PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 2: ENVIRONMENTAL AND SOCIAL BASELINE STUDIES

Part 6: Upstream Terrestrial Biodiversity Baseline Report
Annex 1b: Upstream Vegetation Mapping and Forest Condition Baseline Report

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TOTAL E&P PNG LIMITED

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Upstream Vegetation Mapping and Forest Condition Baseline Report

Papua LNG Project

Total E&P PNG Limited

August 2017

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Author/s:	Howard Rogers
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Contact:	Howard Rogers, h.rogers@booyong.biz, + 61 7 3289 9081 (M) 0412 013 217

Booyong Forest Science Pty Ltd
ABN: 47 117 077 808

Kananbie
46 Dales Road
Kobble Creek
Qld 4520
Australia

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EXECUTIVE SUMMARY

This report presents the baseline vegetation mapping for PRL-15 and the export pipeline corridor of the upstream Papua LNG Project area. Total E&P PNG Limited (TEP PNG) is proposing to develop the Papua LNG Project (the Project) to commercialize the natural gas resource present in the Elk-Antelope gas field in Gulf Province, Papua New Guinea (PNG).

The vegetation mapping study area includes the extent of coverage by LIDAR imagery across PRL-15 and the export pipeline corridor:

- PRL-15 comprises an area of 763,522 ha.
- The export pipeline corridor comprises an area of 208,761 ha.

The study involved a revision of the existing vegetation mapping units to align with the Papua New Guinea Forest Inventory Mapping System (FIMS) and associated nomenclature. The baseline map was based on the following data sources:

- Papua New Guinea FIMS.
- Recent LIDAR imagery from 2016.
- Papua New Guinea Resource Information System (PNGRIS) literature.
- Digital elevation model generated 1 m contour layer.

The revised mapping identified a number of discrepancies with the original FIMS mapping. These discrepancies and the subsequent changes fall into the following categories:

- Changes to the boundary between hill forest and alluvial forest on the Delta Swamps and Plains ecological zone.
- Changes to the boundary of areas dominated by land use to reflect increased loss of forest from subsistence agriculture.
- Reclassification of vegetation types where interpretation of the LIDAR imagery and aerial survey indicated significant discrepancies with the original FIMS mapping.
- Mapping of areas of mangroves associated with small creeks through the villages of the Orokolo Bay that had not been previously mapped in the original FIMS mapping.
- Mapping of areas of littoral forest not mapped in the original FIMS mapping.

Of the combined area of PRL-15 and the export pipeline corridor 83.7% (806,952 ha) comprises hill and alluvial forest. Freshwater swamps, cover approximately 9.3% (90,457 ha) of the combined area. Mangroves, comprise 1.5% (14,751 ha) of the combined area but are limited in occurrence to the tidal areas of the export pipeline corridor. Grassland and herbland, cover 1.9% (17,306 ha) of the area, 0.1% (932 ha) is littoral forest, 1.4% (13,439) is dominated by land use and the remaining 2.1% is waterbodies (20,415 ha).

Forest condition in PRL-15 is mostly intact apart from several discrete disturbances associated with gas field infrastructure construction. Forest within the export pipeline corridor has been primarily impacted by disturbance from logging, subsistence agriculture and to a lesser extent gas field infrastructure. Hill forests had mostly been impacted across the export pipeline corridor and to a lesser extent PRL-15, with 681,054 ha (nearly 100%) classified as having mainly slight disturbance. However, this does not reflect disturbance across the entire hill forest mapping polygons, but reflects the presence of disturbed areas within each polygon. For alluvial forest only 55,776 ha (48%) was classified as disturbed of which 20,120 ha (16%) was heavily disturbed. For freshwater swamps 29,395 ha (32.5%) were slightly disturbed. Mangroves were the least disturbed with only 387 ha (2.6%) classified as slightly disturbed.

GLOSSARY AND ABBREVIATIONS

amsl	above mean sea level
EIS	Environmental Impact Statement
FIMS	Forest Inventory Mapping System
ha	hectare
km	kilometer
LIDAR	Light detection and ranging
PNGLNG	Papua New Guinea Liquefied Natural Gas
PNGRIS	Papua New Guinea Resource Information System
PRL	Petroleum Retention License

1 INTRODUCTION

1.1 BACKGROUND

The following Project description is focused on the upstream components of the Papua LNG Project and aims at providing minimal but appropriate context for the baseline reports.

Joint venture partners are currently planning the development of the Elk-Antelope gas field, which is located within Petroleum Retention License 15 (PRL-15) in the Gulf Province, Papua New Guinea. Total E&P PNG Limited (TEP PNG), a wholly owned subsidiary of TOTAL S.A (TOTAL) has the largest interest in the Elk-Antelope gas field and is the operator of the Papua LNG Project (the Project) on behalf of the other joint venture partners.

The Elk-Antelope gas field is a significant gas discovery in Papua New Guinea consisting of a gas reservoir with several trillion cubic feet of gas reserves located approximately 120 km inland from the township of Kerema, and 340 km northwest of Port Moresby.

The Project will comprise upstream production well development and associated infrastructure at the gas field within PRL-15, construction of an upstream central processing facility (CPF) and delivery of gas and condensate via onshore and offshore export pipelines to a LNG Plant site at Caution Bay, Central Province, 20 km northwest of Port Moresby. The design life for the Project will be 25 years.

The Project area comprises the physical footprint of the various Project components and associated infrastructure as detailed below.

- Production, processing and related facilities (within PRL-15):
  - Wellpads and the associated gathering system (including flowlines and trunkline).
  - CPF.
  - Logistics base and river offloading facilities, accommodation camps, airstrip, roads and bridges.
  - Quarries, communications infrastructure.
  - Initial section of the onshore export pipeline.
- Onshore pipeline (outside PRL-15):
  - Remainder of the onshore export pipeline to landfall on the Gulf coast including valve stations.
  - Temporary laydown areas and camps.
  - Quarries, communications infrastructure.
- Transport (river) corridors:
  - River transport routes — the Purari, Urika-Ivo and Wame-Varoi rivers.
- Offshore pipeline:
  - Offshore section of the export pipeline to a LNG Plant site, Caution Bay.

As part of the Project environmental, social and health impact assessment (ESHIA), a terrestrial biodiversity baseline study has been commissioned to provide a baseline characterization of terrestrial biodiversity and conservation values present in the vicinity of the upstream Project area. This report presents the description of vegetation communities reviewed as part of the terrestrial biodiversity baseline study. An inventory of the weeds and documentation of the flora are reported separately (Rogers, 2017, Venter, 2017).

1.2 UPSTREAM TERRESTRIAL BIODIVERSITY STUDY AREA AND ECOLOGICAL ZONES

The upstream terrestrial biodiversity study area (hereafter 'study area') covers approximately 7,290 km^2 of the Gulf Province lowlands (to c. 600 m above sea level (asl)). The study area is divided into five ecological zones (i.e. Middle Purari Hills, South East Coast, Southeast Hills, Delta Swamps and Plains and Mangroves) each of which is expected to support a distinct assemblage of terrestrial biota.

The study area encompasses the upstream project area of influence (upstream PAOI), the area within which the Project may potentially and measurably impact biodiversity. The terrestrial biodiversity field surveys were focused at representative sites within the upstream PAOI, hereafter referred to in this

report as survey sites. Further description of the PAOI is provided in the main upstream ESBS report and is no longer referred to in this report.[1]

The upstream terrestrial biodiversity study area and its component ecological zones are described in more detail in the Upstream Terrestrial Biodiversity Baseline Report (ERIAS Group, 2017). This study area differs from the vegetation mapping study area of this report which is defined in Section 1.3 and presented in Figure 1-1.

1.3 TECHNICAL STUDY OBJECTIVES

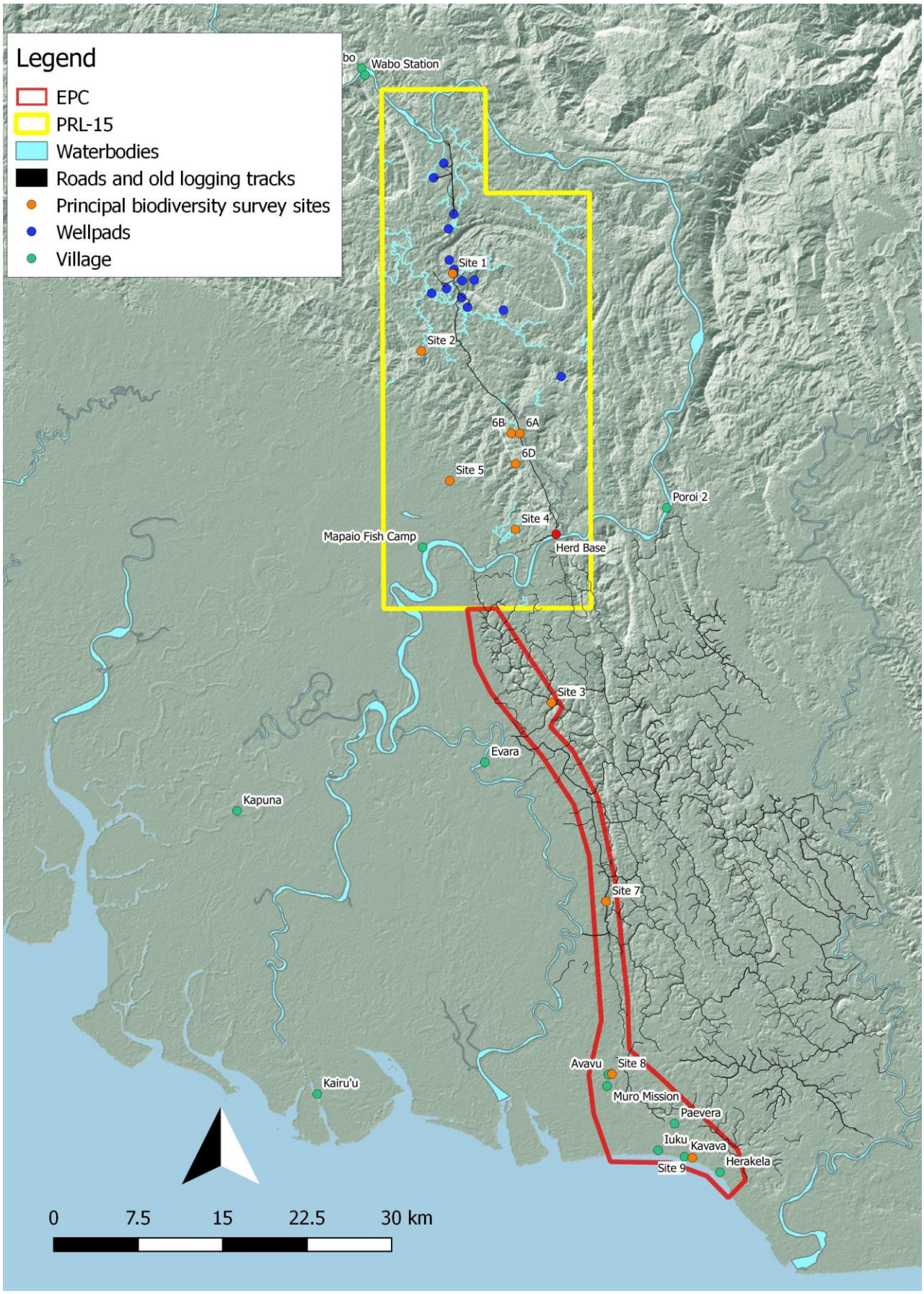
The objectives of this technical study are:

- To map the distribution and condition of major vegetation types present within PRL-15 and the export pipeline corridor based on the existing FIMS classification.

For the vegetation mapping study, the vegetation mapping study area refers to the area covered by PRL-15 and the export pipeline corridor only, for which recent (2016) LIDAR imagery was acquired (see Figure 1-1).

[1] The boundary of the PAOI is shown in figures for context only.

Figure 1-1 The vegetation mapping study area which is defined by PRL-15 and the export pipeline corridor



2 METHODS

The approach to the revision of the mapping units is based on a revision of the boundaries of the FIMS spatial data set based on the LIDAR imagery and supporting data sets (contours, field survey and aerial photographs). The FIMS definition for classification of structural formations of vegetation (i.e., forest, woodland, savanna, scrub, grassland and mangrove) and classification of vegetation types was used where practicable to define each mapping unit to ensure consistency with the original interpretation. The FIMS classification of structural formations of vegetation is based on the presence of the dominant life form, e.g., trees, shrubs, grasses, etc., tree crown size, the degree of canopy closure and the canopy profile (irregular, uneven or even). The FIMS classification of vegetation types is based on a combination of altitude zone, species composition, canopy height and the degree of canopy closure (Hammermaster and Saunders, 1995). (A full mapping unit terminology is provided in Appendix A).

To update the FIMS mapping units for the vegetation mapping study area in relation to the FIMS classification system, a range of data sources was used, including the following:

- Papua New Guinea FIMS.
- Airborne LIDAR imagery.
- LIDAR generated contours.
- Field data from the flora survey.
- Papua New Guinea Resource Information System (PNGRIS) literature.
- Oblique aerial photography from aerial surveys undertaken in 2016.

The data sources are discussed in the following sections:

2.1 PAPUA NEW GUINEA FOREST INVENTORY MAPPING SYSTEM

The FIMS mapping provides a comprehensive level of vegetation mapping based on the delineation of vegetation types from black and white SKAIPIKSA series (panchromatic) photographs taken in 1973 to 1974 across the whole of Papua New Guinea. The scale of the SKAIPICSA series was variable but averaged 1:110,000 which was used to produce base maps at a scale of 1:100,000 by CSIRO (Hammermaster and Saunders, 1995), and includes vegetation mapping units subject to human disturbance. A total of 63 vegetation type codes are employed by the FIMS. The generalized floristics of these units was based on personal observations, CSIRO Resource Survey Reports, and from Paijmans (1976). However, the limitation of the scale of mapping results in some polygons being mapped as a mixture of vegetation types that can result in discrepancies with field observations and some substantial errors in vegetation unit boundaries, particularly in the lowlands between hill forest and alluvial forest, and amongst the range of alluvial forest types. This is attributed to the limitations of the 40 m contour interval available at the time of the original mapping which would have prevented an accurate delineation of the boundary between these forest types. In particular, alluvial forest types are distributed along a drainage gradient which typically reflects small differences in elevation, i.e., a few meters.

2.2 IMAGERY

The imagery was provided by TEP PNG and was captured using airborne LIDAR for PRL-15 and the pipeline corridor only. A Riegal – LMS-Q1560 scanning system was used to capture the imagery over eleven days between the 22nd March and the 9th April 2016.

2.3 CONTOURS

A smoothed 1 m contour layer was derived from the LIDAR data provided by TEP PNG. This was used to assist with correcting boundary errors between hill forest and alluvial forest, and for the identification of vegetation types subject to inundation such as swamp woodland.

2.4 FIELD DATA

The field data comprises vegetation descriptions from a range of survey locations derived from the biodiversity flora survey (Venter, 2017). The biodiversity flora survey provides a detailed description of vegetation types and plant taxonomy (comprehensive lists of species with current nomenclature) at the biodiversity sites 1 – 9. This data was supported by observations made during other vegetation

related field survey components and dedicated aerial survey to verify FIMS vegetation types and potential mapping anomalies.

2.5 PNGRIS LITERATURE

The PNGRIS literature comprises several publications on the natural resources of Papua New Guinea, including some of the earliest vegetation maps and vegetation descriptions for the whole country. The following publication was reviewed:

- Forest Resources and Vegetation Mapping of Papua New Guinea: PNGRIS Publication No. 4 (Hammermaster and Saunders, 1995).

2.6 VEGETATION MAPPING UNITS

A systematic approach was applied to the identification and revision of the FIMS vegetation mapping units involving several basic characteristics of features evident in the imagery, as follows:

Shape: The general form, configuration, or outline of individual vegetation types (e.g., natural vegetation type boundaries and shape of individual tree crowns) where homogeneous.

Pattern: Pattern relates to the spatial arrangement of homogeneous areas of vegetation in relation to landforms (e.g., hills, ridge lines and plains visible in the imagery and landforms mapped in the PNGRIS spatial data) and position in the landscape.

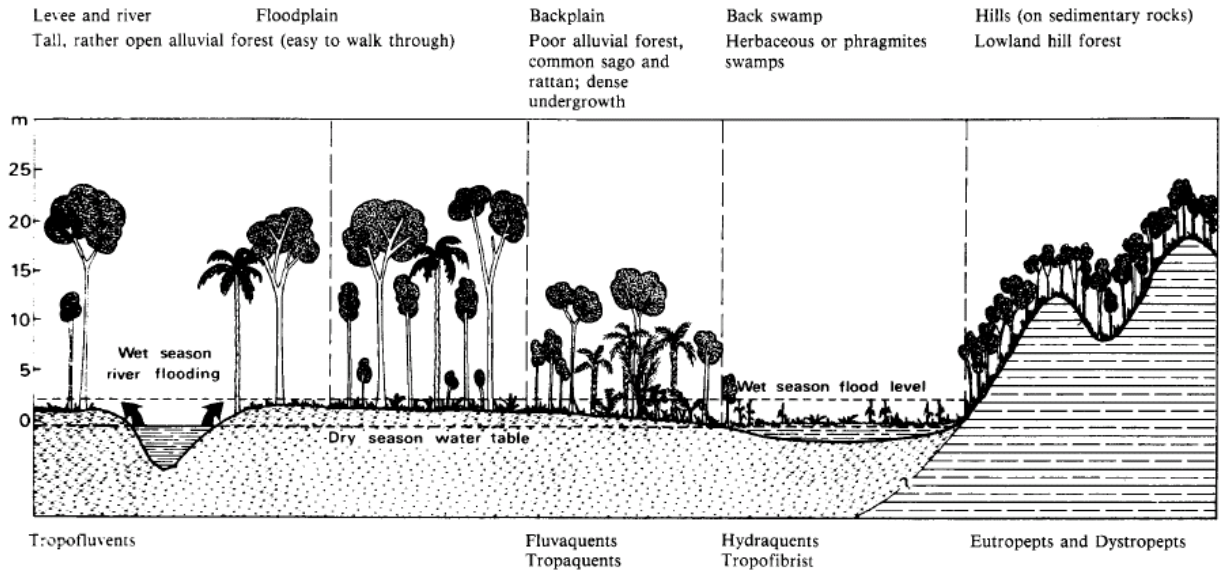
Tone: Tone refers to the relative brightness or color of objects on the image tiles. This characteristic often varies amongst image tiles so it was mostly applied within individual tiles.

Texture: Texture is the frequency of tonal change within an image. Texture is produced by an aggregation of unit features (e.g., different trees, palms or grass swards) that may be too small to be discerned individually in the imagery at small scales. It is the product of the individual shape, size, pattern, shadow, and tone of species within a vegetation type that determines the overall visual "smoothness" or "coarseness" of the image features.

Site: Site refers to topographic or geographic location and is a particularly important aid in the identification of vegetation types and disturbance. Different forest types generally occur within specific geographic limits (e.g., altitude) or are associated with specific landform types or geology. Similarly, disturbed vegetation/regrowth typically occurs in populated areas and near roads.

Association: This refers to the occurrence of certain vegetation types in relation to others which reflects natural changes associated with environmental gradients. An example of this is provided in Figure 2-1.

Figure 2-1 Vegetation, landform and soil association



(Adapted from (Bleeker, 1983)).

2.7 MAPPING UNIT DIGITIZING

The updated mapping units were digitized in the GIS platform MAPINFO. Digitizing was carried out at a range of scales up to the resolution of the imagery. A grid of approximately 500 m squares was overlaid across the imagery and each square was systematically assessed to ensure the entire imagery was reviewed. This involved zooming in and out of the imagery to interpret the characteristics described in Section 2.6. The majority of the digitizing involved realignment of the vegetation type boundaries using the 1 m contour layer.

2.8 FOREST CONDITION AND AREAS OF DISTURBANCE

Forest (vegetation) condition refers to levels of anthropogenic disturbance to the canopy structure (i.e., the amount of gaps in the canopy), e.g., from logging, food gardens and settlements and infrastructure. This was predominantly assessed from the LIDAR imagery, with field verification of the disturbance type (e.g., logging) undertaken during other vegetation related surveys where practicable. Forest condition for this study does not consider the amount of disturbance to the ground or to layers of vegetation below the canopy since this is not detectable from LIDAR imagery. Disturbance to the ground exposing soil is assessed as part of the deforestation study (Watt *et al.*, 2016) where satellite imagery was used. Moreover, LIDAR imagery can only be used to identify disturbance prior to the canopy closing after disturbance. Consequently, unless vegetation is completely cleared from a site, or a large clearing is made within forest, forest condition is unlikely to be detected between 5 – 10 years after a disturbance due to rapid lateral growth in the forest canopy adjacent to the gap.

Vegetation condition was applied to individual mapping polygons based on the FIMS disturbance classes: nil disturbance, slight disturbance 8-9, moderate disturbance 6-7, heavy disturbance 4-5, and very heavy disturbance < 4. Each digit indicates the percentage of forest cover, e.g., 8 & 9 = 80% and 90% forest cover respectively. For example, a 90% forest cover for this study refers to the average forest cover across the mapping polygon which could reflect minor disturbance to the whole mapping polygon, or the presence of a logging road incursion across the polygon indicating a discrete disturbance (e.g., vegetation clearing) to a small part of the polygon, rather than disturbance to otherwise intact forest across a polygon. For this study, this mostly relates to the latter to provide a practical solution to considering road disturbance impacts.

In addition to revisions of the FIMS code for canopy disturbance and areas dominated by land use an overall disturbance layer was digitized from the LIDAR imagery. For this layer landslips and areas of forest clearance were identified as discrete polygons. The areas of clearing mostly reflect sites where there appeared to be bare ground, a low vegetation cover of weeds or recent regeneration after clearing. This layer includes clearings for early exploration Project-related infrastructure such as accommodation camps and wellpads.

2.9 VEGETATION TERMINOLOGY

Vegetation types are referred to in the text using a set of FIMS equivalent terms developed specifically for the upstream terrestrial biodiversity baseline study (Appendix B). These closely follow the formal FIMS descriptors, which are based on the founding vegetation descriptions (Hammermaster and Saunders, 1995, Paijmans, 1976), but are less cumbersome and have been ground-truthed at the terrestrial biodiversity survey sites and reviewed more broadly by aerial survey.

Where a specific vegetation type is referred to in the text it is normally capitalized and followed in brackets by its FIMS code in all other Papua LNG Project Baseline Reports. In this way reference is made to vegetation mapping units present in surveyed areas, for example 'Hill forest (Hm)' and 'Open alluvial forest/Swamp forest (Po/Fsw)'. However, this has not been done is this study due to the frequent use of the terms. The FIMS codes are provided in tables and section headings only to simplify the text.

Where more general reference is made to broader vegetation types that include multiple possible variants within the study area (and more widely in Papua New Guinea) it appears without capitals or a FIMS code, for example 'hill forest' and 'alluvial forest'. These generic types closely follow the various basal FIMS vegetation types, which in these examples are coded 'H' and 'P' respectively.

A full list of FIMS vegetation types present within the study area, and equivalent terms used in the upstream terrestrial biodiversity baseline study, is presented in the Upstream Terrestrial Biodiversity Baseline Report.

3 VEGETATION MAPPING

3.1 EXISTING VEGETATION MAPPING ERRORS

The existing FIMS mapping is subject to a range of errors that mostly reflect the limitations of vegetation mapping inherent in the original panchromatic photos, and absence of substantial ground-truthing (see Section 2.1 above). Ground-truthing of the original mapping was based on patrol reports and annotated topographical maps with a 40 m contour interval. The contours were derived from stereophotogrammatic methods that were not sufficiently accurate to delineate some of the boundaries in the alluvial vegetation. The spatial pattern of alluvial vegetation is strongly correlated with small changes in topography reflecting differences in drainage conditions, i.e., an environmental gradient.

In addition to mapping related errors the original mapping was based on photography which is approximately 43 years old. Although the spatial pattern of vegetation types mostly does not change over time, the location of disturbed forest and land clearing does. The main exception to changes in the spatial pattern of vegetation types is where the extent of a landform changes due to loss from erosion or accretion from sedimentation resulting in a reduction or increase in areas of vegetation respectively. These processes most commonly occur in coastal environments.

Based on the known original mapping issues the following errors were corrected:

- FIMS mapping unit boundaries, particularly the boundary between hill forest and vegetation types on the alluvial plains of the Delta Swamps and Plains ecological zone, including alluvial forest, swamp forest and swamp woodland, and amongst alluvial forest types.
- FIMS mapping unit code where a polygon appeared to have been assigned an incorrect vegetation type.
- Disturbance code, particularly where there was evidence of increased disturbance from gardens and recent logging (< 5 - 10 years ago), and where a polygon had been incorrectly classified as "land use". This was applied to one polygon only where part of the polygon was remapped as Open alluvial forest (Po).

3.2 REVISED VEGETATION MAPPING

The revision of the vegetation mapping resulted in a range of refinements to the original FIMS mapping, including revisions to vegetation unit boundaries, changes to the FIMS vegetation type including The FIMS unit "O" (non-vegetation and areas dominated by land use) and the digitizing of new polygons. A summary of the main changes is presented in Table 3-1. The summary indicates where one or more polygons of a FIMS mapping unit have been recoded. In addition, polygon boundary changes have been made throughout the data set some of which may reflect projection errors between the FIMS mapping and the LIDAR imagery.

Table 3-1 Major FIMS mapping unit revisions

FIMS Type	Original FIMS Code	Change to FIMS code	Comment
Hill forest - Low altitude forest on uplands - below 1000 m			
Medium crowned forest	Hm	None	Boundary changes and additional polygons demarcated based on contours within PRL-15 and the export pipeline corridor.
Small crowned forest	Hs	None	Boundary changes and additional polygons demarcated based on contours within the export pipeline corridor.
Hill forest with scrub	HmSc	Hm	Scrub not present but represents regenerating forest on slumps within PRL-15.

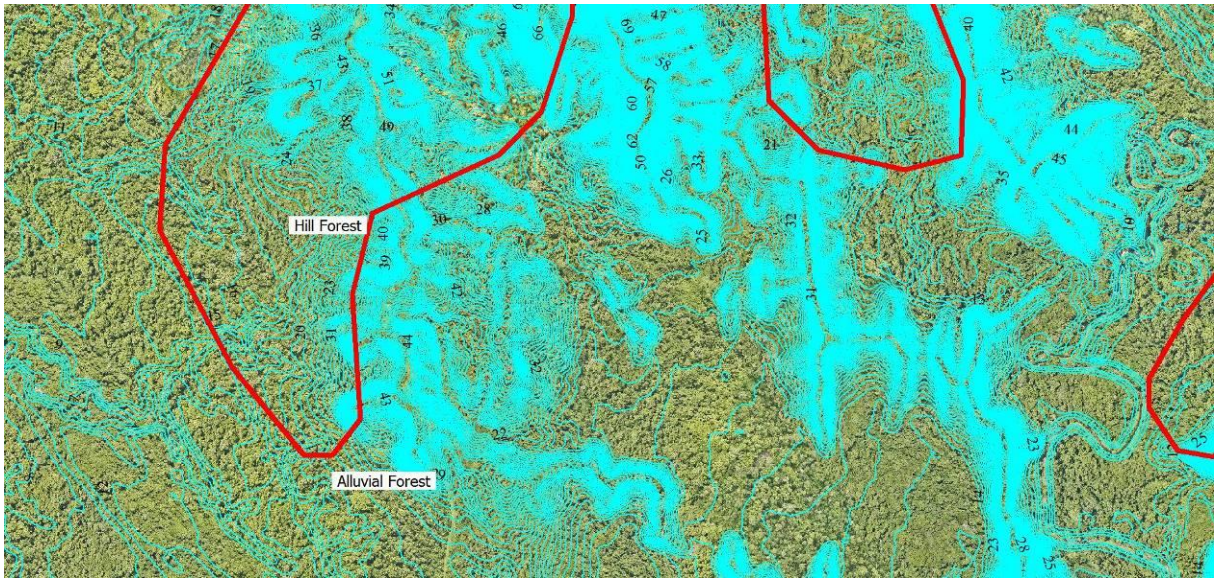
FIMS Type	Original FIMS Code	Change to FIMS code	Comment
Alluvial forest - Low altitude forest on plains and fans - below 1000 m			
Alluvial forest	Pl	None	Boundary changes based on contours for the export pipeline corridor and PRL-15.
Alluvial forest	Pl	Pl/Fsw	Swamp forest patches present within large to medium crowned forest based on the occurrence of sporadic sago palms visible in the imagery within PRL-15.
Alluvial forest	Pl8	Hsw/Fsw	A discrete herbaceous swamp/Swamp forest complex south of Arehave 2.
Alluvial forest	Pl8	Pl5	Heavy disturbance in the southern export pipeline corridor since the original mapping caused by food gardens, the planting of sago and coconut plantations.
Open alluvial forest	Po	O	Areas of open alluvial forest near the coast reclassified as land use due to clearance for food gardens and extensive areas of planted sago.
Open alluvial forest	Po	None	Boundary changes based on contours and level of gaps observed in the imagery for PRL-15. Numerous canopy gaps in alluvial forest formations typically indicate the presence of open alluvial forest.
Open alluvial forest/Swamp forest	Po/Fsw	Po/Fsw/Hm	Addition of the hill forest unit reflecting the presence of a complex landform unit with several small hills supporting hill forest. Primarily demarcated from the contour along the central and western side of the southern portion of PRL-15.
Swamp Forest/Swamp woodland & Grassland			
Swamp forest/Grassland swamp	Fsw/Gsw	Wsw/Gsw	The Swamp woodland/Grassland swamp complex was identified within a Swamp forest /Grassland swamp polygon near the Oxbow wetland in PRL-15. The presence of extensive stands of sago indicated the original mapping error.
Swamp forest/Swamp woodland	Fsw/Wsw	None	Boundary changes based on contours in the southern export pipeline corridor.
Swamp forest/Swamp grassland	Fsw/Gsw	Wsw/Gsw	Presence of extensive areas of sago and open areas in the imagery near Aivai indicated the presence of Swamp woodland/Swamp grassland.
Swamp woodland	Wsw	None	Boundary changes based on contours in the southern export pipeline corridor.
Estuarine communities			
Mangroves	M	None	Changes to the boundaries and addition of new polygons along the creeks, particularly near Orokolo Bay, based on the presence of extensive stands of the mangrove palm *Nypa fruticans.*
Littoral forest			
Mixed forest	Not mapped	B	Mixed forest and associated littoral vegetation (herbaceous beach vegetation, beach scrub) was noted on an extensive sand bar (marine sands) in the south east of the export pipeline corridor along the coast.
Grassland and Herbland			
Riverine successions dominated by grass	Not mapped	Gri	A small area (3 ha) of riverine successions dominated by grass was identified in an area of open alluvial forest in PRL-15. Indicated by the presence of grassland with occasional trees adjacent to a meandering river.

Examples of the main changes to the vegetation mapping are provided in the following sections.

3.2.1 Hill forest and alluvial forest boundary changes

Plate 1 shows the obvious boundary error between hill forest and alluvial forest in the original FIMS mapping based on the contours, with elevations of up to 62 m amsl in the image. The original alluvial forest boundary overlapped areas of high relief.

Plate 1 Boundary errors between hill forest and alluvial forest



Contours – blue. Vegetation boundary – red

3.2.2 Hill forest with scrub (HmSc) change to Hill forest (Hm)

Plate 2 shows the FIMS unit Hill forest with Scrub which has been revised to Hill forest only. Scrub is defined by FIMS as a community of dense shrubs up to 6 m height with *Hibiscus tilleaceous* and *Desmodium umbellatum* which are more commonly associated with coastal areas. However, what appears to have been classified as Scrub was regenerating forest on large-scale slumps across unstable sedimentary landforms. Vegetation classified as Scrub was visited at Site 2 where it was confirmed to be regenerating Hill forest.

Plate 2 Regenerating Hill forest previously classified as Scrub

3.2.3 Swamp forest/Swamp woodland (Fsw/Wsw) change to Swamp woodland/Swamp grassland (Wsw/Gsw)

Plate 3 shows an area of the complex Swamp woodland (sago palms)/Swamp grassland which was originally classified as Swamp forest/Swamp woodland. There are no forested areas in the new polygon.

Plate 3 The complex Swamp woodland/Swamp grassland

Contours – blue

3.2.4 Alluvial forest (Pl) change to large to medium crowned forest/Swamp forest (Pl/Fsw)

One polygon of Alluvial forest was identified as having numerous patches of sago palms, which typically occur where forest is subject to prolonged period of inundation from flooding, which is more commonly associated with Swamp forest (Plate 4). Alluvial forest is usually well to moderately well drained and typically does not support stands of sago palms.

Plate 4 Patches of sago palms indicating the presence of Swamp forest

3.2.5 Alluvial forest (Pl) change to Herbaceous swamp/Swamp forest (Hsw/Fsw)

Plate 5 shows a 527 ha Herbaceous swamp/Swamp forest complex that was classified as Alluvial forest in the original FIMS mapping. This area is located approximately 300 m south of Arehava 2 in a depression with extensive Herbaceous swamp and fringing Swamp forest.

Plate 5 Herbaceous swamp/Swamp forest

Contours - blue

3.2.6 Alluvial forest slight disturbance (Pl8) change to heavy disturbance (Pl5)

Plate 6 shows Alluvial forest that was classified as having slight disturbance (Pl5) in the original mapping but has since been subject to heavy disturbance (Pl8). The image shows disturbance from food gardens, coconut plantations and planted sago. The area is located approximately 2.5 km from the coast.

Plate 6 Heavy disturbance in Alluvial forest

3.2.7 Mangrove (M)

Coastal creeks were lined with Mangroves in Orokolo Bay that had not been identified in the original FIMS mapping. Plate 7 shows a creek lined with the mangrove palm *Nypa fruticans* running through the villages of Mareke and Hururu.

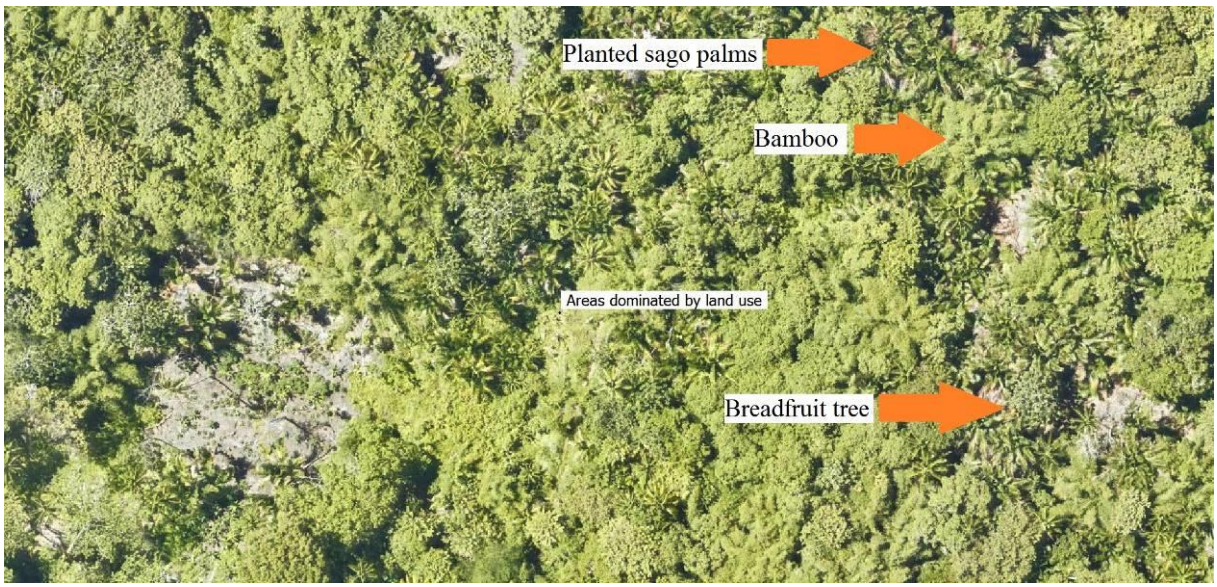
Plate 7 Mangrove lined creek showing the mangrove palm *Nypa fruticans*

Vegetation boundary – red

3.2.8 Open alluvial forest (Po) change to land use (O)

Plate 8 shows vegetation that was classified as Open alluvial forest in the original FIMS mapping but has been reclassified as land use. The image shows various land use elements including planted sago, bamboo and breadfruit trees but a forest canopy is absent from the image.

Plate 8 Land use



3.2.9 Littoral forest (B)

Littoral forest, which is typically confined to marine sand dunes was not mapped in the original FIMS mapping. It was identified in the southeast corner of the export pipeline corridor on what appears to be an accreting sand bar. Patchy littoral forest occurs across the marine sand dunes as shown in Plate 9.

Plate 9 Littoral forest on marine sand dunes

3.2.10 Accuracy assessment of the revised vegetation mapping

No accuracy assessment was undertaken of the revised vegetation mapping since this could only be achieved by extensive ground-truthing in remote terrain, often with difficult access which was not practicable. However, where adjacent vegetation types are distinctly different in structure vegetation type boundaries are clearly visible in the imagery, and therefore accuracy is expected to be 100%. Where vegetation types have more subtle differences (i.e., more similar appearance in the imagery), e.g., the boundary between Alluvial forest (Pl) and Swamp forest (Fsw), there is potential for mapping error in the boundary. However, this error has been reduced by the use of the LIDAR generated contours to assist with the identification of more subtle vegetation type changes which are reflected by a very small change in elevation (e.g., 1 - 3 m), indicating the different drainage conditions that underlie the different alluvial vegetation types. Moreover, changes in vegetation type are not always abrupt and therefore discrete boundaries are not always present, reflecting where different vegetation types integrate, otherwise known as an ecotone.

4 VEGETATION UNIT DESCRIPTIONS

The vegetation unit descriptions are adapted from Hammermaster and Saunders (1995) which provide the baseline FIMS unit descriptions. These are derived from detailed vegetation community descriptions in "New Guinea Vegetation" (Paijmans, 1976), however the vegetation unit descriptions have been expanded where field observations appear to be more widely applicable to PRL-15 and the export pipeline corridor. Taxonomically detailed descriptions of the FIMS vegetation units for each of the biodiversity sites are presented in the Upstream Flora Baseline Report (Venter, 2017).

4.1 ALLUVIAL FOREST – LOW ALTITUDE FOREST ON PLAINS AND FANS BELOW 1,000 M

4.1.1 Alluvial forest - Pl

Alluvial forest occurs on well to imperfectly drained alluvial plains and on gently sloping undissected fans (Plate 10). Flooding occurs occasionally but is typically infrequent and of short duration. This tall forest has a canopy height of up to 40 m but on exceptional sites emergent trees may reach 50 m height. The canopy is typically uneven in profile with a cover of 70 – 80%. The species composition of the canopy is mixed and typically includes *Pometia pinnata*, *Octomeles sumatrana*, *Ficus*, *Alstonia scholaris* and *Terminalia*. Other commonly occurring genera include *Pterocarpus*, *Artocarpus*, *Planchonella*, *Canarium*, *Elaeocarpus*, Cryptocarya, Celtis, Dracontomelon, Dysoxlum, Syzygium, Vitex, Spondias and Intsia. Alluvial forest occurs in the southern sections of PRL-15 and the export pipeline corridor.

Plate 10 Alluvial forest

4.1.2 Open alluvial forest - Po

Open alluvial forest occurs on flood plains and low levees subject to short inundation or flooding, and on back plains subject to more prolonged seasonal flooding. The canopy can reach 30 m height often with large crowned emergents of the tree *Octomeles sumatrana* and occasionally strangling figs to 40 m. However, in the vegetation mapping study area at Site 4, the canopy was relatively low with a height range of 20 - 30 m which was probably associated with poor drainage. The canopy of open alluvial forest is often characterized by many gaps that are often colonized by the thorny rattan palms *Calamus* and *Korthalsia*. The canopy tree species composition typically includes the trees *Planchonia*, *Bischofia*, *Intsia*, *Tijsmanniodendron*, *Nauclea, Neonauclea* and *Vitex*. Open alluvial forest in the vegetation mapping study area also included an abundance of fig species in the lower canopy layers, the dipterocarp *Vatica papuana*, several *Terminalia* species and the palm *Hydriastele costata*. An example of Open alluvial forest is shown Plate 11. Open alluvial forest occurs in the southern section of PRL-15 and in the northern and southeastern section of the export pipeline corridor.

Plate 11 Open alluvial forest with characteristic canopy gaps

4.2 HILL FOREST – LOW ALTITUDE FOREST ON UPLANDS – BELOW 1000 M

4.2.1 Hill forest – Hm

Hill forest is characteristic of hilly terrain below 1,000 m amsl and is common throughout Papua New Guinea on a wide range of landforms, slopes, soils, rock type and climate. The canopy of the forest is 25 – 30 m in height, is generally slightly uneven and has a 60 – 80% canopy cover (Plate 12). Typically, below 500 m amsl, the tree species present are similar to those found in the forests on the low altitude plains and fans. Common genera include *Pometia*, *Canarium*, *Cryptocarya*, *Terminalia*, *Syzygium*, *Ficus*, *Celtis*, *Dysoxylum* and *Buchanania*. Occasionally *Castanopsis acuminatissima* may be present but this species is typically confined to the drier ridges and hill crests. Trees up to 70 cm diameter at breast height (dbh) and larger, often with large buttresses, may be present in areas of stable terrain. An unusual characteristic of hill forest in some parts of the vegetation mapping study area is the relatively high abundance of the thorny climbing palms, *Korthalsia zippelii* and *Calamus* spp. in areas of regenerating forest that occur on the unstable Pliocene mudstones of the Orubadi Formation (e.g., Site 2). Medium crowned hill forest is widespread across PRL-15 and the northern export pipeline corridor.

Plate 12 Hill forest

4.2.2 Small crowned forest – Hs

Small crowned forest typically occurs on steep terrain but can also occur on more undulating terrain on poor soils. Soils are usually skeletal soils or strongly weathered. The forest has an almost closed canopy (60 – 80% closure), is uneven in profile and varies in height from 20 – 30 m with no emergents. Similar to Hill forest this forest type occurs widely across Papua New Guinea and is variable in species composition across the country, but the species composition is very similar to Hill forest. An example of Small crowned forest from the LIDAR imagery is presented in Plate 13. Small crowned forest occurs in the southern section of the export pipeline corridor.

Plate 13 Small crowned forest

4.3 FRESHWATER SWAMP HABITATS

4.3.1 Swamp forest – Fsw

Swamp forest occurs on low-lying, permanently swampy river back plains often behind better drained alluvial forest on alluvial terraces. The forest has an irregular open, almost even canopy of medium to small crowned trees 20 to 30 m in height. Canopy cover is variable depending on the distribution of sago palms but may be up to 70% where trees dominate the canopy. Tree diameters are typically small reflecting slow growth in the poor drainage. Commonly occurring species include *Campnosperma*, *Terminalia*, *Syzygium*, *Nauclea* and *Myristica*. Occasional groves of sago palms (*Metroxylon sagu*) and *Pandanus* may also be present (Plate 14). Swamp forest occurs predominantly in the southwest of PRL-15 and the export pipeline corridor.

Plate 14 Swamp forest with groves of sago palms

4.3.2 Swamp woodland – Wsw

Swamp woodland occurs in permanent to near permanent shallow swamps. As the depth of the swamp increases the vegetation grades into swamp grassland or herbaceous swamp which is often reflected in a mapping unit complex, e.g., Swamp woodland/Swamp grassland. The woodland comprises a dense upper layer of sago palms or pandans with or without scattered trees. The ground layer may be almost bare apart from a few ferns or may consist of tall sedges and ferns, particularly where the canopy is dominated by *Pandanus*. Where trees occur, the species are similar to Swamp forest. Across PRL-15 and the export pipeline corridor sago dominated Swamp woodland was most common (Plate 15) but some distinctive stands of *Pandanus* dominated woodland were present, particularly on the east bank of the Purari River opposite Aivai village (Plate 16) and near the Oxbow wetland.

Plate 15 Swamp woodland dominated by sago palms

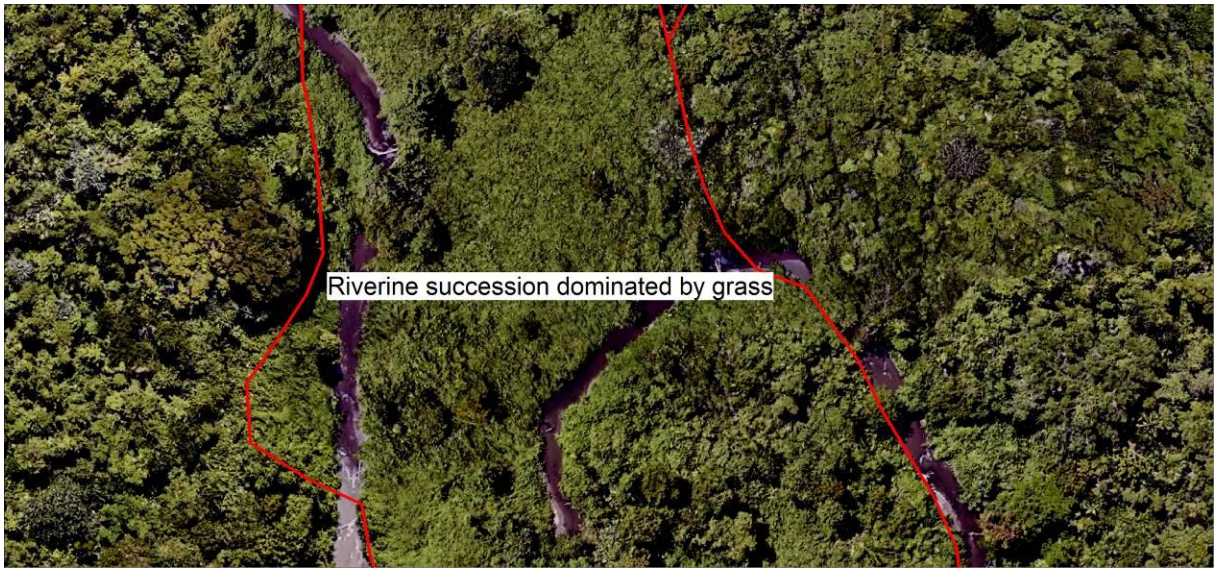
Plate 16 Pandanus dominated swamp woodland near Aivai

4.4 GRASSLAND AND HERBLAND

4.4.1 Riverine successions dominated by grass – Gri

This community is characterized by tall grassland found in low altitude areas on river scroll bars, scroll arches and on the banks of meandering rivers. On frequently flooded sites *Saccharum robustum* is the dominant grass but on swampier sites the grass *Phragmites karka* may dominate in association with the bulrush *Typha* sp. Patches of forest and woodland may occur where less frequently flooded. An example of riverine mixed successions from the LIDAR imagery is provided in. Riverine succession dominated by grass is mapped in PRL-15 in one location.

Plate 17 Riverine successions dominated by grass



Red = Vegetation boundary.

4.4.2 Swamp grassland – Gsw

Swamp grassland occurs across the low altitude plains in permanent to intermittently dry swamps (Plate 18). The community is dominated by *Phragmites karka*, *Saccharum robustum* and *Coix lachrymal-jobi*, however only the first two species were observed in the vegetation mapping study area. In permanent swamps the main species are *Leersia hexandra*, *Oryza* spp. and *Hymenachne acutigluma*, however the presence of these species in the permanent swamps of the study area, e.g., the Oxbow wetland has not been verified by ground based field survey.

Plate 18 Swamp grassland

4.4.3 Herbaceous swamp – Hsw

Herbaceous swamps in the lowlands are usually dominated by the lily, *Hanguana malayana,* with the sedges *Thoracostachyum sumatranum* and *Scleria* spp. The fern *Stenochlaena palustris* may also be widespread. This community is often associated with the more open areas within sago woodland. The main occurrence of Herbaceous swamp in the vegetation mapping study area is in the vicinity of the Oxbow wetland (Plate 19), however it also occurs in association with Swamp woodland south of the village Arehava 2, approximately 4 km north of the coast (Plate 20).

Plate 19 Herbaceous swamp associated with the Oxbow wetland

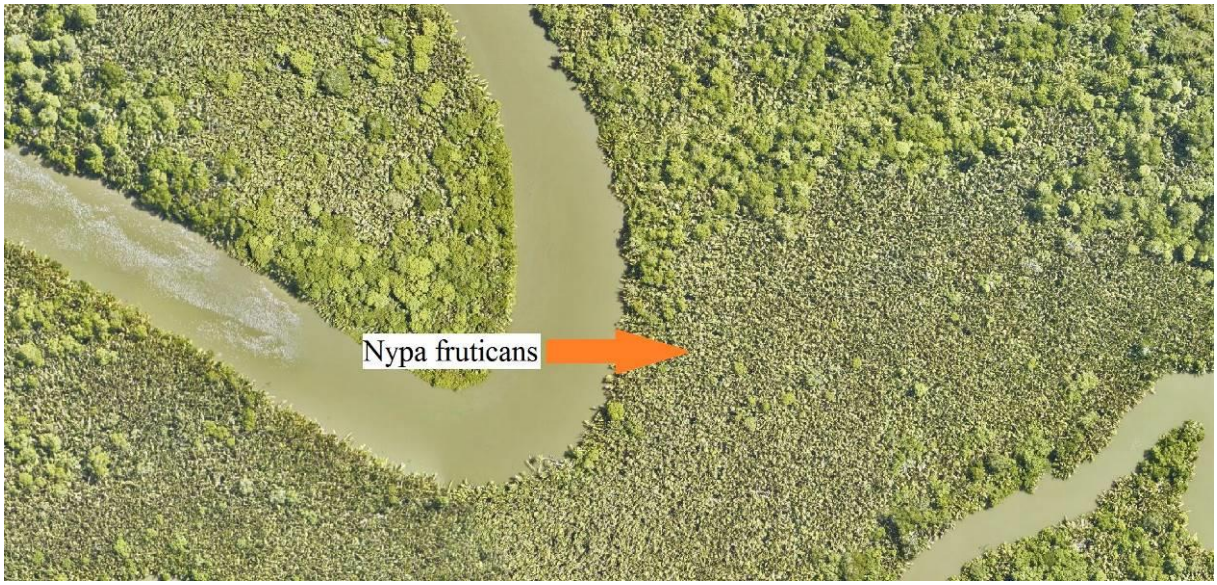
Plate 20 Herbaceous swamp near Arehava 2

4.5 ESTUARINE COMMUNITIES

4.5.1 Mangrove – M

Mangrove communities occur on gently sloping, sheltered shores and estuaries ranging from environments which are totally saline to the brackish upper limits of tidal creeks. Mangrove communities are diverse and range from scattered halophytic shrubs across almost bare tidal flats to almost closed canopy mangrove forests over 30 m in height. Mangrove tree species often occur in specific zones. On the seaward edge a low scattered scrub of *Avicennia*, *Sonneratia caseolaris* and sometimes *Ceriops tagal* develops. Inland extensive stands of *Rhizophora* and *Bruguiera* form. Further inland, as the habitat becomes less saline *Rhizophora* and *Bruguiera* are mixed with other mangrove species including *Heritiera littoralis*, *Xylocarpus moluccanas* and *Xylocarpus granatum*, *Brownlowia argentata, Intsia pallembanica* (swamp kwila), and shrubs of *Aegiceras corniculatum* may also be present. A particular feature of the vegetation mapping study area is the presence of large areas of the mangrove palm, *Nypa fruticans* which grows where land is subject to tidal flooding by brackish water (Plate 21), particularly along the lower Purari River.

Plate 21 Mangroves of the lower Purari River with extensive *Nypa fruticans*



4.6 LITTORAL FOREST – B

Littoral forest occurs on beach ridges and beach plains. The only example in the vegetation mapping study area appeared to be littoral forest in the early stages of succession which had not established the characteristics of mature littoral forest. Mature Littoral forest is characterized by tree species 20 – 30 m height of *Calophyllum*, *Barringtonia*, *Pongamia* and *Hibiscus* in seaward locations. The early successional stage woody species included scattered patches of *Hibiscus tiliaceous*, *Desmodium umbellatum*, *Barringtonia asiatica* and *Premna serrata* to 4 m height. The regenerating littoral forest also included herbaceous beach vegetation which included the beach vine *Ipomea pes-carpae*, the parasitic vine *Cassytha filiformis* and the grass *Ischaemum muticum*. Littoral forest in early stages of succession is shown in Plate 22.

Plate 22 Regenerating littoral forest near Herakela

4.7 LAND USE – O

Areas dominated by land use mostly occur in coastal areas but are also associated with villages, where much of the remnant native vegetation has been extensively modified for subsistence agriculture in and around each village. However, along Orokolo Bay there has also been substantial past clearing for coconut plantations prior to independence (Plate 23), extensive gardening and planting of sago palms as a staple food crop.

Plate 23 Coastal coconut plantations in Orokolo Bay

5 VEGETATION AND LAND USE SUMMARY

Approximately 84% of the combined area of PRL–15 and the export pipeline corridor comprises hill and alluvial forest (this includes complexes that contain other vegetation types as secondary components etc.). Freshwater swamps, which are primarily Swamp woodland complexes and Swamp forest cover approximately 9.3% of the combined area. Mangroves, most of which are dominated by the mangrove palm *Nypa fruticans* comprise 1.5% of the combined area but are limited in occurrence to the tidal areas of the export pipeline corridor. Grassland and herbland, much of which is associated with wetland depressions cover 1.8% of the area. Only 1.4% is dominated by land use, which is mostly associated with clearance for village settlements and food gardens. The total includes vegetation that has been subject to anthropogenic disturbance which is discussed in Section 6.1. The areas of each vegetation type and land use are presented in Table 5–1. Figures 5–1 and 5–2 show the extent of the main vegetation formations and individual vegetation types across PRL-15 and the export pipeline corridor.

Table 5-1 Vegetation and land use areas

Vegetation Formation	Export Pipeline Corridor	PRL-15	Total (ha)	% of combined total
Alluvial forest	55,188	68,101	123,289	12.8
Hill forest	81,100	602,564	683,663	70.9
Freshwater swamp	31,863	58,594	90,457	9.4
Mangrove	14,751	0	14,751	1.5
Littoral forest	932	0	932	0.1
Grassland & herbland	3,387	13,919	17,306	1.8
Land use	13,439	0	13,439	1.4
Waterbodies	18	20,397	20,415	2.1
Total	**200,678**	**763,575**	**964,252**	**100**

Figure 5-1 Vegetation mapping for PRL-15

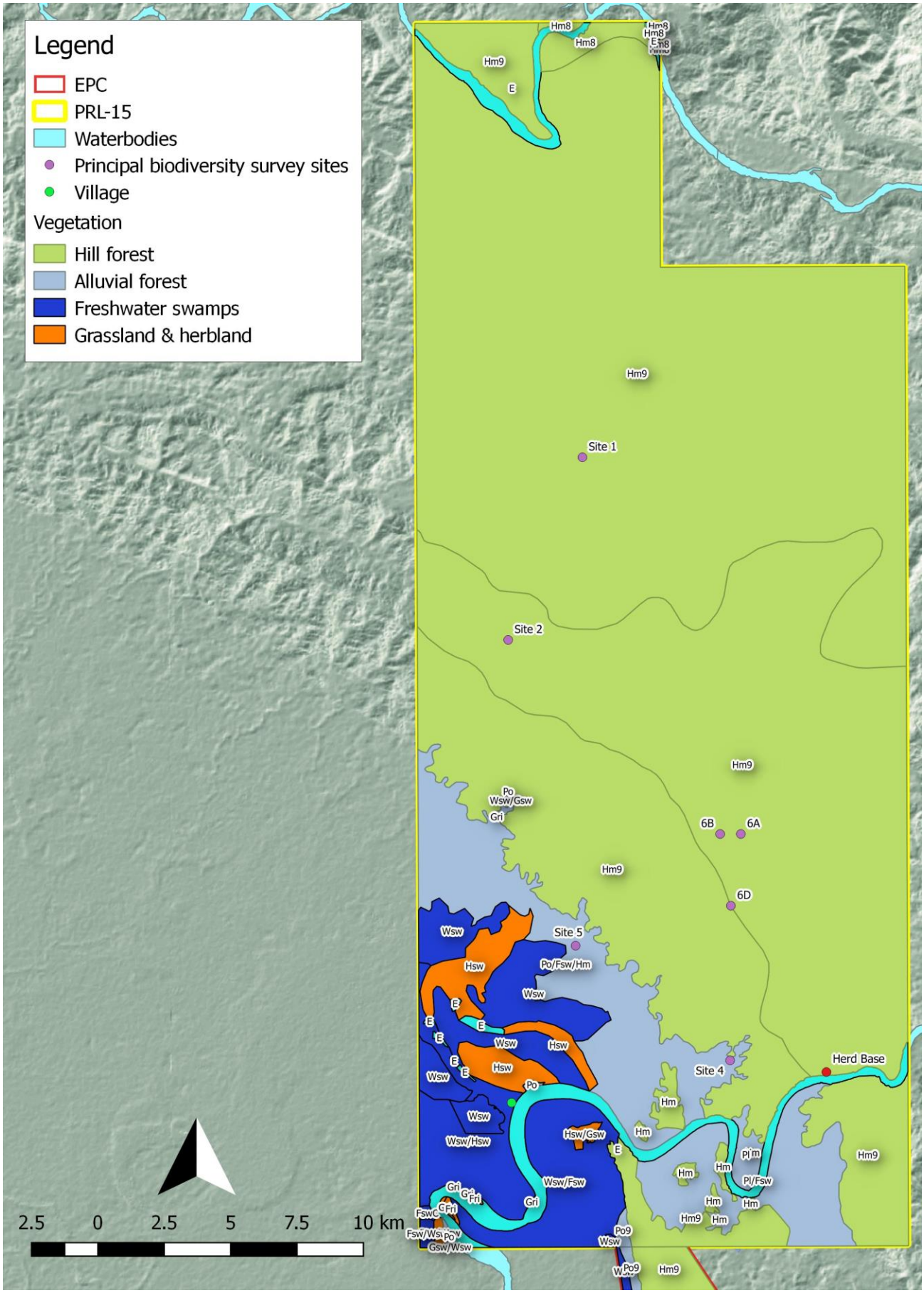
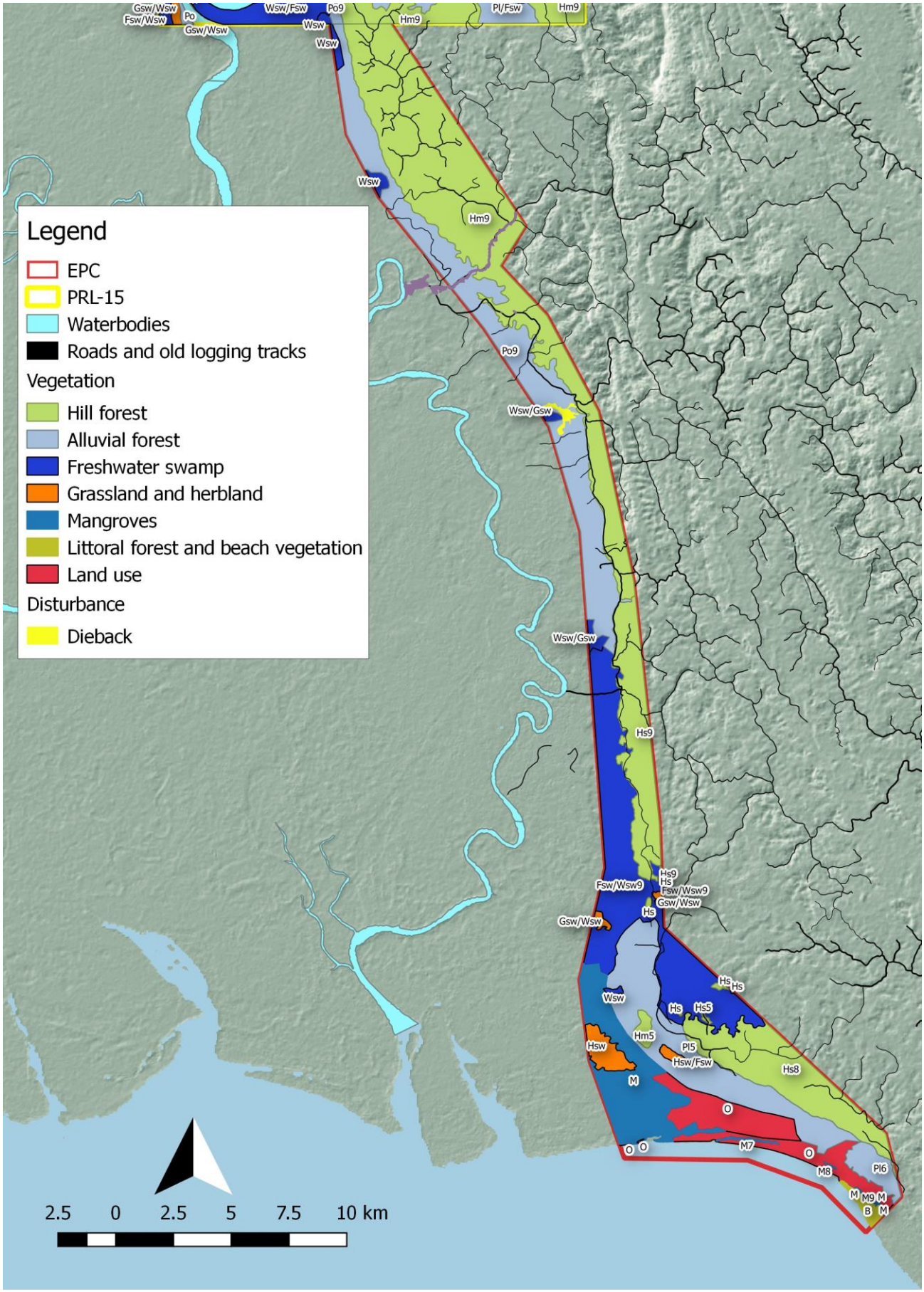


Figure 5-2 Vegetation mapping for the Export Pipeline Corridor



6 DISTURBANCE AND FOREST CONDITION

Forest condition across the export pipeline corridor has been impacted by two main anthropogenic drivers of deforestation and forest degradation (disturbance) which are logging and subsistence agriculture. Subsistence agriculture results in forest loss for clearance for food gardens and from planting the staple food crop sago palms. Land cleared for food gardens are usually left to regenerate back to forest for 10 - 20 years after which they are cleared again to replant food crops. Logging mostly results in forest degradation rather than forest loss and is typically variable across a logging concession, resulting in a mosaic of intact forest (e.g., forest on waterlogged alluvial soils, steep terrain and where commercial log volumes are low) and degraded forest. Forest has also been lost from clearance for coconut plantations in coastal areas, which mostly occurred prior to independence. Project related infrastructure has also resulted in several areas of forest clearance but these are mostly discrete and relatively small in area. The largest of which relate to clearances for Herd Base (38 ha) and the Purari airstrip (27 ha) several years earlier. These drivers of forest change have been analyzed and discussed as part of the deforestation study (Watt *et al.*, 2016).

Forest across PRL-15 is mostly intact but has been impacted by road construction, small-scale clearances for infrastructure and subsistence agriculture along the banks of the Purari River. The road construction and infrastructure are mainly discrete disturbances that have not degraded the majority of forest across PRL-15.

Forests are also subject to a range of natural disturbances which can also impact the condition of the vegetation, particularly when large scale natural catastrophes occur such as widespread flooding or storm related windthrow. Natural disturbances can include windthrow, flooding, lightning strike (particularly in mangroves), mass-movement (slumps and landslides) (Johns, 1986) and plant pathogen related dieback. Of these only landslides are coded by FIMS with the subcode "l" where common in a vegetation type, however in this study they have been mapped as discrete polygons and were not common enough to warrant formal classification. The only large scale natural disturbance was an area of dieback (Plate 24) affecting approximately 60 ha of Open alluvial forest in the export pipeline corridor. The dieback was located in a low-lying swampy site part of which had been logged. The dieback was most likely related to extensive flooding across the Purari River catchment in 2014. Alluvial forests typically show signs of dieback when areas are inundated for long periods as opposed to the normal cycle of short duration floods. Prolonged inundation reduces the oxygen available for fine roots which will quickly die leading to poor water and mineral uptake, wilting of leaves and reduced photosynthesis. In addition to the effect of oxygen starvation there are problems of toxic compounds produced by anaerobic soils (e.g., hydrogen sulphide) (Thomas, 2000), causing changes in plant metabolism and physiological processes. Prolonged anaerobic conditions will also reduce plant vigor predisposing vegetation to insect and or disease attack and eventual mortality.

Plate 24 Severe forest dieback in alluvial forest

6.1 MAPPING OF DISTURBANCE AND FOREST CONDITION

6.1.1 Forest Condition

Forest condition is inherent in the FIMS disturbance codes which reflect the overall level of canopy disturbance for a polygon. Where forest remains, but has been subject to anthropogenic disturbance a disturbance code is provided ranging from 1 – 9 where 9 indicates 90% of the canopy is intact. The degree of disturbance is defined in four categories:

- Slight disturbance 8 – 9 (for this study includes the presence of roads through otherwise intact forest).
- Moderate disturbance 6 – 7.
- Heavy disturbance 4 – 5.
- Very heavy disturbance < 4.

Disturbance codes were revised where the existing codes under represented the percentage of canopy disturbance visible from LIDAR imagery and aerial survey. This was mostly applied to areas subject to logging particularly in hill forest areas throughout the export pipeline corridor, and in areas of increased subsistence agriculture activities towards the coast. The disturbance codes applied to logging areas were based on observations of canopy disturbance from the LIDAR imagery and aerial survey, but was also applied to forest where roads were present in otherwise intact forest such as PRL-15. However, the disturbance code does not necessarily reflect the level of disturbance to the internal forest structure and ground which are likely to show higher levels of disturbance compared to canopy disturbance, because of the relatively rapid canopy closure that occurs after logging within 10 years or less.

The only exception to the above approach was where there had been sporadic disturbance across a polygon rather than ubiquitous degradation of the canopy. In particular, this relates to PRL-15 where access roads, seismic exploration, accommodation camps and wellpads resulted in typically discrete disturbance footprints. For this area the code 9, "slight disturbance" was applied to reflect infrastructure incursion across the predominant hill forest which is otherwise intact (i.e., in good condition).

Disturbance codes for individual FIMS vegetation type polygons are provided in Figure 6–1 and Figure 6–2 and a summary of the areas of disturbance across PRL-15 and the export pipeline corridor is provided in Table 6–1. The largest area of disturbed forest was hill forest (681,054 ha) most of which was classified as having slight disturbance, although this includes the mostly intact hill forest of the PRL-15 which had primarily been impacted by several small discrete disturbances (wellpads etc). For alluvial forest 58,776 ha was classified as having heavy to slight disturbance, of which 20,120 was classified as having heavy disturbance. For mangroves, which are confined to the export pipeline corridor only 387 ha were classified as having canopy disturbance. This disturbance was confined to the mangrove communities that fringed the creeks in the coastal villages.

Table 6-1 Canopy disturbance (ha) by forest formation

FIMS	Heavy Disturbance		Moderate Disturbance		Slight Disturbance		Total Disturbance of FIMS type
	Export Pipeline Corridor	PRL - 15	Export Pipeline Corridor	PRL - 15	Export Pipeline Corridor	PRL - 15	
Hill forest (Hm & Hs)	1,124	0	0	0	79,649	600,281	681,054 (99.6%)
Alluvial forest (PI & Po)	20,120	3,032	3,032	0	32,035	557	58,776 (47.7%)
Freshwater swamps	0	0	0	0	29,395	0	29,395 (32.5%)
Mangroves	0	0	157	0	230	0	387 (2.6%)
Total	**21,244**	**3,032**	**3,189**	**0**	**141,309**	**600,838**	**769,612**

*Areas classified as Very Heavy Disturbance were not present.

6.1.2 Land use

In addition to the canopy disturbance codes, areas that were dominated by anthropogenic disturbance, were denoted by the FIMS code "O" (PNGRIS agricultural land use intensity classes 0-4[2] (Bellamy and McAlpine, 1995) reflecting areas dominated by land use. The areas mapped as dominated by land use were reviewed and adjusted to reflect increased area of land use for subsistence agriculture (food gardens and planted sago). However, in one instance an area of alluvial forest in the southeast of the export pipeline corridor had been mapped as "O" but was remapped as Alluvial forest, disturbance code 6.

6.1.3 Natural disturbances

Natural disturbances from landslides and dieback have been mapped as discrete polygons and are presented in Table 6–2 and in Figures 6–1 and 6–2.

6.1.4 Project, logging and dieback related disturbance

Project related disturbance are mapped as discrete clearing in Figure 6–1 and Figure 6–2 and include facilities and related clearings (e.g., laydown areas), wellpads and airstrips. Logging related disturbances includes roads and clearings for log landings and facilities (e.g., logging camps). The logging roads reflect active roads and skidding tracks that were identified as part of the deforestation study (Watt *et al.*, 2016) using Landsat imagery. Most of the smaller side tracks were not visible in the LIDAR imagery because of the forest canopy closing across the tracks. Thus, areas of regenerating secondary forest could not be differentiated in the imagery as disturbed forest.

There is no FIMS code that can be used to adequately classify infrastructure and areas cleared for logging infrastructure. Other non-vegetated areas can be classified as "Z" for bare areas and "U" for larger urban areas. The code "Z" was not used since cleared areas usually become vegetated within 12 months and project related infrastructure is not of sufficient size to be coded as larger urban centers. Therefore, these disturbances were not incorporated into the land use layer defined by the symbol "O". Rather their disturbance areas were incorporated into the numeric canopy disturbance system described in Section 6.1.1.

Table 6-2 Project, logging and dieback related disturbance

Disturbance	Area (ha)
Dieback	60
Project infrastructure and related clearings*	88
Wellpads	77
Landslides	126
Total area of disturbance	**351**

*Project infrastructure and related clearings includes project facilities (e.g., Herd base and workshops) wellpads, airstrips, and laydown areas.

[2] Land use intensity class 0 = Very high with tree crops, anthropogenic vegetation (AV) 75%, 1 = Very high, AV 75%, 2 = High, AV 50% 3 = Moderate, AV 20 – 50%, 4 = Low

Figure 6-1 Areas of anthropogenic disturbance and landslides across PRL-15

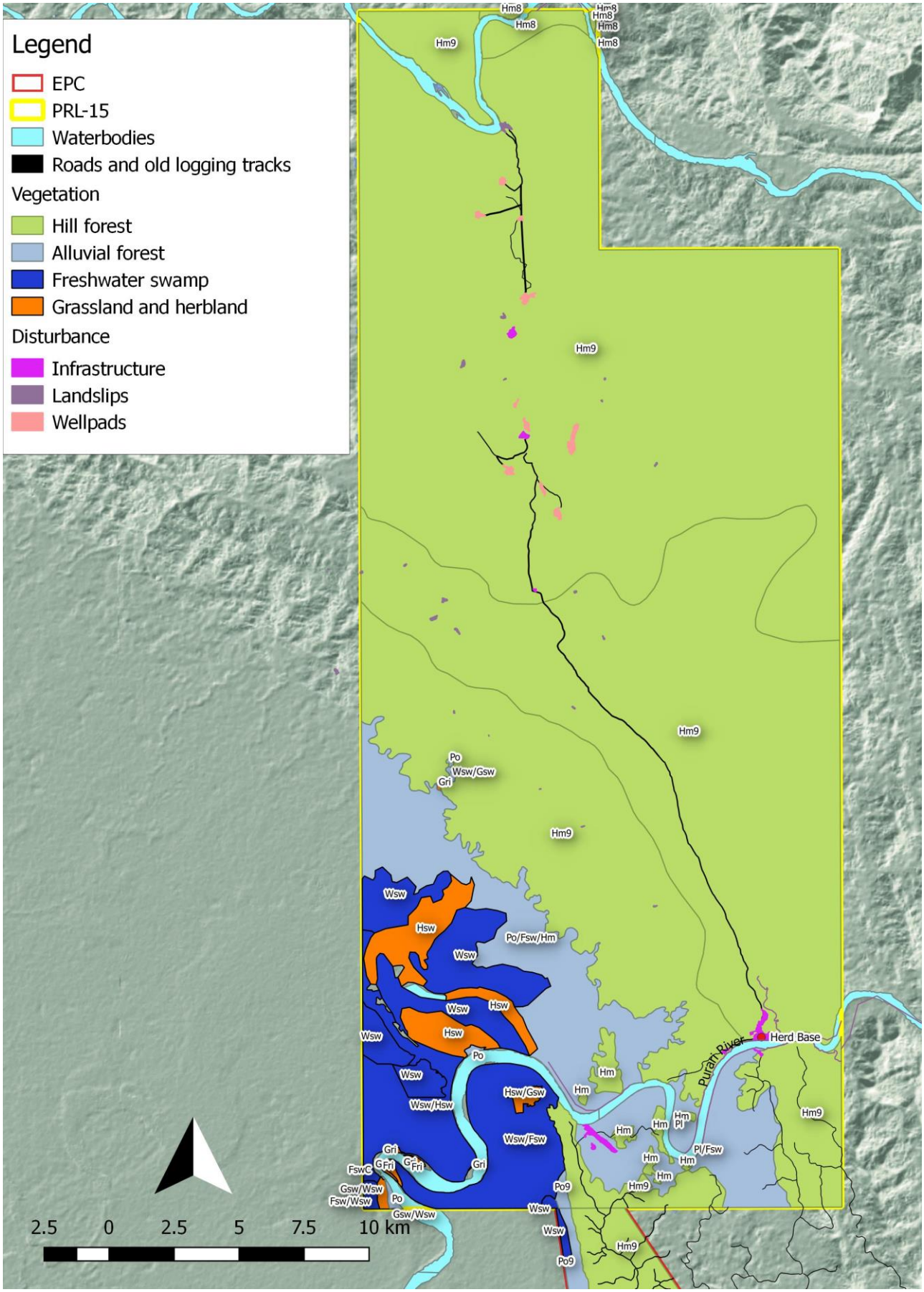
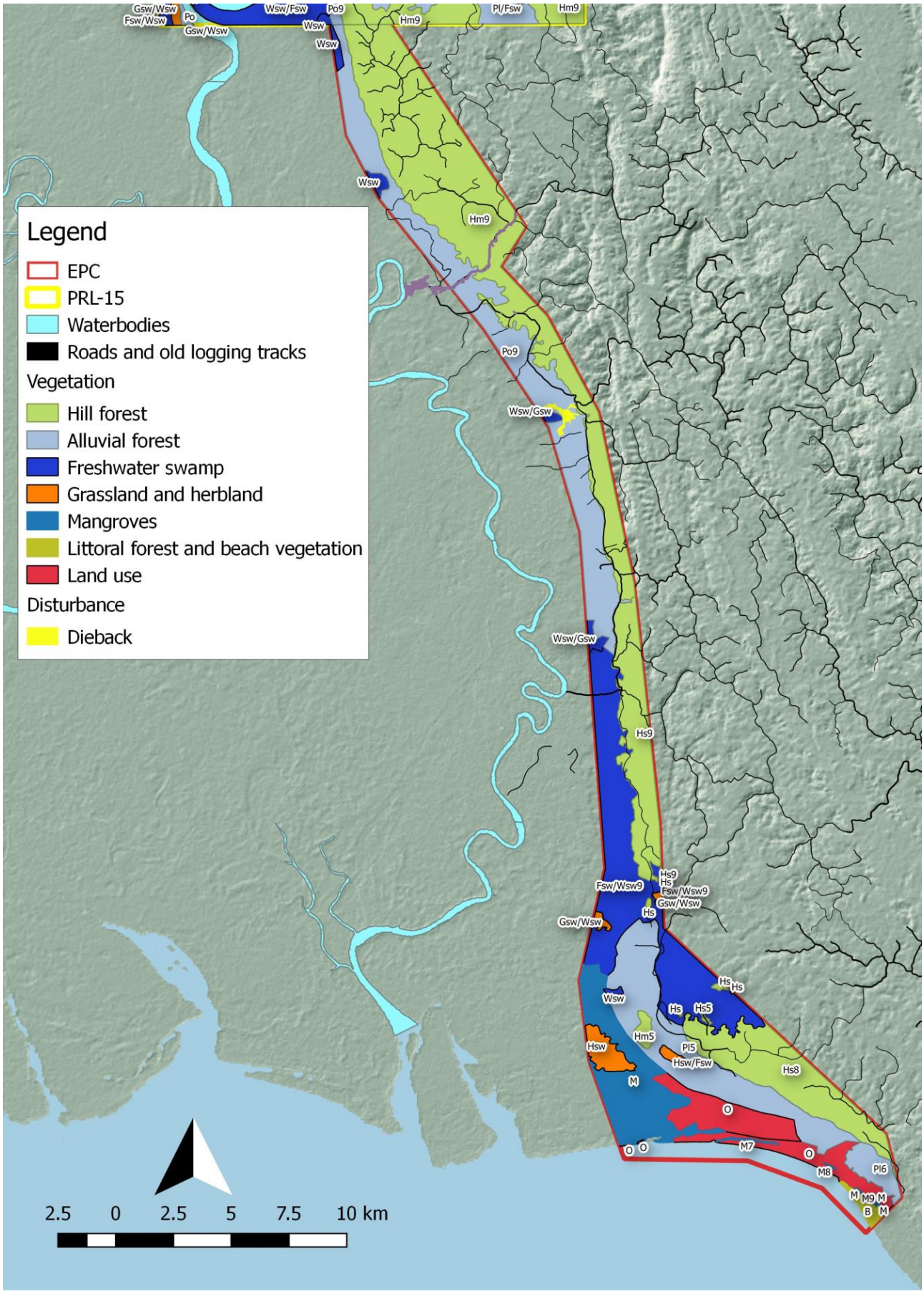


Figure 6-2 Areas of anthropogenic disturbance, landslides and dieback across the Export Pipeline Corridor



7 CONCLUSION

The study has achieved its baseline objectives of mapping the distribution and condition of major vegetation types present within PRL-15 and the export pipeline corridor based on the existing FIMS classification.

The vegetation of the study area is dominated by forests, which are almost entirely intact in PRL-15 apart from several relatively small discrete disturbances, of which potentially the most major is the road linking Herd Base to the wellpads. Although nearly 100% of the hill and alluvial forests are classified as disturbed, this simply reflects mostly discrete disturbances and the limitations of the existing FIMS methodology. Consequently, the forests within PRL-15 are in good condition despite the "slightly disturbed" classification.

For the export pipeline corridor, disturbance is more widespread due to logging rather than isolated discrete disturbances, although the full extent can't be seen in the LIDAR imagery because of canopy closure since logging. However, the most severely disturbed forest (Heavy disturbance) occurs in the south of the export pipeline corridor due to clearances for gardens in Alluvial forest, which occurred after logging. Here the Alluvial forest, coded Pl5 and Pl6 are in poor condition, but are typically a mosaic of heavily disturbed forest and small patches of undisturbed forest.

Based on interpretation of the LIDAR imagery, aerial survey, ground-truthing and forest condition classification the vegetation mapping study area's important environmental values are:

1. The presence of large tracts of mostly intact landscape level forests, particularly in PRL-15, and all but the southern section of the export pipeline corridor, that are predominantly contiguous with extensive areas of forest to the north, east and west.
2. The presence of extensive areas of mangroves in the export pipeline corridor that are mostly undisturbed and are contiguous with natural vegetation to the north and west.
3. The presence of extensive Herbaceous swamps (Hsw), Swamp grassland (Gsw) and Swamp woodland (Wsw) in the southwest of PRL-15.
4. The presence of an isolated Herbaceous swamp/Mixed swamp forest complex (Hsw/Fsw) in the southern portion of the export pipeline corridor.
5. The presence of lowland forests that appear to be free of plant pathogen induced dieback.
6. The presence of extensive landuse in coastal areas, where forest has been cleared.

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APPENDIX A

VEGETATION TERMINOLOGY

Table 1 Vegetation Terminology

Broad vegetation group/FIMS code	FIMS Group/Description	Biodiversity Study term
Natural vegetation types		
Hill forest		
H	***Low altitude forest on uplands (below 1,000 m)***	***Hill forest***
Hm	Medium crowned forest	Hill forest
Hm.Ar	Medium crowned forest - Presence of *Araucaria* noted	Hill forest, *Araucaria* noted
Hm/Hs	Complex: Medium crowned forest/Small crowned forest	Hill forest/small crowned hill forest
Hs	Small crowned forest	Small crowned hill forest
Alluvial forest		
P	***Low altitude forest on plains and fans (below 1,000 m)***	***Alluvial forest***
Pl	Large to medium crowned forest	Alluvial forest
Pl/Fsw	Complex: Large to medium crowned forest/Mixed swamp forest	Alluvial forest/Swamp forest
Po	Open forest	Open alluvial forest
Po/Fsw	Complex: Open forest/Mixed swamp forest	Open alluvial forest/Swamp forest
Po/Fsw/Hm	Complex: Open forest/Mixed swamp forest/Medium crowned low altitude forest on uplands	Open alluvial forest/Swamp forest/Hill forest
Po/Fsw/M	Complex: Open forest/Mixed swamp forest/Mangrove	Open alluvial forest/Swamp forest/Mangrove
Po/Hsw	Complex: Open forest/Herbaceous swamp	Open alluvial forest/Herbaceous Swamp
Po/Wsw	Complex: Open forest/Swamp woodland	Open alluvial forest/Swamp woodland
Ps	Small crowned forest	Small crowned alluvial forest
Fri	***Seral forest***	
Fri	Riverine mixed successions	Riverine seral forest
Freshwater swamp vegetation		
Fsw	***Swamp forest***	
Fsw	Mixed swamp forest	Swamp forest
FswC	Swamp forest with *Campnosperma*	Swamp forest with *Campnosperma*
Fsw/Gsw	Complex: Mixed swamp forest/Swamp grassland	Swamp forest/Swamp grassland
Fsw/M	Complex: Mixed swamp forest/Mangrove	Swamp forest/Mangrove
Fsw/Wsw	Complex: Mixed swamp forest/Swamp woodland	Swamp forest/Swamp woodland
W	***Woodland***	
Wsw	Swamp woodland	Swamp woodland
Wsw/Fsw	Complex: Swamp woodland/Mixed swamp forest	Swamp woodland/Swamp forest
Wsw/Gsw	Complex: Swamp woodland/Swamp grassland	Swamp woodland/Swamp grassland
Wsw/Hsw	Complex: Swamp woodland/Herbaceous swamp	Swamp woodland/Herbaceous swamp
G/Hsw	***Grassland and herbland***	
Gsw/Fsw	Complex: Swamp grassland/Mixed swamp forest	Swamp grassland/Swamp forest
Gsw/Wsw	Complex: Swamp grassland/Swamp woodland	Swamp grassland/Swamp woodland
Gri	Riverine successions dominated by grass	Riverine successional grassland
Hsw	Herbaceous swamp	Herbaceous swamp
Hsw/Fsw	Complex: Herbaceous swamp/Mixed swamp forest	Herbaceous swamp/Swamp forest
Hsw/Gsw	Complex: Herbaceous swamp/Swamp grassland	Herbaceous swamp/Swamp grassland
Hsw/Wsw	Complex: Herbaceous swamp/Swamp woodland	Herbaceous swamp/Swamp woodland
Littoral forest		
B	***Littoral forest***	
B	Mixed forest	Littoral forest
Mangroves		
M	***Estuarine Communities***	
M	Mangrove	Mangrove

Broad vegetation group/FIMS code	FIMS Group/Description	Biodiversity Study term
Non-vegetation and land use areas		
Converted lands		
O	Non-forest areas dominated by land use	Land use
U	Larger urban areas	Urban areas
Open water		
E	Lakes and large rivers	Rivers and lakes