding habitats.

Mangroves also support a diverse and unique biota. The mesh of mangrove roots produces a quiet marine region for many plants and animals, and provides an important breeding and nursery grounds for a suite of commercially important fish and crustacean species. Many local fishermen rely on fishing grounds in front of the mangrove forests that fringe the coast of the Study Area.

Mangroves are marginal ecosystems, vulnerable to sudden or drastic changes in the environment. Alterations of hydrography and substrate have considerable impact; mangroves are susceptible to pollution, particularly oil and other petroleum compounds. Mangroves do not recover spontaneously after the impact of natural or manmade catastrophic events such as cyclones or clearing, and changes in siltation, leading to altered levels of forest floor muds and soils, can seriously affect regeneration capabilities.

8.2.2.2 Presence at the Study Area

Mangrove communities at the Study Area occur along most of the block's coastline and extend up the Vaihua River and into a series of sub-coastal ephemeral wetlands **(Figures 3 & 5; Plates 1−5)**. The site supports some 261 ha of mangrove habitat, most of which are situated next to the proposed site for the LNG Plant's onshore facilities. The mangroves also lie between the LNG Plant's onshore and offshore facilities and will be subject to clearing for linear infrastructure developments including the jetty and gas pipeline ROW.

The quality of mangrove habitat varies considerably within the Study Area. Many areas on site are already somewhat fragmented and disturbed by processes such as firewood collection and harvesting of other natural resources. Nevertheless, healthy, closed canopy mangrove forest

does remain in many areas, particularly along to the shoreline where taller statured species predominate.

8.2.2.3 Regional Context

Estimates of the extent of mangrove habitat remaining in PNG range from 400,000 to 600,000 ha (Saunders 1993; McAlpine & Quigley 1998; Aizpuru *et al*. 2000; Sabuin 2001) with a decline in total area occurring over the last 35 years (Wilkie and Fortuna 2003). Despite this reduction, large areas of habitat remain sparsely populated, relatively intact and little disturbed. Western New Guinea, consisting of the Indonesian provinces of Papua and West Papua, currently supports the largest expanse of mangrove forest in the world. Extensive areas of mangroves also occur in mainland PNG, particularly in the west near the mouths of the Sepik and Ramu rivers on the north coast and in the Gulf of Papua in the south, particularly those associated with the Fly, Kikori and Purari River systems (Sekhran and Miller 1994). In the southeast mangroves tend to form more narrow fringing coastal forests in the absence of large tidal river systems. In the heavily settled Port Moresby area remaining mangrove forests are relatively fragmented and heavily disturbed. However, within the local region a large, non-linear area of mangroves persists around Galley Reach and along the coast just 40 km north of the Study Area **(Figures 2 & 4)**. This is the second largest mangrove area remaining in the Central Province and a vital component of the 'Central Province Dry Zone', a biologically important area as defined by the PNG CNA (Swartzendruber 1993).

As noted above (8.2.1.2), combining mangrove and sub-coastal wetlands/flats, the total area of these habitats present at the Study Area amounts to just over 1.5% of the mangrove and sub-coastal wetland areas present in the local region.

8.2.2.4 Biodiversity and Endemism

New Guinea supports among the world's most species-rich mangrove ecosystems. The New Guinea Mangroves comprise one of WWF's Global Ecoregion's.[2]

As well as supporting a rich biota that inhabits both mangroves and adjacent terrestrial and aquatic ecosystems, these forests also provide habitat for a range of animals found only or almost exclusively in mangrove habitats. New Guinea mangrove specialists include a number of bird (Mangrove Robin, Red-headed Myzomela, Mangrove Gerygone, Mangrove Fantail, Black-tailed Whistler, Broad-billed Flycatcher) and reptile species (Mangrove Monitor, White-bellied Mangrove Snake, Richardson's Mangrove Snake). Some of these have already been observed at the Study Area (Mangrove Robin), while the rest may occur.

8.2.2.5 Biodiversity Values at the Study Area

Despite restricted access to mangroves, observed bird diversity was high compared to other habitats with 21 species recorded. More than 70 additional terrestrial vertebrates may occur, including three Near Threatened and five nationally listed species **(Appendix 2; Table 7)**.

Mangroves at the Study Area are fairly small and isolated compared to the extensive forests that occur at nearby Galley Reach to the north. Moreover, some of the habitat present at the Study

[2] The Global Ecoregions program is a science-based global ranking of the Earth's most biologically outstanding terrestrial, freshwater and marine habitats, and provides a critical blueprint for biodiversity conservation at a global scale.

Area has been degraded by processes such as firewood collection. No globally threatened taxa are predicted to occur and a large proportion of specialist mangrove species may be absent.

Nevertheless, mangroves on site:

- Represent a substantial area of moderately intact habitat with few invasive species.
- Provide habitat that may support a number of habitat endemics, Near Threatened and/or nationally listed species.
- Provide important ecosystem services in maintaining local biodiversity by offering habitat for waterbirds, regulating hydrology and protecting sub-coastal wetlands, and helping regulate contaminant levels and system pH.

Mangroves at the Study Area are therefore considered to be of **Moderate Value** (Cat. 3).

8.2.3 Savanna

8.2.3.1 Ecology and Occurrence the Study Area

Savanna occurs in areas characterised by a long and marked dry season, and is dominated by a variety of *Eucalyptus* species with a predominantly grassy understorey that includes cycads and banksias. Fires are frequent in the dry season. Small patches of gallery forest may occur in sheltered areas.

The Port Moresby savannas are threatened by human-related disturbances including clearance for agriculture, settlement and industrial developments, frequent burning, introduction of weeds and feral animals and over-hunting.

An extensive area of savanna occurs at the Study Area on hilly terrain in the south and east of the block **(Figure 5; Plates 16−19)** and extends onto the alluvial flats in areas that have not been cleared.

8.2.3.2 Regional Context

Large areas of savanna occur in the Trans-Fly area and near Port Moresby **(Figure 4)**. Savannas at the Study Area cover more than 6% of this habitat's range throughout the local region **(Table 6).**

8.2.3.3 Biodiversity and Endemism

New Guinea's savannas support a biota that is distinct from that found in the more diverse rainforest habitats that characterise much of the island. In contrast to the high degree of endemism found in New Guinea's rainforests, the flora and fauna of the island's savannas are largely of Australian origin. Thus many of the mammals, birds, reptiles and amphibians found in these habitats also occur in northern Australia.

8.2.3.4 Biodiversity Values at the Study Area

Faunal diversity is expected to be high in savanna compared to other habitats at the Study Area. The second highest number of bird species was recorded in savanna in April 2008, and a large number of birds, mammals and reptiles are expected to occur that have not yet been recorded (**Appendix 2; Table 7**).

Savanna woodlands in the Port Moresby area are known to support a large number of animal species, many of which are found almost exclusively in this habitat. However, biodiversity in the disturbed savannas of the Port Moresby area may be relatively low compared to similar habitats in the Trans-Fly and northern Australia (e.g. Bell 1982). Moreover, savanna at the Study Area is heavily disturbed and likely to support only a portion of those taxa found in this habitat throughout the local region.

No listed species were found in savanna during the survey (**Appendix 1; Table 7**). However, access to this habitat was restricted compared to grassland and open woodland habitats, and up to nine IUCN-listed species may be present, 5 of which are Threatened (New Guinean Planigale – VU, Troughton's Sheathtail-bat – VU, Greater Long-eared Bat – VU, New Guinea Big-eared Bat – CR, Big-eared Mastiff-bat – VU) (**Appendix 2; Table 7**).

An endangered sandalwood (*Santalum macgregoriae*) is possibly the only plant of critical significance which could be present in places like the LNG tract. However, these trees have not been seen in the Moresby area since the 1970s (Takeuchi 2005) and are probably extinct, especially in light of the population pressures now present throughout that district.

Although heavily modified by long-term human activity, savanna at the Study Area may support a range of Threatened and Near Threatened mammals, including the potentially extinct and Critically Endangered New Guinea Big-eared Bat. This habitat is therefore considered to be of **High Value**.

8.2.4 Grassland and Open Woodland

8.2.4.1 Ecology and Occurrence at the Study Area

Grassland on alluvial plains comprises the dominant habitat present within the LNG Facilities site footprint. Much of New Guinea's grasslands are maintained and/or created by human activity. The grasslands on site were largely created through clearing for agriculture during the early twentieth century, and are still subject to frequent large-scale anthropogenic disturbance through burning.

Floristically the grassland at the Study Area is dominated by *Heteropogon* and *Dichanthium* species native to southern New Guinea, though it also possesses a diverse alien component that includes many noxious weeds (e.g. *Alysicarpus vaginalis*, *Atylosia scarabaeoides*, *Clitorea ternatea*, *Panicum maximum*, *Passiflora foetida*, *Sida acuta*, and *Tridax procumbens*). Although a number of cycad species are IUCN-listed, those present at the Study Area (*C. schummanniana*) are not of conservation concern.

A variety of open woodland communities occur across the grassland-dominated areas, including areas with scattered trees on alluvial flats, patches of Rain Trees (*Samanea saman*) (**Plate 15**) and *Pandanus* that line the minor drainage systems (**Plate 14**).

In the habitat classifications shown in **Figure 5** the grassland and open woodland habitats have been included together within a single vegetation class. This is due to:

1. Their similar ecology and floristic components, with grasses and sedges dominating the ground layer in both habitat types.
2. The difficulty in accurately defining boundaries between these two habitats.

3. The high proportion of vertebrate fauna that are predicted to occur in both habitats at the Study Area. Of 74 species possibly occurring in either habitat, 52 are predicted to occur in both (70.3%; **Appendix 2**).

8.2.4.2 Regional Context

Grassland and open woodland at the Study Area amount to nearly 9.5% of the grassland-dominated habitats present throughout the local region (**Table 6**).

8.2.4.3 Biodiversity Values at the Study Area

As with savanna habitats, the grasslands and open woodlands of the Port Moresby district and Central Province lowlands support few endemics and a high proportion of species that also occur in Australia.

Grasslands and open woodlands yielded the highest number of terrestrial vertebrates recorded in 2008 (**Appendix 1**), and provide suitable habitat for the second highest number of species that may still occur on-site (**Appendix 2, Table 7**). No IUCN-listed species were found in these habitats during the survey, though up to nine may occur (**Table 7**), including the New Guinean Planigale (VU), which prefers rocky habitats, the Canefield Rat (NT) and seven bat species which rely on woodland habitats. One of these is the Critically Endangered New Guinea Big-eared Bat, which if not extinct may persist in savanna and other woodland areas.

Two nationally listed bird species were recorded over the grasslands in April 2008, the Papuan Marsh Harrier (R) and Brown Falcon (R), and a further six may occur, five of which are also diurnal raptors. All of these species are listed as subject to restricted trading regulations. No nationally protected (P) species are expected to occur in these habitats.

The relatively high potential diversity of these habitats is attributable to the variety of microhabitats present, including creek-side vegetation, very sparse savanna, rocky ridges, tall grasses and wetland edges. In April 2008 these habitats were the most accessible and were subject to the most intensive survey efforts, accounting for the high number of species recorded there. However, compared to New Guinea's forests, and to grasslands and other dry-land habitats in less disturbed areas, overall plant and animal diversity in the grasslands and open woodlands of the Study Area is expected to be low.

Although five Threatened taxa may occur in these habitats at the Study Area, most of these are expected to occur in woodland habitats rather than grassland. Taking grassland alone, only one IUCN-listed species may occur in this habitat within the Study Area – the Canefield Rat (NT). Listed species that may be found in woodland are most likely to occur in savanna, and may only occur in woodland areas with relatively dense tree cover, particularly those adjacent to areas of savanna and other forest types. For the purposes of impact assessment grassland and open woodland are therefore separated.

Grassland habitat on site is considered of **Low Value**.

Open woodland is of **Moderate Value**, largely due to the potential for tree hollows to support roosting bats.

8.2.5 Gallery Forest

8.2.5.1 Ecology and Occurrence at the Study Area

Gallery forest occurs within savanna in areas sheltered from fire, such as along creeks and small rivers. Essentially a form of rainforest, it is often densely clothed in vines. At the Study Area gallery forest has been located along the Vaihua River between Lea Lea Road and the sub-coastal habitats that include wetlands and salt-flats, *Melaleuca* woodland, rocky ridge lines and mangroves.

8.2.5.2 Biodiversity Values at the Study Area

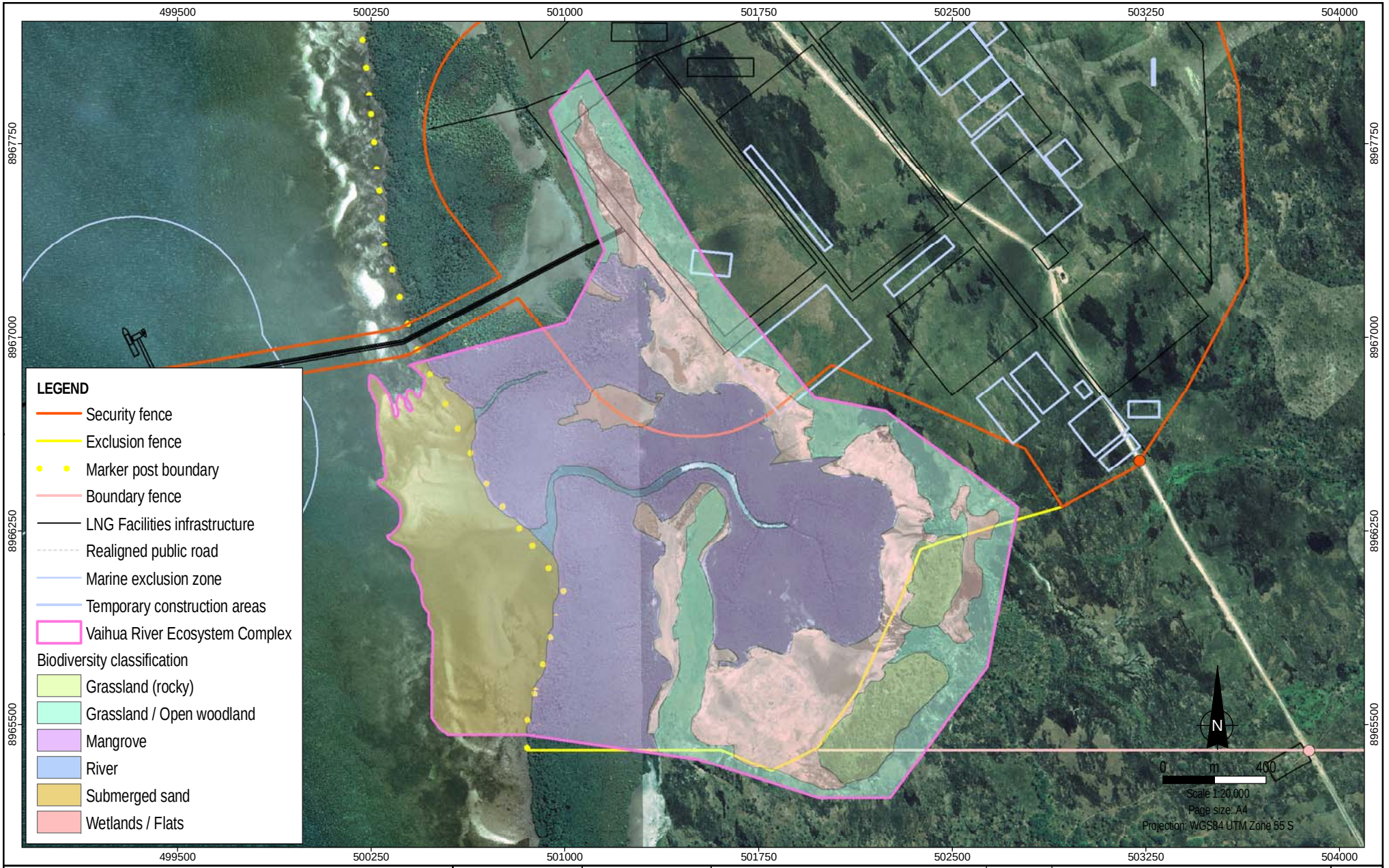
Gallery forest often serves as a refuge for a variety of rainforest fauna that are less tolerant of drier habitats such as the surrounding savanna. These include a variety of listed species such as birds-of-paradise, all of which are nationally protected.

Access to gallery forest was severely restricted during the April 2008 survey and relatively few species were recorded there. However, gallery forest provides suitable habitat for the highest number of species listed in **Appendix 2** that may occur at the Study Area. No listed species were recorded in gallery forest in 2008, though seven IUCN-listed and 14 nationally listed species may occur (**Table 7**). However, the gallery forest present on site is likely to be small, isolated, heavily disturbed and rich in non-native flora. Consequently, gallery forest near the LNG plant is expected to support only a subset of the faunal communities found in similar habitat in surrounding areas. Nevertheless, it is here conservatively assigned **Moderate Value** due to the potential importance of this habitat type for a variety of listed fauna and for overall biodiversity values within the Study Area.

8.3 Focal Area – Vaihua River Ecosystem Complex

During the April 2008 survey one area near the proposed site of the LNG Plant stood out as being of particular importance to biodiversity within the overall Study Area. The area is outlined in **Figure 9** and covers a wide range of habitat types that exhibit high connectivity, including:

- Submerged and inter-tidal coastal marine reefs and sediments.
- The Study Area's largest non-linear area of mangrove forest.
- The coastal approaches of the site's two largest waterways, including the Vaihua River.
- Rocky ridges with grassland and open woodland.
- Sub-coastal wetlands between the ridges and the coast that are regulated by tidal and freshwater flows.
- Wetlands inland from the rocky ridges likely to be regulated predominantly or solely by freshwater flows.
- *Melaleuca* woodland.
- A small inland buffer zone of grassland and open woodland on alluvial flats.



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Habitats within the Vaihua River Ecosystem Complex (VREC) and location of the LNG Plant and associated linear infrastructure

Figure No: 9

This zone, here termed the ‘Vaihua River Ecosystem Complex’ (VREC), constitutes a potentially important area for a variety of nationally listed and IUCN-listed species. All IUCN and nationally listed species occurring in the mangroves, wetlands, grasslands and open woodlands may occur in the VREC. Moreover, it may be the most important area for waterfowl and migratory shorebirds at the Study Area, as it includes a well connected series of coastal marine, sub-coastal and freshwater foraging habitats, and a variety of potentially important roost sites on spits and in the mangroves. Although in a regional context the VREC is relatively small and isolated compared to similar habitats nearby:

- It represents a substantial area of intact habitat with few invasive species.
- It may support habitat endemics, Near Threatened and/or nationally listed species.
- It includes a variety of distinct habitats with high connectivity and provides ecosystem services important in maintaining local biodiversity by offering habitat for waterbirds, regulating hydrology and protecting sub-coastal wetlands, and helping regulate contaminant levels and system pH.
- It is a sensitive ecosystem complex that will be difficult to restore or regenerate following significant disturbance.

The VREC is therefore considered to be of **High Value** (Cat. 3).

In the following sections, potential impacts on the VREC are assessed separately for relevant processes.

9. IMPACT MAGNITUDE

The following sections discuss the degree to which individual impacts may influence biodiversity values present at the Study Area. Relevant processes are divided into direct and indirect impacts. Direct impacts are those that directly result from project-related construction and operations activities and occur at the same time and place at which the activity in question occurs. Indirect impacts are not immediately related to project activities, but occur indirectly as a result of the project's presence. Indirect impacts may occur at or far away from the project area, and may occur at the same time or later than the causal activity.

The following sections are not structured around a formal distinction between construction and operational impacts. Rather, it is acknowledged in advance that most impacts resulting from LNG project activities are expected to arise during the construction phase, with a number of impacts continuing to varying degree during project operations. **Table 8** relates the relevance of various impacts to flora and fauna and to what degree they may continue during project operations.

Table 8 Direct and indirect impacts potentially imparted on biodiversity values during construction and/or operation phases of the LNG Facilities and associated infrastructure

Impact Type	Construction[1]		Operations[1]	
	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
Erosion, movement of soil & 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	

[1] 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.

9.1 Direct Impacts

9.1.1 Habitat Losses

9.1.1.1 General Considerations and Methods

Loss, degradation and fragmentation of habitat are primary causes of the loss of biodiversity. The magnitude of impact depends upon:

- The amount of habitat lost.
- The shape of the cleared area.
- The shape, size and isolation of remnant habitat patches.
- The duration of loss.
- The extent to which regeneration occurs.

Clearing per se need not represent a major impact. Various forms of disturbance, such as tree falls, landslides, earthquakes and coastal cyclones, are a natural part of tropical ecosystem dynamics. However, permanent change may occur when substrates or disturbance regimes are irrevocably altered (e.g. an increase in fire frequency, continuous and expanding clearing, loss of soils, changes to hydrology, etc.).

Terrestrial habitat losses at the Study Area will result primarily from the construction of:

- The LNG Plant and associated camps and facilities.
- The jetty/causeway linking the LNG Plant and marine loading facilities.
- The Gas Pipeline Right-of-Way (ROW) between the LNG Facility landfall and the LNG Plant.
- New public and upgraded private roads.

Habitat losses associated with each of these developments are discussed below. The areal extent of clearings was estimated using ArcView (ArcGIS version 9.2). Habitat losses were calculated for each of the following four habitat types identified within the LNG Plant and associated infrastructure development footprint and shown in **Figure 5**:

- Grasslands and woodland.
- Savanna.
- Mangroves.
- Wetlands.

A breakdown of predicted losses for each project component and its options is given in **Table 9**. Table 9 also itemises the percentage losses of various habitats from within the Study Area and broader LCR. **Table 10** lists the total and proportional losses of the VREC and its constituent habitats.

9.1.1.2 LNG Plant Facilities and Camps – Non-linear, Long-term Habitat Loss

Figures 5 & 9 show the areal extent of habitat that, for the purposes of this assessment, is assumed will be converted for the construction, operation and maintenance of the LNG Plant, including facilities and offsites, and LNG jetty. This combined area lies within the perimeter of the security fence and is referred to as the LNG Facilities site.

Most of the LNG Facilities site is conservatively assumed to constitute a continuous conversion plot. Much of the site will be prepared level or to a terraced level condition and include earthen (crushed rock) foundations (e.g. EPDB 11: 4; PNG LNG Concept Selection Project 2007b). Much

of the remaining area will be subject to high levels of anthropogenic disturbance (e.g. temporary dumps and storage areas, walkways and almost 17 km of intrasite roads) which will preclude natural ecological functioning.

By contrast, at least 75% of the mangrove and sub-coastal wetland habitat within the LNG Facilities site is predicted to remain intact, and is enclosed within the security fence to exclude local residents from entering the blast radius of the storage tanks.

Permanent/Long-term Facilities

The LNG Plant will include the following major long-term facilities shown in **Figure 3**:

- LNG processing plants and support buildings to be constructed during Phase 1.
- Additional LNG processing units constructed as part of a subsequent project expansion.

In addition to various other smaller enclosures, the main LNG plant buildings will include (EPDB 9: 5):

- Main control room.
- Warehouse.
- Chemical storage.
- Fire station and medical clinic.
- Maintenance workshop.
- Laboratory.
- Electrical substations.
- Equipment shelters.

Major off-site facilities at the LNG Plant will include **(Figure 3)**:

- LNG and condensate storage tanks.
- Permanent staff camps.
- Flare.
- Helipad.

These facilities will be designed to last the estimated 30-year life of the project.

An earthen causeway will pass through mangroves, wetlands/mudflats and grassland habitats between the LNG Plant's onshore and offshore facilities **(Figures 3, 5 & 10)**. It will be sufficiently large to support (EPDB 9: 25):

- LNG vapour and return lines.
- Condensate lines and future additional LNG and vapour return lines.
- Utilities.
- A roadway capable of accommodating trucks, ambulances, small cranes and pedestrian traffic

Construction Camps and Temporary Facilities

Temporary construction facilities are shown in **Figures 3 & 9**. These include temporary and pioneer construction camps, workshops, materials storage and waste disposal areas. Most of these facilities and service areas will be located in sites earmarked for construction of long-term infrastructure. For example, the temporary construction camp, which will provide on site accommodation and facilities for approximately 7,500 people, will cover an area of approximately

75 ha in the northeast section of the LNG Facilities site. Parts of this temporary construction camp may remain to become part of the permanent staff rotator camp for the life of the project.

By contrast, the 500,000 m^2 spoils area to be located north and west of the flare will not support any subsequent long-term facilities. However, development of this site during construction is conservatively assumed to result in long-term habitat conversion via significant impacts on the substrate, restoration capacity and ultimate floristic structure of this grassland area.

Storage Tank Blast Radius

Approximately 45 ha of mangroves (21.4 ha) and sub-coastal wetlands (23.5 ha) lie within the security fence immediately to the west of the LNG and Condensate storage tanks, and to the north and south of the eastern-most section of the LNG Jetty **(Figure 3)**. This area is enclosed within the security fence to exclude local residents from entering the blast radius of the storage tanks.

Within the LNG Facilities site, some mangrove and wetland habitat will be lost for construction of the LNG Jetty, security fence and associated patrol road/boardwalk, and some LNG Plant offsites (e.g. storage tanks) and temporary construction areas. However, most of this habitat is predicted to remain intact. For the purposes of this assessment, it is conservatively assumed that 25% of these habitats present within the LNG Facilities site will be lost **(Table 9)**.

Overall LNG Facilities Site Losses

Table 9 summarises the losses (total and per habitat) within the LNG Facilities site and the proportional losses in relation to the overall Study Area and the LCR.

Long-term losses within the LNG Facilities site will cover a total area of 687.4 ha. Most of this habitat is grassland, assessed to be of low value/sensitivity, with scattered areas of moderate value open woodland (588.7 ha; 85.6%). These losses will amount to 37.9% of the total grassland and open woodland habitat present within the Study Area, and 3.6% of the total grasslands present in the LCR.

The LNG Facilities site also covers 38.1 ha of moderate value wetland habitats and 52.6 ha of moderate value mangroves. Most of this habitat (≥75%) will not be converted for construction of the LNG Plant, but will be separated from remaining habitat by a 3.5 m high fence and 6 m wide road or boardwalk. Total loss of these habitats within the LNG Facilities site is therefore conservatively set at 25%, amounting to 9.5 ha of wetlands and 13.2 ha of mangroves, or 7.9% and 5.1% respectively of the total area of these habitats within the Study Area, and <0.1% of the mangrove/sub-coastal wetland habitat present in the LCR.

A small area of high value savanna (8.0 ha) will be lost within the LNG Facilities site, representing <1% of savanna within the Study Area and <0.1% of savanna present within the LCR.

The LNG Facilities site also covers 64.7 ha (17.2%) of the VREC special area (**Table 10; Figure 9**), deemed to be a high value biodiversity asset. Most of this area is sub-coastal wetland/flats (23.5 ha; 36.3%) and mangroves (21.4 ha; 33.1%). Almost all of this mangrove habitat lies within the southern section of the LNG Facilities site's blast radius, and much of it will not be converted. Loss of mangroves from the VREC is conservatively set at 20% of the area that lies within the LNG Facilities site, amounting to 4.3 ha or 2.9% of the VREC's total mangrove habitat. A higher proportion of the VREC's wetlands/flats will be converted for construction of the various LNG

Table 9 Total areal losses, and losses per habitat, through clearing for various components of the construction and operation of the LNG Plant. The percentage of each habitat lost in relation to its distribution throughout the Study Area (SA) and Local Contextual Region (LCR) is also shown

	Total	Grassland (Low value)/ Open woodland (Moderate Value)			Savanna (High Value)			Mangroves (Moderate Value)		Wetlands/Flats (Moderate Value)		Mangroves & Wetlands*
		Total	%SA	%LCR	Total	%SA	%LCR	Total	%SA	Total	%SA	%LCR*
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 Rd upgrade (27 m)	6.4	6.4	0.4	<0.1	0	-	-	0	-	0	-	-
New public (10 m)	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**	**<0.1**	**<0.1**	**13.7**	**5.3**	**10.2**	**8.5**	**<0.1**

*Note: The area of mangroves and wetlands lost from the Study Area were combined to calculate percentage losses from the LCR, since these habitats are combined under FIMS vegetation classifications.

Table 10 Total and proportional areal losses, and losses per habitat, incurred within the VREC through clearing for development within the LNG Facilities site. The proportion (%) of the total area and the area of each habitat that will be lost is also shown

Project Component	Total		Grassland/OW		Mangroves		Wetlands/Mudflats	
	Total	%	Total	%	Total	%	Total	%
LNG Facilities site	39.4	10.5	19.8	24.1	4.3	1.6	15.3	12.6

Plant components, including LNG and Condensate Storage tanks, intrasite roads and a temporary EPC Contractor Material Control Area. Loss of wetlands from the VREC is conservatively set at 65% of the area that lies within the LNG Facilities site, amounting to 15.3 ha or 18.6% of the VREC's total wetland habitat.

A total of 19.8 ha of grassland/open woodland habitat within the VREC will also be converted during construction of the LNG Facilities site. Much of this habitat serves as a buffer for the more sensitive wetlands.

A total of 39.4 ha of VREC habitat is estimated to be lost during construction and operation of the project, all of it from within the LNG Facilities site.

9.1.1.3 Long-term Linear Developments

The following linear developments will remain functional for at least the project's estimated 30-year lifespan.

Lea Lea Road Upgrade

An existing 4.7 m wide paved road (Lea Lea Road) currently provides public access to the LNG Facilities site from Port Moresby. Approximately 7.2 km of the public road will require widening and strengthening within the Study Area to support construction and long-term operations (EPDB 11:3). Current plans for stick-built facilities construction will require a road of 9 m width. However, the road will need to be wider if it is to accommodate modularised components (PNG LNG Concept Selection 2007c):

- 16 m for various pre-assembled piperacks (PARs).
- 27 m for various pre-assembled units (PAUs).

Modularisation may prove cost effective though the degree to which it will be adopted is yet to be determined (PNG LNG Concept Selection 2007c).

Habitat losses for construction of a 27 m wide road amount to 6.4 ha of low value grassland and moderate value open woodland (combined). These losses do not include the area covered by the existing paved road.

New Public Road

The existing public road connecting Port Moresby with Papa and Lea Lea to the north of the Study Area will also need to be re-routed east of the boundary of the LNG Facilities site (EPDB 11: 4). The new public road will be approximately 7.4 km long and 6 m wide **(Figures 3 & 5)**.

Assuming a 10 m clearance width for construction and operation, the new section of public road will result in an estimated loss of 5.8 ha of linear habitat, including 5.3 and 0.5 ha of low value grassland and high value savanna respectively **(Table 9)**.

9.1.1.4 Short-term Linear Developments

Pipeline ROW

The offshore pipeline will interface with the LNG Facility's onshore pipeline at a tie-in point approximately 100 m from the shoreline (EPDB 7: 8). The pipeline from the tie-in point to the LNG Plant's pig receiver will be considered the onshore pipeline. The pipeline ROW at the LNG Facilities site will not be adjacent to project roads.

The following discussion considers impacts on habitats and terrestrial biodiversity from the mangroves and shoreline to the LNG Plant.

The pipeline will be buried within a cleared ROW, a surface from which crews can install the pipeline (EPDB 10:13) and which is wide enough to safely accommodate trench digging machinery, trench, trench spoil and a road to allow vehicles to pass safely.

Generally, construction consists of surveying the lines prior to clearing with heavy machinery. Large trees are generally felled and the logs may be salvaged, while the smaller trees and debris are variously pushed to the side, burnt, or otherwise removed and/or salvaged. Drainage and, where specified, appropriate erosion control systems are installed, the ROW surface formed sufficiently and, if necessary, a thin rock pavement installed (EPDB 10:12) for traffic.

Pipeline construction is carried out by one or more "spreads" mobilised each day from the camps. A trench is dug to one side of the ROW using excavators and/or rock hammers and spoil stored on the other side.

Pipe sections are transported to the spread and strung alongside the trench to be welded, tested, coated and lowered into the trench, which is then refilled once the spread has moved on. The minimum depth of cover for gas pipelines in rural areas is 750 mm, and 1,200 mm for pipelines under and beside roads (EPDB 6:10-11). Parts of the ROW may then be allowed to revegetate or deliberately planted depending upon locality.

Design Criteria for the ROW can be found in EPDB Table 11.2.3-1 and the rational for ROW width in EPDB 10:13. The design criteria for overland pipeline ROWs specify an ROW Formation Width of 21.6 m on gentle terrain. Habitat traversed by the pipeline ROW at the LNG Facility site is characterised by flat and gently sloping terrain.

Three landfall options were considered for pipeline construction. Only the northern route option (7n), shown in **Figures 3 & 5**, is considered here as the others have been discounted.The overland route is approximate and was drawn without information from project engineers or other staff.

Assuming a 30 m clearance for pipeline construction, the total area cleared for the pipeline route is estimated to be 1.3 ha.

Compared to previously considered options this route will result in the least disturbance to terrestrial biodiversity. It will traverse the smallest areas of moderate value sub-coastal wetlands (0.7 ha) and mangroves (0.5 ha) and will not impede upon the high value VREC. The low value

grasslands that lie between the landfall and the LNG Facility site are abundant in surrounding areas and rich in invasive plant species and expected to support no IUCN-listed or nationally protected animal species.

Impact on mangroves and sub-coastal systems and species present will be **low.** Impact on grassland and species present **negligible.**

9.1.1.5 Side Cast Factors

Difficult/steep terrain can increase the effective area of clearing associated with ROWs due to side cast factors. For example, in steep terrain that requires significant benching, side cast will smother downslope vegetation and may cause tree deaths.

F. Crome (2008) developed a side cast ranking to be applied to ROW developments along the Upstream portion of the PNG LNG Project. He applied a factor (multiplier) of 1−3 to impacts associated with ROWs along increasingly steep terrains:

- Class 1 – little clearing expected beyond the nominal ROW.
- Class 2 – steep terrain but with slopes generally less than 12% but up to 15%.
- Class 3 – very rugged terrain with slopes sometimes exceeding 20%.

Because of the gentle sloping terrain that dominates the LNG Facilities site, side cast factors are expected to be minimal along the pipeline and road ROWs to be constructed there. A side cast factor of 1 is therefore assumed to apply to ROWs at the LNG Facilities site.

9.1.1.6 Other Facilities

Groundwater Wells

At least 10 wells will be drilled across the Study Area for groundwater supplies. The location of well sites is yet to be determined. Clearing for construction of groundwater wells is expected to be minimal, and less so for long-term operation, resulting in **negligible to low impact magnitude**.

9.1.1.7 Overall Losses and Impacts

It is estimated a total of approximately 700.9 ha will be cleared, of which 85.7% (600.5 ha) will be low to moderate value grassland and open woodland habitat. Most of the habitat lost from this vegetation class will be low value open grassland, which dominates the LNG Facilities site, rather than the marginally higher value woodland habitats that line the site's larger streams and edges of savanna.

Other habitat losses include 10.2 ha of sub-coastal wetlands and 13.7 ha of mangroves **(Table 9)**, both of which are considered to be moderate value habitats. Proportionally these losses are highest for the sub-coastal wetlands, with 8.5% of this habitat potentially lost from the Study Area. 5.3% of the site's mangroves may also be lost. However, in a regional context these losses amount to less than 0.1% of the mangrove and sub-coastal wetland habitats present in the local region.

Total losses for high value savanna amount to 8.5 ha, just 0.3% of the savanna present on site **(Table 9)**.

These figures should not be considered exact and may vary by 15 to 20% depending upon the final configuration of the project. Nevertheless, these figures are considered accurate enough to characterise likely impacts.

It is not possible to give an accurate assessment of the percentage loss of individual habitats from within the LCR because the FIMS data:

- Has only approximate information on condition and extent of each vegetation class, and this information has been verified by little or no ground-truthing.
- Combine Mangrove and sub-coastal wetland habitats in a single vegetation class. The percentage loss for these habitats at the Study Area is therefore combined for this analysis.

Taking all project components together, **overall losses** at the Study Area represent:

- A **medium impact on moderate value mangroves**, with 5.3% lost from the Study Area resulting in the division of what is currently a single block of habitat by construction of the LNG jetty.
- A **medium level impact on moderate value wetlands**, with more than 10% lost from the Study Area, increasing fragmentation of an already patchy habitat.
- A **low impact on high value savanna**, with only small peripheral areas lost.
- A **medium level impact on low value grassland**, with high proportions lost from the Study Area (38.7%) and nearly 4% from the local region.
- A **low level impact on moderate value woodlands**.
- A **medium level impact on the high value VREC**, with more than 10% of this area lost, including a substantial proportion (>12%) of its wetlands.

9.1.2 Edge Effects

Impact processes associated with edge effects are outlined in Crome (2008, pp. 104−105):

“Edge effects occur in forest that abuts cleared areas which result in physiological and ecological effects propagating into the forest from the edge of a clearing. These effects can result in continued degradation of forest adjacent to the edge and possibly continuing retreat of the forest edge. They come about by:

- Exposure of the forest edge to sun and wind that dries out the edge and changes the forest microclimate….
- The invasion of weeds and exotic species….
- Invasion of forest next to the edge by vertebrate species adapted to drier habitats and secondary forest.”

Edge effects are not expected to be an important factor impacting forest and other wooded habitats at the Study Area, since:

- Moisture levels of mangrove forest are overwhelmingly dictated by marine tidal flows and will not be altered by increases in light penetration.
- Mangrove forest is not likely to be influence by invasive species since it supports predominantly specialist flora already adapted to severe marine environments.
- Savanna and open woodland habitats at the Study Area are already adapted to seasonally dry conditions and include a variety of invasive plant and animal species.

- All wooded habitats at the Study Area, including mangroves, have adapted to a long history of anthropogenic disturbances including pastoral practices, periodic burning and/or firewood collection.

Edge effects are therefore predicted to impart a **low to minimal impact** on habitats at the Study Area.

9.1.3 Barrier Effects and Fragmentation

Impact processes associated with barrier effects are outlined in Crome (2008, p. 105):

"Barrier effects occur where a strip of open habitat provides a barrier of hostile habitat that discourages or prevents fauna species…, or the seeds or pollen of flora species, from moving across the gap, thus splitting or fragmenting populations.

As well as clearings, barrier effects may result from an inability of certain species to pass physical barriers such as the LNG Jetty/causeway or security fence.

"…. The important issue in the impacts of barrier effects is whether the ability to cross a gap is reduced to the extent that population dynamics of a species is altered and there is an increased risk of local extinction of populations."

It is unlikely the pipeline ROW or roads will provide a serious barrier to any species currently inhabiting the Study Area or otherwise result in significant fragmentation of habitat.

By contrast, the LNG jetty causeway, with a width of over 100 m, and to a lesser extent the security fence, may severely impede movement of some non-flying fauna including mammals, reptiles and amphibians, from crossing between segregated mangrove and wetland/flat areas. This may effectively fragment populations of some species currently residing at the Study Area that are expected to occur almost exclusively in these habitats, and may even reduce the viability of populations on-site. Potentially affected species include mangrove specialist reptiles such as the mangrove monitor, white-bellied mangrove snake and Richardson's mangrove snake. Barrier effects associated with LNG Facilities site infrastructure are mitigated by the presence of large areas of mangrove habitat present at Galley Reach north of the Study Area.

Barrier effects will have a **negligible to low impact** in most habitats, but may have a **medium level impact in moderate value mangrove** communities.

9.1.4 Physical Damage and Disturbance to Caves

No caves have been identified at the Study Area, and none are predicted to occur on the alluvial flatlands, wetlands and inter-tidal habitats that will be subject to the bulk of project's construction and operation activities.

9.1.5 Erosion, Movement of Soil and Spoil

Erosion and dumping of spoil may impact biodiversity through further loss of habitat and siltation and contamination of waterways and wetlands. Impact magnitude depends on the area of disturbance, soil type, steepness of the terrain, rainfall and habitat. Areas of spoil disturbance outside the LNG Facilities site are likely to be minimal due to the flat terrain. Erosion away from the waterways is also likely to be reduced due to the flat terrain and seasonally dry conditions.

However, development of the LNG Facilities site and linear infrastructure may lead to erosion and siltation of the Study Area's waterways including the Vaihua River. Moreover, the grassland on alluvial flats that dominates the LNG Facilities site slopes gently downwards towards the coast and sub-coastal wetlands. Spoil and other erodibles may be carried on to wetland flats during heavy rain, and if allowed to build up, alter the hydrology within these systems.

Unmitigated, erosion and soil/spoil movement may have a **medium impact on some habitats**.

9.1.6 Changes to Wetland and Mangrove Hydrology

Hydrological changes can impact ecosystems and result in major effects on habitats. For example, altered tidal flows may lead to death of mangrove areas and reduction in flows to sub-coastal wetlands. Hydrological changes can impact fauna directly through changes in seasonal and breeding cycles and through habitat loss. Species adapted to mangrove and wetland habitats are most at risk.

The LNG jetty/causeway to be constructed at the LNG Facilities site carries the potential to alter long shore drift dynamics and influence sediment build-up offshore. This in turn could have a major effect on the natural marine hydrological processes affecting the Study Area's mangroves and sub-coastal wetlands. Sediment build-up may have a positive effect on mangrove habitat as the forest progresses outward from the present shoreline to colonise new areas of suitable habitat. By contrast, sediment build-up may significantly reduce the flow of tides into existing mangrove areas and sub-coastal wetlands, resulting in the death of large areas of mangrove forest and a reduction or collapse of ecosystem functioning in large areas of sub-coastal wetlands.

Onshore, the jetty/causeway will segregate areas of wetlands/flats that currently function as a single system. Without culverts allowing flow of water between these areas, this may result in the loss of wetland habitat.

In the absence of proper mitigation and management, changes to local hydrology may result in a **high level impact** on some habitats and local biodiversity[3].

9.1.7 Materials Handling, Disposal and Pollution

Fuels and oils, chemicals and spoil entering watercourses and wetlands during construction have the potential to impact on species dependent upon these habitats such as frogs and waterbirds. Terrestrial fauna can be directly impacted by ingesting or contacting contaminants or becoming entangled or otherwise injured by wire and other abandoned hardware. Artificial nutrient enrichment of water bodies, such as through sewage contamination, can have a deleterious effect on waterbird foraging habitat and reduce the carrying capacity of wetlands.

Hydrotest fluids can contain biocides, oxygen scavengers and other additives and their disposal presents two special issues: one related to the potential toxicity impacts of biocides on aquatic organisms in the receiving waters and the other to the translocation of organisms. Biocides in the hydrotest fluid at the point of discharge have the potential to impact on receiving water organisms such as amphibians through residual toxicity. On the other hand, hydrotest fluid without biocides could allow the transport of living organisms, including pathogens, between stream catchments

[3] Subsequent to the completion of this report, the causeway has been shortened to prevent these impacts.

(i.e., translocation). It is not only exotic species that are of concern. Cross-contamination of streams with native species also serves to break down natural biodiversity patterns.

During construction there is the potential for contaminants to enter waterways and off-river water bodies. Poor materials handling, including fuel spills, has the potential to impart a **medium and short-term impact** on local biodiversity. If unchecked, chronic poor practices resulting in contamination may result in a **high impact on medium value wetlands and mangroves**.

9.1.8 Dust

Dust may coat the leaves of plants and reduce photosynthesis. Excessive dust from construction during the dry season may also temporarily displace local fauna from the immediate vicinity. Impacts are expected to be local and temporary, with residual dust washed away during rain. **Low impact** significance.

9.1.9 Noise, Lights and Other Disturbance to Fauna

Fauna adapt readily to noise but lights can affect the behaviour of nocturnal birds. Impacts are very local, and experience from operations of existing oil and gas facilities suggests that fauna have not been impacted by noise and lights.

Direct disturbance by humans does impact on fauna. For example, a number of studies have shown that increased disturbance from human-related activities may cause a reduction in habitat quality and can significantly affect the behaviour, mortality and breeding success of migratory shorebirds (Harding *et al*. 2007; Tomkovich and Weston 2007). Human related activities causing disturbance to shorebirds include human pedestrian traffic, the presence of domestic animals, construction work and vehicular traffic on roads, trails, beaches and water.

Disturbance to fauna from construction will be temporary and, as long as subsequent impacts are controlled, fauna should return to the site. Waterbirds are highly mobile and many species are non-territorial when not breeding. Disturbance from construction will displace birds to other areas but is not likely to force them to move off-site given the availability of other wetland areas at the Study Area. Disturbance resulting from construction and operations may result in a **moderate impact on wetland birds**. A **low to negligible impact** is predicted for other taxa.

9.1.10 Project Traffic and Other Operations

Fauna may be killed or injured by project traffic and machinery. Off-road traffic may destroy habitat/sites important for nesting, display, feeding, etc. Increased speed of public traffic on new and improved sections of road may also lead to higher rates of fauna mortality.

If normal controls are set in place, traffic is expected to result in a **low impact** on local fauna. Impacts from traffic on echo-locating microchiropteran bats are expected to be negligible.

9.1.11 Loss of Breeding and Display Grounds

Many birds-of-paradise and bowerbirds are lekking species where males display communally or individually in special display areas and compete for the attention of females. Display areas may be in trees or in specially prepared sites on the ground. Lekking areas are often traditional and form the breeding epicenters for local subpopulations of species (Frith and Beehler 1998). Bowers and other display areas may be lost during construction.

The Study Area is not expected to provide important habitat for birds-of-paradise, and the most likely member present, the Crinkle-collared Manucode, is a monogamous, biparental caring species that does not engage in the outlandish displays observed in other species, such as the Raggiana Bird-of-paradise (Frith and Beehler 1998). However, bowers of the Fawn-breasted Bowerbird, which has been recorded on site (Appendix 1), may be displaced or lost during construction of roads and other infrastructure, particularly in savanna and other wooded habitats. These birds are common in the area and tolerant of human disturbance, also occurring in gardens in local villages (e.g. Papa, pers. obs.). Loss of some bowers will not therefore disrupt breeding activities of a significant proportion of the local population, and all affected birds are likely to relocate their bowers, particularly when the original bower was lost to linear infrastructure developments, which will not remove an individual's entire territory.

Loss of breeding grounds will impart a **low impact** on local populations and is not expected to impact any conservationally significant species.

9.2 Indirect Impacts

In the Upstream portion of the PNG LNG Project Area, all of the 2005 and 2008 biodiversity reports concluded that indirect impacts resulting from improved access along roads associated with the Project are likely to impact more heavily on flora and fauna than direct impacts. The main mechanism of this impact will occur through people gaining increased access to remote forest areas via access roads.

In contrast to the Upstream PNG LNG Project Area, which includes large areas of well connected, intact and little disturbed forest habitats, flora and fauna at the Study Area have adapted to a long history of anthropogenic disturbances including fire, hunting, pastoral practices and invasion of exotic plants and animals. Nevertheless, a range of indirect impacts to present a threat to terrestrial biodiversity at the site, particularly due to the importing of equipment and materials from offshore required for project development.

9.2.1 Fire

Fire presents a real danger to local biodiversity values, particularly during the dry season when vegetation burns most easily. However, habitat at the Study Area is already subject to regular burning initiated by local residents, with the current biota representing a subset of the local vegetation and faunal communities that are fire tolerant. Nevertheless, such burning is usually seasonal and largely restricted to the dry season. The grasslands, woodlands and savanna understorey that are subject to regular burns, and the fauna they support, thus undergo periods of growth during the wet season.

The completed LNG Plant will possess "full onsite fire fighting capabilities", which include fire hydrants throughout the site, fire monitors, freshwater storage and fresh and seawater pumps (EPDB 9: 19).

Fire therefore presents the greatest risk to terrestrial biodiversity at the Study Area:

- During periods when the land is traditionally left unburned (wet season).
- During the construction phase.

However, fires initiated as a result of LNG Plant construction or operations are expected to have a **low impact** on habitats at the Study Area, since:

- Local flora and fauna are already adapted to frequent burning.
- Aseasonal burns are expected to remain localised during the wet season.
- Fire management systems set in place during construction and operation will minimise the risk of fire.

Fires initiated by local residents in the surrounding grasslands, woodlands and savanna during regular, seasonal burns present a risk to the LNG Plant and associated facilities. Discouraging burns close to the LNG Plant will help to reduce this risk and may help to increase biodiversity values in the immediate vicinity, as the flora and fauna communities currently present are likely to represent a fire-adapted/tolerant subset of those communities inhabiting other, less disturbed seasonally dry habitats in the region.

9.2.2 Dieback

Dieback is the phenomenon of loss of vigour sometimes leading to death of trees and is caused by a range of factors. Plants affected by dieback include a wide range of eucalypts, including savanna species, and mangroves. Prominent among the causes of dieback is the root-rotting fungal genus *Phytophthora*, of which the most destructive species is *P. cinnamomi*, which causes serious disease and death of a huge variety of plants including many eucalypts. Other causes of dieback include drought, changes to drainage patterns (e.g. through road construction), pollution, storm damage, human-induced plant damage and changes in salinity (Fensham and Holman 1999; Kirkwood and Dowling 2002; Rogers 2005 a, b).

Dieback has been found in parts of the KICDP area. *Phytophthora* dieback spends its entire life in the soil and in plant tissue. It causes root rot in susceptible plants, thereby limiting or stopping the uptake of water and nutrients. The pathogen is able to survive within plant roots during the dry soil conditions commonly experienced during the dry season.

Dieback of savanna eucalypts and mangroves may occur as a result of changes in drainage patterns, pollution and introduction of *Phytophthora* pathogens into novel areas. Habitats at the Study Area are expected to be relatively robust to dieback threats since:

- A wide range of anthropogenic disturbances is already well established on site in both savanna and mangrove habitats, including traffic potentially carrying contamination from surrounding areas.
- Patches of savanna affected by construction of the new public road are small, isolated and already very sparsely populated by trees.

Nevertheless, mangroves may be susceptible to a wider range of causes of dieback such as through pollution and changes in hydrology. Moreover, all habitats may be subject to pathogens brought in from overseas or other areas in PNG.

If virulent causes are introduced to the area, dieback may lead to a **medium level impact** on local habitats.

9.2.3 Invasive Species – Weeds and Plant Pathogens

Exotic weeds are very significant issues for forest conservation worldwide and many weeds present serious problems to local and regional environments and agriculture. Once weeds penetrate native habitats they can bring about permanent changes including major changes to

ecology resulting in system collapse and resultant biodiversity loss. The impacts of weeds may not be immediate and a lag period of several decades may go by before a species “breaks out” and becomes a pest.

Habitats at the Study Area are already rich in exotic plant species, from grasses to large trees (e.g. Rain Trees). However, project developments will include the importation of a large amount and wide range of materials from overseas. This presents the threat of introducing new and possibly virulent species to the site and possibly PNG. In the worst instance, the accidental introduction of non-indigenous plants, fungi and other organisms may result in a **very high impact** on local and regional biodiversity. This presents one of the most serious and potentially ecosystem-wide impacts associated with the project.

9.2.4 Invasive Species – Fauna

Like weeds, invasive animals can have far reaching landscape impacts. Species such as Small Indian Mongoose (*Herpestes javanicus),* Rosy Wolfsnail (*Euglandina rosea*) and Slider Turtle (*Trachemys scripta elegans*) have had a major impact in tropical areas. Of particular concern is the spread of the yellow crazy ant (*Anoplolepis gracilipes*) and fire ant (*Solenopsis invicta*), now established in Australia, and the Crab-eating Macaque (*Macaca fascicularis*) established in West Irian. Exotics can be introduced accidentally on freight and in containers, deliberately or by ignorance.[4]

Like weeds, exotic animals can have serious agricultural as well as environmental impacts.

The Study Area already supports a variety of introduced animal pest species, including a number of rodents and the Cane Toad (*Bufo marinus*). The latter species is particularly destructive to local native fauna and is very common at the Study Area. Despite the presence of these alien taxa, the potential exists for other species, such as the Crazy Ant, to be introduced to the site and have a **high impact** on local and regional biodiversity.

9.2.5 Hunting

Hunting both for subsistence and commercial exploitation for bush meat has become a significant biodiversity impact in tropical forests. Many birds and the larger mammals and turtles of Papua New Guinea suffer greatly from hunting pressure, in particular, those species that are specifically targeted for food and/or decorative plumage. Species of particular interest to hunters include: tree kangaroos, cuscus and possums, the larger rats, flying foxes, cassowaries, megapodes, Blyth’s Hornbill, larger lorikeets, parrots, pigeons, raptors, New Guinea Flightless Rail, crocodiles, freshwater turtles, and numerous well-plumed birds-of-paradise including Black Sicklebill, Brown Sicklebill, Black-billed Sicklebill, Carola's Parotia, Lawes's Parotia, Magnificent Riflebird, Ribbon-tailed Astrapia, King-of-Saxony Bird-of-Paradise, Twelve-wired Bird-of-paradise, Raggiana Bird-of-paradise and Blue Bird-of-paradise.

Hunting is already widely practiced throughout the Study Area by local residents from a number of surrounding villages. Species most commonly targeted include larger mammals such as the Agile Wallaby and Southern Common Cuscus. These and other species now appear to be rare or locally extirpated due to severe, long-term hunting pressure and continuous controlled burning of habitat.

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[4] http://www.issg.org/database/species provides a lead into this subject.

Additional hunting by project employees and contractors may result in the loss of few individuals, though given their scarcity this may place undue pressure on already depleted populations, and potentially contribute to local extinctions and a **medium level impact**.

9.2.6 Collection of Flora

Sustained collection of specific plants (e.g. orchids), firewood or construction timber may result in the local degradation of habitat. Collection of firewood is already widely practiced throughout the Study Area by local residents from a number of surrounding villages. Additional pressure associated with the project is expected to have a **low impact**.

9.2.7 Seismic, Meteorological and Oceanographic Hazards

The processing and storage of large amounts of volatile fuels and toxic chemicals presents an enhanced risk to local flora and fauna through random natural events such as earthquakes, storms and large waves. Seismic, meteorological and oceanographic modeling procedures are currently underway to determine the risk of severe events.

The overall risk from such events is considered to be **low** due to:

- The incorporation of extreme natural event criteria into the design and construction of individual facilities and utilities.
- The specific location of the LNG Facilities site. Although all of PNG is considered seismically active, the Study Area is located away from areas of highest seismicity (EPDB 2:31) with no earthquakes higher than 3 on the Richter Scale recorded in the Central Province since 1900 (EPDB 14: 23). The persistence of a healthy coastal mangrove community at the Study Area and other areas nearby (including Galley Reach) also indicates that major storm and wave surge events are rare at this location.

10. RECOMMENDATIONS

10.1 Habitat Loss

The following mitigations are suggested to reduce impacts of clearing. These recommendations apply to developments in all habitats, though they are particularly important to construction and operation activities being carried out in mangroves, savanna, woodlands and wetlands.

10.1.1 LNG Facilities Site

- Minimise ground disturbance and vegetation clearing for facilities, camps, lay down areas, etc., outside the perimeter of the LNG Facilities Site.
- The base case design of LNG and Condensate Storage Tanks and an EPC Contractor Material Control Area, and access roads and tracks around and between these facilities, should be optimised in the detailed and final design to limit impacts on wetlands.
- Minimise clearing of streamside vegetation and vegetation surrounding/buffering wetlands/flats.
- Where practicable, allow vegetation near boundary of the LNG Facilities site to regenerate, particularly grassland and open woodland buffering wetlands/flats.
- Retain trees wherever practicable and safe to do so.
- Check for presence of Sandalwood (*Santalum macgregorii*) and retain these trees, diverting routes if practicable. Sandalwood is considered likely extinct in the Port Moresby region. A management plan should be developed in the event of encountering this and other listed species. If present, any trees should be considered of high conservation value and rerouting may apply to a single tree or stand as far as practicable. Transplanting mature trees is difficult since they are at least semi-parasitic and therefore dependent on an adjacent host tree.

10.1.2 Clearance for Linear Infrastructure

An Environmental Management Plan (EMP) should be developed outlining guidelines for minimising impacts from construction of pipelines and roads. Management plans should aim to ensure, *inter alia*, the following practices:

- Minimise the width of the clearings on the ROWs and roads as far as possible, and do not exceed the design disturbance width.
- Prevent machinery from leaving the ROW and road construction areas and unnecessarily clearing or otherwise disturbing surrounding habitat.
- Minimise clearing of streamside vegetation.
- Minimise disturbance to mangroves to reduce potential for generation of acid sulfate soils.
- Avoid erosion and siltation of streams. This will be important in maintaining present levels of frog diversity on-site. Mitigation at river crossings is covered further in Supporting Study 13 to Enesar (2005).
- Minimise traversing of wetlands and flats with linear infrastructure.
- Where the pipeline ROW traverses the wetlands/flats, rehabilitate surface to as near original condition as practicable in order to maintain original hydrological functioning.

- Allow as much of the ROWs and road construction areas to regenerate and, in mangroves and other woodland areas, the canopy to close over the gap wherever possible.
- Retain trees wherever practicable and safe to do so.
- Check for presence of Sandalwood (*Santalum macgregorii*) and retain these trees, diverting infrastructure routes if practicable.
- Where their removal is necessary, directionally fell trees so they land in natural slots between standing trees or along ROW or road routes. Do not land into or across streams. Minimise damage to surrounding habitats.
- Prior to felling, trees should be inspected for potential roost hollows that may be used by bats and other fauna. All trees should be felled gently[5] and left overnight before further treatment to allow any bats inside to move to an alternative roost. This practice will minimise impacts on local bat populations, including potentially present Threatened taxa such as the Critically Endangered *Pharotis imogene* (also *Saccolaimus mixtus* (VU), *Saccolaimus flaviventris* (NT), *Nyctophilus timoriensis* (VU) and *Otomops papuensis* (VU)).
- Avoid scraping stems of standing trees to be retained with machinery.
- Minimise the number of, and avoid clearance for, special vehicle parks.
- No firewood collection by operation workforce or contractors.
- Develop and implement a fire management plan for the LNG Facilities site.

10.1.3 Temporary Construction Areas

An EMP should be developed outlining guidelines for minimising impacts from temporary construction areas. Management plans should aim to ensure, *inter alia*, the following practices:

- Clear vegetation at or above ground level leaving any intact rootstock that will not obstruct machinery.
- Roll or flatten areas of light vegetation (low shrubs and ground cover) with machinery.
- Stockpile cleared vegetation for rehabilitation and reduction of erosion of temporarily cleared areas such as along side streams.
- Remaining stockpiled vegetation can be chipped and used for landscaping on site. This will reduce land surface disturbance and conserve topsoil and propagules. Chipping will reduce the need for importing mulch and thus also the risk if importing weeds and pathogens.
- Burn excess vegetation safely on site.
- The base case design of an EPC Contractor Material Control Area should be optimised in the detailed and final design to limit impacts on wetlands.

10.2 Barrier Effects

- After the gas pipeline is laid, re-fill the trench in order to restore substrate as close to its original condition as possible, and allow vegetation to regenerate across the ROW.

[5] Contact author for further advice on this method.

- 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.

10.3 Erosion, Movement of Soil and Spoil

EMPs developed for construction activities should include the following guidelines, among others, to minimise potential impacts on habitats from erosion and dumping of soil and spoil:

- Minimise area of habitat covered by spoil.
- Avoid dumping spoil in waterways.
- Minimise clearance of habitat at stream edges.
- Roads and ROWs should be constructed to minimise sediment run-off.
- Erosion control is covered in Supporting Study 13 of the EIS.

Mangrove muds may become acidic on exposure to air and rainwater. Develop and implement Acid Sulfate Soils management plan.

10.4 Changes to Wetland and Mangrove Hydrology

- Monitor and determine patterns of long shore drift and hydrological flow into and out of the system of sub-coastal wetlands (across seasons) and mangroves. Subsequent measures should be undertaken to maintain these patterns.
- Maintain present tidal flows into mangroves and sub-coastal wetlands by limiting offshore sediment build up.
- Minimise temporary disturbances to wetlands/flats through e.g. laying the gas pipeline and constructing the security fence.
- Replace wetland substrates as close to natural levels as possible.
- Hydrological issues and mitigations are also discussed in the marine impact assessment (Coffey Natural Systems 2008).

10.5 Materials Handling, Disposal and Pollution

The PNG LNG Project description will adopt ‘good practice’ materials handling procedures. These include stringent requirements regarding discharge into the environment of water contaminated with oil and grease, acid or alkaline water, phenols, sulfides, trace metals, etc. (EPDB 5: 23). Camps will also be provided with appropriately sized sewage treatment plants. Refuse will be sorted, segregated, incinerated and disposed of on site (EPDB 11: 7). Waste management plans should be developed to ensure, *inter alia*, the following practices:

- Ensure no disposal of wastes on dry land habitats, in streams or wetlands.
- Establish waste management procedures to ensure all non-biodegradable materials are disposed of off-site.
- Prevent sewage enriched water from entering the wetlands.
- Ensure no wash-down or fuel handling in or near streams.
- Monitor changes in levels of contaminants. Prior to construction undertake baseline characterisation of the distribution and abundance of soil/sediment contaminants on site

(marine areas, mangroves, wetlands, alluvial flat grasslands and open woodlands). Conduct subsequent regular assessments.

10.6 Dust

Normal dust and noise reduction procedures as appropriate for worker health and as in EMP. Guidelines should include:

- Smooth-round stockpiles of soil and overburden.
- Regularly spray un-sealed roads and limit speed of traffic.
- Revegetate areas no longer required for construction or support services.

10.7 Noise, Lights and Other Disturbance to Fauna

EMPs should be developed outlining guidelines for minimisation of disturbance to fauna through noise, lights and other activities. Management plans should aim to ensure, *inter alia*, the following practices:

- Minimise disturbance to wetland and mangrove habitats during construction and operations.
- Wherever possible, avoid vehicle and pedestrian traffic across the salt pans, mud flats and in adjacent habitat to within 25 m of the edge of the wetlands/flats.
- Staff and contractors should not walk through the mangroves unless for construction/maintenance purposes.
- Do not allow employees or contractors to cross wetlands/flats unless necessary for construction or maintenance purposes.
- Establish a blasting management plan (for both the terrestrial and marine environments) considering ANZECC guidelines, or similar and in consultation with local communities.

10.8 Project Traffic and Other Operations

- 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.
- Do not allow project employees or contractors to drive off-road unless vital for construction, maintenance procedures.

10.9 Fire

- Develop and implement fire management systems during construction and operation.
- Discourage burning by local residents in the vicinity of the LNG Plant and associated infrastructure as far as industry-community relations allow.

10.10 Dieback, Weeds and Plant Pathogens

These impacts present among the most serious and potentially ecosystem-wide threats associated with the project. Impact potential can be reduced by adopting stringent and hygienic importation procedures. In order to be effective mitigations need to be rigorously applied to curb the potential for introduction of both internationally exotic species and native species from other parts of PNG.

- Thoroughly clean off soil and weed seeds and disinfect plant and machinery brought into the Study Area from overseas or other areas of PNG.
- Incorporate pest and weed quarantine procedures, including measures for:
  - Implementing appropriate and stringent importing, quarantine, wash-down, disinfection and transport procedures in an EMP.
  - Quarantine of materials and equipment arriving without clearance pending wash-down in a designated safe area.
  - Monitoring spread of weeds and pathogens. Prior to construction undertake a baseline characterisation of the weed species present on site. Conduct subsequent surveys at the end of each wet season.

10.11 Invasive Fauna

Impact potential can be reduced by adopting stringent and hygienic importation procedures. Mitigations should include:

- A fit-for-purpose quarantine plan focusing on preventing particular pest species entering the site (e.g. with incoming freight or personnel).
- No cats should reside at the LNG Plant. No cats should be fed or otherwise cared for.

10.12 Hunting and Collection of Flora

The project can mitigate hunting by:

- Prohibiting hunting and gathering of plants or bush foods by staff and contractors.
- Implementing appropriate inductions to ensure staff and contractors comply with hunting and collecting regulations.

11. SIGNIFICANCE OF IMPACTS ON HABITATS AND SPECIAL AREAS

The significance of direct and indirect impacts on habitats and special areas before and after mitigation is shown in **Table 11**.

11.1 Sub-coastal Wetlands/Flats

Unmitigated, **direct impacts** may have a **moderately significant impact** on the Study Area's wetlands.

A total of 10.2 ha of wetlands are set to be lost as a result of clearing for development of the LNG Plant and associated facilities/infrastructure, amounting to 8.5%of this habitat present on site. Adopting suggested mitigations will reduce this amount. In particular, Storage Tanks and a temporary Contractor Material Control Area make up most of the area of wetlands that will be lost due to developments other than the LNG jetty/causeway within the LNG Facilities site. Although the Storage Tanks can not be moved, if the temporary Contractor Material Control Area is moved or reoriented, and if areas cleared around the permanent Storage Tanks are kept to a minimum, this will minimise the area of wetlands lost within the LNG Facilities site and to the project as a whole.

The major direct threats facing the wetlands are pollution and changes to hydrology. Adopting standard and stringent controls on materials and waste handling, storage and disposal will significantly reduce the risk of contamination. By contrast, mitigating high impact threats of changes in hydrology, particularly from construction of the jetty/causeway, calls for the development and maintenance of novel and site-specific systems. Installing culverts in the causeway, and/or regularly dredging offshore sediments, may be required to maintain current hydrology patterns vital in sustaining mangrove and wetland ecosystems.

Successful adoption of these recommendations is expected to reduce direct impacts to a **low significance** level.

The greatest potential **indirect impact** will result from the introduction of exotic weeds and pathogens. **Prior to mitigation** these present a **moderate threat**. Rigorous application of stringent importing, quarantine, wash-down, disinfection and transport procedures, together with regular environmental monitoring, is predicted to result in **minimal impact** from indirect processes.

11.2 Mangroves

Due to their proximity and similar dependence on hydrological factors, mangroves are susceptible to many of the threats that face the site's wetlands. Direct impacts on mangroves through **clearance and barrier effects** are difficult to mitigate without relocating the causeway. Nevertheless, these effects are expected to result in a **low impact** significance even before mitigation.

As with the wetlands, the major direct threats facing the mangroves are pollution and changes to hydrology. **Unmitigated**, these may result in a **moderate impact** on mangroves at the Study Area. Successful adoption of recommended mitigations is expected to reduce direct impacts to a **low significance** level.

Table 11 Impact analysis for habitats and the Vaihua River Ecosystem Complex (VREC) special area

Habitat	Value[1]	Direct Impacts[2]							Indirect Impacts[2]				Impact Significance Before Mitigation		Impact Significance After Mitigation	
		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	Low	Minimal
Mangroves	3	M	L	M	M	H	H	L	L	M	VH	L	Moderate	Major	Low	Low
Savanna	2	L	N	N	L	N	L	L	L	M	VH	L	Low	Major	Minimal	Low
Grassland	4	M	N	N	L	N	L	L	L	N	H	N	Low	Low	Low	Minimal
Open Woodland	3	L	N	N	L	N	L	L	L	L	H	L	Low	Moderate	Minimal	Minimal
Gallery Forest	3	N	N	N	N	M	M	L	L	L	H	L	Low	Moderate	Minimal	Minimal
VREC	2	M	L	L	M	H	H	L	L	M	VH	L	Moderate	Major	Low	Low

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

[2] The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low; N – Negligible.

Dieback, and particularly the introduction of exotic weeds and pathogens, present the greatest potential **indirect impacts**. **Prior to mitigation** these present a **major threat**. Rigorous application of stringent importing, quarantine, wash-down, disinfection and transport procedures, together with regular environmental monitoring, will greatly reduce this threat to a **low impact** significance.

11.3 Savanna

Unmitigated, **direct impacts** on savanna are predicted to be **low**, largely due to the small areas of savanna that overlap with the project footprint, all of which represents isolated and/or low density habitat that has already been subjected to a long history of disturbance. Adopting measures to mitigate habitat loss, pollution and erosion will reduce the impact of these processes to a **minimal** level.

Threats from **indirect impacts** follow those outlined for mangroves. **Prior to mitigation** these present a **major threat**. Rigorous application of stringent control and monitoring procedures is predicted to result in a **low impact** from indirect processes

11.4 Grassland

Unmitigated, both **direct and indirect impacts** are predicted to result in a **low** overall **impact** on the Study Area's disturbed and alien-rich grasslands. Grassland covers easily the greatest proportion of area (>85%) that will be lost to various site developments, so post-mitigation impacts will not be reduced below this already acceptable level. However, adopting recommendations designed to tackle indirect impacts, particularly the introduction of exotic weeds and pathogens, is predicted to result in **minimal impact** from indirect processes.

11.5 Open Woodland

Unmitigated, **direct impacts** on open woodland are predicted to be **low**, largely due to the small areas of habitat that overlap with the project footprint. Adopting measures to mitigate habitat loss, pollution and erosion will reduce the impact of these processes to a **minimal** level.

The greatest potential **indirect impact** will result from the introduction of exotic weeds and pathogens. **Prior to mitigation** these present a **moderate threat**. Rigorous application of stringent control and monitoring procedures, together with measures designed to minimise the risk of fire, dieback and harvesting of plant material, is predicted to result in **minimal impact** from indirect processes.

11.6 Gallery Forest

Gallery forest is particularly susceptible to processes impacting on waterways as it typically occurs in areas sheltered from drought and fire, such as along rivers and streams. Although no Gallery forest will be lost to clearing for development of the LNG Plant or associated facilities/infrastructure, this habitat may be **impacted directly** by processes including changes to hydrology and release of contaminants into the Vaihua River. In general, these processes are expected to result in short-term and localised impacts. Since areas of Gallery forest observed on site were more than 250 m downstream from the site where Lea Lea Road crosses the Vaihua River, these impacts are predicted to represent a medium level impact on this habitat type, and a **low impact significance prior to mitigation**. Impact is expected to be **minimal after mitigation**.

Indirect impacts present the most serious potential problem. As with other habitats, the greatest potential impact will result from the introduction of exotic weeds and pathogens. Gallery forest is already degraded due to the presence of environmental weeds. Nevertheless, other invasive flora and introduced pathogens may lead to **major impact prior to mitigation**, particularly through introduction of. The rigorous adoption of mitigation procedures will significantly reduce the potential for contamination and result in a **minimal impact significance**.

11.7 Special Area – The Vaihua River Ecosystem Complex

The VREC potentially faces a **moderately significant impact** from unmitigated **direct impact** processes. Major processes include changes to hydrology and pollution that threaten the mangrove and wetland habitats which comprise 61.4% of the VREC area **(Table 6)**. Adopting standard and stringent controls on materials and waste handling, storage and disposal will significantly reduce the risk of contamination to the VREC's constituent habitats. Moderating offshore sediment build up to maintain tidal and freshwater flows through the VREC, along with concerted efforts to maintain substrate topography and integrity, will help maintain current hydrology patterns and significantly reduce these impacts. Combined with recommendations for reducing loss of wetland habitat associated with developments within the LNG Facilities site (see 11.1), these mitigations are expected to reduce the impact from direct processes to a **low** level.

Threats from **indirect impacts** follow those outlined for mangroves and savanna. **Prior to mitigation** these present a **major threat** to the high value VREC. Rigorous application of stringent control and monitoring procedures will significantly reduce the likelihood of introducing exotic weeds and pathogens. The potential for mangrove dieback may be reduced through measures designed to tackle direct impacts (see 10.12). Taken together, these mitigations are expected to result in a **low impact** from indirect processes.

12. SIGNIFICANCE OF IMPACTS ON LISTED SPECIES

The significance of direct and indirect impacts on sensitive taxa before and after mitigation is shown in **Table 12**.

Species discussed below include those IUCN-listed (Threatened, Near Threatened or Data Deficient) or nationally protected (P) species already recorded **(Appendix 1)** or that may occur **(Appendix 2 and 3)** at the Study Area. Restricted trade species (R) are not discussed, though impacts on these species before and after mitigation are also shown in Appendix 6. Accounts include current knowledge on habitat requirements, status and distribution, and likely impacts on populations associated with development of the LNG Plant and associated infrastructure.

12.1 Plants

The **Sandalwood** (*Santalum macgregorii*) **(EN)** is a parasitic or semi-parasitic species found in open savanna vegetation and in savanna gully forest. As with all other sources of sandalwood, this species is overexploited for its scented wood, which is used for incense, perfume, essential oil and carving. In PNG the exploitation began at the turn of the last century and few mature trees or virgin stands remain. This species has not been seen in the Moresby area since the 1970s (Takeuchi 2005) and is probably locally extinct, especially in light of the population pressures now present throughout the district. **Direct impacts** are expected to be low prior to mitigation, given the restricted amounts of savanna that will be cleared, and **minimal** following mitigation.

If Sandalwood persists at the Study Area, then **indirect impacts** from the introduction of exotic weeds and pathogens and/or collection of plant materials by staff and contractors may be **very high**, potentially threatening the persistence of this species within the local region. **After mitigation** these impacts are expected to be **low**.

Table 12 **Impact analysis for conservation listed terrestrial flora and fauna. The value of individual taxa follows the system outlined in Table 3: 1 – Very High Value; 2 – High Value; 3 – Moderate Value; 4 – Low Value. The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low**

Scientific Name	Common Name	Value	Direct Impacts						Indirect Impacts			Impact Significance Before Mitigation		Impact Significance After Mitigation	
			Habitat Loss	Barrier & Edge Effects	Pollution	Disturbance	Traffic	Loss of Display Area	Fire	Exotic Fauna, Weeds & Pathogens	Hunting/ Flora Collection	Direct	Indirect	Direct	Indirect
Plants															
Santalum macgregorii	Sandalwood	2	L						L	VH	VH	Low	Major	Minimal	Low
Mammals															
Peroryctes broadbenti	Giant Bandicoot	3	L				L		L	M	M	Low	Low	Low	Minimal
Planigale novaeguineae	New Guinean Planigale	2	L		L	L	L		L	H	L	Low	Moderate	Low	Minimal
Rattus sordidus	Canefield Rat	3	M		L		L		L	M		Low	Low	Low	Minimal
Dobsonia minor	Lesser Bare-backed Fruit-bat	3							L		M	Minimal	Low	Minimal	Minimal
Nyctimene aello	Greater Tube-nosed Bat	3							L			Minimal	Low	Minimal	Minimal
Nyctimene draconilla	Lesser Tube-nosed Bat	2							L			Minimal	Low	Minimal	Minimal
Paranyctimene raptor	Unstriped Tube-nosed Bat	3							L			Minimal	Low	Minimal	Minimal

Table 12 Impact analysis for conservation listed terrestrial flora and fauna. The value of individual taxa follows the system outlined in Table 3: 1 – Very High Value; 2 – High Value; 3 – Moderate Value; 4 – Low Value. The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low (cont'd)

Scientific Name	Common Name	Value	Direct Impacts						Indirect Impacts			Impact Significance Before Mitigation		Impact Significance After Mitigation	
			Habitat Loss	Barrier & Edge Effects	Pollution	Disturbance	Traffic	Loss of Display Area	Fire	Exotic Fauna, Weeds & Pathogens	Hunting/ Flora Collection	Direct	Indirect	Direct	Indirect
Mammals (cont'd)															
Emballonura dianae	Large-eared Sheathtail-bat	2	L						L			Low	Low	Minimal	Minimal
Emballonura furax	New Guinea Sheathtail-bat	2	L						L			Low	Low	Minimal	Minimal
Emballonura raffrayana	Raffray's Sheathtail-bat	3	L						L			Low	Low	Minimal	Minimal
Taphozous australis	Southern Sheathtail-bat	3	L						L			Low	Low	Minimal	Minimal
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	3	L			L			L			Low	Low	Minimal	Minimal
Saccolaimus mixtus	Troughton's Sheathtail-bat	2	L			L			L			Low	Low	Minimal	Minimal
Hipposideros muscinus	Fly River Horseshoe-bat	2	L						L			Low	Low	Minimal	Minimal
Hipposideros wollastoni	Wollaston's Horseshoe-bat	3	L						L			Low	Low	Minimal	Minimal

Table 12 **Impact analysis for conservation listed terrestrial flora and fauna. The value of individual taxa follows the system outlined in Table 3: 1 – Very High Value; 2 – High Value; 3 – Moderate Value; 4 – Low Value. The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low (cont'd)**

Scientific Name	Common Name	Value	Direct Impacts						Indirect Impacts			Impact Significance Before Mitigation		Impact Significance After Mitigation	
			Habitat Loss	Barrier & Edge Effects	Pollution	Disturbance	Traffic	Loss of Display Area	Fire	Exotic Fauna, Weeds & Pathogens	Hunting/ Flora Collection	Direct	Indirect	Direct	Indirect
Mammals (cont'd)															
Rhinolophus philippinensis	Large-eared Horseshoe-bat	3	L						L			Low	Low	Minimal	Minimal
Nyctophilus timoriensis	Greater Long-eared Bat	2	L			L			L			Low	Low	Minimal	Minimal
Pharotis imogene	New Guinea Big-eared Bat	1	H			L			L			Major	Moderate	Low	Minimal
Pipistrellus papuanus	Papuan Pipistrelle	3	L			L			L			Low	Low	Minimal	Minimal
Pipistrellus wattsi	Watt's Pipistrelle	3	L			L			L			Low	Low	Minimal	Minimal
Otomops papuensis	Big-eared Mastiff-bat	2	L			L			L			Low	Low	Minimal	Minimal
Birds															
Limosa limosa	Black-tailed Godwit	3	L		M	M					L	Low	Low	Low	Minimal
Numenius minutus	Little Curlew	4	L			L					L	Low	Low	Minimal	Minimal
Limnodromus semipalmatus	Asian Dowitcher	3	L		M	M					L	Low	Low	Low	Minimal
Esacus giganteus	Beach Thick-knee	3	L		M	M					M	Low	Low	Minimal	Minimal

Table 12 Impact analysis for conservation listed terrestrial flora and fauna. The value of individual taxa follows the system outlined in Table 3: 1 – Very High Value; 2 – High Value; 3 – Moderate Value; 4 – Low Value. The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low (cont'd)

Scientific Name	Common Name	Value	Direct Impacts						Indirect Impacts			Impact Significance Before Mitigation		Impact Significance After Mitigation	
			Habitat Loss	Barrier & Edge Effects	Pollution	Disturbance	Traffic	Loss of Display Area	Fire	Exotic Fauna, Weeds & Pathogens	Hunting/ Flora Collection	Direct	Indirect	Direct	Indirect
Birds (cont'd)															
Pandion haliaetus	Osprey*	3			M	L					M	Low	Low	Minimal	Minimal
Haliaeetus leucogaster	White-bellied Fish-Eagle	4	L		M	L					M	Low	Low	Minimal	Minimal
Circus approximans	Swamp Harrier	4	L			L	L				L	Low	Low	Low	Minimal
Circus spilothorax	Papuan Marsh-Harrier*	4	L			L	L				L	Low	Low	Low	Minimal
Falco cenchroides	Australian Kestrel	4	L			L	L				L	Low	Low	Low	Minimal
Falco berigora	Brown Falcon*	4	L			L	L				L	Low	Low	Low	Minimal
Falco severus	Oriental Hobby	4	L			L	L				L	Low	Low	Low	Minimal
Falco longipennis	Australian Hobby	4	L			L	L				L	Low	Low	Low	Minimal
Falco peregrinus	Peregrine Falcon	4	L			L	L				L	Low	Low	Low	Minimal
Egretta garzetta	Little Egret*	3	L		M	M	L				L	Low	Low	Low	Minimal
Ardea alba	Great Egret*	3	L		M	M	L				L	Low	Low	Low	Minimal
Mesophoyx intermedia	Intermediate Egret*	3	L		M	M	L				L	Low	Low	Low	Minimal
Ephippiorhynchus asiaticus	Black-necked Stork	3	L		M	M					M	Low	Low	Minimal	Minimal

Table 12 Impact analysis for conservation listed terrestrial flora and fauna. The value of individual taxa follows the system outlined in Table 3: 1 – Very High Value; 2 – High Value; 3 – Moderate Value; 4 – Low Value. The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low (cont'd)

Scientific Name	Common Name	Value	Direct Impacts						Indirect Impacts			Impact Significance Before Mitigation		Impact Significance After Mitigation	
			Habitat Loss	Barrier & Edge Effects	Pollution	Disturbance	Traffic	Loss of Display Area	Fire	Exotic Fauna, Weeds & Pathogens	Hunting/ Flora Collection	Direct	Indirect	Direct	Indirect
Birds (cont'd)															
Pseudobulweria rostrata	Tahiti Petrel	3			L							Low	Minimal	Minimal	Minimal
Puffinus heinrothi	Heinroth's Shearwater	2			L							Low	Minimal	Minimal	Minimal
Manucodia atra	Glossy-mantled Manucode	3	L			L	L	L	L		M	Low	Low	Minimal	Minimal
Manucodia keraudrenii	Trumpet Manucode	3				L	L	L	L		M	Low	Low	Minimal	Minimal
Ptiloris magnificus	Magnificent Riflebird	3				L	L	L	L		M	Low	Low	Minimal	Minimal
Cicinnurus regius	King Bird-of-paradise	3				L	L	L	L		M	Low	Low	Minimal	Minimal
Paradisaea raggiana	Raggiana Bird-of-paradise	3	L			L	L	L	L		M	Low	Low	Minimal	Minimal
Reptiles															
Crocodylus porosus	Estuarine Crocodile	4	L		L	L					L	Low	Low	Minimal	Minimal
Varanus indicus	Mangrove Monitor	4	M	M	H	L					L	Low	Low	Minimal	Minimal

Table 12 **Impact analysis for conservation listed terrestrial flora and fauna. The value of individual taxa follows the system outlined in Table 3: 1 – Very High Value; 2 – High Value; 3 – Moderate Value; 4 – Low Value. The magnitude of direct and indirect impacts follows the system outlined in Table 4: VH – Very High; H – High; M – Medium; L – Low (cont'd)**

Scientific Name	Common Name	Value	Direct Impacts						Indirect Impacts			Impact Significance Before Mitigation		Impact Significance After Mitigation	
			Habitat Loss	Barrier & Edge Effects	Pollution	Disturbance	Traffic	Loss of Display Area	Fire	Exotic Fauna, Weeds & Pathogens	Hunting/ Flora Collection	Direct	Indirect	Direct	Indirect
Reptiles (cont'd)															
Varanus prasinus	Emerald Monitor	4	M	M	H	L			L		L	Low	Low	Minimal	Minimal
Candioa aspera	Ground boa	4				L			L		L	Low	Low	Minimal	Minimal
Morelia viridis	Green tree python	4				L			L		L	Low	Low	Minimal	Minimal
Apodora papuana	Papuan python	4	L			L	L		L		L	Low	Low	Low	Minimal
Morelia amethistina	Amethystine python	4	L			L	L		L		L	Low	Low	Low	Minimal

12.2 Mammals

The **Giant Bandicoot (DD)** is a poorly known species recorded only in the lowlands of PNG, including the Port Moresby area. This largest of all bandicoots is targeted by hunters, and no recent records exist from the area (Flannery 1995). The specific habitat requirements of this species are poorly known, though it is highly unlikely to be present at the Study Area due to the high level of hunting pressure imposed by local residents from Boera and Papa. **Direct and indirect impacts** on this species are likely to be **low** before mitigation, given the suite of disturbance factors that already faces this mid-sized terrestrial mammal on site (fire, hunting, pastoral practices, dogs, etc.). Impacts will be **low to minimal after mitigation**.

The **New Guinea Planigale (VU)** is known from a handful of specimens centred on two localities, both in southern PNG. Along with three individuals taken from the southern Trans-Fly, most specimens (>25) are known from the Port Moresby area, including Waigani Swamp 16 km west of the capital and close to the Study Area. Little is known of the ecological requirements of this species, other than it has sometimes been found in rock-strewn areas and is somewhat tolerant of human-modified habitats; the specimen from Waigani Swamp was found among coral boulders that had been transported to an abandoned war-time airfield (Flannery 1995). It is possible that this species persists at the Study Area. Suitable habitat may occur among the savanna-covered hills in the block's south and east, and among the low, north-south oriented rocky ridges that line the broadest areas of saltpans, wetlands and mangroves in the southeast of the VREC **(Figure 10)**.

Unmitigated, additional pressures stemming from project developments may result in a **moderate indirect impact** on any present populations. Relevant impacts include the potential introduction of exotic flora and fauna, particularly an increase in numbers of domestic or feral cats in the area. **After mitigation** direct and indirect impacts are expected to be **low to minimal**.

The **Canefield Rat (NT)** occurs in savanna grassland in New Guinea and northern Australia, where it is a major pest in sugarcane plantations (Flannery 1995). There are numerous records from the Port Moresby area and it is likely to occur in suitable habitat at the Study Area. Project infrastructure will result in the conversion of suitable habitat in the block's northwest. However, if present the species will persist in large areas of suitable habitat present throughout the remainder of the block. **Overall impact** on local and regional populations will be **low before mitigation**. **Indirect impacts** may be reduced to **minimal** levels if recommendations for preventing fires and introduction of exotic fauna (e.g. cats) are adopted.

The **New Guinea Big-eared Bat (CR)** is a member of the long-eared bat group. These bats generally forage by gleaning prey from substrates such as bark or leaves, and for this purpose they have short and broad wings that allow slow and manouverable flight. Very little is known about the biology and ecology of *P. imogene*. Prior assessments of its conservation status include Flannery (1995) who considered that it was "probably extinct" and Bonaccorso (1998) who believed that "the species probably still exists". However, given that the species has not been recorded for more than 108 years it seems most likely that this species is extinct. A more thorough history of our knowledge of this species was prepared by Dr G. C. Richards for a previous project and is repeated here in **Appendix 5**.

As doubtful as it may be, if *P. imogene* was present on-site then it would reside in the savanna and woodland areas of the Study Area. Although minimal areas of woodland and savanna are set to be cleared for developments at the LNG Facilities site and associated linear infrastructure, the

loss of individual trees containing colonies of this very rare species may result in a **major direct impact** on regional and national populations. Direct impacts should be **low if mitigations** set out in section 10.17.3 **are followed**.

Indirect impacts are predicted to be **minimal** if recommendations for preventing fires are adopted.

Watt's Pipistrelle (NT) is known only from south-eastern PNG. At the Study Area it is likely to favour mangroves as foraging habitat, though it has also been recorded roosting in houses and feeding around villages (Flannery 1995). With the jetty set to displace over 100 m width of mangroves some foraging habitat for this species, if present, is likely to be lost. However, the overall impact will be mitigated by the likely presence of this species (a) in other woodland habitats and (b) in other, larger areas of mangroves north of the Study Area around Galley Reach. **Direct impacts** on this species are expected to be **low before mitigation**. Although some mangroves will be lost to construction of the causeway, there exists the potential for the project to improve remaining mangrove habitat by enclosing some areas within the security fence, thereby reducing disturbance from the collection of firewood and other resources by local residents. Assuming present hydrology patterns within mangroves are maintained, improving remaining mangrove habitat may counter habitat loss and result in a **minimal direct impact**. **Indirect impacts** are predicted to be **minimal** if recommendations for preventing fires are adopted.

Troughton's Sheathtail-bat (VU), Yellow-bellied Sheathtail-bat (NT), Greater Long-eared Bat (VU) and the **Big-eared Mastiff-bat (VU)** are all species that may occur in the savanna and woodland areas on site. Little or no impact is expected upon foraging habitat and if the tree clearance protocol suggested above for *P. imogene* is followed, then **minimal impact** would occur to colonies in tree roosts. **Indirect impacts** are predicted to be **minimal** if recommendations for preventing fires are adopted.

The **Papuan Pipistrelle (NT)** is tolerant of modified habitats and is often very common in villages where it may roost and forage. It almost always roosts in hollows in coconut palms. Open woodland areas are likely to provide suitable foraging habitat at the Study Area. Development of the LNG Plant is likely to impart little or no measurable impact on local populations given the abundance of suitable habitats in the immediate vicinity. If the tree clearance protocol suggested above for *P. imogene* is followed, then **minimal impact** would occur to colonies in tree roosts. **Indirect impacts** are predicted to be **minimal** if recommendations for preventing fires are adopted.

The remaining 11 bat species listed in Appendix 6 may occur at the Study Area only if cave roosts or suitable rainforest foraging habitat are present. Neither of these critical habitat requirements has yet been identified on site.

Although the four rainforest foraging species − **Lesser Bare-backed Fruit-bat (NT), Greater Tube-nosed Bat (NT), Lesser Tube-nosed Bat (VU), Unstriped Tube-nosed Bat (NT)** – may occasionally occur in gallery forest, no gallery forest will be cleared for development and post-mitigation impacts on this habitat are set to be minimal **(Table 11)**. If other mitigations are followed **overall impacts** are expected to be **minimal**.

Seven IUCN-listed species may occur if cave roosts are present in the Study Area: **Large-eared Sheathtail-bat (VU), New Guinea Sheathtail-bat (VU), Raffray's Sheathtail-bat (NT), Southern Sheathtail-bat (NT), Fly River Horseshoe-bat (VU), Wollaston's Horseshoe-bat**

(NT) and **Large-eared Horseshoe-bat (NT)**. No caves are believed to occur in areas earmarked for construction and operation of the LNG Plant and associated infrastructure, and if measures are taken to minimise threats from fire then the overall disturbance on these species will be **minimal**.

12.3 Birds

The **Osprey (P)** is a specialist piscivore with a global distribution. It is widely though sparsely distributed around New Guinea's coastlines where it mostly frequents marine coastal waters (Coates 1985). This species was listed as "very uncommon" in the Port Moresby area by Mackay (1970) with pairs known only from the Kapakapa and Bootless Bay areas to the east. During our survey a single Osprey was observed hunting in the shallow waters at and around the mouth of the Vaihua River. This site may provide regular feeding grounds for this and other individuals. Direct impacts through pollution, disturbance and reduction in quality of feeding habitat in the vicinity of the causeway and mouth of the Vaihua River represent the greatest threats to this species. These impacts will be localised and may reduce the quality of overall feeding territories or result in the death of some individuals through poisoning. Mitigating release of contaminants and maintaining current hydrology patterns will help reduce **direct impacts** to a **minimal** level. Prohibiting hunting by staff and contractors will result in **minimal indirect impacts**.

The **Great, Intermediate and Little Egrets (P)** are all protected under the PNG Fauna Act. All three species are commonly observed in wetlands in the Port Moresby area (Mackay 1970), though their populations are also augmented by non-breeding visitors from Australia (Coates 1985). All three species were recorded in the wetlands near the LNG Facilities site during our survey, with the Great and Intermediate Egrets being most common. Though some egrets are present in PNG all year round, the breeding status of each species is poorly understood; it is unknown whether the Study Area supports breeding birds.

Pollution and disturbance present the greatest potential threats to these and other waterbirds. Disturbance from construction will be short-term, and mitigating release of contaminants and maintaining current hydrology patterns will keep **direct impacts** to a **low** level. Prohibiting hunting by staff and contractors will result in **minimal indirect impacts**.

Along with the wide variety of migratory shorebirds already recorded at the site, the **Black-tailed Godwit (NT)** and **Asian Dowitcher (NT)** may also utilise wetland habitats near the LNG Facilities site. Both species breed in Siberia, Mongolia and northern China, with populations travelling along the East Asian Australasian Flyway through Southeast Asia to Australia (Geering *et al*. 2007). Both are found most commonly along coastal mudflats, and both have been recorded in wetlands of the Port Moresby area (Mackay 1970; Coates 1985).

Threats from **direct and indirect impacts** follow those outlined for egrets. **Prior to mitigation** these present a **low threat**. Rigorous application of stringent control and monitoring procedures is predicted to result in a **low to minimal impacts**.

The **Beach Thick-knee (NT)** is a widely though sparsely distributed shorebird of sandy beaches, tidal mudflats, reefs and mangroves. It nests on sandy beaches where it is susceptible to disturbance and egg harvesters. It is rarely recorded in the Port Moresby area (Mackay 1970; Coates 1985) and although the Study Area provides some suitable coastal foraging habitat for this species the small and frequently disturbed beach is unlikely to be suitable for breeding.

Pollution, disturbance and hunting may impact on any birds present. Disturbance from construction will be short-term, and mitigating release of contaminants, maintaining current hydrology patterns and prohibiting hunting by staff and contractors will result in **minimal impacts**.

The **Black-necked Stork (NT)** 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 also an unconfirmed record of large storks seen in the Port Moresby area (Mackay 1970; Coates 1985). This species is highly unlikely to rely on habitat at the Study Area. **After mitigation**, **impacts** on any visiting birds will be **minimal**.

The **Tahiti Petrel (NT)** and **Heinroth's Shearwater (VU)** are pelagic, ocean-going seabirds. Neither is believed to breed on the main island of New Guinea or its satellite islands. There appear to be no significant seabird colonies in the area although terns likely nest on Idihi island. The Tahiti Petrel is occasionally recorded in waters off New Guinea's south coast, including near Port Moresby (Coates 1985), and both are capable of long distance movements and may occur near the Study Area from time to time. The project will not noticeably impact upon these species.

All birds-of-paradise are protected under the PNG Fauna Act. The Study Area lies within the range of five species that utilise habitat found on the site. The **Glossy-mantled Manucode** inhabits a variety of non-rainforest habitats, including gallery forest in savanna, heavy savanna and mangroves (Coates 1990; Frith and Beehler 1998), including in the Port Moresby area (Mackay 1970). This is perhaps the most likely bird-of-paradise to occur on site. Clearance of mangroves may result in the loss of some suitable habitat. However, the potential for improvement to remaining mangrove habitat may reduce or negate this effect.

Though less common, the **Trumpet Manucode** is also known from gallery forest running through savanna in the Port Moresby area (Mackay 1970) and may therefore occur at the Study Area. The **Magnificent Riflebird, King** and **Raggiana Birds-of-paradise** are typically rainforest species though they are moderately tolerant of habitat disturbance and may be found in forest edge, secondary growth and occasionally other forest habitats. The Magnificent Riflebird and King Bird-of-paradise have sometimes been recorded in gallery forest (Coates 1990; Frith and Beehler 1998), while the Raggiana Bird has been seen in savanna between rainforest patches in the Port Moresby district (Mackay 1970). These species are more likely to be targeted by local hunters than either of the manucodes, and they are less tolerant of the habitat found at the Study Area, particularly given the isolated nature of the marginally suitable habitats found there. Their presence at the Study Area can not be ruled out, though the area is unlikely to support permanent populations.

Impacts on all birds-of-paradise are expected to be **low prior to mitigation**, and **minimal after** mitigation, particularly by reducing risks from hunting, fire, disturbance and collisions with traffic.

12.4 Reptiles and Amphibians

No IUCN-listed or nationally protected (P) terrestrial reptiles or amphibians have been recorded or are likely to occur at the Study Area.

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Appendices

APPENDIX 1

Vertebrate taxa recorded at the Terrestrial Biodiversity Study Area in April 2008, their residency/migratory status (Res), endemism (End), conservation status and recorded habitat. Conservation status indicates those birds protected (P) or trade restricted (R) under the PNG Fauna Act (PNG). No IUCN-listed species were recorded. Species are listed as endemic to the main island of New Guinea +/- satellite islands (NG) or as non-native species introduced to PNG (Intr.). Birds are defined as breeding residents (BR), migrants (M) or breeding residents with populations seasonally augmented by non-breeding visitors (BR+M). Habitats in which species were recorded include savanna (Sv), gallery forest (GF), open woodland (OW), grassland (G), rivers, wetlands and mud flats (W), mangroves (Mv) and oceans and coastal marine habitats (OC). Three mammal species were not recorded directly but indicated as present by local residents during village interviews (Vi).

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**End**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Mammals												
MACROPODIDAE	*Macropus agilis*	Agile Wallaby				X						
PHALANGERIDAE	*Phalanger intercastellanus*	Southern Common Cuscus					Vi					
MURIDAE	*Melomys lutillus*	Grassland Melomys							X			
MURIDAE	*Rattus leucopus*	Cape York Rat				Vi	Vi					
MURIDAE	*Rattus rattus*	Black, Ship, Roof Rat		Intr.					Vi			
MURIDAE	*Mus musculus*	House Mouse		Intr.					X			
Reptiles												
AGAMIDAE	*Lophognathus temporalis*	Ta-ta Lizard				X		X	X			
SCINCIDAE	*Carlia bicarinata*					X		X	X	X		
SCINCIDAE	*Cryptoblepharus yulensis*							X		X		
SCINCIDAE	*Sphenomorphus fragilis*					X						
GEKKONIDAE	*Hemidactylus frenatus*	Asian House Gecko				X						
GEKKONIDAE	*Nactus sp cf pelagicus*	Pelagic Gecko				X						
ACROCHORDIDAE	*Acrochordus granulatus*	Little Filesnake									X	

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**End**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Reptiles (cont'd)												
ELAPIDAE	*Demansia vestigiata*	Lesser Black Whipsnake				X			X			
PYTHONIDAE	*Morelia spilota*	Carpet python							X			
Amphibians												
HYLIDAE	*Litoria caerulea*	Green Tree Frog						X				
HYLIDAE	*Litoria infrafrenata*	White-lipped Tree Frog							X			
BUFONIDAE	*Bufo marinus*	Cane Toad		Intr.		X		X	X	X		
Birds												
PHASIANIDAE	*Coturnix ypsilophora*	Brown Quail	BR						X			
ANATIDAE	*Tadorna radjah*	Radjah Shelduck	BR							X		
ANATIDAE	*Anas superciliosa*	Pacific Black Duck	BR+M							X		
ANATIDAE	*Anas gracilis*	Grey Teal	BR+M							X		
TURNICIDAE	*Turnix maculosa*	Red-backed Buttonquail	BR						X			
DACELONIDAE	*Dacelo leachii*	Blue-winged Kookaburra	BR			X		X	X		X	
DACELONIDAE	*Todirhamphus macleayii*	Forest Kingfisher	BR+M			X						
DACELONIDAE	*Todirhamphus sanctus*	Sacred Kingfisher	M			X		X			X	
MEROPIDAE	*Merops ornatus*	Rainbow Bee-eater	BR+M			X		X	X		X	
CUCULIDAE	*Cacomantis variolosus*	Brush Cuckoo	BR+M			X	X					
CENTROPODIDAE	*Centropus phasianinus*	Pheasant Coucal	BR			X		X				
PSITTACIDAE	*Trichoglossus haematodus*	Rainbow Lorikeet	BR			X		X			X	
PSITTACIDAE	*Geoffroyus geoffroyi*	Red-cheeked Parrot	BR				X					
APODIDAE	*Aerodramus vanikorensis*	Uniform Swiftlet	BR						X			
COLUMBIDAE	*Chalcophaps indica*	Emerald Dove	BR				X				X	
COLUMBIDAE	*Geopelia striata*	Zebra Dove	BR			X	X	X			X	

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**End**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont')												
COLUMBIDAE	*Geopelia humeralis*	Bar-shouldered Dove	BR					X			X	
SCOLOPACIDAE	*Numenius phaeopus*	Whimbrel	M							X	X	
SCOLOPACIDAE	*Numenius madagascariensis*	Far Eastern Curlew	M							X	X	
SCOLOPACIDAE	*Tringa nebularia*	Common Greenshank	M							X		
SCOLOPACIDAE	*Heteroscelus brevipes*	Grey-tailed Tattler	M								?	
SCOLOPACIDAE	*Calidris ruficollis*	Red-necked Stint	M							X		
SCOLOPACIDAE	*Calidris acuminata*	Sharp-tailed Sandpiper	M							X		
CHARADRIIDAE	*Pluvialis fulva*	Pacific Golden-Plover	M								X	
CHARADRIIDAE	*Pluvialis squatarola*	Grey Plover	M							X		
CHARADRIIDAE	*Charadrius mongolus*	Mongolian Plover	M							X		
CHARADRIIDAE	*Charadrius leschenaultii*	Greater Sand Plover	M							X		
CHARADRIIDAE	*Vanellus miles*	Masked Lapwing	BR+M							X		
LARIDAE	*Gelochelidon nilotica*	Gull-billed Tern	M							X		
LARIDAE	*Sterna bergii*	Great Crested-Tern	BR									X
LARIDAE	*Sterna hirundo*	Common Tern	M									X
LARIDAE	*Sterna albifrons*	Little Tern	M									X
LARIDAE	*Anous stolidus*	Brown Noddy	BR									X
ACCIPITRIDAE	*Pandion haliaetus*	Osprey	BR		P							X
ACCIPITRIDAE	*Haliastur sphenurus*	Whistling Kite	BR			X		X	X			
ACCIPITRIDAE	*Haliastur indus*	Brahminy Kite	BR				X				X	
ACCIPITRIDAE	*Circus spilothorax*	Papuan Marsh-Harrier	BR	NG?	R				X			
ACCIPITRIDAE	*Accipiter fasciatus*	Brown Goshawk	BR			X			X			
FALCONIDAE	*Falco berigora*	Brown Falcon	BR		R			X	X			

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**End**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont')												
PHALACROCORACIDAE	*Phalacrocorax sulcirostris*	Little Black Cormorant	BR+M							X		
ARDEIDAE	*Egretta garzetta*	Little Egret	BR?+M		P					X		
ARDEIDAE	*Egretta sacra*	Pacific Reef-Egret	BR								X	X
ARDEIDAE	*Ardea alba*	Great Egret	BR+M		P					X		
ARDEIDAE	*Mesophoyx intermedia*	Intermediate Egret	BR?+M		P					X		X
THRESKIORNITHIDAE	*Threskiornis molucca*	Australian Ibis	BR?+M							X		
FREGATIDAE	*Fregata ariel*	Lesser Frigatebird	M									X
PTILONORHYNCHIDAE	*Chlamydera cerviniventris*	Fawn-breasted Bowerbird	BR			X						
MALURIDAE	*Malurus alboscapulatus*	White-shouldered Fairywren	BR	NG				X				
MELIPHAGIDAE	*Lichenostomus flavescens*	Yellow-tinted Honeyeater	BR			X		X				
MELIPHAGIDAE	*Philemon novaeguineae*	New Guinea Friarbird	BR			X	X				X	
MELIPHAGIDAE	*Conopophila albogularis*	Rufous-banded Honeyeater	BR			X		X				
PETROICIDAE	*Eopsaltria pulverulenta*	Mangrove Robin	BR								X	
CORVIDAE	*Colluricincla harmonica*	Grey Shrike-thrush	BR			X						
CORVIDAE	*Corvus orru*	Torresian Crow	BR			X	X	X	X		X	
CORVIDAE	*Cracticus mentalis*	Black-backed Butcherbird	BR			X		X				
CORVIDAE	*Artamus leucorynchus*	White-breasted Woodswallow	BR			X		X	X			
CORVIDAE	*Oriolus szalayi*	Brown Oriole	BR	NG			X					
CORVIDAE	*Coracina novaehollandiae*	Black-faced Cuckooshrike	BR+M			X	X	X			X	
CORVIDAE	*Coracina papuensis*	White-bellied Cuckooshrike	BR			X		X			X	
CORVIDAE	*Coracina tenuirostris*	Slender-billed Cicadabird	BR+M				X					
CORVIDAE	*Lalage tricolor*	White-winged Triller	BR+M			X		X				
CORVIDAE	*Rhipidura leucophrys*	Willie-wagtail	BR			X	X	X			X	

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**End**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont')												
MUSCICAPIDAE	*Saxicola caprata*	Pied Bushchat	BR					X				
HIRUNDINIDAE	*Hirundo tahitica*	Pacific Swallow	BR			X		X	X		X	
HIRUNDINIDAE	*Hirundo nigricans*	Tree Martin	M					X	X			
CISTICOLIDAE	*Cisticola exilis*	Golden-headed Cisticola	BR					X	X			
ALAUDIDAE	*Mirafra javanica*	Australasian Lark	BR						X			
NECTARINIIDAE	*Nectarinia jugularis*	Olive-backed Sunbird	BR					X			X	
PASSERIDAE	*Lonchura caniceps*	Grey-headed Munia	BR					X				
PASSERIDAE	*Lonchura castaneothorax*	Chestnut-breasted Munia	BR					X				

APPENDIX 2

Species possibly occurring but not yet recorded in the Terrestrial Biodiversity Study Area, their conservation status, residency/migratory status (Res) and habitat preference (Hab). Conservation status indicates species listed by the IUCN as globally Threatened (CR – Critically Endangered; VU – Vulnerable), Near Threatened (NT) OR Data Deficient (DD) and those birds protected (P) or trade restricted (R) under the PNG Fauna Act (PNG). Birds are defined as breeding residents (BR; BRis = island breeding seabirds), migrants (M) or breeding residents with populations seasonally augmented by non-breeding visitors (BR+M). Habitat preferences include savanna (Sv), gallery forest (GF), open woodland (OW), grassland (G), rivers, wetlands and mud flats (W), mangroves (Mv) and oceans and coastal marine habitats (OC).

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Non-volant mammals												
PERORYCTIDAE	*Peroryctes broadbenti*	Giant Bandicoot		DD	R		X					
DASYURIDAE	*Planigale novaeguineae*	New Guinean Planigale		VU	R	X		X				
MURIDAE	*Melomys leucogaster*	White-bellied Melomys				X	X	X			X	
MURIDAE	*Melomys rufescens*	Black-tailed Melomys						X	X			
MURIDAE	*Rattus exulans*	Pacific Rat				X	X	X	X			
MURIDAE	*Rattus mordax*	Eastern Rat				X	X	X	X			
MURIDAE	*Rattus sordidus*	Canefield Rat		NT		X			X			
MURIDAE	*Uromys caudimaculatus*	Mottled-tailed Giant-rat				X	X	X	X			
Bats												
PTEROPODIDAE	*Macroglossus minimus*	Northern Blossom-bat									X	
PTEROPODIDAE	*Pteropus alecto*	Black Flying-fox				X	X	X				
PTEROPODIDAE	*Pteropus hypomelanus*	Variable Flying-fox				X	X	X				
PTEROPODIDAE	*Pteropus macrotis*	Big-eared Flying-fox				X	X	X				
PTEROPODIDAE	*Pteropus scapulatus*	Little Red Flying-fox				X	X	X				

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Bats (cont'd)												
PTEROPODIDAE	*Syconycteris australis*	Common Blossom-bat									X	
EMBALLONURIDAE	*Saccolaimus flaviventris*	Yellow-bellied Sheathtail-bat		NT		X	X	X				
EMBALLONURIDAE	*Saccolaimus mixtus*	Troughton's Sheathtail-bat		VU		X	X	X				
EMBALLONURIDAE	*Saccolaimus saccolaimus*	Naked-rumped Sheathtail-bat				X	X	X				
VESPERTILIONIDAE	*Chalinolobus nigrogriseus*	Hoary Bat				X	X	X				
VESPERTILIONIDAE	*Nyctophilus bifax*	North Queensland Nyctophilus				X	X	X				
VESPERTILIONIDAE	*Nyctophilus microtis*	Small-eared Nyctophilus				X	X	X				
VESPERTILIONIDAE	*Nyctophilus timoriensis*	Greater Long-eared Bat		VU		X	X	X				
VESPERTILIONIDAE	*Pharotis imogene*	New Guinea Big-eared Bat		CR		X	X	X				
VESPERTILIONIDAE	*Philetor brachypterus*	Rohu's Bat				X	X	X				
VESPERTILIONIDAE	*Pipistrellus angulatus*	New Guinea Pipistrelle									X	
VESPERTILIONIDAE	*Pipistrellus papuanus*	Papuan Pipistrelle		NT		X	X	X				
VESPERTILIONIDAE	*Pipistrellus wattsi*	Watt's Pipistrelle		NT		X	X	X			X	
VESPERTILIONIDAE	*Scotorepens sanborni*	Little Northern Broad-nosed Bat									X	
MOLOSSIDAE	*Chaerephon jobensis*	Northern Mastiff-bat							X			
MOLOSSIDAE	*Mormopterus beccarii*	Beccari's Mastiff-bat							X			
MOLOSSIDAE	*Mormopterus loriae*	Little Northern Mastiff-bat									X	
MOLOSSIDAE	*Otomops papuensis*	Big-eared Mastiff-bat		VU		X	X	X				

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Reptiles												
CROCODYLIDAE	*Crocodylus porosus*	Estuarine Crocodile			R						X	X
VARANIDAE	*Varanus indicus*	Mangrove Monitor			R						X	
VARANIDAE	*Varanus prasinus*	Emerald Monitor			R		X				X	
ELAPIDAE	*Oxyuranus scutellatus canni*	Taipan				X	X	X	X	X		
ELAPIDAE	*Pseudechis papuanus*	Papuan Black Snake				X	X	X	X	X		
COLUBRIDAE	*Fordonia leucobalia*	White-bellied Mangrove Snake									X	
COLUBRIDAE	*Myron richardsoni*	Richardson's Mangrove Snake									X	
PYTHONIDAE	*Candioa aspera*	Ground boa			R		X					
PYTHONIDAE	*Morelia viridis*	Green tree python			R		X					
PYTHONIDAE	*Apodora papuana*	Papuan python			R	X	X	X		X		
PYTHONIDAE	*Morelia amethistina*	Amethystine python			R	X	X	X		X		
PYTHONIDAE	*Leiopython albertisii*	White-lipped Python					X			X		
Birds												
PHASIANIDAE	*Coturnix chinensis*	Blue-breasted Quail	BR					X	X			
DENDROCYGNIDAE	*Dendrocygna guttata*	Spotted Whistling-Duck	BR							X		
DENDROCYGNIDAE	*Dendrocygna arcuata*	Wandering Whistling-Duck	BR+M							X		
ANATIDAE	*Nettapus pulchellus*	Green Pygmy-goose	BR							X		
ANATIDAE	*Aythya australis*	Hardhead	BR?							X		
CORACIIDAE	*Eurystomus orientalis*	Dollarbird	BR+M			X	X	X			X	
ALCEDINIDAE	*Alcedo atthis*	Common Kingfisher	BR							X		

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
ALCEDINIDAE	*Alcedo azurea*	Azure Kingfisher	BR							X		
ALCEDINIDAE	*Alcedo pusilla*	Little Kingfisher	BR							X		
ALCEDINIDAE	*Ceyx lepidus*	Variable Kingfisher	BR							X		
DACELONIDAE	*Dacelo gaudichaud*	Rufous-bellied Kookaburra	BR				X					
DACELONIDAE	*Todirhamphus chloris*	Collared Kingfisher	BR								X	
DACELONIDAE	*Melidora macrorrhina*	Hook-billed Kingfisher	BR				X					
DACELONIDAE	*Syma torotoro*	Yellow-billed Kingfisher	BR				X					
DACELONIDAE	*Tanysiptera sylvia*	Buff-breasted Paradise-Kingfisher	M				X					
CUCULIDAE	*Cuculus saturatus/optatus*	Oriental/Himalayan Cuckoo	M			X	X	X				
CUCULIDAE	*Cacomantis castaneiventris*	Chestnut-breasted Cuckoo	BR				X					
CUCULIDAE	*Chrysococcyx russatus*	Gould's Bronze-Cuckoo	M?				X				X	
CUCULIDAE	*Chrysococcyx lucidus*	Shining Bronze-Cuckoo	M			X	X	X			X	
CUCULIDAE	*Eudynamys scolopacea*	Asian Koel	BR			X	X	X				
CUCULIDAE	*Scythrops novaehollandiae*	Channel-billed Cuckoo	M			X	X	X				
CENTROPODIDAE	*Centropus menbeki*	Greater Black Coucal	BR				X					
PSITTACIDAE	*Chalcopsitta sintillata*	Yellow-streaked Lory	BR			X	X	X			X	
PSITTACIDAE	*Pseudeos fuscata*	Dusky Lory	BR			X	X	X				
PSITTACIDAE	*Charmosyna placentis*	Red-flanked Lorikeet	BR			X	X	X				
PSITTACIDAE	*Cyclopsitta gulielmitertii*	Orange-breasted Fig-Parrot	BR			X	X	X				

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
PSITTACIDAE	*Cyclopsitta diophthalma*	Double-eyed Fig-Parrot	BR				X	X				
APODIDAE	*Collocalia esculenta*	Glossy Swiftlet	BR			X	X	X				
APODIDAE	*Hirundapus caudacutus*	White-throated Needletail	M			X	X	X	X	X	X	
HEMIPROCNIDAE	*Hemiprocne mystacea*	Moustached Treeswift	BR			X	X	X				
TYTONIDAE	*Tyto alba*	Barn Owl	BR			X	X	X				
STRIGIDAE	*Ninox connivens*	Barking Owl	BR			X	X	X				
STRIGIDAE	*Ninox theomacha*	Jungle Hawk-Owl	BR			X	X	X				
AEGOTHELIDAE	*Aegotheles cristatus*	Australian Owlet-Nightjar	BR			X	X	X				
AEGOTHELIDAE	*Aegotheles bennettii*	Barred Owlet-Nightjar	BR				X					
PODARGIDAE	*Podargus papuensis*	Papuan Frogmouth	BR			X	X	X				
PODARGIDAE	*Podargus ocellatus*	Marbled Frogmouth	BR				X	X				
EUROSTOPODIDAE	*Eurostopodus mystacalis*	White-throated Eared-Nightjar	M			X	X	X	X			
EUROSTOPODIDAE	*Eurostopodus papuensis*	Papuan Eared-Nightjar	BR				X					
CAPRIMULGIDAE	*Caprimulgus macrurus*	Large-tailed Nightjar	BR			X	X	X	X			
COLUMBIDAE	*Columba livia*	Rock Pigeon	BR					X	X	X		
COLUMBIDAE	*Macropygia amboinensis*	Slender-billed Cuckoo-Dove	BR				X	X				
COLUMBIDAE	*Macropygia nigrirostris*	Black-billed Cuckoo-Dove	BR				X	X				
COLUMBIDAE	*Reinwardtoena reinwardtsi*	Great Cuckoo-Dove	BR				X	X				
COLUMBIDAE	*Ptilinopus magnificus*	Wompoo Fruit-Dove	BR				X					
COLUMBIDAE	*Ptilinopus perlatus*	Pink-spotted Fruit-Dove	BR				X					

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
COLUMBIDAE	*Ptilinopus aurantiifrons*	Orange-fronted Fruit-Dove	BR			X	X	X			X	
COLUMBIDAE	*Ptilinopus superbus*	Superb Fruit-Dove	BR				X					
COLUMBIDAE	*Ptilinopus coronulatus*	Coroneted Fruit-Dove	BR				X	X				
COLUMBIDAE	*Ptilinopus iozonus*	Orange-bellied Fruit-Dove	BR			X	X	X			X	
COLUMBIDAE	*Ptilinopus naina*	Dwarf Fruit-Dove	BR				X					
COLUMBIDAE	*Ducula spilorrhoa*	Torresian Imperial-Pigeon	BR+ M			X	X	X			X	
RALLIDAE	*Gallirallus philippensis*	Buff-banded Rail	BR						X	X	X	
RALLIDAE	*Amaurornis moluccana*	Rufous-tailed Waterhen	BR				x		X	X	X	
RALLIDAE	*Porzana pusilla*	Baillon's Crake	BR						X	X	X	
RALLIDAE	*Porzana tabuensis*	Spotless Crake	BR						X	X	X	
RALLIDAE	*Porzana cinerea*	White-browed Crake	BR						X	X	X	
RALLIDAE	*Porphyrio porphyrio*	Purple Swamphen	BR						X	X	X	
RALLIDAE	*Gallinula tenebrosa*	Dusky Moorhen	BR							X		
SCOLOPACIDAE	*Gallinago hardwickii*	Latham's Snipe	M						X	X		
SCOLOPACIDAE	*Gallinago megala*	Swinhoe's Snipe	M						X	X		
SCOLOPACIDAE	*Limosa limosa*	Black-tailed Godwit	M	NT						X	X	X
SCOLOPACIDAE	*Limosa lapponica*	Bar-tailed Godwit	M							X	X	X
SCOLOPACIDAE	*Numenius minutus*	Little Curlew	M		R				X			
SCOLOPACIDAE	*Tringa stagnatilis*	Marsh Sandpiper	M							X	X	
SCOLOPACIDAE	*Tringa glareola*	Wood Sandpiper	M						X	X	X	
SCOLOPACIDAE	*Xenus cinereus*	Terek Sandpiper	M							X	X	x

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
SCOLOPACIDAE	*Actitis hypoleucos*	Common Sandpiper	M						X	X	X	x
SCOLOPACIDAE	*Heteroscelus incanus*	Wandering Tattler	M							X	X	x
SCOLOPACIDAE	*Arenaria interpres*	Ruddy Turnstone	M							X		x
SCOLOPACIDAE	*Limnodromus semipalmatus*	Asian Dowitcher	M	NT						X	X	x
SCOLOPACIDAE	*Calidris tenuirostris*	Great Knot	M							X	X	x
SCOLOPACIDAE	*Calidris canutus*	Red Knot	M							X	X	x
SCOLOPACIDAE	*Calidris melanotos*	Pectoral Sandpiper	M							X	X	x
SCOLOPACIDAE	*Calidris ferruginea*	Curlew Sandpiper	M							X	X	x
SCOLOPACIDAE	*Limicola falcinellus*	Broad-billed Sandpiper	M							X	X	x
JACANIDAE	*Irediparra gallinacea*	Comb-crested Jacana	BR							X		
BURHINIDAE	*Esacus giganteus*	Beach Thick-knee	BR	NT								X
CHARADRIIDAE	*Himantopus leucocephalus*	White-headed Stilt	BR							X		
CHARADRIIDAE	*Charadrius dubius*	Little Ringed Plover	BR						X	X		
CHARADRIIDAE	*Charadrius veredus*	Oriental Plover	M						X	X		
CHARADRIIDAE	*Erythrogonys cinctus*	Red-kneed Dotterel	BR?							X		
GLAREOLIDAE	*Glareola maldivarum*	Oriental Pratincole	M						X	X		
GLAREOLIDAE	*Stiltia isabella*	Australian Pratincole	BR?+ M						X	X		
LARIDAE	*Sterna caspia*	Caspian Tern	M							X		X
LARIDAE	*Sterna bengalensis*	Lesser Crested-Tern	BR+ M?									X
LARIDAE	*Sterna dougallii*	Roseate Tern	BRis									X

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
LARIDAE	*Sterna sumatrana*	Black-naped Tern	BRis									X
LARIDAE	*Sterna anaethetus*	Bridled Tern	BRis									X
LARIDAE	*Sterna fuscata*	Sooty Tern	BRis									X
LARIDAE	*Chlidonias hybridus*	Whiskered Tern	M							X		
LARIDAE	*Chlidonias leucopterus*	White-winged Tern	M							X		
LARIDAE	*Anous minutus*	Black Noddy	BRis									X
ACCIPTRIDAE	*Aviceda subcristata*	Pacific Baza	BR			X	X	X			X	
ACCIPTRIDAE	*Elanus axillaris*	Black-shouldered Kite	BR			X		X	X			
ACCIPTRIDAE	*Milvus migrans*	Black Kite	BR			X	X	X	X	X	X	
ACCIPTRIDAE	*Haliaeetus leucogaster*	White-bellied Fish-Eagle	BR		R					X		X
ACCIPTRIDAE	*Circus approximans*	Swamp Harrier	M?		R	X		X	X	X	X	
ACCIPTRIDAE	*Accipiter novaehollandiae*	Grey Goshawk	BR			X	X	X				
ACCIPTRIDAE	*Accipiter poliocephalus*	Grey-headed Goshawk	BR			X	X	X				
ACCIPTRIDAE	*Accipiter cirrocephalus*	Collared Sparrowhawk	BR			X	X	X			X	
ACCIPTRIDAE	*Hieraaetus morphnoides*	Little Eagle	BR			X	X	X	X	X	X	
FALCONIDAE	*Falco cenchroides*	Australian Kestrel	BR+ M		R	X		X	X	X		
FALCONIDAE	*Falco severus*	Oriental Hobby	BR		R	X	X	X	X	X		
FALCONIDAE	*Falco longipennis*	Australian Hobby	M		R	X	X	X	X	X		
FALCONIDAE	*Falco peregrinus*	Peregrine Falcon	BR		R	X	X	X	X	X		X
PODICIPEDIDAE	*Tachybaptus novaehollandiae*	Australasian Grebe	BR							X		

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
SULIDAE	*Sula sula*	Red-footed Booby	M									X
SULIDAE	*Sula leucogaster*	Brown Booby	M									X
ANHINGIDAE	*Anhinga novaehollandiae*	Australian Darter	BR+ M							X		X
PHALACROCORACIDAE	*Phalacrocorax melanoleucos*	Little Pied Cormorant	BR+ M							X		X
ARDEIDAE	*Egretta novaehollandiae*	White-faced Heron	BR+ M						X	X	X	X
ARDEIDAE	*Ardea sumatrana*	Great-billed Heron	BR								X	
ARDEIDAE	*Ardea picata*	Pied Heron	BR?							X	X	
ARDEIDAE	*Butorides striata*	Striated Heron	BR				X			X	X	
ARDEIDAE	*Nycticorax caledonicus*	Rufous Night-Heron	BR+ M?				X			X	X	
ARDEIDAE	*Dupetor flavicollis*	Black Bittern	BR				X			X		
THRESKIORNITHIDAE	*Plegadis falcinellus*	Glossy Ibis	BR?+ M							X		
THRESKIORNITHIDAE	*Threskiornis spinicollis*	Straw-necked Ibis	M						X	X		
THRESKIORNITHIDAE	*Platalea regia*	Royal Spoonbill	M							X		
CICONIIDAE	*Ephippiorhynchus asiaticus*	Black-necked Stork	BR	NT						X		X
FREGATIDAE	*Fregata minor*	Great Frigatebird	M									X
PROCELLARIIDAE	*Macronectes giganteus*	Antarctic Giant-Petrel	M									X
PROCELLARIIDAE	*Pseudobulweria rostrata*	Tahiti Petrel	M	NT								X
PROCELLARIIDAE	*Pachyptila turtur*	Fairy Prion	M									X
PROCELLARIIDAE	*Calonectris leucomelas*	Streaked Shearwater	M									X

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
PROCELLARIIDAE	*Puffinus pacificus*	Wedge-tailed Shearwater	M									X
PROCELLARIIDAE	*Puffinus carneipes*	Flesh-footed Shearwater	M									X
PROCELLARIIDAE	*Puffinus tenuirostris*	Short-tailed Shearwater	M									X
PROCELLARIIDAE	*Puffinus heinrothi*	Heinroth's Shearwater	M	VU								X
PROCELLARIIDAE	*Oceanites oceanicus*	Wilson's Storm-Petrel	M									X
PROCELLARIIDAE	*Fregetta grallaria*	White-bellied Storm-Petrel	M									X
PITTIDAE	*Pitta sordida*	Hooded Pitta	BR				X					
PITTIDAE	*Pitta erythrogaster*	Red-bellied Pitta	BR				X					
MELIPHAGIDAE	*Myzomela obscura*	Dusky Myzomela	BR			X	X	X			X	
MELIPHAGIDAE	*Myzomela erythrocephala*	Red-headed Myzomela	BR								X	
MELIPHAGIDAE	*Melilestes megarhynchus*	Long-billed Honeyeater	BR				X	X				
MELIPHAGIDAE	*Glycichaera fallax*	Green-backed Honeyeater	BR				X					
MELIPHAGIDAE	*Lichmera alboauricularis*	Silver-eared Honeyeater	BR			X	X	X				
MELIPHAGIDAE	*Meliphaga albonotata*	Scrub Honeyeater	BR			X	X	X				
MELIPHAGIDAE	*Meliphaga aruensis*	Puff-backed Honeyeater	BR				X					
MELIPHAGIDAE	*Meliphaga analoga*	Mimic Honeyeater	BR				X	X				
MELIPHAGIDAE	*Meliphaga gracilis*	Graceful Honeyeater	BR			X	X	X			X	
MELIPHAGIDAE	*Meliphaga flavirictus*	Yellow-gaped Honeyeater	BR				X					

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
MELIPHAGIDAE	*Lichenostomus versicolor*	Varied Honeyeater	BR				X	X			X	
MELIPHAGIDAE	*Xanthotis flaviventer*	Tawny-breasted Honeyeater	BR				X	X				
MELIPHAGIDAE	*Xanthotis polygramma*	Spotted Honeyeater	BR			X	X	X				
MELIPHAGIDAE	*Melithreptus albogularis*	White-throated Honeyeater	BR			X						
MELIPHAGIDAE	*Pycnopygius stictocephalus*	Streak-headed Honeyeater	BR				X	X				
MELIPHAGIDAE	*Ramsayornis modestus*	Brown-backed Honeyeater	BR			X	X	X			X	
PARDALOTIDAE	*Gerygone olivacea*	White-throated Gerygone	BR			X		X				
PARDALOTIDAE	*Gerygone chrysogaster*	Yellow-bellied Gerygone	BR				X	X				
PARDALOTIDAE	*Gerygone magnirostris*	Large-billed Gerygone	BR				X	X			X	
PARDALOTIDAE	*Gerygone levigaster*	Mangrove Gerygone	BR								X	
PETROICIDAE	*Microeca fascinans*	Jacky-winter	BR			X		X				
PETROICIDAE	*Microeca flavigaster*	Lemon-bellied Flyrobin	BR			X		X			X	
CORVIDAE	*Pachycephala simplex*	Grey Whistler	BR				X	X			X	
CORVIDAE	*Pachycephala melanura*	Black-tailed Whistler	BR								X	
CORVIDAE	*Pachycephala leucogastra*	White-bellied Whistler	BR			X		X			X	
CORVIDAE	*Colluricincla megarhyncha*	Little Shrike-thrush	BR				X	X				
CORVIDAE	*Pitohui ferrugineus*	Rusty Pitohui	BR				X					

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
CORVIDAE	*Manucodia atra*	Glossy-mantled Manucode	BR		P	X	X				x	
CORVIDAE	*Manucodia keraudrenii*	Trumpet Manucode	BR		P		X					
CORVIDAE	*Ptiloris magnificus*	Magnificent Riflebird	BR		P		X					
CORVIDAE	*Cicinnurus regius*	King Bird-of-paradise	BR		P		X					
CORVIDAE	*Paradisaea raggiana*	Raggiana Bird-of-paradise	BR		P	X	X					
CORVIDAE	*Cracticus cassicus*	Hooded Butcherbird	BR				X					
CORVIDAE	*Cracticus quoyi*	Black Butcherbird	BR				X				X	
CORVIDAE	*Sphecotheres viridis*	Green Figbird	BR			X	X	X				
CORVIDAE	*Coracina boyeri*	Boyer's Cuckooshrike	BR				X					
CORVIDAE	*Coracina schisticeps*	Grey-headed Cuckooshrike	BR				X					
CORVIDAE	*Lalage leucomela*	Varied Triller	BR			X	X	X			X	
CORVIDAE	*Rhipidura rufiventris*	Northern Fantail	BR			X	X	X			X	
CORVIDAE	*Rhipidura leucothorax*	White-bellied Thicket-Fantail	BR				X				X	
CORVIDAE	*Rhipidura phasiana*	Mangrove Fantail	BR				X				X	
CORVIDAE	*Rhipidura rufifrons*	Rufous Fantail	BR+ M			X	X	X			X	
CORVIDAE	*Monarcha melanopsis*	Black-faced Monarch	M				X	X				
CORVIDAE	*Monarcha guttulus*	Spot-winged Monarch	BR				X					
CORVIDAE	*Myiagra rubecula*	Leaden Flycatcher	BR+ M			X	X	X			X	
CORVIDAE	*Myiagra ruficollis*	Broad-billed Flycatcher	BR								X	

Species			Status			Habitat						
Family	**Scientific Name**	**English Name**	**Res**	**IUCN**	**PNG**	**Sv**	**GF**	**OW**	**G**	**W**	**Mv**	**OC**
Birds (cont'd)												
CORVIDAE	*Myiagra cyanoleuca*	Satin Flycatcher	M			X	X	X				
CORVIDAE	*Myiagra alecto*	Shining Flycatcher	BR				X				X	
STURNIDAE	*Aplonis cantoroides*	Singing Starling	BR			X	X	X				
STURNIDAE	*Aplonis metallica*	Metallic Starling	BR+ M				X	X				
STURNIDAE	*Mino anais*	Golden Myna	BR				X	X				
STURNIDAE	*Mino dumontii*	Yellow-faced Myna	BR				X	X				
SYLVIIDAE	*Locustella fasciolata*	Gray's Grasshopper-Warbler	M					X				
SYLVIIDAE	*Acrocephalus arundinaceus*	Great Reed-Warbler	M						X	X		
SYLVIIDAE	*Acrocephalus stentoreus*	Clamorous Reed-Warbler	BR						X	X		
NECTARINIIDAE	*Dicaeum geelvinkianum*	Red-capped Flowerpecker	BR				X	X				
NECTARINIIDAE	*Nectarinia aspasia*	Black Sunbird	BR				X	X			X	
MELANOCHARITIDAE	*Toxorhamphus iliolophus*	Plumed Longbill	BR				X					
MELANOCHARITIDAE	*Oedistoma pygmaeum*	Pygmy Longbill	BR				X					
PASSERIDAE	*Passer domesticus*	House Sparrow	BR					X	X			
PASSERIDAE	*Lonchura tristissima*	Streak-headed Munia	BR					X				
PASSERIDAE	*Lonchura grandis*	Grand Munia	BR						X			

APPENDIX 3

Additional bat species not yet recorded but that may occur at the Terrestrial Biodiversity Study Area, their conservation status and critical habitat requirements. These species have been omitted from Appendix 2 as they require (a) caves for diurnal roost sites or (B) rainforest or its ecotones as primary foraging habitat that have not yet been identified at the site.

Family	Scientific Name	English Name	IUCN	Limiting Habitat
PTEROPODIDAE	*Dobsonia magna*	Great Bare-backed Fruit-bat		Rainforest foraging habitat
PTEROPODIDAE	*Dobsonia minor*	Lesser Bare-backed Fruit-bat	NT	Rainforest foraging habitat
PTEROPODIDAE	*Nyctimene aello*	Greater Tube-nosed Bat	NT	Rainforest foraging habitat
PTEROPODIDAE	*Nyctimene albiventer*	Common Tube-nosed Bat		Rainforest foraging habitat
PTEROPODIDAE	*Nyctimene cephalotes*	Pallas's Tube-nosed Bat		Rainforest foraging habitat
PTEROPODIDAE	*Nyctimene draconilla*	Lesser Tube-nosed Bat	VU	Rainforest foraging habitat
PTEROPODIDAE	*Paranyctimene raptor*	Unstriped Tube-nosed Bat	NT	Rainforest foraging habitat
PTEROPODIDAE	*Pteropus conspicillatus*	Spectacled Flying-fox		Rainforest foraging habitat
PTEROPODIDAE	*Rousettus amplexicaudatus*	Rousette Bat		Cave roosts
EMBALLONURIDAE	*Emballonura beccarii*	Beccari's Sheathtail-bat		Cave roosts
EMBALLONURIDAE	*Emballonura dianae*	Large-eared Sheathtail-bat	VU	Cave roosts
EMBALLONURIDAE	*Emballonura furax*	New Guinea Sheathtail-bat	VU	Cave roosts
EMBALLONURIDAE	*Emballonura raffrayana*	Raffray's Sheathtail-bat	NT	Cave roosts
EMBALLONURIDAE	*Mosia nigrescens*	Dark Sheathtail-bat		Cave roosts
EMBALLONURIDAE	*Taphozous australis*	Southern Sheathtail-bat	NT	Cave roosts
HIPPOSIDERIDAE	*Aselliscus tricuspidatus*	Trident Horseshoe-bat		Cave roosts
HIPPOSIDERIDAE	*Hipposideros ater*	Dusky Horseshoe-bat		Cave roosts
HIPPOSIDERIDAE	*Hipposideros calcaratus*	Spurred Horseshoe-bat		Cave roosts
HIPPOSIDERIDAE	*Hipposideros cervinus*	Fawn Horseshoe-bat		Cave roosts
HIPPOSIDERIDAE	*Hipposideros diadema*	Diadem Horseshoe-bat		Cave roosts

Family	Scientific Name	English Name	IUCN	Limiting Habitat
HIPPOSIDERIDAE	*Hipposideros maggietaylorae*	Maggie Taylor's Horseshoe-bat		Cave roosts
HIPPOSIDERIDAE	*Hipposideros muscinus*	Fly River Horseshoe-bat	VU	Cave roosts
HIPPOSIDERIDAE	*Hipposideros wollastoni*	Wollaston's Horseshoe-bat	NT	Cave roosts
RHINOLOPHIDAE	*Rhinolophus euryotis*	New Guinea Horseshoe-bat		Cave roosts
RHINOLOPHIDAE	*Rhinolophus megaphyllus*	Eastern Horseshoe-bat		Cave roosts
RHINOLOPHIDAE	*Rhinolophus philippinensis*	Large-eared Horseshoe-bat	NT	Cave roosts
VESPERTILIONIDAE	*Miniopterus australis*	Little Bentwing-bat		Cave roosts
VESPERTILIONIDAE	*Miniopterus macrocneme*	Small Melanesian Bentwing-bat		Cave roosts
VESPERTILIONIDAE	*Miniopterus magnater*	Western Bentwing-bat		Cave roosts
VESPERTILIONIDAE	*Miniopterus medius*	Javan Bentwing-bat		Cave roosts
VESPERTILIONIDAE	*Miniopterus propitristis*	Large Melanesian Bentwing-bat		Cave roosts
VESPERTILIONIDAE	*Miniopterus schreibersii*	Common Bentwing-bat		Cave roosts
VESPERTILIONIDAE	*Myotis moluccarum*	Northern Large-footed Myotis		Cave roosts

APPENDIX 4

Groupings of FIMS vegetation types occurring within the Local Contextual Region (LCR).

Broad Vegetation Group	Veg Type	Veg Type Description
Low altitude forest on uplands - below 1,000 m	Hm/Hs.f	Complex - Medium crowned forest/Small crowned forest - Flush of leaves or flowers noted.
	Hs	Small crowned forest
	Hs.f/Hm	Complex - Small crowned forest - Flush of leaves or flowers noted/Medium crowned forest
	Hs/Sa	Complex - Small crowned forest/Savanna
Low altitude forest on plains and fans - below 1,000 m	Po	Open forest
	Po/G	Complex - Open forest/Grassland
Swamp forest	Fsw/Wsw	Complex - Mixed swamp forest/Swamp woodland
Savanna	Sa	Savanna
	Sa/G	Complex - Savanna/Grassland
	Saf/W	Complex - Savanna with gallery forest/Woodland
Woodland	W	Woodland
	W/Sa	Complex - Woodland/Savanna
	W/Saf	Complex - Woodland/Savanna with gallery forest
	Wsw	Swamp woodland
	Wsw/G	Complex - Swamp woodland/Grassland
	Wsw/Gsw	Complex - Swamp woodland/Swamp grassland
Mangrove	M	Mangrove
Scrub	Sc	Scrub
Grassland and herbland	G	Grassland
	G/Sc	Complex - Grassland/Scrub
	Gsw	Swamp grassland
	Gsw/Wsw	Complex - Swamp grassland/Swamp woodland
	Hsw	Herbaceous swamp
Land use and other non-vegetation areas	O	Land use intensity class low to very high
	E	Lakes and larger rivers
	U	Larger urban centres

APPENDIX 5

History of the New Guinea Big-eared Bat (*Pharotis Imogene*) (from Richards 2005).

Very little is known about the biology and ecology of *P. imogene*. With regard to conservation status, prior assessments include Flannery (1995) who considered that it was "probably extinct" and Bonaccorso (1998) who believed that "the species probably still exists". In their 1994 assessment, the IUCN classified this bat as Critically Endangered. Revision of this status is current, but becomes obvious through the chequered history of specimens attributed to *P. imogene*, which is outlined as follows:

1890 A collection of 45 specimens was made by Dr Lamberto Loria at Kamali on the Lower Kemp Welch (Wanigela) River in Central Province, which was lodged in the Museo di Storia Naturale, Genoa. Flannery (1995) states that these specimens can no longer be traced in Genoa, but some can now be found in museums in London (n=3), New York (n=1), Copenhagen (n=1) and Sydney (n=1). Swapping of specimens between museums is part of their function, and has serendipitously preserved some of the original series.

Pre-1897 Bonaccorso (1998) stated that Thomas (1897) wrote about a specimen from Kapa Kapa that was collected by Dr Loria. This specimen was later lost due to flooding at the Museo di Storia Naturale (pers. comm. from Flannery to Bonaccorso, cited in Bonaccorso 1998).

1985 A specimen (PM 25374) attributed to *P. imogene* was collected by T. Anderson at Rogut Village, Tuman River, Central Province (Bonaccorso 1998) from the crown of a pandanus tree.

1988 The Rogut Village specimen was examined by Dr Harold Parnaby as part of his PhD revision of the genus *Nyctophilus*, and he confirmed that it instead represented *N. microdon* (H. Parnaby pers. comm. to IUCN).

1992 The PNG Museum catalogue shows an entry that declared the 1985 Rogut Village specimen as either lost or destroyed.

Having described *P. imogene* in 1914, Thomas would have doubtfully made an error in the identification of this species, so the pre-1897 Kapa Kapa specimen appears to be the last one collected and identified with any accuracy. With the 1985 specimen now discounted by a longeared bat expert as being a *Pharotis* but instead a *Nyctophilus*, and in view of *P. imogene* not being accurately recorded for more than 108 years, then the only available conclusion is that this species is extinct."

Plates

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Plate 1. Mangroves and sub-coastal wetlands/mud flats around the Vaihua River (Vaihua River Ecosystem Complex – VREC). The area of grassland behind the wetlands is the site proposed for development of the LNG Plant. (Photo by F. Crome)

Plate 2. Mangrove forest along the Vaihua River.

Plate 3. Coastal mangroves at the northern end of the Study Area.

Plate 4. Mangrove scrub on the eastern (inland) boundary of the VREC.

Plate 5. Mangroves and sub-coastal wetlands/mud flats, facing west towards the coast.

Plate 6. Sub-coastal wetlands at the northern end of the Study Area.

Plate 7. Freshwater wetlands at the eastern boundary of the VREC.

Plate 8. Freshwater wetlands at the eastern boundary of the VREC.

Plate 9. Sub-coastal wetlands/flats at the northern end of the Study Area (dry season). (Photo by F. Crome)

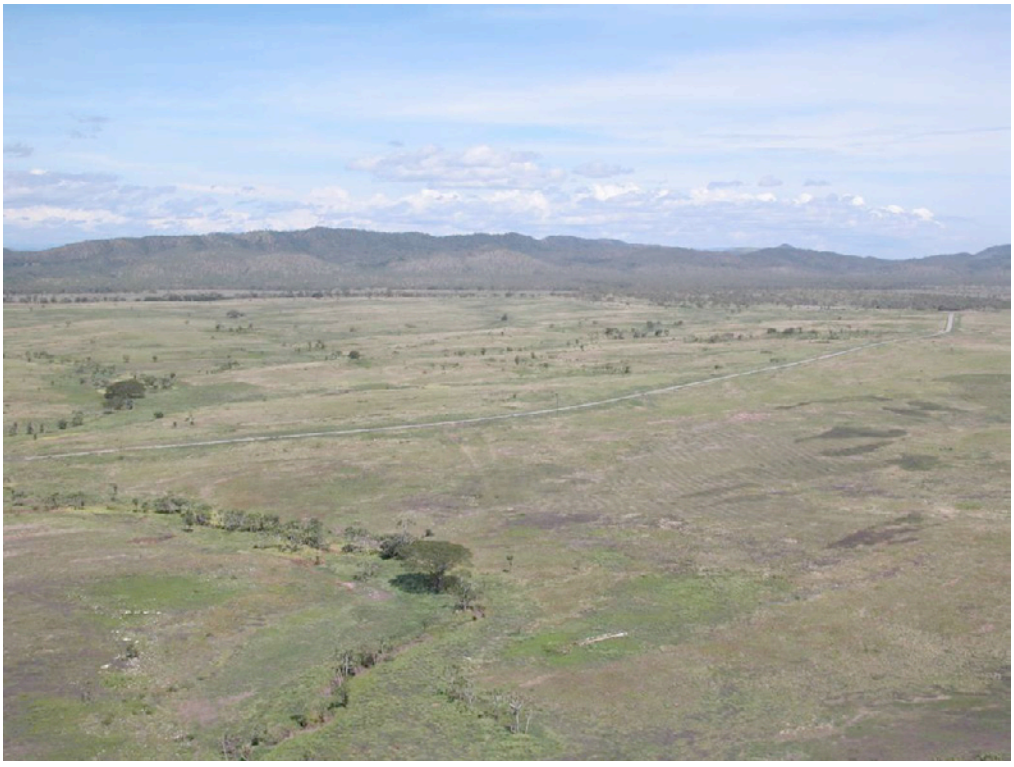

Plate 10. Grassland with streamside open woodland formations along Lea Lea Road. (Photo by F. Crome)

Plate 11. Grassland at the LNG Plant site. (Photo F. Crome)

Plate 12. Post-fire grassland regeneration. (Photo by F. Crome)

Plate 13. Grassland and open woodland extending east from Lea Lear Road.

Plate 14. Pandanus open woodland.

Plate 15. Open woodland with introduced Rain Trees (*Samanea saman*).

Plate 16. Open woodland on the edge of savanna.

Plate 17. Savanna on hills near Boera.

Plate 18. Savanna with cycad near the Vaihua River.

Plate 19. Savanna on alluvial flats near the Vaihua River.

Plate 20. Gallery forest on the Vaihua River.