Appendix 1 – Project Developments

1. Upstream Project Area

1.1 NEW UPSTREAM PROJECT FACILITIES

The new upstream facilities will include wellpad facilities at Hides, Angore and Juha; the Hides Gas Conditioning Plant; the Juha Production Facility and associated upstream infrastructure, and are designed to optimize development of the primary gas fields with proven technologies and demonstrated design concepts.

1.1.1 Development Drilling

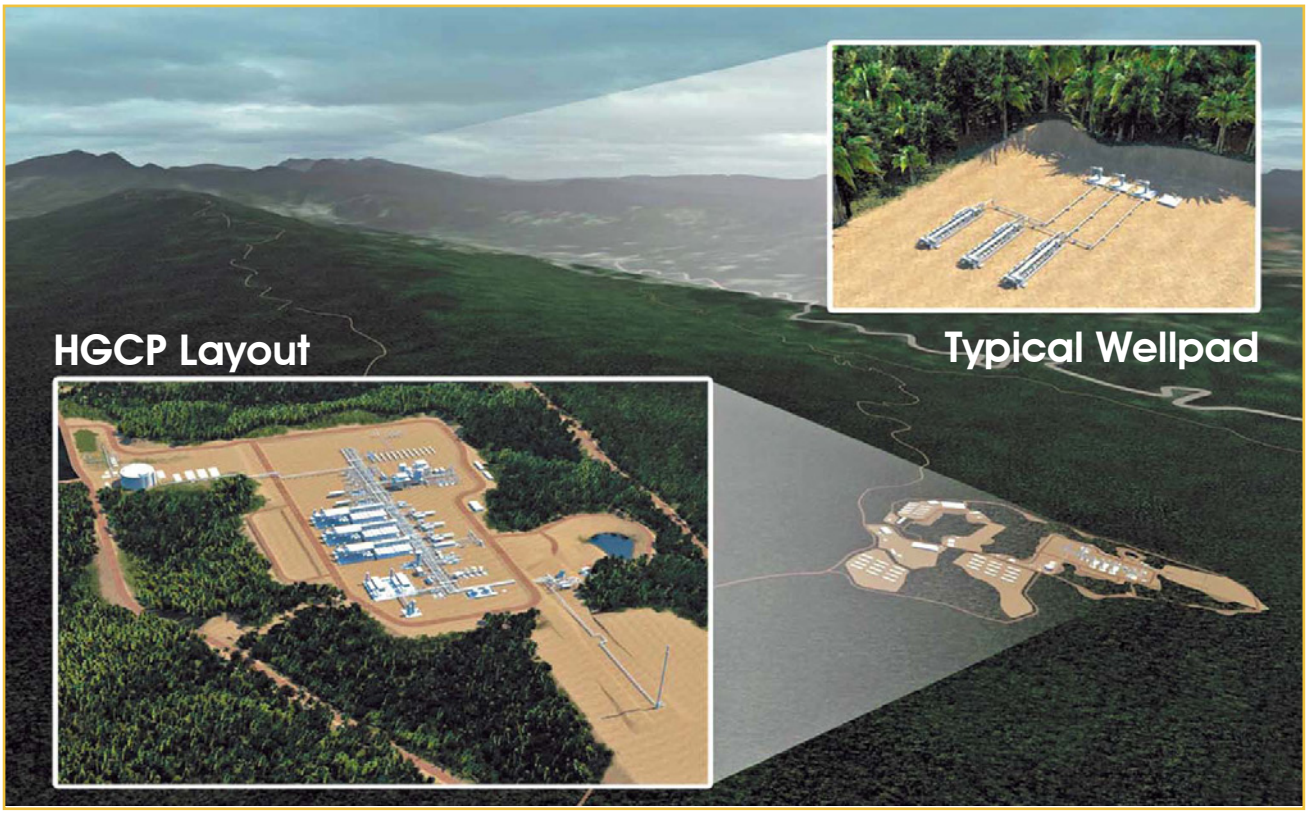
The drilling activity associated with the Project comprises a total of 14 new wells in the Hides (eight wells), Angore (two wells), and Juha (four wells) fields and re-completing two existing Hides Wells (Hides 1 and 4). Drilling activities will occur in a phased approach, with the Hides and Angore activities occurring under a combined Phases 1 and 2 Drilling Campaign, and the Juha activities under a subsequent Phase 3 Drilling Campaign.

Six of the eight Hides development wells comprising the Phases 1 and 2 Drilling Campaign are planned to be drilled directionally. The wellpads (some with multiple drills) will be customized for each location to provide a surface that allows safe and efficient drilling, workover and production operations while reducing the footprint and the amount of vegetation clearance required.

1.1.2 Hides Gas Conditioning Plant

The Hides Gas Conditioning Plant (Figure A1.1) will be located in the Southern Highlands Province at the southeast end of Hides Ridge near the village of Laite (1.5 kilometers from the existing Hides A Wellpad). The plant will include the processing facility, rotator housing community and industrial park.

Figure A1.1: Artist's impression of Hides Gas Conditioning Plant and typical wellpads



The Hides Gas Conditioning Plant will process gas and liquids from the Hides field and will be designed to stabilize condensate and gas. Process systems include slug handling, gas and liquid inlet separation, dewpoint conditioning, compression, produced water injection, condensate stabilization and condensate transfer system. The facility includes a number of supporting utility systems. A housing community will be developed, geographically separated from but within a shared security zone of the processing facility. An industrial park will be a separate security area adjacent to the processing facility and will provide the facilities necessary to support ongoing operations and maintenance. It will include a warehouse, chemical and hazardous materials storage shelter, outdoor storage yard, and maintenance workshop.

Monoethylene glycol (MEG) will be used to prevent the formation of hydrates in the well production tubing and in the surface wellstream collection pipelines. The MEG will be regenerated by removal of trapped water at the Hides Gas Conditioning Plant and recirculated to injection points as required.

Over time, as reservoir pressure in the gas field naturally declines, additional booster compression will need to be installed during Phase 3 of the Project to maintain production volumes. After the Juha Field is developed, its wellstream products will be transported to the Hides Gas Conditioning Plant after being separated into natural gas and liquids at the Juha Production Facility.

1.1.3 Juha Production Facility

The wellstream products from the Juha gathering system will be transported to the Juha Production Facility for gas and liquids separation prior to transportation to the Hides Gas Conditioning Plant for further liquid stabilization and gas treating/compression.

The Juha Production Facility will be installed approximately 60 kilometers northwest of the Hides Gas Conditioning Plant during Phase 4 of the Project and will provide 295 thousand standard cubic meters per hour (250 thousand standard cubic feet per day) separator gas to the Hides Gas Conditioning Plant inlet.

Other process systems and utilities at the Juha Production Facility will include power generation, MEG storage, a diesel system, open and closed drainage, a flare system and a water system.

1.1.4 Komo Airfield

A new government-certified international airfield is to be constructed at Komo in the Hides area, approximately 10 kilometers southeast of the Hides Gas Conditioning Plant. The Komo Airfield is required as part of the Project in order to enable the delivery of large, heavy and bulky plant and equipment to the Hides Gas Conditioning Plant in a timely, efficient and dependable manner. The airport is to be situated east of the existing Komo airstrip. It is designed for use by Dash 8 aircrafts and Antonov AN 124-100 aircraft with capability for heavy lift. The new Komo Airfield will comprise a 3,400-meter-long runway, navigation and landing aids, aircraft parking aprons, taxiway to runway, two helicopter pads, meteorological station, terminal building, hangar, freight and equipment storage area, fuel depot, fire station, boundary and security fencing, internal and external access roads, powerhouse/airfield lighting equipment room, entrance guard house and pump house.

1.1.5 Early Works Upstream Project Infrastructure

A program of infrastructure upgrades will be undertaken in advance of main construction activities in the Gulf Province and Southern Highlands Province. This program includes civil works at and in the areas of Hides and Kutubu and the upgrade or new construction of roads and bridges along two main logistics routes. The scope of this work, referred to as Upstream Infrastructure, is summarized below:

- Construction of approximately 30 kilometers of new road and upgrade of approximately 280 kilometers of existing road to enable vehicular access to upstream facilities and materials supply points.

- Upgrade or replacement of 20 to 30 bridges and construction of up to five new bridges to allow connection of existing and new roads.
- Construction of a new wharf at Kopi to serve as an Upstream Project Area supply point for the onshore portion of the LNG Project Gas Pipeline and oversized equipment needed for construction of Project facilities.
- Establishment of telecommunications to enable communication between facilities.
- Establishment of permanent waste disposal sites, including incinerators and landfill sites.
- Construction of the Hides Industrial Park to support ongoing operation and maintenance of the Hides Gas Conditioning Plant.
- Creation of contractor construction camps along the length of the onshore portion of the LNG Project Gas Pipeline and permanent operator camps at or near the Hides Gas Conditioning Plant and Juha Production Facility to house both operations staff and contractor personnel.
- Installation of new helipads at several locations for emergency medical evacuations.

Reliable transport routes are required during construction and operation of the Project. These logistical transportation corridors will comprise a combination of existing public roads, restricted access roadways and new Project roads. Key considerations in determining the routing of the Project roadways include environmental, social and safety issues, construction logistics, construction risks, earthworks and reducing pipeline length.

1.1.6 Onshore Pipelines

An extensive pipeline network will be constructed to transport gas from the individual wellpad facilities to the Hides Gas Conditioning Plant and on to the LNG Facilities site, and liquids from the Hides Gas Conditioning Plant to the Kutubu Central Processing Facility. The pipeline facilities will consist of an onshore pipeline network and an offshore pipeline (discussed below) with the interface between the two sections being located at the landfall of the offshore portion of the LNG Project Gas Pipeline at the Omati River. Approximately one-third of the onshore portion of the LNG Project Gas Pipeline will be constructed along the existing crude oil export pipeline corridor.

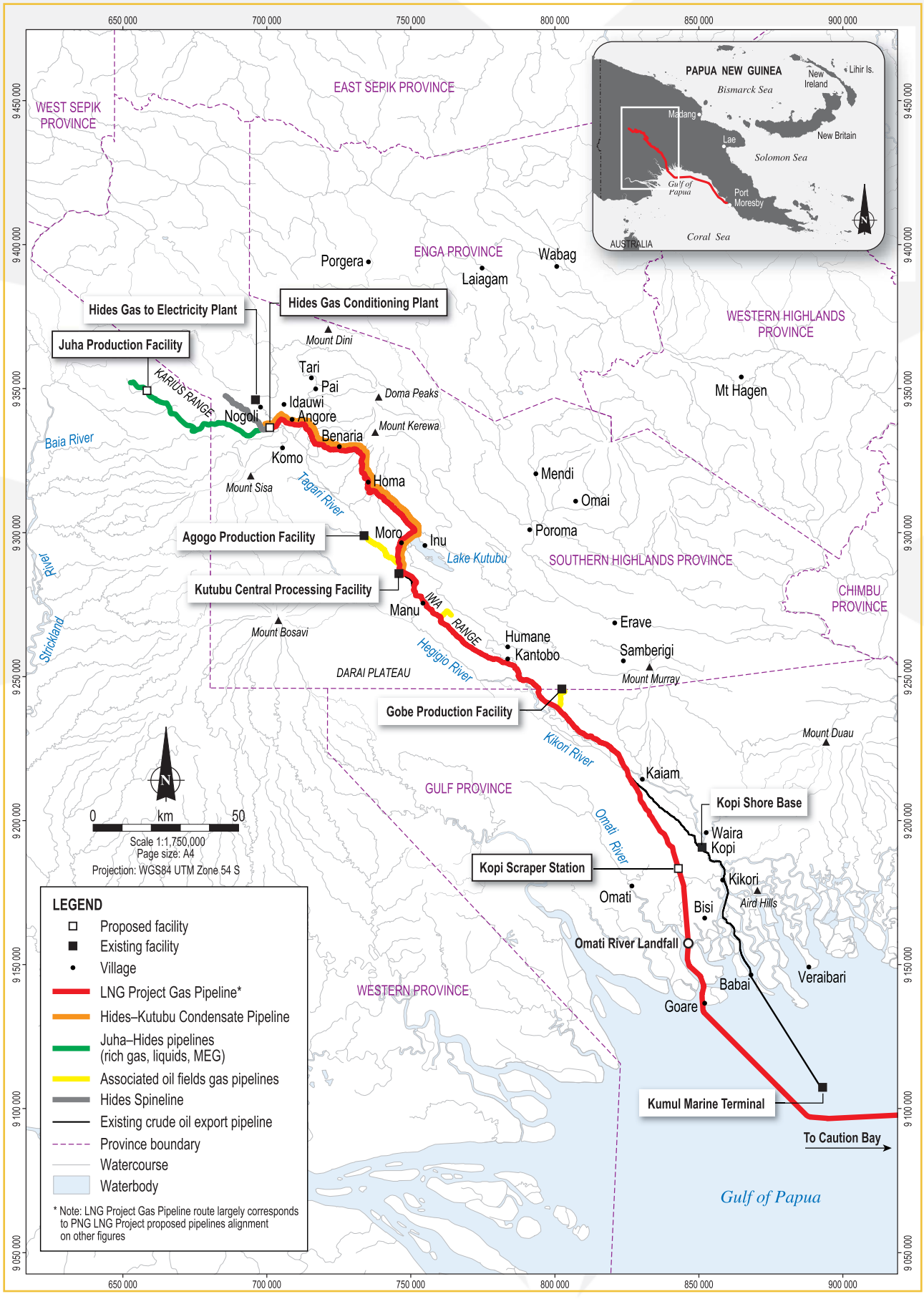
The onshore portion of the Project pipeline network will consist of:

- Approximately 284 kilometers of a 34-inch diameter gas pipeline – the onshore portion of the LNG Project Gas Pipeline – starting from the Hides Gas Conditioning Plant to landfall at the Omati River.
- Approximately 104 kilometers of an 8-inch diameter condensate pipeline running from the Hides Gas Conditioning Plant to the Kutubu Central Processing Facility.
- Approximately 266 kilometers of pipeline gathering systems for transportation of wellstream products from the Hides field and Angore field wellpad facilities to the Hides Gas Conditioning Plant, from the Juha field wellpad facilities to the Juha Production Facility and gas and liquids separated at the Juha Production Facility to the Hides Gas Conditioning Plant.
- Approximately 31 kilometers of 10-inch to 12-inch diameter associated gas tie-in from the existing oil fields.

Figure A1.2 sets out the route of the onshore portion of the Project pipeline network from the Hides Gas Conditioning Plant to the Omati River and the associated gas tie-ins.

The onshore pipeline system includes facilities such as pig launchers and receivers, main line valve stations, check valve stations and cathodic protection sites.

Figure A1.2: Upstream Project pipelines



1.2 UPGRADE OF EXISTING UPSTREAM PROJECT FACILITIES

The existing non-Project upstream facilities that will be utilized for the Project include the Kutubu Central Processing Facility, the Agogo Production Facility, the Gobe Production Facility, and the associated gas field wellpad facilities and the Kutubu crude oil export system. Several upgrades to these facilities will be required to enable integration with the Project and to extend the life of these existing facilities beyond their original design life to be consistent with the Project design life. These include upgrades to the field processing facilities to bring the associated gas within required specifications for transportation to and liquefaction at the LNG Facilities site.

1.2.1 Kutubu Central Processing Facility

The Kutubu Central Processing Facility will receive condensate extracted at the newly constructed Hides Gas Conditioning Plant and blend it with stabilized crude. The blended product will be pumped from storage tanks through the existing 260-kilometers-long, 20-inch-diameter crude oil export pipeline to the existing Kumul Marine Terminal in the Gulf of Papua.

Plate A1.1: Kutubu Central Processing Facility

The Kutubu Central Processing Facility was installed between 1990 and 1992 as part of the Oil Search-operated Kutubu Oil Project and has been producing oil for export since 1992.

As part of the development of the Project, new installations will be put in place to integrate the existing production facilities at the Kutubu Central Processing Facility with Project infrastructure. These include installation of gas metering, two enhanced dehydration and regeneration packages, battery limit valving, piping to the Project's gas metering station and modifications to the tank farm isolation and emergency shutdown systems to enhance the capacity to reliably import condensate from the Hides Gas Conditioning Plant. Modifications will also be made to the gas re-injection system.

Plate A1.2 : Agogo Production Facility

1.2.2 Agogo and Gobe Production Facilities

The Agogo Production Facility is located approximately 20 kilometers from the Kutubu Central Processing Facility and is connected by road. The Gobe Production Facility is located approximately 90 kilometers southeast of the Kutubu Central Processing Facility.

New developments required for the supply of associated gas from these facilities will consist of installation of gas metering, new valving to allow isolation, additional piping and enhanced gas dehydration and regeneration packages.

2. Marine Project Area

The offshore portion of the LNG Project Gas Pipeline length will be approximately 407 kilometers from the Omati River onshore/offshore pipeline tie-in to the LNG Facilities site onshore/offshore tie-in. The Omati River Landfall section of the pipeline will start at an onshore tie-in location approximately 200 meters onshore from the river bank. This section of pipeline will be pulled ashore from a Shallow Water Lay Barge (SWLB) through a prepared trench to the tie-in location with the onshore pipeline. The shallow water section of the offshore portion of the LNG Project Gas Pipeline includes areas of pipe lay in water depths less than 10 meters lowest astronomical tide. From the tie-in location with the onshore portion of the LNG Project Gas Pipeline at the Omati River Landfall, the pipeline will run from the landfall for 24 kilometers until it reaches the open sea at the mouth of the Omati River.

The offshore section of the LNG Project Gas Pipeline will start at a location beyond the mouth of the Omati River, in the Gulf of Papua. The pipeline will be laid on the seabed by lay barge through the Gulf of Papua until it reaches the landfall at the LNG Facilities site. The onshore tie-in point at the LNG Facilities site is located at approximately +1 meter highest astronomical tide. The shore approach zone is approximately 1.3 kilometers in length. The pipeline will be pulled ashore through a prepared trench to the tie-in location.

Offshore pipeline construction activities include pipelaying, pipeline protection and stabilization, and pre-commissioning activities (i.e., cleaning, hydrotesting and dewatering). The offshore portion of the LNG Project Gas Pipeline will include a concrete weight coat to ensure that the pipeline is stable on the seabed under design environmental conditions. Additionally, the weight coating provides protection against natural and or third-party impact. Due to the prevalence of soft deltaic sediments in the Gulf of Papua, the pipeline is expected to embed in these sediments for most of its length.

The offshore portion of the LNG Project Gas Pipeline will be buried for protection against impacts from vessels and anchors in the Omati River (and for some distance beyond the river mouth to a water depth of between 5 and 10 meters) and seaward from the landfall in Caution Bay to a water depth of 15 meters. In addition, the pipeline will be trenched and buried for the shipping channel crossing offshore from the LNG Facilities site.

3. LNG Project Area

The LNG Facilities site will be located at Caution Bay approximately 20 kilometers northwest of Port Moresby. The plant will receive and process gas into approximately 6.3 million tonnes per annum of LNG. An impression of the LNG Facilities site layout is provided in Figure A1.3.

A program of early works will be undertaken at the LNG Facilities site and environs. The scope of this work, is summarized below:

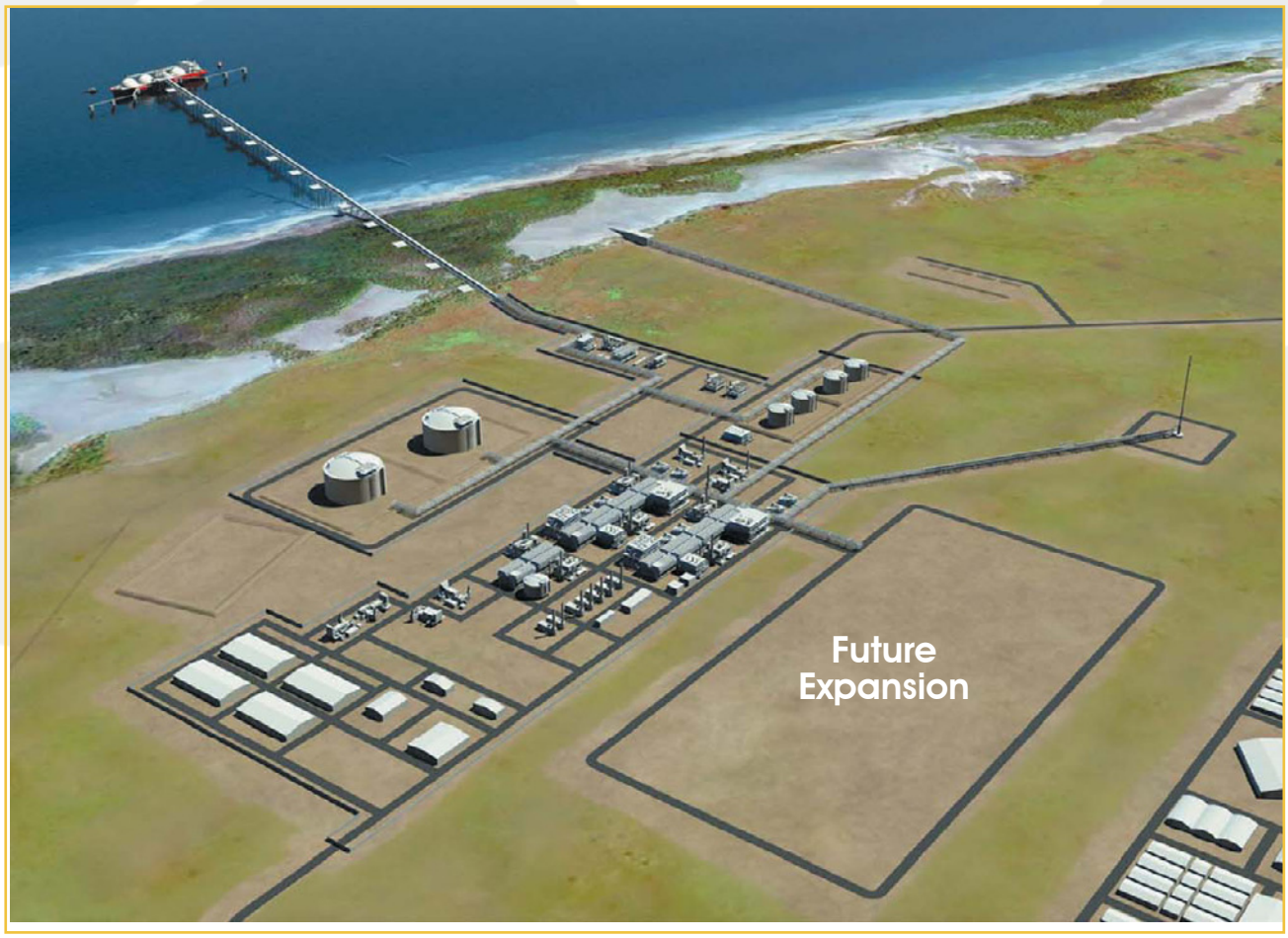
- Upgrade of the existing public road from Motukea Island to LNG Facilities site.
- New bypass road (rerouting of existing public road, which transects LNG Facilities site).
- LNG Facilities site security fence.
- A 7,500-person temporary construction camp.
- Desalination facilities to provide water to the site during construction and operations.

The LNG Plant's processing facilities include inlet gas receiving, acid gas removal unit, dehydration, mercury removal, refrigeration, liquefaction and condensate fractionation. Major utilities include power generation, hot oil, air and nitrogen systems. Major offsite systems at the LNG Facilities site include LNG storage (2 x 160,000 cubic meters) tanks, condensate storage (2 x 8,500 cubic meters) tanks, firewater system, flare systems, fresh water system and effluent handling.

The LNG Facilities site's marine facilities design will accommodate the loading of LNG carriers in the size range of 125,000 cubic meters to 220,000 cubic meters and condensate tankers of 7,000 dead weight tonne. The marine facilities include LNG export berth, condensate export berth, tug landing area and materials offloading facility with permanent tug mooring berths.

A permanent operator personnel camp will also be installed within the boundary of the LNG Facilities site.

Figure A1.3: Impression of proposed LNG Facilities site layout



Appendix 2 – Environmental Impact Statement Documents

This appendix outlines the specialist appendix reports that have been prepared for the EIS.

1. Upstream and Offshore Pipeline

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

2. LNG and Marine Facilities

- Biodiversity Impact Assessment. Appendix 12 to the EIS.
- Aquatic Fauna Impact Assessment. Appendix 13 to the EIS.
- Hydrology and Sediment Transport Impact Assessment. Appendix 14 to the EIS.
- Water and Sediment Quality Baseline Impact Assessment. Appendix 15 to the EIS.
- Groundwater Impact Assessment. Appendix 16 to the EIS.
- Soils and Rehabilitation Impact Assessment. Appendix 17 to the EIS.
- Air Quality Impact Assessment. Appendix 18 to the EIS.
- Noise Impact Assessment. Appendix 19 to the EIS.
- Visual Impact Assessment. Appendix 20 to the EIS.
- Road User Survey. Appendix 21 to the EIS.
- Hydrodynamic Modeling. Appendix 22 to the EIS.
- Nearshore Marine Impact Assessment. Appendix 23 to the EIS.
- Resource Use Survey of Caution Bay. Appendix 24 to the EIS.
- Greenhouse Impact Assessment. Appendix 25 to the EIS. This is a Project-wide study.
- Social Impact Assessment (including Cultural Heritage). Appendix 26 to the EIS. This is a Project-wide study.
- LNG Facilities Onshore Preconstruction Summary Report. This report includes information on terrestrial ecology, aquatic ecology, weeds, hydrology, groundwater and cultural heritage.

Appendix 3 – Environmental and Social Management Plan Appendices

The following are the appendices to the Environmental and Social Management Plan. Those with more of an environmental focus number the management and mitigation measures included as well as the associated objectives.

- **Appendix 1:** Ecological Management Plan. One hundred eighty-six management and mitigation measures included. Objective is to:
  - Reduce impacts on habitat and specific ecological aspects and species arising from construction activities.
- **Appendix 2:** Air Emissions Management Plan. Fourteen management and mitigation measures included. Objectives are to:
  - Reduce the impact of Project activities on ambient air quality.
  - Optimize equipment to reduce greenhouse gases.
- **Appendix 3:** Noise and Vibration Management Plan. Fourteen management and mitigation measures included plus three in common with the Air Emissions Management Plan and two with the Ecological Management Plan. Objective is to:
  - Reduce noise and vibration impacts from Project activities to local residents and specific fauna habitat, including marine fauna and bats.
- **Appendix 4:** Waste Management Plan. Twenty-five management and mitigation measures included. Objectives are to:
  - Contain, transport, handle and dispose of solid and liquid wastes arising from Project construction activities in such a manner as to avoid impacts to human health and the environment.
  - Dispose of wastes at facilities approved by Esso Highlands Limited, for which disposal (with or without prior treatment) is the only practicable option.
- **Appendix 5**: Water Management Plan. Twenty-three management and mitigation measures included plus three in common with the Waste Management Plan. Objectives are to:
  - Reduce the impact on water quality (and associated beneficial values) from construction activities.
  - Reduce the impact on existing surface water flow regimes and groundwater aquifers (and associated beneficial values) arising from construction activities.
- **Appendix 6:** Spill Prevention and Response Plan. Twenty-five management and mitigation measures included. Objectives are to:
  - Prevent spills.
  - In the event of a spill, reduce environmental and social impact.
- **Appendix 7:** Hazardous Materials Management Plan. Twenty-seven management and mitigation measures included plus one in common with the Water Management Plan and six with the Spill Prevention and Response Plan. Objectives are to:
  - Avoid the use of chemicals and hazardous materials subject to international bans or phase-outs.
  - Prevent uncontrolled release of hazardous materials during transportation, handling, storage and use.

- **Appendix 8:** Weed, Plant Pathogen and Pest Management Plan. Seventy-six management and mitigation measures included and one in common with each of the Ecological Management, Noise and Vibration Management, Spill Prevention and Response and Water Management Plans. Objectives are to:
  - Prevent exotic weeds, plant pathogens and pests from entering, spreading or becoming established in the Project Areas during construction works.
  - Identify and contain, suppress or manage significant weeds, plant pathogens and pests already in the Project Area to prevent spread by Project activities.
  - Implement measures to reduce the risk of spread of dieback in *Nothofagus* forests.
- **Appendix 9:** Erosion and Sediment Control Management Plan. Eighty-three management and mitigation measures included plus one in common with the Air Emissions Management Plan and five with the Ecological Management Plan. Objectives are to:
  - Maintain stable landforms to reduce erosion and enhance reinstatement.
  - Maintain integrity of assets (through stable landforms).
  - Reduce adverse impacts on stream water quality, and associated beneficial values, and in-stream sedimentation.
- **Appendix 10:** Raw Materials Management Plan. Seven management and mitigation measures included plus twelve in common with the Erosion and Sediment Control Management Plan and one with the Ecological Management Plan. Objectives are to:
  - Extract aggregate from Esso Highlands Limited-approved locations and manage according to the relevant, individual management plans.
  - Maximize use of cleared timber and purchase additional timber supplies from known and approved sources.
- **Appendix 11:** Reinstatement Management Plan. Fifteen management and mitigation measures included. Objectives are to:
  - Establish stable landform conditions in areas disturbed as a result of construction activities.
  - Create ground conditions conducive to natural plant regeneration.
- **Appendix 12:** Induced Access Management Plan. Three management and mitigation measures included. Objective is to:
  - Control access to new Project roads and reduce the occurrence of potentially damaging non-Project activities (i.e., via improved access).
- **Appendix 13:** Cultural Heritage Management Plan. One hundred eight management and mitigation measures included plus one in common with the Induced Access Management Plan. Objectives are to:
  - Avoid known cultural heritage sites (including both archaeological sites and oral tradition sites) where necessary and practicable.
  - Where avoidance is not possible, manage cultural heritage sites in consultation with the PNG Government and landowners.
- **Appendix 14:** Hydrotest Management Plan. Eighteen management and mitigation measures included. Objective is to:
  - Reduce environmental impacts related to hydrotest water abstraction and discharge.

- **Appendix 15:** Acid Sulfate Soils Management Plan. One management and mitigation measure included. Objectives are to:
  - Provide measures to avoid or minimize the disturbance of acid sulfate soils and to contain, mitigate and minimize the impacts of disturbed acid sulfate soils.
  - Protect the local environment from adverse impacts arising from the disturbance of actual acid sulfate soils and potential acid sulfate soils.
- **Appendix 16:** Dredge Management Plan. Three management and mitigation measures included. Objectives are to:
  - Reduce impacts of dredging on the marine life and water quality.
  - Reduce sediment (turbid plume) mobilization during dredging and placement of dredge material.
- **Appendix 17:** Community Health and Safety Plan.
- **Appendix 18:** Community Impacts Management Plan.
- **Appendix 19:** Labor and Worker Conditions Management Plan.
- **Appendix 20:** Camp Management Plan.
- **Appendix 21:** Procurement and Supply Management Plan.
- **Appendix 22:** Community Engagement Plan.
- **Appendix 23:** Community Infrastructure Management Plan.
- **Appendix 24:** Community Health, Safety and Security Management Plan.
- **Appendix 25:** Community Support Strategy.
- **Appendix 26:** Resettlement Framework Document.
- **Appendix 27:** Stakeholder Engagement Plan.
- **Appendix 28:** Environmental Monitoring Plan.
- **Appendix 29:** Social Monitoring Plan.
- **Appendix 30:** Environmental Performance Indicators and Statutory Reporting and Notification Requirements.
- **Appendix 31:** Quarantine Management Plan.

Appendix 4 – Vegetation in the Upstream Project Area

Montane Forest (greater than 3,000 meters) with/without Grassland – is very small crowned mossy forest ('elfin' forest) and alpine grassland complexes. It is low, 5 to 15 meters high with thin, crooked stems and lacks emergents. It only occurs in the far north of the Upstream Project Area and no Project infrastructure is planned in this vegetation.

Grasslands – within the Upstream Project Area are mostly alpine grasslands above the tree line in the north and no Project infrastructure is planned in this vegetation.

Rocky Scrub – occurs on the extreme slopes of the Karius Range. No Project infrastructure is planned in this vegetation.

Lower Montane Small Crowned Forest – occurs above 1,000 meters altitude. It has an even to undulating canopy 20 to 30 meters high and is very dense to almost closed. *Nothofagus* is absent or very rare but, in the vicinity of Idauwi and Nogoli, the forests on the ranges have many emergent *Araucaria*. Ferns and epiphytes are common. Trees tend to be thin, and oaks *(Castanopis and Lithocarpus)* are common, dominating in some areas. While somewhat less diverse in tree species composition than other forests, it can have high diversity of smaller plants and epiphytes. At lower elevations in the river valleys, clearing for gardens has heavily disturbed the forest. Areas of this vegetation occur frequently at the eastern end of the pipeline corridor between the Juha Production Facility and the Hides Gas Conditioning Plant and for a long length of the onshore portion of the LNG Project Gas Pipeline between the Hides Gas Conditioning Plant and Lake Kutubu at elevations of approximately 1,200 meters altitude and above.

Lower Montane Small Crowned Forest with Conifers – only occurs in the high far northeast of the Upstream Project Area. Emergent conifers include the genera *Dacrydium, Libocedrus and Phyllocladus.* No Project infrastructure is planned in this vegetation.

Lower Montane Small Crowned Forest with *Nothofagus* – has a closed, even to slightly undulating canopy 20 to 30 meters high and is dominated by *Nothofagus pullei* and *N. rubra.* This is a classical mossy forest. *Nothofagus* is concentrated along ridgelines and subcrests. In the drainage channel subcatchments, the canopies are usually lower and the mixed communities typical of Papuasian habitats become more apparent. Small patches of seral growth are scattered through the forest as a result of natural canopy-opening mechanisms (e.g., wind throws and tree senescence and death). Generally, the dynamics of *Nothofagus* communities tend to be site-specific; however, the forests on Hides Ridge and the Homa Deviation are clearly being maintained by a classic process of patch dynamics and spatial rotation of forest units in different stages of maturation. In the Homa Deviation area, fire has influenced this vegetation. As in most other places that this vegetation group occurs, on Hides Ridge it contains large numbers of epiphytic ferns and orchids, which may represent up to 75 percent of the local plant diversity.

Large areas occur on the Doma Peaks, Mount Sisa, Hides Ridge and between the Benaria and Kondari rivers. The eastern end of the pipeline corridor between the Juha Production Facility and the Hides Gas Conditioning Plant traverses this vegetation and the onshore portion of the LNG Project Gas Pipeline crosses large expanses of this forest above 1,600 meters between the Benaria and Kondari rivers and sporadically at higher elevations between the Kondari River and Lake Kutubu.

Lower Montane Very Small Crowned Forest Complexes – occurs on the central eastern boundary of the Upstream Project Area northeast of Gobe. No Project infrastructure is planned within this vegetation.

Lower Montane Very Small Crowned Forest Complexes with *Nothofagus* – is concentrated in the uplands surrounding the Kutubu Central Processing Facility. The forest has a dense, evenly textured, dark-toned canopy 5 to 15 meters high. Around Kutubu, *Nothofagus* dominates in areas such as along ridges but is far less obvious than in the higher regions to the north. There are fewer ferns but more vines in this vegetation. The onshore portion of the LNG Project Gas Pipeline traverses this forest type either side of the Kutubu Central Processing Facility, as does the South East Hedinia Spineline.

Medium Crowned to Small Crowned Forest Complexes – covers large areas of the southern and central parts of the Upstream Project Area. It has a canopy 25 to 30 meters high with 60 to 80 percent closure, the smaller crowned forest having thinner trees and a more even canopy with no emergents, while the medium crowned forest has emergents up to 40 meters high. The smaller crowned forest tends to develop on the more difficult pavement sites. The Gobe Gas Pipeline and South East Hedinia Spineline encounter this forest type as does the onshore portion of the LNG Project Gas Pipeline between Wassi Falls and the Mubi River and between the Kikori River crossing and the Omati River Landfall.

Medium Crowned to Small Crowned Forest Complexes with *Nothofagus* – occurs in the central eastern part of the Upstream Project Area. It has a canopy 25 to 30 meters high with 60 to 80 percent closure and is a mixture of medium crowned forest and small crowned forest. The latter tends to have a more even canopy with no emergents; the former has emergents up to 40 meters high. There is an abundance of a range of *Nothofagus* species. The South East Hedinia Spineline crosses some of this forest type and the onshore portion of the LNG Project Gas Pipeline crosses large areas between the Kutubu Central Processing Facility and the Ai'io River.

Low Altitude Large Crowned Forest – occurs on the slopes of Mount Bosavi. It has an uneven canopy 30 to 35 meters high and 80 percent closure with emergents to 40 meters. No Project infrastructure is planned within this vegetation.

Low Altitude Medium Crowned Forest – occurs widely in the Upstream Project Area. The canopy is 25 to 30 meters high with 60 to 80 percent closure with emergents up to 40 meters high. Species composition varies widely according to altitude and substrate. In the Juha area, it has many upland forest features and plants other than trees may dominate the flora. Project infrastructure mostly encounters this vegetation at Juha and along the Juha–Hides Rich Gas Pipeline and again sporadically between Lake Kutubu and the Gobe turnoff where it merges into open lowland forest on the edge of the karst pavements.

Low Altitude Small Crowned Forest with *Nothofagus* – has a fairly even canopy approximately 30 meters high with emergents up to 35 meters high. Tree crowns average between 8 and 15 meters in diameter, orchids and figs are very common, ferns are moderately common, and palms and pandanus are sparse. Conifers such as *Papuacedrus* spp. and *Phyllacladus* spp. can be abundant, and oaks (*Castanopis* and possibly *Lithocarpus)* are common. A single area occurs east of the Kutubu Central Processing Facility and the proposed Agogo Gas Pipeline traverses part of this.

Large to Medium Crowned Lowland Forest – occurs in small areas in or near the Sirebi Bioregion on alluvial fans. It is tall with a canopy 30 to 35 meters high and emergents exceed 50 meters. Structurally it is the best-developed forest in the Upstream Project Area. No Project infrastructure is planned within this vegetation.

Small Crowned Lowland Forest – has a canopy 25 to 30 meters high composed of dense small crowns with no emergents, and the canopy is often dominated by single species such as *Intsia* sp. and dipterocarps. This type of forest often occurs on very poor or badly drained substrates, such as limestone pavements. It will be crossed by the onshore portion of the LNG Project Gas Pipeline between the Gobe turnoff and the Omati River Landfall.

Open Lowland Forest – consists of small and medium crowned trees with large crowned emergents up to 40 meters high. The canopy profile is very uneven with many large gaps produced probably by frequent tree falls on the limestone pavements. A variety of palms occur, and climbing rattans are common. In low-lying areas, sago palm (*Metroxylon sagu*) stands develop, and where they have the opportunity, broad-leaved trees can reach great sizes (greater than 1 meter diameter at breast height). The onshore portion of the LNG Project Gas Pipeline encounters this forest type near Gobe and, while the Forest Inventory Management System does not map it as such, the forest at Baia River is also of this type.

Open Lowland Forests and Freshwater Swamps – is a complex of open forest and mixed swamp forest. The onshore portion of the LNG Project Gas Pipeline crosses this forest type several times either side of the Gobe turnoff.

Swamp Forest Complexes – occurs patchily but widely in the Upstream Project Area wherever impeded drainage allows its development. The trees can be large (greater than 1 meter diameter at breast height) and up to 30 meters tall. Lianas are common, and epiphytes abundant. *Selaginella* is common on the forest floor. A feature of this area is the abundance of palms. In frequently inundated areas, sago palms can form almost pure stands. In areas where karstification has produced some relief within these basins or plains, sago palms dominate in the small hollows or dolines, while the raised ridges of limestone support medium crowned or small crowned forest. Where inundation is less frequent, other palms, such as *Arenga* sp. and *Galubia* sp., are dominant. There are large areas behind the mangrove of the Kikori River mouth and scattered patches towards the centre of the Upstream Project Area. The onshore portion of the LNG Project Gas Pipeline traverses large areas approaching the Omati River Landfall.

Swamp Woodland and Forest Complexes – occurs around the north of Lake Kutubu, near Kantobo and behind the Kikori River mangroves. Swamp woodland is a dense layer of sago palms with scattered broad-leafed trees and an understorey of sedges, ferns, reeds and/or grass. Swamp forest has an irregular open canopy of medium to very small crowned trees 20 to 30 meters high and an understorey of sago palms visible in gaps in the canopy. Sago and tree density varies, giving this type of forest a very patchy appearance. The onshore portion of the LNG Project Gas Pipeline crosses this forest type to the north of Lake Kutubu and in the Ai'io River valley.

Mangroves – are extensive in the Kikori River delta. The onshore portion of the LNG Project Gas Pipeline does not cross mangrove vegetation except for a fringe of *Nypa* palms at the landfall.

Appendix 5 – Determining Magnitude of Residual Impacts

These tables are reproduced from Appendix 1 to the EIS.

Table A5.1 Magnitude of impact categories used in assessment

Magnitude of Impact	Habitat	Other Ecological Effects (Barrier Effects, Contamination, Exotics, etc.)	Populations
Very high	Large impact on substrates and habitats that will be permanent and reduce ecosystem survival and health over large areas within the Upstream Project Area or a local region possibly even leading to system collapse. Recovery, if possible, is likely to take more than 25 years or never.	Impact may be widespread effecting greater than 10 percent of Project Area or local region, perhaps even up to a national scale.	Populations will be lost from impact site and losses may cause local extinctions in a Special Area or within the entire Project Area or local region.
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. Loss and/or degradation of habitat extends more than 1 kilometer beyond impact site. Habitat regeneration, if allowed, will be slowed and good tree cover in forest may take up to 25 years after substrate treatment or replacement. Loss of habitat may affect up to 10 percent of the habitat's range within the Upstream Project Area or within any one Special Area.	Impact is regional affecting up to 10 percent of Project Area or local region.	Impacts will involve local loss of population for at least 25 years or recolonisation may never occur. Any losses of local population likely to seriously reduce chances of species persisting in a Special Area and/or would significantly reduce likelihood of species persisting in the Upstream Project Area or local region. No national impacts.
Medium	Substrates will be lost and replacement or treatment may be necessary to initiate successions. However there is unlikely to be any long-term reduction in site capacity to support original habitat. Loss of and/or degradation of habitat extend up to 500 meters beyond impact site. Habitat regeneration will be slowed and good tree cover in forest may take up to 12 years after substrate treatment.	Detectable up to 10 kilometers from impact site.	Impacts will involve local loss of population for up to seven years or recolonisation may never occur. However loss of the local population highly unlikely to affect persistence of the species within the Upstream Project Area or local region.
Low	Substrates may be disturbed or lost but habitat can readily develop on remaining substrate with slowing of successions by only one to three years at most. Generally only a short-term (one to three years) reduction in site capacity to support original habitat. Impacts restricted to immediately around impact site. Habitat regeneration capable of starting within one to three years and successions likely to proceed normally to good tree cover in forest within five years after start of succession.	Effects immediate surrounds from impact and detectable up to 2 kilometers 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 three years after development of successions to the stage of canopy closure.
Negligible	Deleterious impacts unlikely to be detectable on habitats.	Not detectable.	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, i.e., those around the Project component site. Changes only detectable by intensive population monitoring pre and post impact.

Table A5.2 Biodiversity value and/or sensitivity of receptor

Value Category	Sites and/or Habitats	Species
Category 1 (very high value)	An internationally designated site. A Special Area within the Upstream Project Area. A designated national protected area, e.g., Wildlife Management Area. An area with an unusually high concentration of very high and high value species. Site supports 20 percent or more of a national population of any species.	A population of internationally important species in IUCN category critically endangered.
Category 2 (high value)	A sustainable area of priority habitat identified by WWF. Habitat of peculiar sensitivity that is hard to restore or regenerate (focal habitat). Site supports up to 20 percent of national population of any species.	A population of internationally important species in IUCN categories endangered or vulnerable.
Category 3 (moderate value)	A local reserve. A high diversity area with a moderate concentration of very high and high species. Site supports up to 10 percent of national population of any species.	A population of a species in IUCN category near threatened and/or classified as P under PNG legislation.
Category 4 (minor value)	Sites that enrich the local area. A low to moderate diversity area with a low concentration of very high and high species.	A population of a species that is either classified by IUCN as data deficient and/or as R under PNG legislation.
Category 5 (least value)	Lower ecological value.	A population of a species that is classified by IUCN as of least concern or is unclassified and is not listed under PNG legislation.

Table A5.3 Significance matrix

	Value				
Magnitude of Impact	**Category 1**	**Category 2**	**Category 3**	**Category 4**	**Category 5**
Very high	Major	Major	Major	Low	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

Table A5.4 Examples of impact analysis from the EIS

Value	Potential Impactor	Value of Receptor	Magnitude Before Mitigation	Impact Without Mitigation	Magnitude After Mitigation	Residual Impact	Notes*
Upstream Project Area							
Flora	Edge effects	1	Low	Moderate	Minimal	Minimal	Experience with the oil project indicates that below about 1,800 meters above sea level edge effects from previous pipeline construction are temporary and that the forest edge rapidly seals. Taking care that construction does not excessively damage trees remaining along the edge will reduce or eliminate the potential for further erosion of the edge. The magnitude of the impact of edge effects on flora before mitigation is therefore estimated to be low but negligible after mitigation. Considering the vegetation and flora of the Project Area as a Category 1 conservation asset, the overall significance of the residual impact after mitigation of edge effects on flora is predicted to be minimal.
Vegetation, flora and fauna	Fire	1	High	Major	Low	Moderate	The length of the Project footprint means that propagation of fire from points along the ROW has the potential to promote widespread ecosystem degradation over large areas of the Project Area and KICDP area should wildfire start and spread. In some circumstances, the ROW could act as a firebreak and break the spread of fires from elsewhere in PNG travelling east west or vice versa. This could be a positive impact. The magnitude of the potential impact of fire before mitigation is estimated to be high but low after. Considering the Project Area as a Category 1 conservation asset, the overall significance of the residual impact of fire on biodiversity is predicted to be moderate.
Species of conservation concern - *Bleasdalea papuana* (IUCN endangered tree)	Habitat loss	1	Minimal	Moderate	Minimal	Minimal	"The tree is a presumed Gondwanic relict supposedly restricted to a small number of localities in northern New Guinea (Smith & Haas 1975). The survey collection is the first from the Papuan side. The discovery of *Bleasdalea* on the Kutubu karst represents a biogeographically significant record". The species was located on an abandoned village site at the top of a ridge near Benaria camp. Considering its capacity to grow in disturbed and previously cleared areas, the significance of even unmitigated direct impacts are likely to be minimal. Accidental introduction of an exotic weed could impact on this species but mitigations through quarantine plans could reduce the likelihood of the introduction of such a weed to low levels. The significance of other residual indirect impacts after mitigation are likely to be minimal.
Priority Ecosystems							
Juha area all values	All direct impacts	1	Medium	Moderate	Negligible	Minimal	The direct impacts discussed above are unlikely to operate more severely in the isolated Juha area than elsewhere in the Project Area, except for the fact that the habitats, flora and faunal populations are even less disturbed. Unmitigated, the magnitude of the direct impacts in this area could be medium and considering that this area is a Category 1 conservation asset, the overall significance of the impact without mitigation would be moderate. Once mitigated, however, the impact magnitude could be reduced to negligible and the significance of the residual impact to minimal.
Juha area all values	Induced access	1	Very high	Major	Low	Low	However the major potential impact of the Project will be through reducing the isolation of the area and the protection it engenders which will allow indirect impacts to possibly manifest i.e., wildfire, pests, weeds and diseases, hunting, and increased access. These indirect impacts have the potential to destroy the area's biodiversity and ecological characteristics. If unmitigated the severity of indirect impacts could be very high and the significance of the impact major. The keys to reducing residual impacts in this area to acceptable levels are the plans related to quarantine and access control and control of the Projects workforce. If these are effectively implemented the magnitude of indirect impacts could be reduced to low or negligible and the significance of the residual impacts after mitigation to low or minimal.
Focal Habitats							
Upland streams	Erosion	2	High	Moderate	Low	Low	Protection of the heads of upland streams is meant to protect their amphibian communities. The potential magnitude of impacts could be high but if stream heads above 1,800 meters can be kept free of silt then this could be reduced to low. Upland streams are a Category 2 conservation asset so the significance of residual direct impacts after mitigation is likely to be low.

*Taken verbatim from Appendix 1 to EIS.

Table A5.5 Relevance of residual impacts to biodiversity values

	Direct Effects				Indirect Effects		
Values	**Habitat Loss***	**Edge Effects in High-altitude Karst**	**Barrier and Erosion Effects in High-altitude Karst**	**Barrier and Erosion Effects in High Cuttings**	**Fire**	**Introduction and Spread of Alien Species and Diseases**	**Enhanced Access**
Upstream Project Area							
Extensive intact forest					X	X	X
High floristic diversity		X			X	X	X
High faunal diversity		X	X	X	X	X	X
New species		X	X	X	X	X	X
Endemic species		X	X	X	X	X	X
Unique assemblages of species		X	X	X	X	X	X
Species of conservation concern		X	X	X	X	X	X
Biodiversity of importance to local communities for resource use and cultural and spiritual purposes	X	X	X	X	X	X	X
Priority Ecosystems							
The Juha area	X				X	X	X
Hides Ridge	X	X	X	X	X	X	X
High-altitude forest above 1,800 meters on the Homa Deviation	X	X	X	X	X	X	X
Lake Kutubu Wildlife Management Area	X				X	X	X
Focal Habitats							
Caves	X					X	X
Sinkhole swamps	X		X	X	X	X	X
Upland streams	X			X	X	X	X
Swamp forest	X				X	X	X
Stream refuges in unstable landscapes	X				X	X	X
Lowland rivers in stable landscapes	X				X	X	X
Off-river waterbodies	X				X	X	X
Habitats and flora and fauna of cultural significance	X	X	X	X	X	X	X

*Residual impacts of habitat loss on the Upstream Project Area was determined to be negligible in the EIS; however, it becomes more significant at finer scales.

Appendix 6 – Route Choices

1 PNG LNG Project Pipeline Routes – Broad Scale

The Project's principal pipeline routes have been divided into four sections; Juha Production Facility to Hides Gas Conditioning Plant, Hides Gas Conditioning Plant to Kutubu Central Processing Facility, Kutubu Central Processing Facility to Omati River Landfall, and Omati River Landfall to the LNG Facilities site.

1.1 SECTION A: JUHA PRODUCTION FACILITY TO HIDES GAS CONDITIONING PLANT

There is no option to deliver gas from Juha to Hides Gas Conditioning Plant except through largely uninhabited and undisturbed primary tropical forest. In other words, the Juha–Hides Rich Gas Pipeline and Juha–Hides Liquids Pipeline will break new ground wherever they are located. The route alignment, therefore, is the shortest that can be constructed safely and avoids unstable terrain. This broadly equates to the lowest level of forest clearance and ground disturbance.

1.2 SECTION B: HIDES GAS FIELD TO KUTUBU CENTRAL PROCESSING FACILITY

The LNG Project Gas Pipeline starts at Hides, together with the Hides–Kutubu Condensate Pipeline. Within the vicinity of this pipeline route section is the Agogo Gas Pipeline, which will generally parallel the existing crude oil export pipeline ROW from Agogo to the Kutubu Central Processing Facility.

1.2.1 Eastern or Western Routes

Options for this section involved first a high-level choice between routes east and west of the Tagari and Hegigio rivers.

The western option was some 40 kilometers shorter over an area of more stable ground and easier construction. However, this advantage would be offset by taking the pipeline some distance from the Angore gas field, by having to cross land undisturbed for all but the first few kilometers south of Hides, and by the logistical and practical issues of crossing the large highland Hegigio River as it exists at the Hegigio Gorge.

The eastern option and its features are largely the inverse of the western route. Much of the route has been lightly disturbed by human activity and there are roads at either end. It avoids a major crossing of the Hegigio River and it is more conveniently located in relation to Angore and existing roads. These factors outweigh the distance and terrain advantages of the western route and the eastern route has been selected on this basis.

1.2.2 Options with the Eastern Route

The eastern route will be able to take advantage of the roads and human disturbance at either end. However, alternatives were identified between Homa and Idauwi and again at Wage Creek, north of Lake Kutubu, which offered optimizations.

1.3 SECTION C: KUTUBU CENTRAL PROCESSING FACILITY TO OMATI RIVER MOUTH

While generally following the ROW easement of the existing crude oil export pipeline, the presence of this pipeline in the Kikori River raised safety and operability constraints for what would otherwise have been the most direct way out to sea. Therefore, the next-best landfall, through the delta of the Omati River to the west, was chosen.

The route basically follows the crude oil export pipeline route but significant options were considered and adopted in two important sections: Moro to the Ai'io River, and Kikori River Crossing to Omati River Landfall. A third option to align the pipeline between the Kutubu Central Processing Facility and the Mubi River along the valley of the Digimu River crosses undisturbed country and was rejected to follow existing infrastructure.

1.4 SECTION D: OMATI RIVER LANDFALL TO LNG FACILITIES SITE LANDFALL

From the Omati River Landfall to the Caution Bay Landfall at the LNG Facilities site, the LNG Project Gas Pipeline base case runs 407 kilometers past existing oil export facilities and across two broad subsea environments: the sediments of the Gulf of Papua prograding offshore from the deltas of the Kikori and Purari rivers; and the reefs and coral sand lagoons approaching landfall at Caution Bay.

The alternative for this section is to take the pipeline overland to Port Moresby. This would entail an almost entirely greenfield route, with environmental impacts, land access issues, a number of large river crossings and constraints imposed by special features, such as caves and archaeological sites. The preferred option by sea avoids these issues.

Appendix 7 – Calculation of Offset Debt

The system used for terrestrial habitats was a modification of the Victorian Native Vegetation Framework[1]. The procedure to calculate the offset requirement was as follows.

1. Determine the Broad Vegetation Group (BVG) (see Appendix 4) to be cleared.

2. Determine the quality of the vegetation being cleared. In the Victorian system, this is done by comparing the structure of the vegetation on the site to be cleared with a benchmark set of values of what top quality habitat should look like and further judged on landscape ecology principles as to how the site fits in the landscape. The scores are then normalized to generate a score between 1 and 0 with 1 being pristine habitat in a non-fragmented landscape and 0 being a site bare of vegetation.

   The scoring system for habitat quality used here was based on the vegetation condition classes defined in Table A7.1 (extracted from the Appendix 1 to the EIS). A score was attributed to each habitat condition type based upon the assumption that condition A1 (old growth forest with no disturbance) was the optimum condition and attracted the maximum score of 1. At the other end of the scale, road and facility surfaces do not support biodiversity so are given a score of 0.

3. Determine the area lost in each BVG multiplied by condition class category.

4. Apply multipliers according to the biodiversity value of the habitat being cleared. The highest multiplier as defined by the Victorian Native Vegetation Framework is X2. Considering that the forests in the Upstream Project Area support many rare and threatened species, and that the forests constitute a significant area of the world's intact rainforest, a multiplier of X2 was applied to all scores. In addition a further multiplier of X2 was applied if the cleared area was in a priority ecosystem or in a WWF significant biodiversity area. The multipliers were applied cumulatively. Table A7.2 gives examples of the calculations.

Tables A7.3 and A7.4 present the habitat hectare debt for the Upstream Project Area according to vegetation type and bioregion.

Table A7.1 Habitat condition categories

Condition in EIS	Description	Score for Habitat Hectare Analysis
A1	Old growth forest in non-fragmented landscapes.	1
A2	Reduction in biodiversity value due to small-scale local use near settlements, larger mammals reduced, some medium sized trees cut.	0.8
C	Loss of many medium sized trees and diminution of populations of harvested wildlife.	0.7
D	Forest with many pioneer and secondary species, low populations of forest interior specialists but good populations of generalist species. Poorer structure than other condition classes.	0.5
E	Cleared areas and gardens still have biodiversity value with populations of many species of vertebrates.	0.1
L	Logged forest with severe reduction of commercial trees, disrupted populations of canopy species and forest interior specialists.	0.25
V	River surface - no vegetation.	0
O	Existing oil pipeline ROW – no vegetation.	0
R	Road surface - no vegetation.	0
F	Facility surface - no vegetation.	0

[1] DNRE. 2002. Victoria's native vegetation management: A framework for action. Department of Natural Resources and Environment, Victoria.

Table A7.2 Examples of offset debt calculations

Segment	Bioregion	Broad Vegetation Group	Condition	Area (Hectare)	Habitat Hectare Score	Priority Ecosystem	If Yes, Then X2	In a WWF Area?	If Yes, Then X2	Final Habitat Hectare Score
Juha wells to the Baia River catchment	Western Foothills	Low altitude medium crowned forest	A1	2.70	5.41	Juha	10.82	No	10.82	10.82
Kondari River to Lake Kutubu	Eastern Uplands Volcanics/ Karst	Lower montane small crowned forest	D	3.50	3.50	No	3.50	No	3.50	3.50
Kutubu to Moro	Moro Region	Swamp woodland and forest complexes	R	2.89	0.00	Lake Kutubu	0.00	Yes	0.00	0.00
Ai'io River valley	Mubi River Karst	Medium crowned to small crowned forest complexes	E	0.15	0.01	No	0.01	No	0.01	0.01

Table A7.3 Habitat-hectare debts in various vegetation types

Broad Vegetation Group	Habitat Hectare Debt	Percent
Cultivated or non-vegetated	14	0.2
Low altitude medium crowned forest	1,708	25.9
Low altitude small crowned forest with *Nothofagus*	15	0.2
Lower montane small crowned forest	1,406	21.3
Lower montane small crowned forest with *Nothofagus*	1,243	18.9
Lower montane very small crowned forest complexes with *Nothofagus*	507	7.7
Mangroves	7	0.1
Medium crowned to small crowned forest complexes	922	14.0
Medium crowned to small crowned forest complexes with *Nothofagus*	250	3.8
Open lowland forest	119	1.8
Open lowland forests and freshwater swamps	24	0.4
Small crowned lowland forest	107	1.6
Swamp forest complexes	215	3.3
Swamp woodland and forest complexes	49	0.7
Grand total	**6,586**	**100**

Table A7.4 Habitat-hectare debts in various bioregions

Bioregion	Habitat Hectare Debt	Percent
Eastern Uplands Volcanics/Karst	1,463	22.2
Iagafu Agogo Limestone Uplands	868	13.2
Kikori Lowlands	995	15.1
Moro Region	258	3.9
Mubi River Karst	1,154	17.5
Northern Montane Karst	532	8.1
Western Volcanics	592	9.0
Western Foothills	684	10.4
Western Lowlands	40	0.6
Grand total	**6,586**	**100**

Appendix 8 – Details of Programmed Monitoring Activities (PMAS)

1. PMA 1 Remote Sensing of Indirect Impacts

1.1 AIM

This PMA uses remote sensed imagery analysis to determine to what extent the project has facilitated or increased the occurrence of anthropogenic habitat loss and degradation within the Upstream Project Area. The PMA will also allow estimation of final forest losses after construction.

1.2 METHODS

Various remote sensing techniques are used to:

1. Detect and map changes to forest cover in the Upstream Project Area.
2. Determine which of these are the result of natural processes such as landslides and changes to river morphology and which are the result of anthropogenic processes.
3. Distinguish between anthropogenic processes:
   - Road building.
   - Logging.
   - Development of broad scale agriculture such as oil palms, fish farms and other crops.
   - Broad scale shifting cultivation.
   - Permanent settlement.
   - Other human activities resulting in habitat loss and degradation.
4. Detect and map fires.
5. Determine the geographic source of anthropogenic activities and which have emanated from project infrastructure.

1.3 ADAPTATION

Locations and resolution of imagery may be adapted depending upon results of previous analysis. However, continuity is required so changes must a) be additional to, not instead of, previous imagery acquisition system, and/or b) allow legitimate year-to-year comparisons of the same areas.

1.4 PROPOSED FREQUENCY

Every two years starting in 2011.

2 PMA 2 Aerial ROW Surveys

2.1 AIM

This PMA gathers data on the condition of the whole ROW and Project roads, as well as checking for local indirect impacts by regular aerial inspection and the status of focal habitats located adjacent to the ROW or roads.

2.2 METHODS

Aerial reconnaissance and if possible, videography of the ROW, Project roads and facilities at low level will be carried out by helicopter. On each occasion, the ROW and the nearby focal habitats will be checked for condition. The following aspects of condition will be recorded:

- Measures of ingrowths of regeneration.
- Areas of the ROW not regenerating.
- Areas of erosion not rehabilitating.
- Focal habitats still intact.
- Weed infestation.
- Signs of human intrusion.
- Status of focal habitats identified and mapped during the preconstruction surveys next to the ROW, roads and facilities.

Ground checks will be undertaken as necessary during the flyovers.

2.3 ADAPTATION

This PMA would be adaptive in that, if monitoring indicated remedial action, e.g., weed eradication, was necessary, the monitoring team would carry out the action and adjust monitoring accordingly. However, continuity is required so alterations to the monitoring regime must a) be additional to, not instead of, previous monitoring, and/or b) allow continuity of comparisons of the same areas.

2.4 PROPOSED FREQUENCY

Twice annually starting a year before the start of operations.

3 PMA 3 Regeneration Surveys

3.1 AIM

This PMA gathers data on the progression of successions and faunal communities and the condition of forest adjacent to the ROW and roads and facilities. This PMA is not to be confused with the monitoring to be undertaken as part of the Reinstatement Management Plan under the ESMP during construction under which vegetation cover will be measured quarterly.

3.2 METHODS

1. Regeneration will be monitored using permanent plots stratified by substrate, location and treatments (left to regenerate naturally or assisted regeneration) and scored using a benchmarking system.
2. Forest condition next to the ROW and roads will be monitored to determine if the forest is degrading or maintaining its condition (edge effects).

3.3 BENCHMARKING

Following clearing, succession is predicted to progress to the original forest in structure and species composition. Under natural circumstances, species composition is unpredictable since tree recruitment has a strong stochastic basis driven by dispersal dynamics, seedling competition, sweepstakes establishment in

gaps, and density dependent seed mortality. High, small-scale variability in species composition is a salient characteristic of tropical forests. Were a monitored site to develop an identical species composition to the original, it would be considered that regeneration was successful. However, if it regenerated to a completely different suite of species found in surrounding primary forest, then it would also be considered a success. Thus, knowledge of the exact previous composition is not critical to judging success of regeneration, only whether the regeneration is within the limits found in intact examples of that particular forest type.

A similar argument can be made for structure, which also varies locally but, in this case, it is possible to make finer judgments as to the progression of succession. A regenerating site may have good representation of saplings of 'primary' forest trees but the site's structure as measured by, for example, canopy cover, height, size class distribution of trees, leaf litter development, diversity of life forms and plant functional types, etc., may indicate a retarded succession that will not develop well.

The argument is the same for fauna. A change in community composition is to be expected but would not be considered as evidence of failure because such variability across the forest landscape is to be expected.

Thus, instead of a control–impact/before–after approach, the monitoring system proposed for the Project uses a benchmark approach. Sites will be compared against benchmark values for intact habitat types (see, for example, Parkes et al., 2003)

3.4 FREQUENCY OF SAMPLING, NUMBER OF SAMPLES AND FIELD ROUTINE

The frequency of sampling for PMA 3 is best determined by the expected rate of change of the variables being measured. In the case of the regeneration of forest habitats and build-up of faunal communities, it is useful to consider that there will be an initial rapid colonization of pioneer and secondary plant species, followed by colonization of fauna characteristic of open and secondary areas (generalist forest species according to Appendix 1 to the EIS). Subsequently, there will be gradual maturation of the succession with an increase in frequency of primary forest species then the colonization of adaptable then primary forest fauna species. There is probably a continuum in species dependence on old growth, but this has not been a very active research topic. It should be noted that some primary forest fauna species might not colonize for a couple of decades.

Frequent sampling may be necessary to estimate the speed of succession but the major interest of monitoring is to determine whether progress towards mature forest and faunal communities is occurring. A longer period between samples is preferable as this will enable more resources to be placed in increasing sample size on each sampling occasion.

To monitor if forest is degrading next to the ROW or roads, the plot will be extended into the intact forest and that will be scored against mature forest benchmark. No deviation from benchmark is expected if edge effects ameliorate rapidly.

The number of plots will depend upon final Project layout and accessibility. The level of replication would depend upon final Project layout and logistics. Ideally, several plots would be assessed from each helicopter landing point. The suggested number of sample sites and stratification is shown in Table A8.1. In order to conveniently monitor both regeneration and forest condition next to the ROW, a plot design involving a long plot extending from the ROW or road centerline into the forest will be considered.

Fauna may also be monitored, logistics allowing, at the same sites or a subset of the permanent plots. Methods would be:

1. Birds:

a. Twenty species counts.

b. Species tally walking between plots.

2. Mammals:
    a. Spotlight transects 1 kilometre long for nocturnal mammals.
    b. Species observations walking between plots.

Fauna results are likely to be expressed as abundance of guild types, e.g., frugivores, carnivores.

3.5 PROPOSED FREQUENCY

Years 1 (2 years before start of operations), 2, 4, 7 and every three years thereafter.

Table A8.1 Cross tabulation showing occurrence of substrate, location and treatment combinations and number of replicates for monitoring regeneration using permanent plots

	Substrate								
	Limestone Pavement		Limestone Rubble		Volcanics		Sedimentaries and Alluviums		
Location	**Natural**	**Rehabilitated**	**Natural**	**Rehabilitated**	**Natural**	**Rehabilitated**	**Natural**	**Rehabilitated**	**Totals**
Juha Special Area (Juha Production Facility to Wai Asia River)*			3	2					5
Juha Special Area (Wai Asia River to Karius Range)*							3	3	6
Hides Ridge Special Area (end of pipeline to Wellpad A)			3	3					6
Hides Gas Conditioning Plant to Benaria					3				3
Homa Deviation Special Area (Benaria to Homa)					3	3			6
Kutubu (Tibi Creek to Moro)			2	2			2		6
Moro to Heartbreak Hill			3	3			3		9
Heartbreak Hill to landfall	3	3	3				3	3	15
Totals	3	3	14	10	6	3	11	6	56

* Not to be commenced until Juha section of project is constructed.

4. PMA 4 Road Record Assessment

4.1 AIM

To monitor the use of project roads and infrastructure in order to demonstrate that during construction and operations their use remains restricted to Project activities only.

4.2 METHODS

Compile records being collected under the Induced Access Management Plan of the ESMP during construction.

4.3 PROPOSED FREQUENCY

Six monthly, starting in 2012.

5 PMA 5 Efficacy of Offset Projects

5.1 AIM

To assess the overall efficacy of the Biodiversity Offset Delivery Plan.

5.2 METHODS

Each biodiversity offset project will be designed with its own performance indicators and monitoring plan. Requirements will be included for monitoring results to be integrated with the overall monitoring database utilized for the Biodiversity Monitoring Plan. Performance of each biodiversity offset project will be included in reporting of the Biodiversity Monitoring Plan and the results compiled to provide an overall assessment of the efficacy of the delivery plan.

5.3 PROPOSED FREQUENCY

Yearly.

6 Reference

Parkes, D., Newell, G. and Cheal, D. 2003. Assessing the quality of native vegetation: The 'habitat-hectares' approach. *Ecological Management and Restoration* 4:29–38.

Appendix 9 – Biodiversity Monitoring Targets and Endpoints

Proposed targets and endpoints for the PMAs are provided in Tables A9.1 to A9.3 below.

Table A9.1 Monitoring of values of the Upstream Project Area as a whole

Value	Biodiversity Targets to be Monitored	Biodiversity Goal	Possible Indicator				
			PMA 1	PMA 2	PMA 3	PMA 4	PMA 5
Extensive intact forest	Forest in Project Area	No losses beyond prediction in EIS associated with the Project	Forest cover (hectare)				
	Cleared vegetation allowed to regenerate on stable non-limestone sites	Will regenerate in life of Project with successions the same as on cleared areas outside project footprint	Forest cover on that substrate on the ROW	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Cleared vegetation allowed to regenerate on very erosive volcanic sites.	Will regenerate after reinstatement works with successions the same as those on landslides in vicinity	Forest cover on that substrate on the ROW	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Cleared vegetation allowed to regenerate on limestone rubble or pavement elsewhere.	Rubble: will regenerate after reinstatement works with successions quicker than those on cleared areas outside project footprint but still slowly	Forest cover on that substrate on the ROW.	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Cleared vegetation allowed to regenerate on limestone rubble off Hides Ridge	Pavements where not ripped: regeneration will not progress noticeably in project life	Forest cover on that substrate on the ROW.	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Cleared vegetation allowed to regenerate on limestone rubble off Hides Ridge	Pavements where ripped: regeneration will progress normally	Forest cover on that substrate on the ROW.	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	All habitat next to ROW, roads and facilities	Forest will not degrade below benchmarks	Forest cover within 100 meters of edge of ROW, roads and facilities		Deviation of forest plots from benchmark		
	Weeds	No new species of weeds associated with infrastructure		Number and area of weed infestations in flyovers	Cover of weeds on regeneration plots		
		No expansion of weed areas associated with infrastructure		Identity of weeds in infestations located during survey	Identity of weeds in regeneration plots		
	Dieback	No expansion of dieback associated with infrastructure		Area of dieback detected associated with infrastructure	Dieback evidence from forest plots		
	Fire	No fires associated with infrastructure	No fire scars in change imagery	No evidence of fires generated from infrastructure	No plots burnt		
	Human incursion	No human incursion—not associated with Project or landowners	None evident	None evident			None evident

Table A9.1 Monitoring of values of the Upstream Project Area as a whole (cont'd)

Value	Biodiversity Targets to be Monitored	Biodiversity Goal	Possible Indicator				
			PMA 1	PMA 2	PMA 3	PMA 4	PMA 5
High floristic diversity	Flora	No diminution of species numbers below those recorded for the EIS					
High faunal diversity	Fauna	No diminution of species numbers below those recorded for the EIS					
New species	New species	No diminution of species numbers below those recorded for the EIS					
Endemic species	Endemic species	No diminution of species numbers below those recorded for the EIS					
Unique assemblages of species	Unique assemblages of species	No diminution of species numbers below those recorded for the EIS					
Species of conservation concern	Species of conservation concern	No diminution of species numbers below those recorded for the EIS					
Biodiversity of importance to local communities for resource use and cultural and spiritual purposes	Biodiversity of importance to local communities for resource use and cultural and spiritual purposes	No diminution of species numbers below those recorded for the EIS					

Table A9.2 Monitoring of priority ecosystems

Value*	Biodiversity Targets to be Monitored	Biodiversity Goal	PMA 1	PMA 2	PMA 3	PMA 4	PMA 5
Juha Area							
The remoteness of the region and the lack of human influence on the vegetation and fauna.	Forest in Juha area	No losses beyond prediction in EIS associated with the Project	Forest cover (hectare)				
	All habitat next to ROW, roads and facilities	Forest will not degrade below benchmarks	Forest cover within 100 meters of edge of ROW, roads and facilities				
	Cleared vegetation allowed to regenerate	Will regenerate in life of project with successions the same as on cleared areas outside project footprint.	Forest cover on that substrate on the ROW	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Human incursion	No human incursion—not associated with Project or landowners	None evident	None evident			None evident
The lack of weeds and other exotics in the area.	Weeds	No weeds invading					
	Weeds	No new species of weeds associated with Project infrastructure		Number and area of weed infestations in flyovers on Hides Ridge	Cover of weeds on regeneration plots		
	Weeds	No expansion of weed areas associated with infrastructure		Identity of weeds in infestations located during survey	Identity of weeds in regeneration plots		
	Dieback	No expansion of dieback associated with infrastructure		Area of dieback detected associated with infrastructure	Dieback evidence from forest plots		
	Fire	No fires associated with infrastructure	No fire scars in change imagery	No evidence of fires generated from infrastructure	No plots burnt		
Hides Ridge							
The forest is in good condition and only two exotic weeds were recorded, neither an ecological problem.	Area of forest on Hides Ridge	No losses beyond prediction in EIS associated with the Project	Forest cover (hectare)				
	Human incursion	No human incursion—not associated with Project or landowners	None evident	None evident			None evident

Table A9.2 Monitoring of priority ecosystems (cont'd)

Value*	Biodiversity Targets to be Monitored	Biodiversity Goal	PMA 1	PMA 2	PMA 3	PMA 4	PMA 5
Hides Ridge (cont'd)							
	Cleared vegetation on limestone rubble on Hides Ridge	Will regenerate after reinstatement works with successions quicker than those on cleared areas outside project footprint but still slowly.	Forest cover on that substrate on the ROW	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Cleared vegetation on limestone rubble on Hides Ridge	Where not reinstated regeneration will be the same as cleared areas outside project footprint.	Forest cover on that substrate on the ROW	Forest cover on that substrate on the ROW from videography	Deviation of regeneration plots from benchmark		
	Forest edges next to ROW, roads and facilities	All habitat next to ROW, roads and facilities	Forest will not degrade below benchmarks	Forest cover within 100 meters of edge of ROW, roads and facilities	Deviation of forest plots from benchmarks		
	Weeds	No new species of weeds associated with infrastructure		Number and area of weed infestations in flyovers on Hides Ridge	Cover of weeds on regeneration plots		
	Weeds	No expansion of weed areas associated with infrastructure		Identity of weeds in infestations located during survey	Identity of weeds in regeneration plots		
	Dieback	No expansion of dieback associated with infrastructure		Area of dieback detected associated with infrastructure	Dieback evidence from forest plots		
	Fire	No fires associated with infrastructure	No fire scars in change imagery	No evidence of fires generated from infrastructure	Deviation of forest plots from benchmarks		
	Edge effects in high-altitude karst.	No evidence of edge effects expanding	No retreat of forest away from ROW and road edges	No loss of canopy evident from flyovers	Deviation of forest plots from benchmarks		
	Barrier and erosion effects in high-altitude karst.	Species susceptible to barrier effects still present either side of ROW		No evidence of further erosion from flyovers	Deviation of forest plots from benchmarks		
	Barrier and erosion effects in high cuttings.	Species susceptible to barrier effects still present either side of ROW		No evidence of further erosion from flyovers	Deviation of forest plots from benchmarks		
High-altitude Forest above 1,800 Meters on the Homa Deviation							
Forest area and condition	Area of forest above 1,800 meters	No losses beyond prediction in EIS associated with the Project	Forest cover (hectare)				

Table A9.2 Monitoring of priority ecosystems (cont'd)

Value*	Biodiversity Targets to be Monitored	Biodiversity Goal	PMA 1	PMA 2	PMA 3	PMA 4	PMA 5
High-altitude Forest above 1,800 Meters on the Homa Deviation (cont'd)							
	Forest edges next to ROW, roads and facilities	All habitat next to ROW, roads and facilities	Forest will not degrade below benchmarks	Forest cover within 100 meters of edge of ROW, roads and facilities	Deviation of forest plots from benchmarks		
	Weeds	No new species of weeds associated with infrastructure		Number and area of weed infestations in flyovers	Cover of weeds on regeneration plots		
		No expansion of weed areas associated with infrastructure		Identity of weeds in infestations located during survey	Identity of weeds in regeneration plots		
	Dieback	No expansion of dieback associated with infrastructure		Area of dieback detected associated with infrastructure	Dieback evidence from forest plots		
	Fire	No fires associated with infrastructure	No fire scars in change imagery	No evidence of fires generated from infrastructure	Deviation of forest plots from benchmarks		
	Barrier and erosion effects in high cuttings.	Species susceptible to barrier effects still present either side of ROW		No evidence of further erosion from flyovers	Deviation of forest plots from benchmarks		
Lake Kutubu Wildlife Management Area							
Forest area and condition	Area of forest	Forest cover same as at end of construction	Forest cover (ha)				
	Forest edges next to ROW, roads and facilities	All habitat next to ROW, roads and facilities	Forest will not degrade below benchmarks	Forest cover within 100 meters of edge of ROW, roads and facilities	Deviation of forest plots from benchmarks		
	Weeds	No new species of weeds associated with infrastructure		Number and area of weed infestations in flyovers on ROW within WMA	Cover of weeds on regeneration plots		
	Weeds	No expansion of weed areas associated with infrastructure		Identity of weeds in infestations located during survey	Identity of weeds in regeneration plots		New species of weeds recorded by offset projects
	Dieback	No expansion of dieback associated with infrastructure		Area of dieback detected associated with infrastructure	Dieback evidence from forest plots		
	Fire	No fires associated with infrastructure	No fire scars in change imagery	No evidence of fires generated from infrastructure	Deviation of forest plots from benchmarks		
Fish fauna	Fish	Endemic species still present					Records from offset projects

*These are values as listed in the EIS.

Table A9.3 Monitoring of focal habitats

Focal Habitat	Biodiversity Goal	PMA 1	PMA 2	PMA 3	PMA 4	PMA 5
Caves next to ROW and facilities	No evidence of cave disturbance		Percent of caves next to ROW showing signs of disturbance			
Sinkhole swamps next to ROW and facilities	Swamps still vegetated and filled with water		Area of open water and aquatic vegetation in sinkhole swamps next to ROW (from videography or visual scoring)			
Lowland river crossings	Regenerating normally	Area of bare ground at each crossing	Percent of crossings at benchmark values for regeneration (from videography or visual scoring)			
Swamp forest	Regenerating normally	Area of open ground on ROW where it crosses swamp forest	Percent of open ground on ROW where it crosses swamp forest (from videography or visual scoring)	Deviation of regeneration plots from benchmark		
Upland streams next to ROW and facilities	Regenerating normally	Area of open ground on ROW where it crosses upland streams	Percent of crossings at benchmark values for regeneration (from videography or visual scoring)			
Stream refuges in unstable landscapes	Still intact	Baia River only - Designed later	Baia River only - Designed later	Baia River only - Designed later		
Off river water bodies	Still intact	Baia River only - Designed later	Baia River only - Designed later	Baia River only - Designed later		
Pandanus swamp forest next to ROW and facilities	Not disturbed	Area of pandanus swamp forest	Area of pandanus swamp forest next to ROW remaining undisturbed (from videography or visual scoring)			

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