FRIEDA RIVER

Frieda River Limited

Sepik Development Project

Environmental Impact Statement

Chapter 7 – Description of Existing Environment

SDP-6-G-00-01-T-084-009

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7. DESCRIPTION OF EXISTING ENVIRONMENT

This chapter consists of three sections that describe the existing terrestrial, aquatic and socio-economic environments that comprise the setting of the Project. Each section presents a regional overview, before providing additional location-specific detail for aspects of the existing environment.

7.1 Terrestrial Environment

7.1.1 Location

The Project is located in north-west PNG and spans the Saundaun and East Sepik provinces. The FRCGP and FRHEP are predominantly located in Sandaun Province close to the border with East Sepik Province. The infrastructure corridor, including the main access road, concentrate pipeline, Green River Airport of the SIP, and the transmission line alignment of the SPGP, extends north-west from the mine area through the Saniap, Usake and Upper May river catchments and then generally north across the Sepik River floodplain and over the Bewani Mountains and the northern coastal plain to Vanimo on the northern coast. The mine area is remote and approximately 200 km from the northern coast, 75 km east of the Indonesian border and 50 km from the Sepik River.

The terrestrial environment has been categorised based on elevation in the following sections. Areas below elevation of 100 m above sea level (ASL) are referred to as the ‘lowlands’ (or lowland zone). Areas above 100 m ASL but less than 1,000 m ASL are referred to as ‘hills’ (or hill zone) and those above 1,000 m ASLare mountains (or montane zone). Figure 7.1 shows three-dimensional views of the mine and FRHEP area and illustrates the terrain of the hill zone transitioning into the lowland zone.

7.1.2 Climate

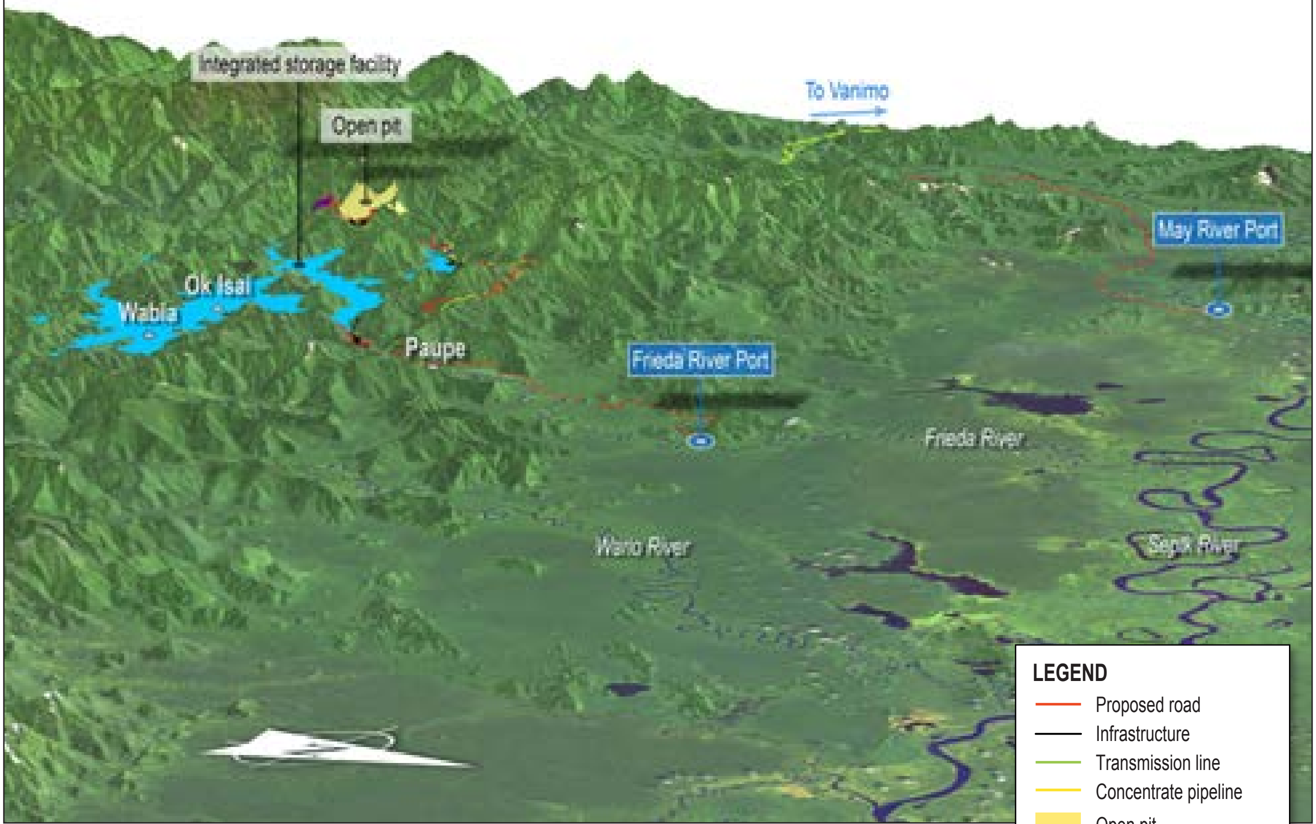
Regional

Northern PNG is strongly influenced by the South Pacific Convergence Zone, which is part of the Intertropical Convergence Zone. The Intertropical Convergence Zone is where weather systems from the southern hemisphere meet those from the northern hemisphere and is subject to seasonal north–south migration over the equator. The region is characterised by frequent tropical storms, heavy rainfall and long periods of calm winds (commonly known as the doldrums), with the heaviest rainfall experienced locally over higher elevation land.

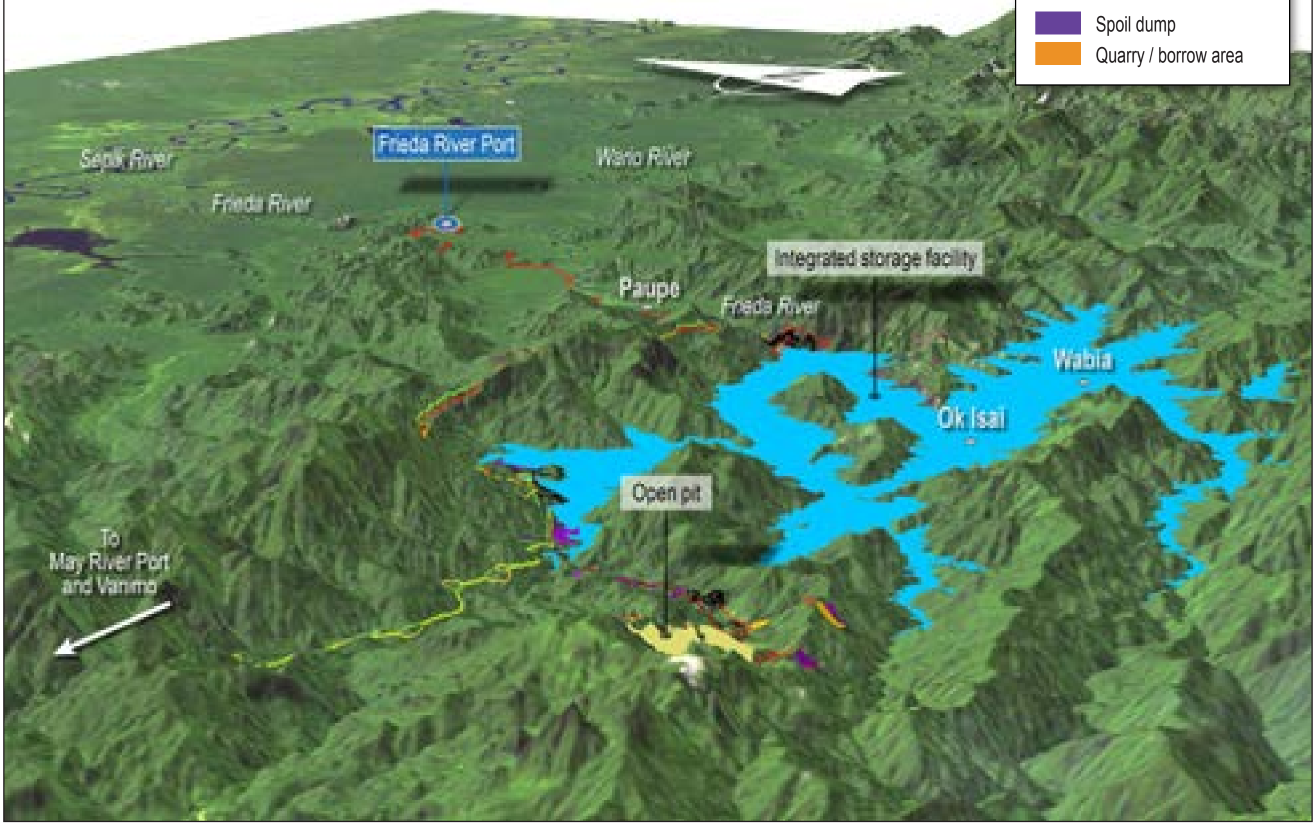
The climate of the region is dominated by two seasons. The north-west monsoon (wet) season occurs between November and April (the austral summer), when north-westerly winds bring in low-pressure troughs that result in heavy rainfall. The south-east monsoon (dry) season occurs between May and October (the austral winter) and is characterised by south-easterly trade winds.

As discussed in Section 1.7 and shown in figures 1.1, 1.2 and 1.3, this EIS discusses the potential impacts associated with the Project in a range of spatial contexts including those defined as the mine and FRHEP areas, infrastructure corridor and ocean port. Information concerning the location and climate relevant to each of these contexts has been derived from Appendix 6 and Appendix 7a and appropriate publicly-available data. The following summary is largely based on information from three Project weather stations installed at Nena River (Site 1053), Iniok (Site 105940) Moruapie (Site 1054), 17 rainfall gauges in the mine area (Figure 7.2) and other publicly-available data.

Looking southwest from lowland zone towards the river port facilities with the mine area in the background



Looking northeast from the hill zone towards the mine area with the river port facilities in the background



Source: Perspective view generated in ArcScene by Coffey. Note: 2x vertical exaggeration.

coffey A TETRA TECH COMPANY	Date: 14.09.2018 Project: 754-ENAUABTF11575 File Name: 11575_11_F07.01_GRA	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Three-dimensional view of the Sepik Development Project	Figure No: 7.1

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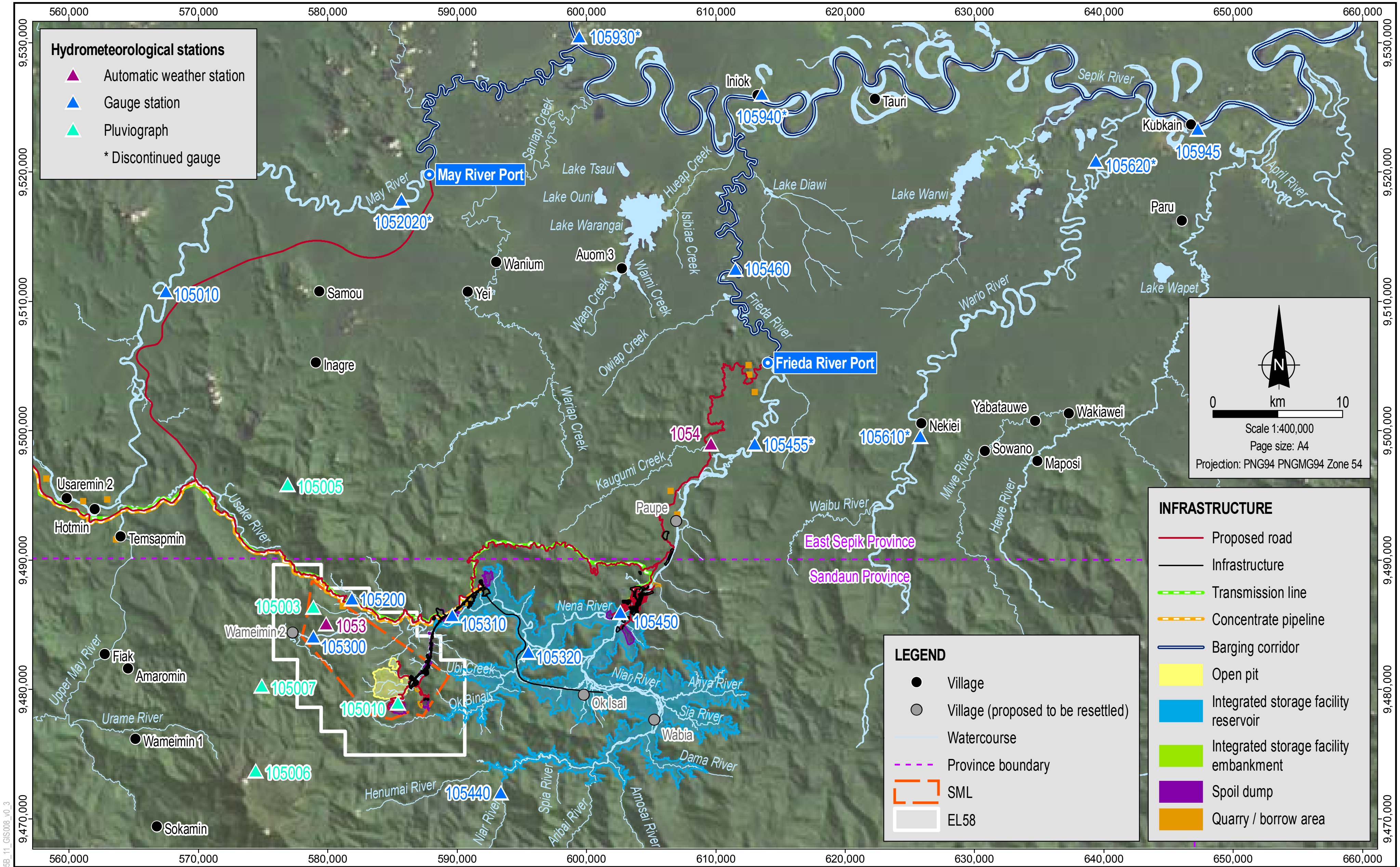

Source:
Hydrometeorological stations, infrastructure, roads and tenements from FRL.
Villages, topographic features, watercourses and water bodies from FRL and Coffey.
Provinces from NMB.
Landsat satellite imagery from FRL (capture date unknown).
Hillshade DEM from SRTM.

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Meteorological monitoring locations around the mine and FRHEP areas

Figure No: 7.2

Mine and FRHEP Areas

The closest weather station to the mine area is located at Nena River, approximately 5 km north-west of the proposed open-pit, and is indicative of the hill zone. The current weather station was installed in April 2008; a previous weather station operated at the same site between October 1994 and April 1999. Additional rainfall data was sourced from several other rainfall gauges located in the hill zone.

Meteorological data from the lowland zone was primarily sourced from the Iniok weather station, located approximately 53 km north-east of the mine area and installed in April 2008. An additional weather station was installed in July 2009 at Moruapie, approximately 30 km north-east of the mine area. This site represents an intermediate location between the hill zone and the lowland zone and generally reported similar data to the Iniok weather station. Additional rainfall data was sourced from nine rainfall gauges in the lowland zone.

The most notable difference in climate between the hill zone and the lowland zone is the amount of rainfall, with the average annual rainfall in the hill zone being approximately twice that in the lowland zone. Figure 7.3 shows the difference in rainfall for six of the meteorological stations in the mine area and infrastructure corridor (see Figure 7.2 for locations). Seasonal variation between the two zones is noticeable, with the lowland zone having a more marked seasonal range, with lower average daily rainfall being recorded from May to October.

Temperature is generally higher in the lowland zone than in the hill zone by about 3°C throughout the year.

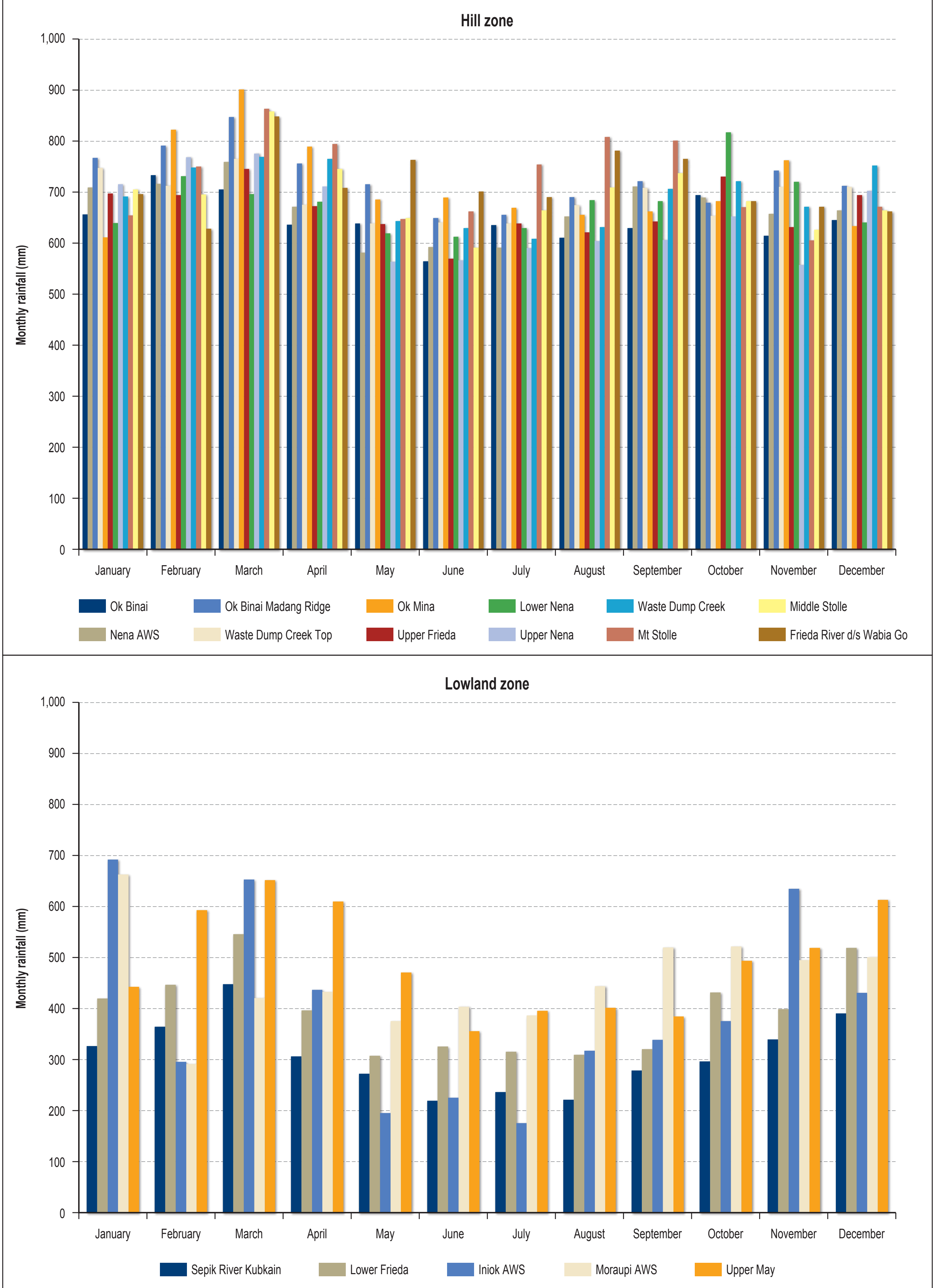
There is little seasonal variation in the wind speeds recorded in the hill zone or the lowland zone. Even though there is a difference in elevation, the Nena and Iniok stations have similar annual average values, however the Moruapie station had greater average wind speeds.

Relative humidity is generally very consistent between the zones with an average monthly range of 81% to 86%. All weather stations recorded a similar pattern with an almost constant value across the year of close to 84%. There is slight seasonality between the zones with higher minimum humidity observed in March to April and lower minimum humidity in August to September. Conversely, the highest maximum humidity occurs in May to July and the lowest maximum values are recorded in January to February.

A summary for meteorological data for both the hill zone and the lowland zone is summarised in the following section.

Rainfall. The average annual rainfall in the mine area was between 7,700 and 8,600 millimetres (mm), with the average daily rainfall being approximately 23 mm and mean monthly rainfall being approximately 700 mm. The number of rain days for this region ranged from 20 to 31 per month, with rain being regularly recorded every day of the month. In the lowland zone of the Sepik River, the average annual rainfall was between 3,700 and 6,000 mm. Mean monthly rainfall was approximately 500 mm and the number of rain days for this region varied from 13 to 26 per month.

Temperature. The average annual temperature in the mine area was 22.9°C. Monthly average temperatures varied from 22.5°C in July to 23.2°C in December. The temperature in the lowland plains of the Sepik River was higher, with average annual temperatures of 27.2°C and 26.5°C for Iniok and Moruapie respectively. Average monthly temperatures varied between 23.0°C (June) and 26.6°C (October) for Iniok, and 27.0°C (April) and 27.1°C (September) for Moruapie.



Source: SRK Consulting, 2016

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Monthly rainfall for the hill zone and lowland zone

Figure No: 7.3

Wind Speed and Direction. Average annual wind speed in the mine area was 0.5 m/s and the frequency of calm conditions was similar between dry and wet seasons. Monthly average wind speeds varied from 0.46 m/s to 0.52 m/s. The dry and wet season wind roses indicate that very light north-east and south-west winds predominated during the day throughout the year (Figure 7.4). The predominant wind direction was from the north-east. Similar patterns were observed for wet and dry night-time records.

In the lowland zone of the Sepik River floodplain, average annual wind speed was 0.84 m/s and 1.34 m/s for Iniok and Moruapie respectively. Average monthly wind speeds varied from 0.77 m/s (September) to 1.27 m/s (June) for Iniok and 0.91 (March and August) to 1.42 m/s (October) for Moruapie. The daytime dry and wet season wind roses indicate that light north-east and south-west winds were predominant (Figure 7.5). Night-time dry and wet season wind roses indicate light north-east and south-east winds were dominant.

Evapotranspiration. Mean monthly evapotranspiration in the mine area ranged from 120 mm in June to 156 mm in March with annual evapotranspiration of 1,651 mm. A similar trend was recorded for the lowland zone of the Sepik River floodplain, where average monthly and annual evapotranspiration was modelled to be 138 mm and 1,651 mm respectively.

Humidity. Both the hill and lowland zones are humid. Mean monthly relative humidity in the hill zone ranged from 81% to 84% with slightly higher relative humidity recorded in the lowland zone from 83% to 86%.

Infrastructure Corridor

The 325-km-long infrastructure corridor spans a range of landforms and elevations. Site specific meteorological data is limited and has been inferred from climatic patterns in the mine area, on the Sepik River (i.e., Iniok and Moruapie) and Vanimo. A summary for meteorological data for the infrastructure corridor is summarised in the following section.

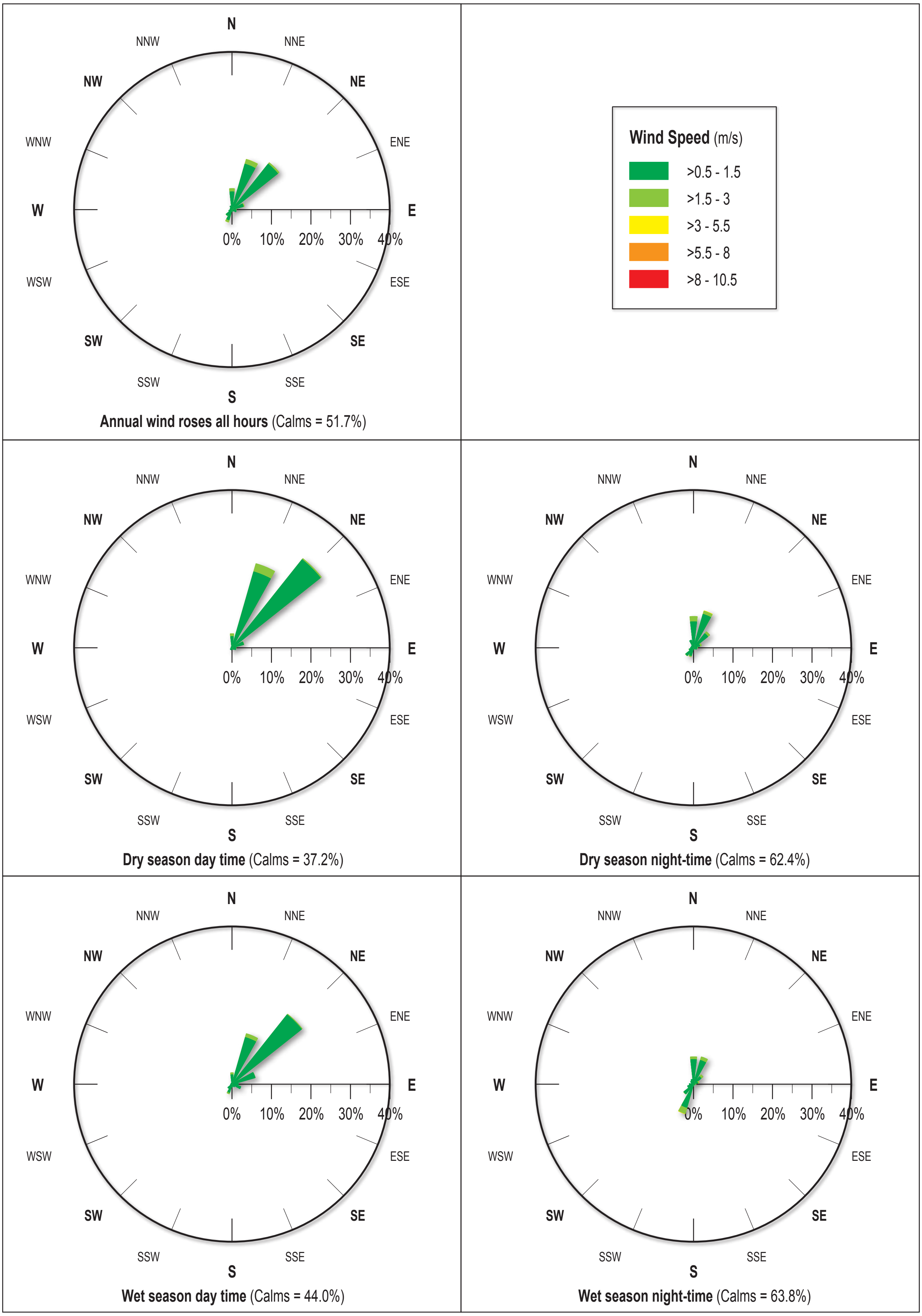
Rainfall. The hill zones of the infrastructure corridor including the northern slopes of the Central Range (i.e., in the Saniap, Usake and Upper May river catchments) and the Bewani Mountains are predicted to have higher rainfall than the lowland zone of the Sepik River floodplain and the coastal plain between the Bewani Mountains and the northern coast. For example, the mine area receives annual rainfall of about 8,000 mm, the lowland zone of the Sepik River floodplain receives approximately 4,000 mm and the northern coast approximately 2,500 mm. The other differences between the hill zone and lowland areas is that the lowland zone experiences a more noticeable dry period from May to October.

Temperature. Temperatures show an inverse pattern with elevation, i.e., generally increasing with decreasing elevation. As such, temperatures are generally higher in the lowland zone of the Sepik River floodplain and northern coast compared to the hill zones of the central and the northern coastal range by up to 3°C throughout the year.

Wind Speed and Direction. There is little seasonal variation in the wind speeds recorded in the hill zone or the lowland zone. Wind speeds recorded in the hill zone near the mine area are low, increase marginally in the lowland plains, but are markedly higher closer to the northern coast.

Evapotranspiration. Mean monthly evapotranspiration in the hill zone and the lowland plains of the Sepik River are similar with higher evapotranspiration expected closer to the northern coast.

Humidity. The entire infrastructure corridor experiences humid conditions. The hill zones are expected to be slightly less humid than the lowland areas of the Sepik River floodplain and the northern coast.



Source: SLR Consulting, 2011

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Annual and seasonal wind roses from the Nena River weather station in 2010	Figure No: 7.4		

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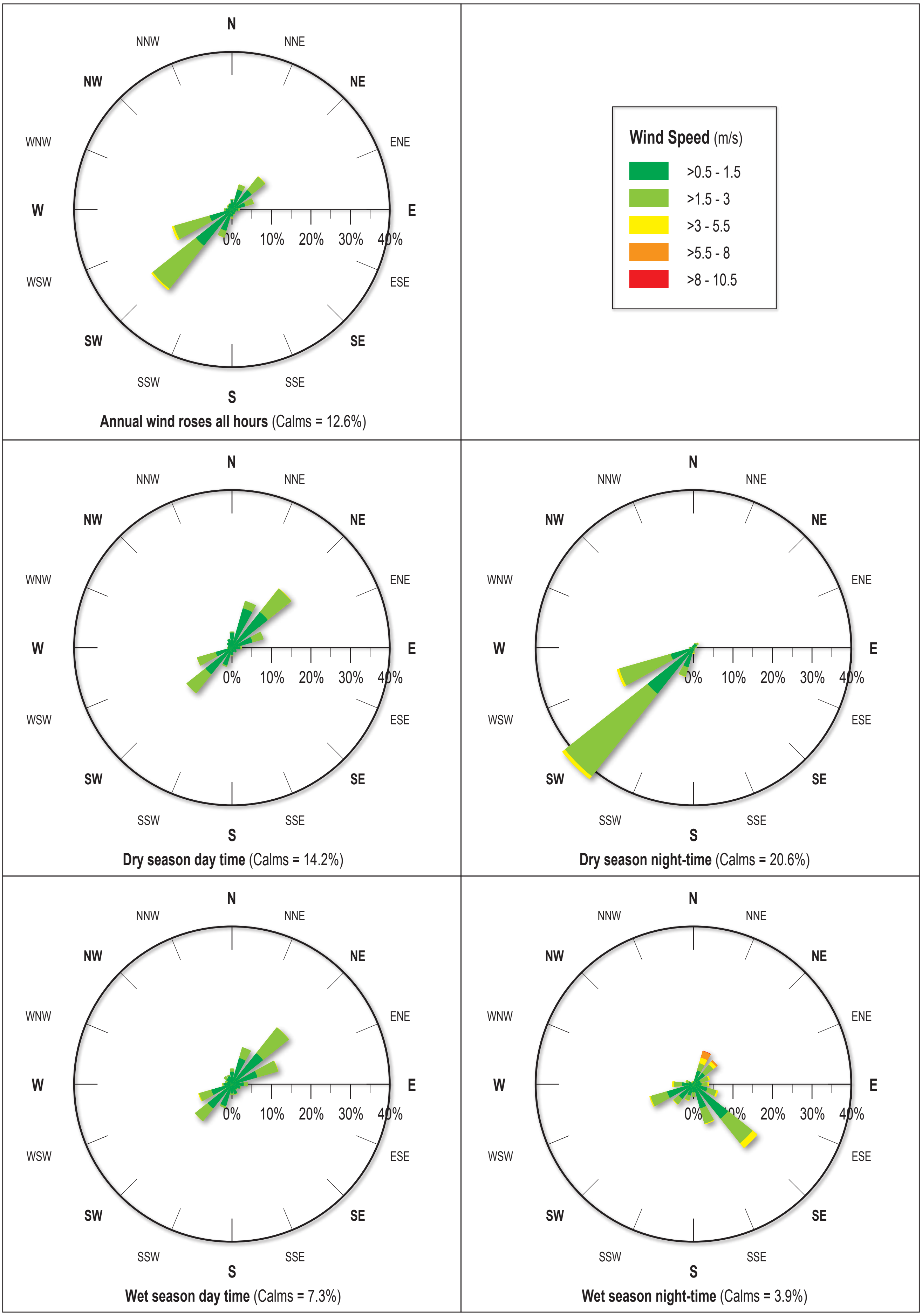

Source: SLR Consulting, 2011

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Annual and seasonal wind roses from the Moruapie weather station in 2010	Figure No: **7.5**		

AI Reference: 11575_11_GRA014.ai_3

Vanimo

A weather station in Vanimo operated between 1964 and 2009 and the meteorological data for the area is summarised in the following section.

Rainfall. The average annual rainfall at Vanimo is approximately 2,650 mm. The driest month is August, with an average of 154 mm of rain and the wettest month is March with an average of 347 mm.

Temperature. The average annual daily temperature was approximately 26°C, with an average minimum temperature of approximately 22°C and average maximum temperature of approximately 30°C. May is the warmest month of the year with an average of approximately 27°C. February has the lowest average temperature of the year at approximately 25°C.

Wind. The average hourly wind speed in Vanimo experiences little seasonal variation over the course of the year. Wind speeds are highest between December and March, with average wind speeds of more than 3 m/s. The prevailing wind direction is from the east between April to November, tending north for the remainder of the year.

Squalls. Also known as gubas, squalls occur occasionally in the region during the north-west monsoon (wet) season. These events are intense storms of short duration, usually up to one hour, with north-westerly winds typically up to 65 km/h that generally occur from midnight to 2.00 a.m.

7.1.3 Regional Geology and Seismicity

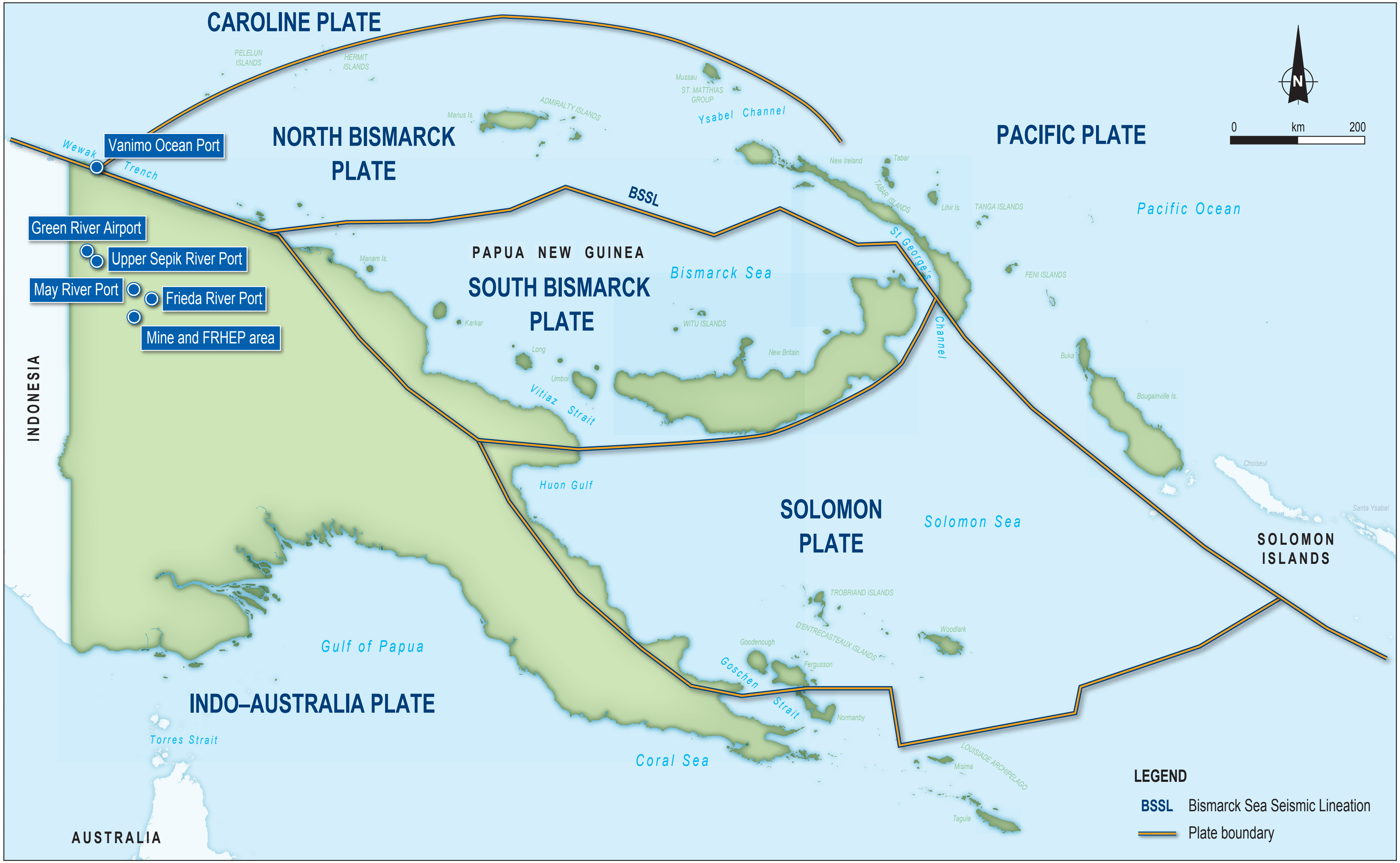
Tectonic Setting

PNG is bounded by several major tectonic plates (Figure 7.6) and is one of the most seismically active regions in the world (SKM, 2008). The high level of seismic activity is a result of ongoing crustal deformation from collision of the Pacific and Australian tectonic plates initiated 34 to 55 million years ago. Compressional tectonics has resulted in the formation of a thrust-and-fold belt and an uplift of the central highlands (Coffey Natural Systems, 2009b) marked by the Torricelli Mountains, located approximately 130 km north of the open-pit. This thrust-and-fold belt extends to just south of the mine site within the Frieda River Igneous Complex (FRIC) (Douglas Partners, 2010).

The mine area and the infrastructure corridor are located on the northern portion of the Indo-Australia Plate, while the Port of Vanimo is located on the North Bismarck Plate. The Indo-Australia Plate is moving in a north-easterly direction at approximately 11 cm per year and is colliding with the south-westerly-moving Pacific Plate, which lies to the north and east of the Indo-Australia Plate (Bechtel, 2010).

Western PNG is divided into four tectonic regions; from north to south, these are:

- The belt of former island arcs, which is the northern rim of PNG including the Bewani-Torricelli and Finisterre Terrane.
- New Guinea Thrust Belt, which includes low-angle thrusting, left-lateral strike-slip structures, and some Cretaceous active volcanism. The mine area is in this belt, adjacent to the southern boundary.
- Papuan Fold Belt, which comprises the Australian continental crust deformed into fold and thrust structures.



Source:
Adapted from Greenbaum et al., 1995.

Note:
Project areas and plate boundaries approximate only.

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Simplified plate configuration of the PNG region

Figure No: 7.6

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- Fly Platform/ Stable Plate/ foreland basin, which is the northern continuation of Australian continental crust.

Major fault zones separate the provinces described above. The Ramu-Markham Fault separates the Bewani-Torricelli and Finisterre Terrane from the New Guinea Thrust belt; the New Guinea Thrust splits the New Guinea Thrust Belt from the Papuan Fold Belt; and the Papuan Thrust divides the Papuan Fold Belt from the Fly Platform.

The Frieda River area is dominated by a series of east–west to east-northeast–west-southwest oriented fault systems. From north to south, these are the Saniap Fault, the Frieda Fault, the Fiak-Leonard Schultz (Fiak) Fault, and the Trangiso, Stolle and Figi faults. The latter three are sometimes grouped together as the Lagaip Fault. All of these faults are part of the New Guinea Thrust Fault Zone (Appendix 2a).

Seismicity

PNG is an active seismic region due to tectonic movements. Due to the high degree of seismic activity in the region, PNG is subject to earthquakes, volcanos and tsunamis.

A total of 12 earthquakes with a magnitude of 7.0 or greater on the Richter scale have occurred in PNG since 1998 (USGS National Earthquake Information Centre, 2018). Between 2010 and 2017, there were five earthquakes with magnitudes greater than 6.0 within a 200-km radius of the mine area and infrastructure corridor. Figure 7.7 shows the location of these natural occurrences that have been recorded in northwest PNG. A magnitude 7.5 earthquake recently occurred in Hela Province in February 2018 (Geoscience Australia, 2018).

As shown in Figure 7.7, the seismicity of the infrastructure corridor and Vanimo Ocean Port is classified as Zone 2, while the mine area is classified as Zone 3. As detailed in the PNG building standards (PNGS, 1982), the zones are arranged in order of increasing expectation of damage, ranging from no damage in Zone 0 to maximum damage in Zone 4. Despite being located in the higher seismic zone rank (i.e., Zone 3), Figure 7.7 suggests the mine area and FRHEP are located in an area that has historically had fewer and less intense earthquakes.

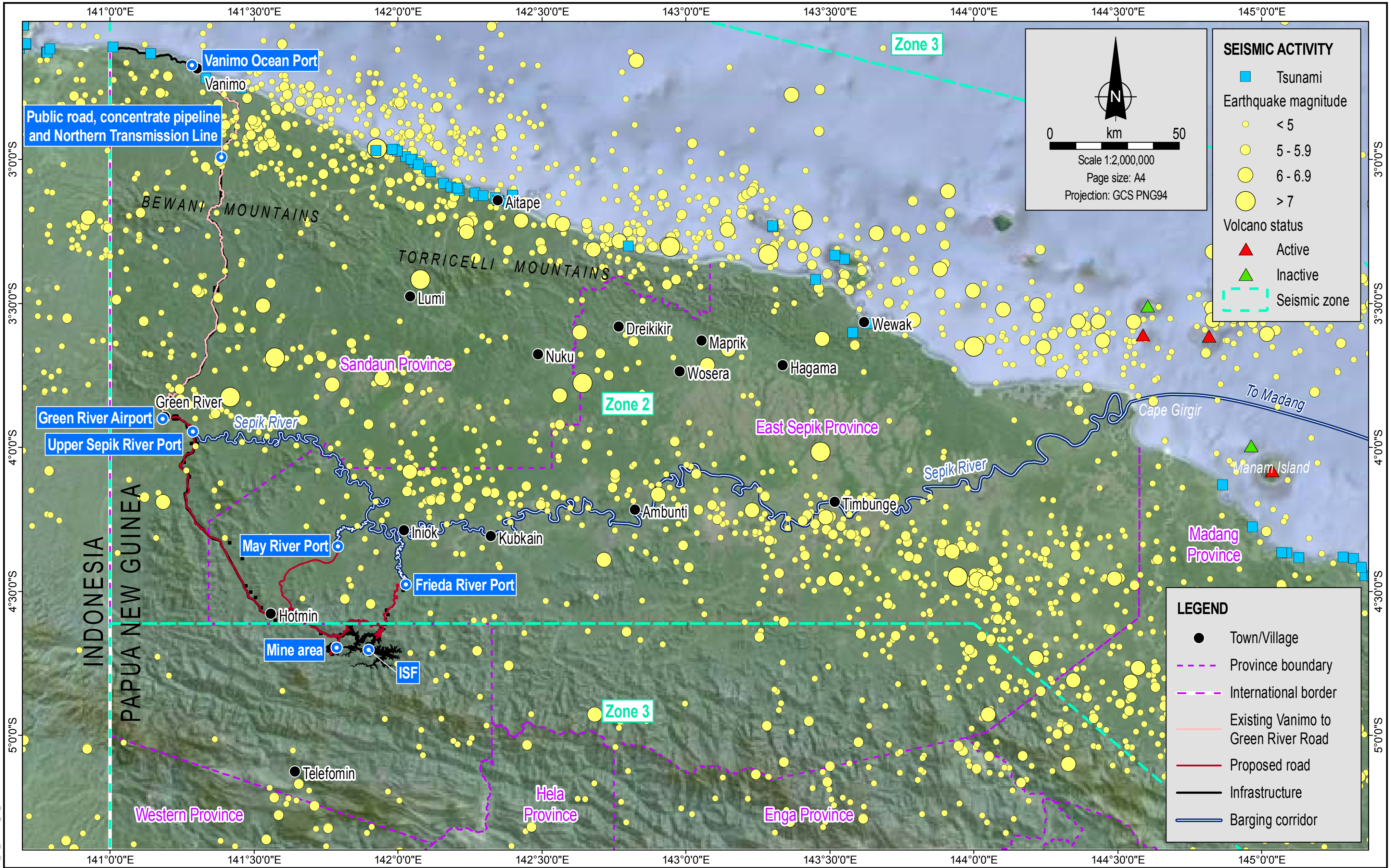
Five volcanoes occur east of Vanimo - three are active and two are inactive (Smithsonian Institution Global Volcanism Program, 2018). The closest active volcano to Vanimo is located offshore in the Bismarck Sea approximately 320 km east of Vanimo (see Figure 7.7).

Since 1768, 182 tsunamis have been recorded for the PNG region, 120 of which have had wave heights recorded. The average recorded wave height is 3.1 m, with the maximum being 15 m at Arop, approximately 30 km north-west of Aitape in 1998 (NOAA, 2011). In 1970, an earthquake with a magnitude of 7.0 generated a 3-m-high tsunami along the coastline north of Madang and, on 17 July 1998, a series of tsunamis struck the north coast of PNG near Aitape and two near Vanimo; wave heights of approximately 8 m were estimated (NSR, 1999).

Geology

The regional geology of the Project area is shown on Figure 7.8.

The mine area is predominantly made up of mixed or undifferentiated metamorphics including diorites and andesites. The geology near the HITEK deposits are dominated by the older intrusive suite including Koki diorite (Plate 7.1), Frieda diorite porphyry (Plate 7.2) and Horse microdiorite (Plate 7.3) (classified as Tmo units) and a younger intrusive suite including Flimtem trachyandesite (Plate 7.4) and Knob diorite (classified as Tmy units). A deep weathering profile has developed through in-situ weathering of the underlying intrusive rock units. The weathering profile has been classified into three key types, including zones of total and partial oxidation and a



Source:
Infrastructure and roads from FRL. Villages from FRL and Coffey. Provinces from NMB.
Imagery from Google Earth (capture date unknown). Hillshade DEM from SRTM.
Earthquake data (1900-2018) from USGS. Tsunami data (1900-2018) from National Centers for Environmental Information.
Volcano data from Smithsonian Global Volcanism Program (2018). Seismic zones from PNGS (1982).
Note: The geological mechanisms, which lead to PNG being tectonically, seismically and volcanically active are still occurring.
As such it is possible that other unrecognised areas in the volcanic belts, or volcanic centers assumed to be inactive may develop activity.

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Earthquakes, volcanoes and tsunamis in the vicinity of the Project

Figure No: 7.7

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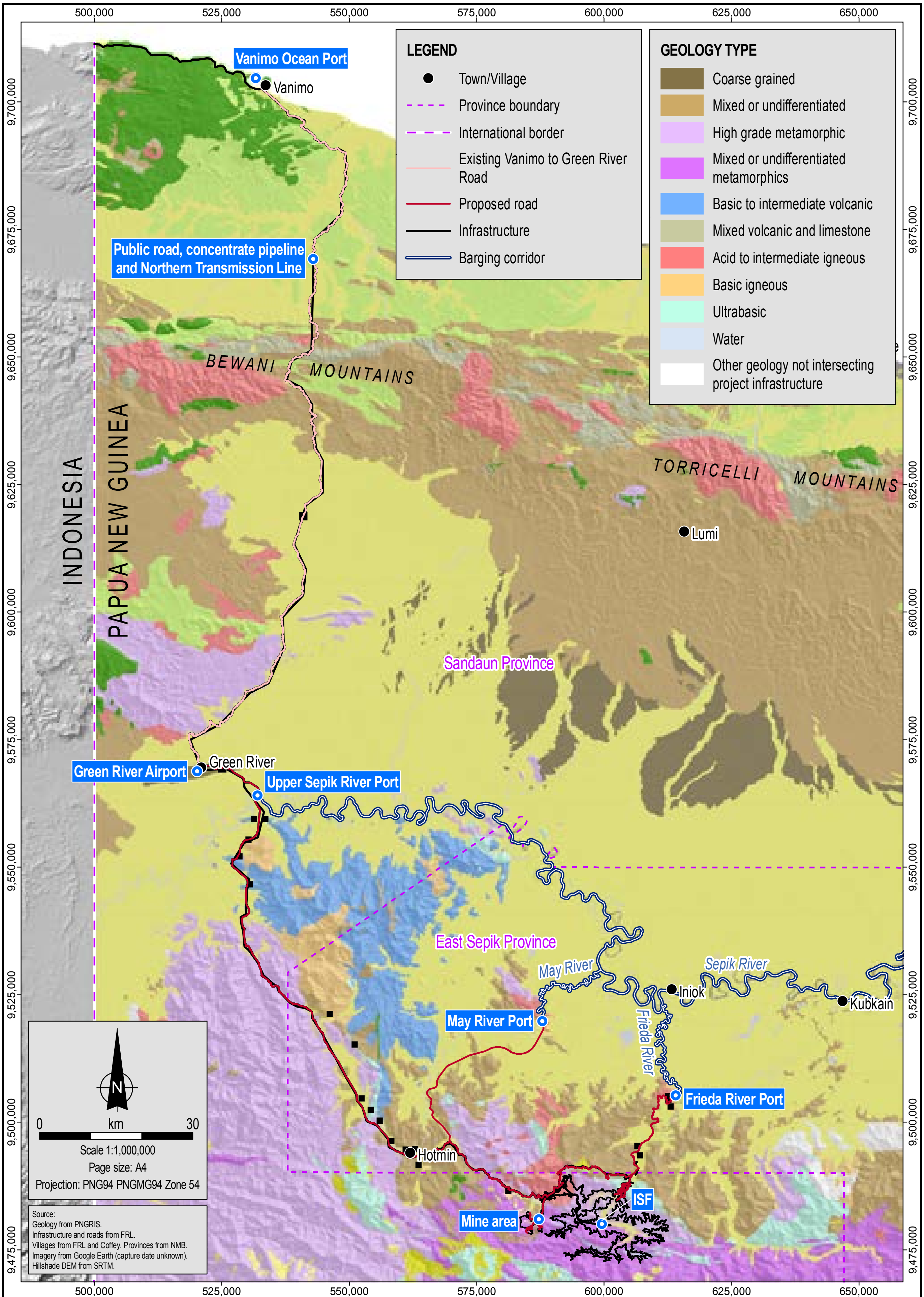

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Geology types in the Project area

Figure No: 7.8

Bechtel

Plate 7.1
Koki diorite

Bechtel

Plate 7.2
Frieda diorite porphyry

Bechtel

Plate 7.3
Horse microdiorite

Bechtel

Plate 7.4
Flimtem trachyandesite

gypsum-anhydrite transition zone (GpAh). Weathering within the ore body has been observed to extend to depths of 50 m.

Figure 7.9 shows the simplified geology and magnetics image of the Frieda River Igneous Complex (FRIC), which is the dominant lithological unit in the mine area. The FRIC is essentially the remains of a single stratovolcano composed of alternating layers of lava and ash, which consists of diorites (dark, granite-textured, crystalline rocks that have little quartz) and andesites (grey, fine-grained volcanic rock). The dominant orientation in the FRIC trends west-northwest and the current outcrop is in the shape of a 17 by 7 km ellipse.

The geology within the ISF is made up of high grade metamorphics, mixed or undifferentiated metamorphics, alluvial deposits, acid to intermediate igneous and ultrabasic material. These geological features include: mica schist with felspar and quartz, some garnet, sillimanite, staurolite, hornblende gneiss with plagioclase and quartz, slate, phyllite, sericite schist, schistose lithic sandstone, conglomorate, volcanics, limestone.

The geology within the infrastructure corridor is dominated by alluvial geological formations made up of gravel, sand, silt, mud and clay. From Vanimo to the Indonesian border along the transmission line, the geology is dominated by alluvial deposits, with smaller areas of limestone and acid to intermediate igneous formations.

7.1.4 Landforms and Soils

Landforms and soils within the Project area have been characterised primarily based on information from the PNG Resource Information Systems Handbook 3rd Edition (PNGRIS) (Shearman and Bryan, 2011) and the soils and rehabilitation study report prepared by Golder Associates Pty Ltd (2011), which included field soil sampling and subsequent laboratory analysis.

Landform

Landform refers to the recurring pattern of topography within the landscape. A landform unit is characterised by a specific set of landform elements, some of which are discussed separately (for example geology and soils). More specifically, landforms units are based on elevation and relief, that influence environmental characteristics of the landscape and environmental processes including erosion, water retention as well as ecosystem functioning.

Twelve landform units occur within the Project area (Figure 7.10). Three broad landform types have been defined using a combination of these landscape units, which occupy more than 98% of the Project area (Table 7.1). The remaining landform units occur in isolated areas of the Vanimo to Green River Road and the infrastructure corridor.

Table 7.1 Major landform types within the Project area

Landform Type	Description
Mountains, hills and ridges	Mountains and hills consisting of steep escarpments and narrow sharp crested ridges, straight slopes, V-shaped valleys and steep river gradients. The landform exhibits high to very high relief (> 100 m) with weak to no structural soil control. Surface slopes in some areas are in excess of 30 degrees. Weathering is very shallow and the soil profile comprises coarse colluvium overlying bedrock.
Alluvial plains and terraces	Alluvial plains comprising a flat or gently undulating winding floodplain with winding stream channels, intermittent levees, small lakes, which transition into back plains and back swamps and / or higher well drained terraces. They comprise sedimentary deposits from stream flow.

Table 7.1 Major landform types within the Project area (cont'd)

Landform Type	Description
Back swamps	Marshy semi-permanently to permanently inundated depressed areas of floodplains with drainage impounded or impeded.

Source: Bryan and Shearman, 2008.

Mountainous terrain dominates the landscape of the proposed mine area and ISF (Table 7.1 and Plate 7.5). Within these areas, high grade metamorphic rocks of coarsely grained structure, such as schists, gneiss and amphibolites, as well as mixed grade or undifferentiated metamorphic rocks characterise the geology. These areas are of high relief (greater than 100 m) with large ridges and straight slopes, which are irregularly cut by small streams and gullies. Within the Project area, approximately two thirds is characterised by the mountains and hills landform including the HITEK pit, 85% of the ISF and approximately 25% of the infrastructure corridor.

Narrow alluvial floodplains with flanking terraces meander through lower slopes of the mine area and ISF landscape. These landforms are made up of unconsolidated sedimentary rocks from alluvial deposits containing recent detrital material from active depositional processes. These areas are subjected to periods of short flash flooding. Alluvial floodplains and flanking terraces make-up approximately 12% of the Project area, predominantly in the lower elevations of the ISF and to a lesser extent in areas of the infrastructure corridor.

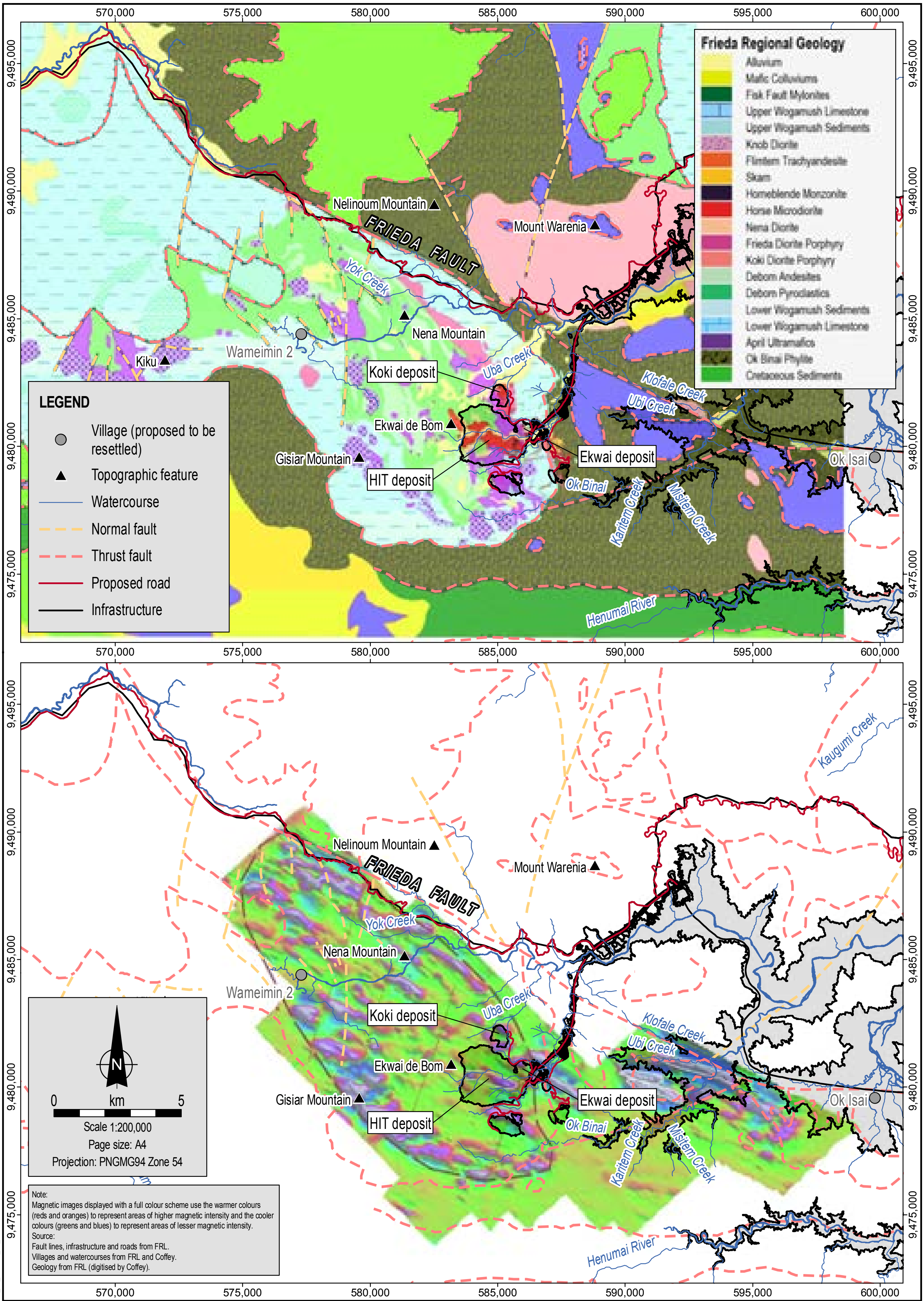
The narrow alluvial floodplains transition into broader meander floodplains north from the ISF. Meander floodplains (Plate 7.6) track along the Frieda and Sepik rivers, dominated by alluvial deposits comprising silt, sand and mud. These areas are prone to regular flooding and active depositional processes. The floodplains transition into expansive back swamps (Plate 7.7), which are semi-permanently to permanently inundated, receiving sand, silt, gravel and other alluvial deposits from the nearby rivers.

To the west of the May, Sepik and Frieda river floodplains, alluvial landforms give way to mountainous terrain. Mountains extends from Hotmin, north through the infrastructure corridor to within approximately 20 km south of Green River Station. Within this mountainous landscape, narrow tracts of depositional landforms weave between the mountains until the villages of Idam are reached. The infrastructure corridor traverses much of these alluvial landscapes on its way from Hotmin to Idam.

From the villages of Idam, through to Green River Station and travelling further north to the southern side of the Bewani Mountains (e.g., the Sepik River floodplains), composite alluvial plains dominate the landscape, with sections of back swamps also present. The drainage regime in this area can vary widely depending on the local conditions. This landform type occurs for approximately half of the infrastructure corridor between Green River and Vanimo.

Within the Bewani Mountains, poor soil structure and steep terrain dominates the landscape. As the infrastructure corridor traverses the Bewani Mountains, a maximum elevation of approximately 700 m is reached before descending to approximately 150 m in the village of Sumumini, on the northern flanks of the mountain range. From Sumumini to Vanimo, the terrain is gentler in relief, with a mix of hilly terrain with weak or no structural control to composite alluvial plains stretching out towards the northern coastline near Vanimo.

Mountains and hills, and composite alluvial plains characterise the terrain along the north-western coastline from Vanimo to the Indonesian border, where the proposed transmission line travels.



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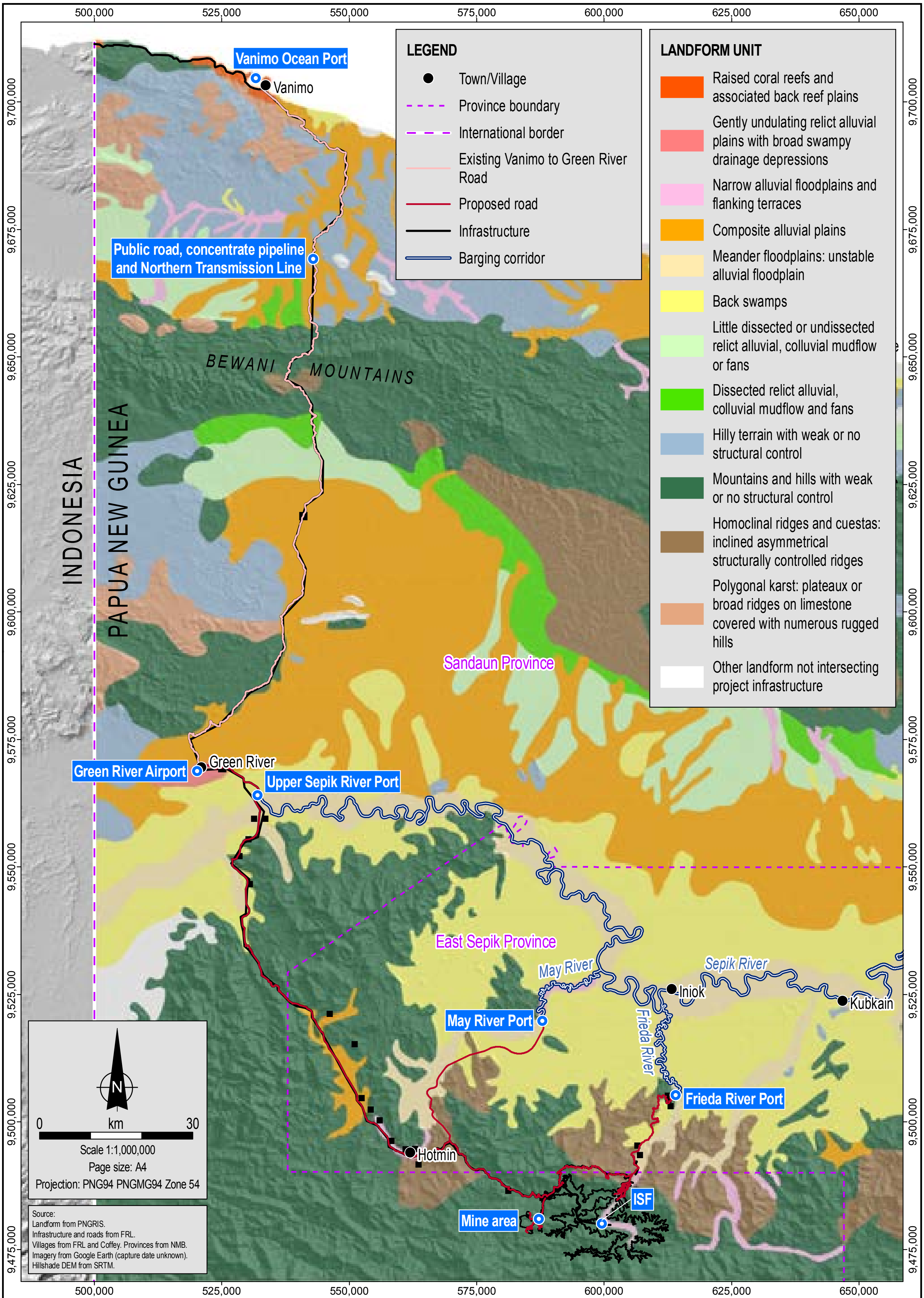
Simplified geology and magnetic image of the mine area

Figure No: 7.9



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coffey A TETRA TECH COMPANY	Date: 29.08.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.10_GIS	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Landform units in the Project area	Figure No: 7.10

Plate 7.5
Typical mountains and hills landform type in the mine area

Plate 7.6
Alluvial floodplain landform type adjacent to the Sepik River

Plate 7.7
Back swamp landform type

Soil Types

Soil types found within the Project area largely reflect the landform units in which they occur. Soil types and the sampling locations within them across the Project area are shown on Figure 7.11.

The soils found in the mine area are mostly made up of Haplorthox soils. These are predominantly acid red to brown clay soils, which are poorly structured, highly erodible with low fertility. Smaller areas of Dystropepts and Troporthents soils also occur in the mine area. These soils generally have low to moderate permeability containing moderate organic matter.

Within the ISF area, the main soil type found is Dystropepts. These soils are moderately erodible, have moderate water holding capacity and are well drained. Fluvaquent soils are found along the narrow alluvial floodplains that weave through the lower reaches of the ISF landscape, leading north towards Frieda River. These soils have been recently formed, contain moderate fine sand and silt, with relatively high organic carbon content, and are poorly draining.

Fluvaquent soils dominant the banks of the Frieda and Sepik rivers. Moving out from these rivers into the back swamps, soils predominantly comprise Hydraquents and Tropofibrists. These waterlogged soils are highly to moderately erodible, moderately fertile, have a depth of greater than 100 cm and are saturated for six or more months a year.

Within the mountainous terrain between the mine area and Green River, along the upper and mid slopes, Tropofluvents and Troperthents soils are dominant. These soils are moderately erodible, moderately fertile and well drained. The lower slopes are typically made up of Dystropepts of similar characteristics to those found in the ISF area.

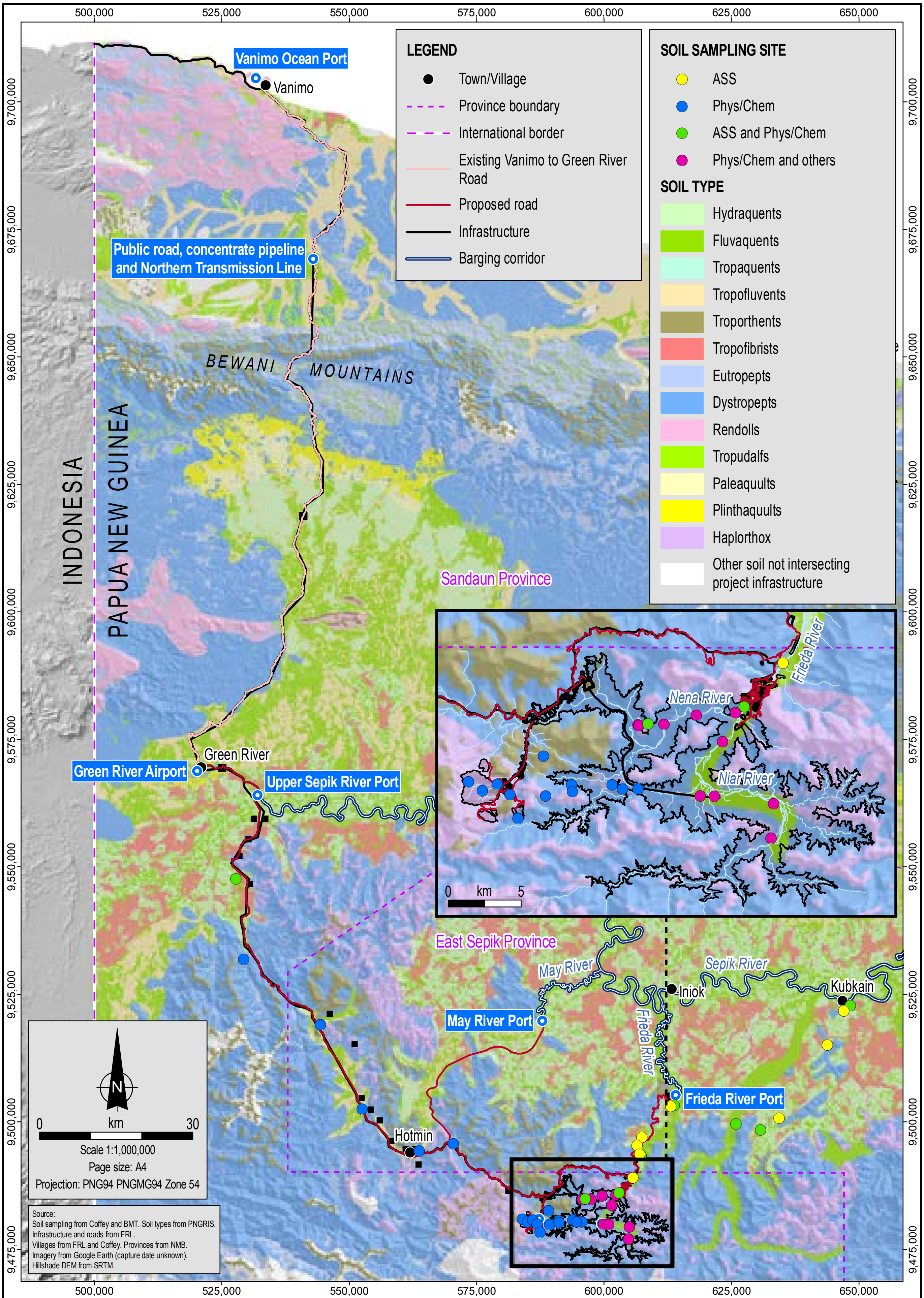
Within the infrastructure corridor from Green River to Vanimo, the soils largely reflect the landform type. Soils are a mosaic of Dystropepts, Fluvaquents and Tropofluvents along the lower slopes of the landscape. Dystropepts dominate the soils found along the eastern fringes of the Border Mountains. These soils give way to poorly draining Fluvaquents in the lower lying areas east of the Border Mountains and south of the Bewani Mountains.

Dystropepts, Fluvaquents and Tropofluvents dominate the soil composition between the Bewani Mountains and Vanimo. Large sections of Rendolls are located in the northern section of the infrastructure corridor, just south of Vanimo. These soils have a shallow depth generally between 15 and 30 cm, which lie on calcareous parent rock, with low erodibility.

Physical and Chemical Features of Soils

To assess the physical and chemical properties of the soil and the presence of ASS, soil samples were collected (in 2011 and 2017) within the mine and FRHEP areas and those areas with the greatest potential for acid sulphate soils (ASS). Figure 7.12 shows the soil sampling locations and selected soil samples are shown in plates 7.8 to 7.11.

Overall, the soil sampling results indicate the probability of ASS occurring on the lowland zone is higher than the hill zone. However, the origin of ASS is still uncertain. The majority of analyses showed that ASS was unlikely to be from a sulphide source, but more likely to be from acidic soils, possibly of volcanic origin, with a lower potential to produce acid drainage. These samples were recorded as either dark brown or dark grey clay or gravelly clay. Given the shallow depth of samples used for investigations to date, it cannot be determined whether ASS of a sulphidic nature underlie those areas beneath the one metre depth limit of the Golder (2011) investigation. In terms of Project components, only the infrastructure corridor and access road to the Frieda River Port coincide with high risk areas for ASS, which generally occur in low-lying floodplain areas.



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Date: 29.08.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.11_GIS

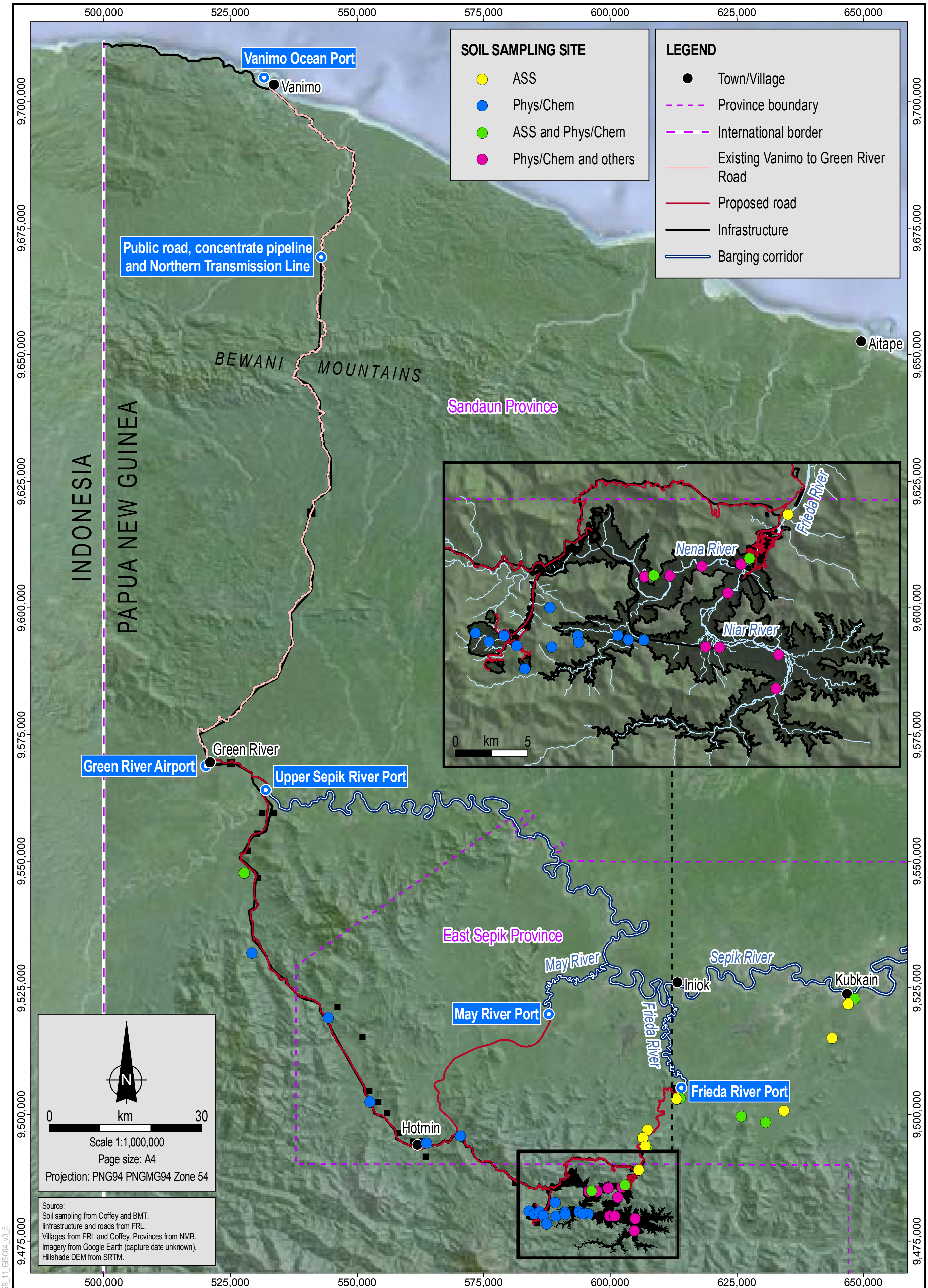
Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Soil types in the Project area and soil sampling locations

Figure No: 7.11



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FRL

Plate 7.8
Soil sample site in the Ok Binai catchment


FRL

Plate 7.9
Ok Binai catchment soil sampling site


FRL

Plate 7.10
Soil sample site near the Nena River upstream of its junction with Ok Binai (sampling site 'Nena 1')


FRL

Plate 7.11
Soil sample site near the Niar River (sampling site 'Niar 5')

Other characteristics of soil samples are described in Table 7.2.

Table 7.2 Physical and chemical characteristics of soils

Soil Aspect	Description
Soil texture and coarse material	The surface soils (0 to 20 cm sampling interval) within the mine area, ISF and from the Sepik River floodplain generally had a high proportion of silt and clay and lower proportions of sand-sized particles. A dense organic layer overlays the soil at the majority of the soil sampling sites.
Structural stability	The lack of complete dispersion within soils upon wetting indicates that they are unlikely to form a surface seal (hard-set) upon drying. However, the results indicate that the dispersion of the clay sized fraction of the soils sampled may exacerbate erosion once disturbed, particularly if these soils remain saturated for extended periods.
Soil pH	The soil pH values ($CaCl_2$) of the 0 to 20 cm depths ranged from 3.8 (strongly acidic) to 6.3 (slightly acidic).
Electrical conductivity (EC)	As would be expected in a high rainfall area, the results indicate that all surface soils sampled were non-saline (less than 0.2 dS/m). There was limited variation in the EC between the samples, with no identifiable correlation between salinity and location.
Soil organic carbon	Given the heterogeneous landscape, the soil organic carbon percentage in the surface soils was variable, but generally high (greater than 2%) at most sampling sites. There was no identifiable correlation between soil organic carbon percentage and location.
Exchangeable sodium percentage	The majority of the soils sampled within the mine area and ISF, and lowland plains were classified as sodic or highly sodic, indicating a high potential for clay dispersion. Although the level of sodicity present within the soils sampled indicates a propensity for dispersion, the actual degree of clay dispersion evident upon soil saturation is limited.
Soil nutrients	**Nitrogen**: The results indicate that there is substantial variation in the amount of plant-available nitrogen in the soils sampled ranging from <1 to 5 milligrams per kilogram (mg/kg). **Phosphorus**: The amount of plant-available phosphorus present in the surface soil samples was variable, ranging from 1 to 20 mg/kg. **Potassium**: Results indicate that the surface soil concentrations of plant-available potassium are variable, ranging from 29 to 128 mg/kg. **Sulphur**: All of the surface soil samples had low amounts of plant-available sulphur, with minor change attributable to location.
Metals	Measurements of water soluble, bioavailable (as determined by weak acid extraction) and total metal concentrations of surface soil samples indicated that variable levels of aluminium (Al), arsenic (As), Cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), nickel (Ni), selenium (Se) and mercury (Hg) were present, with cadmium (Cd) and zinc (Zn) concentrations being below the level of detection. As would be expected, the levels of bioavailable metals present within the soils sampled were generally substantially lower than the total metal concentrations recorded. Total metals and metalloids leached from surface soils exceeded the crustal abundance in some samples for As, Co, Cr, Cu, Pb, Mn, Ni, Se, Zn and Hg.

7.1.5 Groundwater

General

The description of the existing groundwater environment is divided into two study areas:

- Mine area: comprising the open-pits, ISF, process plant and other ancillary infrastructure.
- Downstream area: comprising the Frieda and Sepik river floodplains below the confluence of the Nena and Frieda rivers, extending to the confluence with the Sepik River.

The description of the existing groundwater environment for the mine area and downstream area is based on the available baseline monitoring data which is presented in full in Appendix 4. Baseline data collection was focussed on the mine area as this is where the material impacts on groundwater are expected to occur. The baseline groundwater data used to describe conditions for the mine area and downstream area have also been used to develop a conceptual hydrogeological understanding of the infrastructure corridor.

Mine Area

The regional groundwater flow direction is generally west to east towards major drainage features. On a local scale, groundwater will be topographically controlled and is expected to be a subdued reflection of surface elevation.

Site-specific data presented in Appendix 4 indicates the typical depth to groundwater in the mine area is greater than 70 m below ground level at ridgelines, greater than 40 m below ground level mid-slope and less than 10 m below ground level in the valleys. The available groundwater level data indicates an easterly groundwater flow direction. In topographic lows, such as river valleys, the watertable can intersect the land surface resulting in groundwater discharge to surface water features.

Upward hydraulic gradients have been observed in areas of lower topographic relief and downward hydraulic gradients are typically observed in areas of elevated terrain.

Artesian conditions have been observed at a number of drill holes. At locations where exploration drill holes have penetrated an artesian aquifer, groundwater will naturally rise to or above the ground surface. Data from the vibrating wire piezometer network indicates that depressurisation of the artesian aquifers has occurred. If exploration drill holes are effectively capped then artesian conditions are likely to recover quickly.

In the mine area, the Ekwai Creek groundwater system is expected to be a localised groundwater flow system, where less than 10 km separates recharge and discharge areas. There is a small storage capacity, and the flow system responds relatively quickly to rainfall events and discharges to surface relatively quickly. A large component of the observed stream flow in the catchments surrounding Ekwai Creek is supported by baseflow (groundwater discharge to watercourses).

Downstream Area

Groundwater levels in the downstream area are generally close to ground level. These groundwater systems are expected to be reasonably consistent with those occurring in the mine area, in that regional groundwater flow is generally to the east and controlled locally by topography. It is possible that intermediate groundwater flow systems are also present. Intermediate groundwater flow systems are characterised by having distances between recharge and discharge areas in the order of 10 to 100 km. They have an increased storage capacity in comparison to local flow systems, and will generally discharge to larger surface water features, i.e., the lower Nena and Niar rivers and Ok Binai.

In the downstream area, the groundwater flow systems are likely to range from intermediate to regional. Distances between recharge and discharge areas is typically greater than 100 km. Groundwater recharge is expected in the foothills of the downstream area, where outcropping fractured rock and thin soil profiles allow high infiltration rates. Evaporative discharge zones, where groundwater is expressed at the surface and is subject to evaporative processes, are expected to occur more frequently in the lowlands and swampy areas.

Hydraulic Conductivity

Hydraulic conductivity is a measure of the rate of flow of water through an aquifer or aquitard. Project-specific data available for the upstream study area indicates hydraulic conductivity is highly variable, however generally decreases with depth, consistent with the geological weathering profile.

In the mine area surrounding the HITEK orebodies, hydraulic conductivity is expected to be low due to the reduced potential for secondary porosity (i.e., connected voids and fractures in rock). The HITEK orebodies are expected to have higher permeability based on higher potential for secondary porosity and the deep weathering of the intrusive units. This will, however, reduce with depth based on the understanding that the geological units below the GpAh, which is approximately 300 m below ground level, are less fractured and are typically more competent than overlying layers. This is likely to result in reduced overall occurrence of groundwater in the lower portion of the HITEK orebodies as well as reduced hydraulic conductivity.

In the downstream area, the hydraulic conductivity of surficial aquifers associated with alluvium and colluvium, as well as shallow weathered rock, will be variable, dependent on the lithology and degree of weathering.

A summary of the available hydraulic conductivity data for the four key geologic units across the Project area is presented in Table 7.3. The available hydraulic conductivity data comes primarily from in-situ permeability packer tests carried out along zones of relatively competent rock during geotechnical drilling. Statistical bounds have been estimated for four layers including alluvium, weathered zone, above and below the GpAh.

The hydraulic conductivity measurements range significantly within each geological unit. However, this range is typical of fractured rock and is controlled by the nature of the fracture network.

Table 7.3 Summary of hydraulic conductivity data for key geologic units

Geologic unit	Number of data points	Hydraulic conductivity (m/day)		
		Minimum	Geometric mean	Maximum
Alluvium/colluvium	40	6.0×10^{-2}	1.02	24
Weathered rock	39	5.6×10^{-4}	0.15	15.2
Fresh rock (above GpAh)*	218	4.0×10^{-5}	1.7×10^{-2}	7.3
Fresh rock (below GpAh)*	24	1.0×10^{-5}	6.9×10^{-4}	0.14

* The GpAh layer comprises anhydrite and gypsum and represents the shallowest occurrence of anhydrite in the geologic profile.

Water Quality

Mine Area

Groundwater samples were collected at nine artesian resource drill holes in 2011 and at 33 artesian exploration drill holes in 2014, and analysed for a range of parameters including salinity, pH, major ions and metals. Sample locations are shown in Figure 4.12 of Appendix 4.

A statistical summary of key 2014 groundwater quality results for samples collected from within the mine area is provided in Table 7.4. Analytical results for 2011 were generally within the range of 2014 data, with the exception of salinity, which was lower than the 2014 reported data. Table 7.4 also includes a summary of key analyte concentrations from the available laboratory data, as well as adopted groundwater screening criteria.

Table 7.4 Summary of groundwater quality in the vicinity of the HITEK orebody

Parameter	Units	Minimum	Average	Maximum	WHO Drinking Water *	ANZECC/ ARMCANZ†
pH	pH units	3.4	-	7.8	–	–
Salinity (EC)	µS/cm	126	1,002	2,260	–	–
Salinity (TDS)	mg/L	82	651	1,470	–	–
Bicarbonate	mg/L	0.5	29	77	–	–
Carbonate	mg/L	0.5	0.5	0.5	–	–
Sulphate	mg/L	24	533	1,460	–	–
Magnesium	mg/L	0.5	3.28	8	–	–
Calcium	mg/L	2	226	600	–	–
Chloride	mg/L	0.1	1.33	5	–	–
Arsenic	mg/L	0.0005	0.002	0.015	0.01	0.024 (As^{3+})
Copper	mg/L	0.0005	0.03	0.51	2.0	0.0014§
Nickel	mg/L	<0.0005	0.002	0.006	0.07	0.011§
Zinc	mg/L	0.0025	0.015	0.063	–	0.008§
Cadmium	mg/L	<0.00005	0.00006	0.0002	0.003	0.0002§
Chromium	mg/L	<0.0005	0.0005	0.0005	0.05	0.001 (Cr^{6+})
Lead	mg/L	<0.0005	0.0005	0.0005	0.01	0.0034§
Mercury	mg/L	<0.00005	0.00005	0.00005	0.006	0.00006

Metals and metalloids reported as dissolved concentrations.

* World Health Organization (WHO) guidelines for drinking water quality (2017).

† Australian water quality guidelines for fresh and marine waters (ANZECC/ARMCANZ, 2000). Metal values apply to dissolved concentrations. Trigger values adopted for 95% ecosystem protection for typical slightly to moderately disturbed systems.

§ Based on a hardness of 30 mg/L calcium carbonate ($CaCO_3$) hardness.

mg/L = milligrams per litre.

Groundwater quality of the mine area can be summarised as having:

- pH values ranging from acidic to slightly alkaline.
- Salinity ranging from fresh to brackish.
- Major ion composition dominated by calcium and sulphate, consistent with gypsum/anhydrite presence in the host aquifer.
- Low concentrations of carbonate, chloride and magnesium.
- Metal concentrations consistent with the nature of the HITEK orebody. Maximum reported concentrations indicate:
  - Copper and zinc concentrations in exceedance of ANZECC/ARMCANZ (2000) aquatic ecosystem protection guidelines. Copper concentrations below WHO (2017) drinking water guidelines.
  - Arsenic concentrations below the ANZECC/ARMCANZ (2000) aquatic ecosystem protection guideline, however above the WHO (2017) drinking water guideline.

– Concentrations of cadmium, chromium, lead, nickel and mercury below the aquatic ecosystem and drinking water guidelines.

Further analysis of major ion chemistry suggests that there at two main geochemical processes occurring. These are:

- The dissolution of anhydrite ($CaSO_4$) which is occurring within the artesian groundwaters.
- The oxidation of sulphides, which is evident in a number of surface water samples and a limited number of groundwater samples.

Anhydrite dissolution and pyrite oxidation are the dominant sources of dissolved sulphate in these waters. Distinct trends of mixing between water dominated by anhydrite dissolution and water dominated by pyrite oxidation are inferred from the data and some spatial correlation between these mixed waters is apparent. The oxidation process would be occurring at shallow depths, and infers local mixing between surface waters, deeper groundwaters, and water in contact with oxidising material in the unsaturated zone.

Downstream Area

Groundwater data was not available for the downstream study area. However, it is expected that groundwater beneath the foothills is fresh to brackish (TDS less than 2,000 mg/L), with groundwater becoming more saline beneath the lowlands. Evaporative concentration of salts from shallow watertables may result in TDS concentrations greater than 5,000 mg/L; lower salinity groundwater may be found in deeply buried prior-stream channels (i.e., ancient river beds now buried by sediments).

Groundwater Use

Village Use

Groundwater is not a significant resource for villagers in either the mine area or downstream area as the high rainfall rates (average rainfall up to 8,200 mm per year in the mine area and up to 6,000 mm per year in the downstream area) generally provides sufficient surface water resources. There are some villages that are known to supplement their surface water supplies with groundwater-fed springs. These include Amaromin, Wameimin 1, Wameimin 2, Wabia, Ok Isai, Paupe and Auom 3 (refer Figure 1.3). These villages are located at a distance from the mine area, with Wameimin 2 and Ok Isai located closest to major mining infrastructure at 6.5 km and 7.5 km away respectively. Both Wameimin 2 and Ok Isai will be resettled prior to the start of mining.

There are no known uses of groundwater for economic gain (i.e., revenue raising activities that rely on groundwater) in relation to the activities of local people within the immediate mine area or downstream area.

Groundwater-dependent Ecosystems

Limited studies have been undertaken in either the mine area or downstream areas in relation to groundwater-dependent ecosystems. Consideration of a number of factors indicates that these ecosystems may occur. These include:

- Groundwater contribution to surface water systems as baseflow may be significant, and this will support flow requirements for maintenance of aquatic ecosystems.
- Springs are likely to be widely dispersed within the upstream study areas, particularly at break of slope (Plate 7.12). Springs may support localised ecosystems.

- Shallow and/or perched watertables are likely to be common in the lowlands, possibly supporting terrestrial and wetland ecosystem water requirements, including sago stands in the lowlands.

The plant-available water capacity of soils is very high, with high and relatively consistent rainfall contribution. Therefore, the water in soils is likely to be sufficient to maintain terrestrial vegetation water requirements and limited reliance on groundwater as a primary source of water is expected except during extended periods of drought.

Mine Area

In the upstream study area, groundwater may contribute to the maintenance of ecosystems via:

- Springs at break of slope.
- Baseflow contribution to surface water systems, e.g., Ekwai Creek (Plate 7.13).

Throughout much of the upstream study area, the depth to watertable is too great to support terrestrial vegetation. There is some potential for terrestrial vegetation to access shallow groundwater in valley areas, however plant water requirements are expected to be primarily met by surface water contribution.

Downstream Area

In the downstream study area, groundwater may contribute to the maintenance of ecosystems via:

- Baseflow contribution to surface water systems.
- Discharge to springs and wetlands (i.e., swamps) in the lowlands.
- Access to shallow perched groundwater.

In the downstream study area some terrestrial vegetation is likely to have rooting depths sufficient to access shallow groundwater and/or the capillary zone above the watertable. As outlined above, due to the high rainfall environment resulting in high surface and soil moisture content, this vegetation is unlikely to rely significantly on groundwater for plant water requirements. The exception to this may be during extended periods of drought, where the relative importance of groundwater contribution may increase as surface water availability decreases.

Sago, which is present in low-lying swampy areas in the downstream study area, has relatively shallow rooting depths and is expected to primarily be reliant on surface water contribution. There may be some reliance on shallow perched groundwater/the capillary zone, in particular during extended periods of drought.

Conceptual Hydrogeological Model

Mine Area

A schematic representation of the upstream conceptual hydrogeological model is presented in Figure 7.13. Model components and assumptions include:

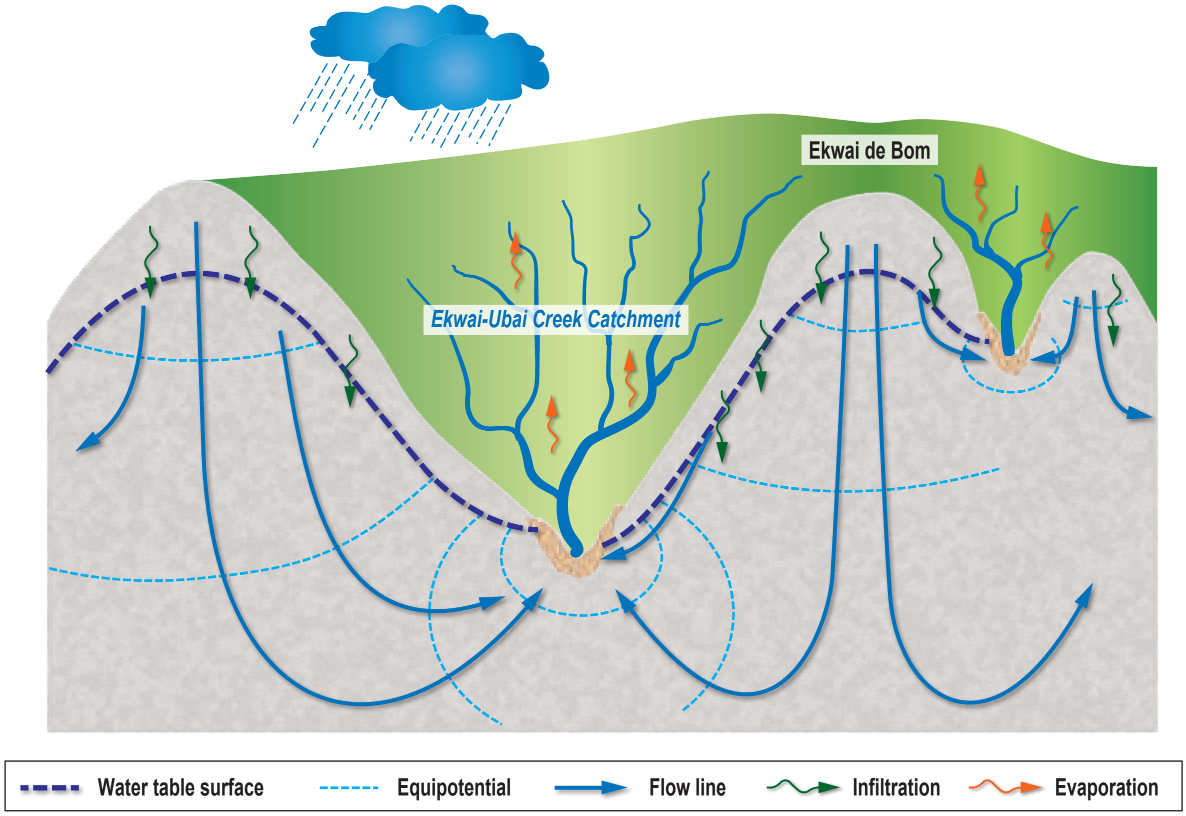
- Groundwater flow generally reflects topography, with regional groundwater flow expected to be from west-southwest to the east-northeast. Local and regional scale geological features will influence the direction of groundwater flow on a local scale.

- Groundwater recharge occurs in areas of elevated topography primarily through direct rainfall infiltration, and in lower lying areas through stream leakage.

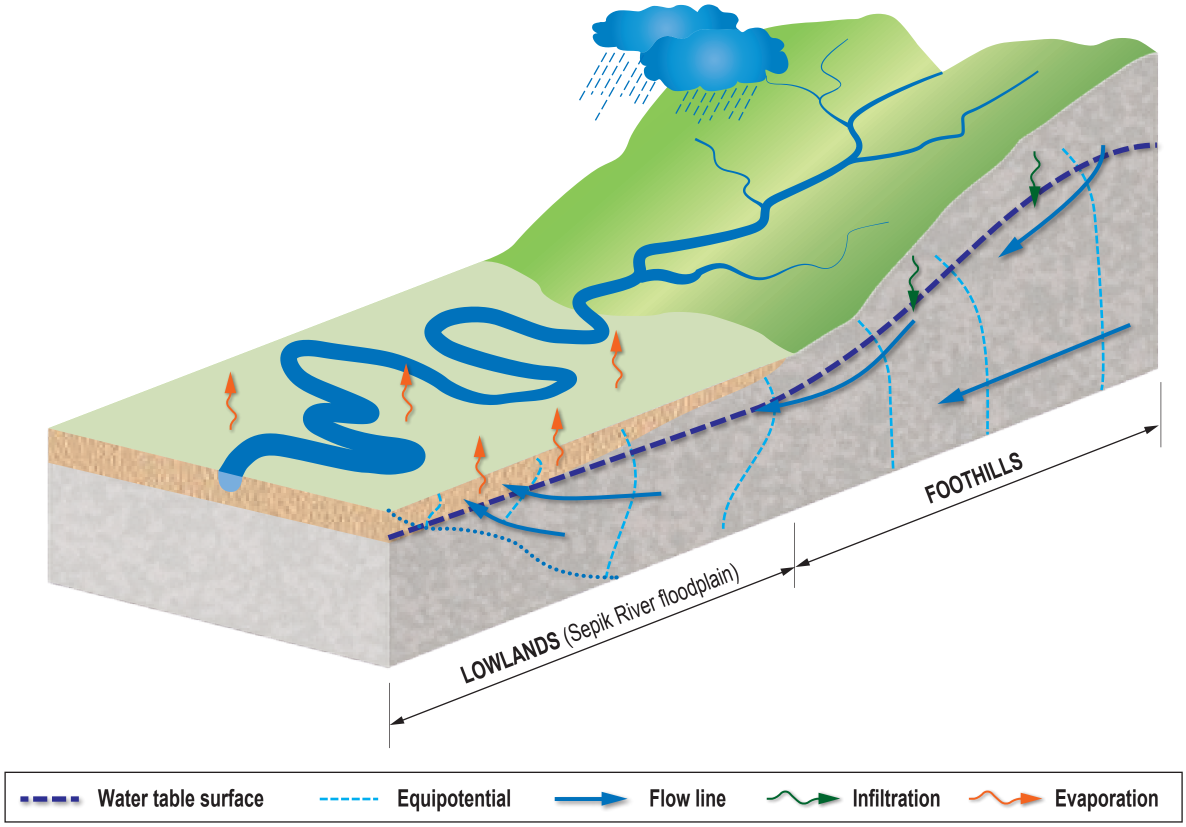
Plate 7.12
Vegetation at a break-in-slope, where the watertable may become shallow

Plate 7.13
Baseflow-fed stream (Ekwai Creek)

a) The mine area



b) The downstream area



coffey A TETRA TECH COMPANY	Date: 29.08.2018 Project: 754-ENAUABTF11575 File Name: 11575_11_F07.13_GRA	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Conceptual hydrogeological models of the groundwater study areas	Figure No: 7.13

AI Reference: 11575_11_GRA035.ai_4

- Groundwater recharge is likely to occur relatively quickly given the secondary porosity of the geologic units above the GpAh.
- Prior to recharge occurring, rainfall infiltration may also move laterally where less permeable layers are intercepted (i.e., the contact between basement rock and overlying soils), and discharge to the land surface.
- Weathering of the near surface rock mass, and structure and faults in the mine area, will increase hydraulic conductivity and influence movement of groundwater in the upstream area.
- The steep topography of the upstream study area results in smaller scale, local to intermediate groundwater flow systems. Local flow systems respond rapidly to rainfall events and the groundwater has shorter residence times. Intermediate scale flow systems will transmit groundwater from local topographic highs to lower elevations, often passing underneath local scale flow systems and discharging at major water courses.
- Depth to groundwater is likely to be in the order of 60 m to 70 m below ground level in the upper reaches of the catchment, and a few metres below ground level, or at ground level, at lower elevations.
- Artesian conditions will exist in areas of lower elevation.
- Groundwater represents a significant proportion of baseflow in some streams and rivers.

Downstream Area

A schematic representation of the downstream conceptual hydrogeological model is presented in Figure 7.13. Model elements and assumptions include:

- Recharge potential remains high in the foothills, with a decreased rainfall rate along the floodplains potentially decreasing recharge rates in these areas.
- Baseflow contribution to watercourses is relatively high.
- The lowlands are likely to be dominated by intermediate to regional groundwater flow systems while local to intermediate flow systems are likely to be present in the foothills.
- The depth to groundwater is likely to be shallow, resulting in evaporative concentration of salts in the shallow watertable or perched groundwater systems.
- Topographic lows, such as the foothills and floodplains represent groundwater discharge zones.

7.1.6 Bioregional Context

New Guinea is among the most biologically diverse and endemically rich regions on Earth. The island is the second largest in the world; it contains the third largest block of unbroken tropical rainforest (behind the Amazon and the Congo) and the largest tract of primary rainforest remaining in the Asia-Pacific region (Beehler, 2007). New Guinea’s forests support more than 5% of the world’s plant and animal species on less than 1% of its land surface (Faith et al., 2001). The high degree of biodiversity is thought to result from a complex interplay of factors, leading to localised isolation for extended periods and resultant speciation.

The Project is located in the Sepik River basin, the largest catchment in PNG covering 78,700 km^2. Vegetation in the catchment is varied and includes mangrove forest, herb swamps, tall lowland rainforest, cloud forest and alpine heaths. The region also contains a high diversity of terrestrial fauna, in particular mammals and frogs, in comparison with other remote areas of the PNG highlands. As such, the Sepik River basin rates as a globally significant area of biodiversity. The Upper Sepik River basin was submitted by the Government of PNG for inclusion on the Tentative List of World Heritage Properties on 6 June 2006 under criteria i, iii, iv, v, vii, viii, ix and x. This has not been progressed by the Government of PNG at this point.

Understanding the existing flora and fauna within the Project disturbance area as a basis for impact prediction required investigation of representative areas. The broad area surrounding the Project has been classified into three zones based on elevation, each with a range of physical (e.g., hydrology, geology, climate) and biological (e.g., vegetation) characteristics:

- **Lowland Zone.** Comprises alluvial landforms that result from past or present overbank flooding of the Sepik River and its major tributaries. Active floodplains of the major channels are subject to inundation on a seasonal or annual basis. There are various elevated landforms including river terraces and at least one peat deposit, which lacks surface drainage. All sites situated below 100 m ASL were treated as lowland zone sites.
- **Hill Zone.** Comprises primary erosional and colluvial (i.e., slope deposit) landforms of the northern foothills of the Central Cordillera (i.e., the New Guinea highlands). Both continuous hills and ranges, and isolated hills, are surrounded by areas of active alluviation. Much of the topography is steep, with significant stretches of cliff-line habitat, and the geology is spatially complex. All sites situated between 100 m ASL and 1,000 m ASL were treated as hill zone sites.
- **Montane Zone.** Consists of primary erosional and colluvial (i.e., slope deposit) landforms comprising the northern foothills of the Central Cordillera above 1,000 m ASL and extends above the hill zone.

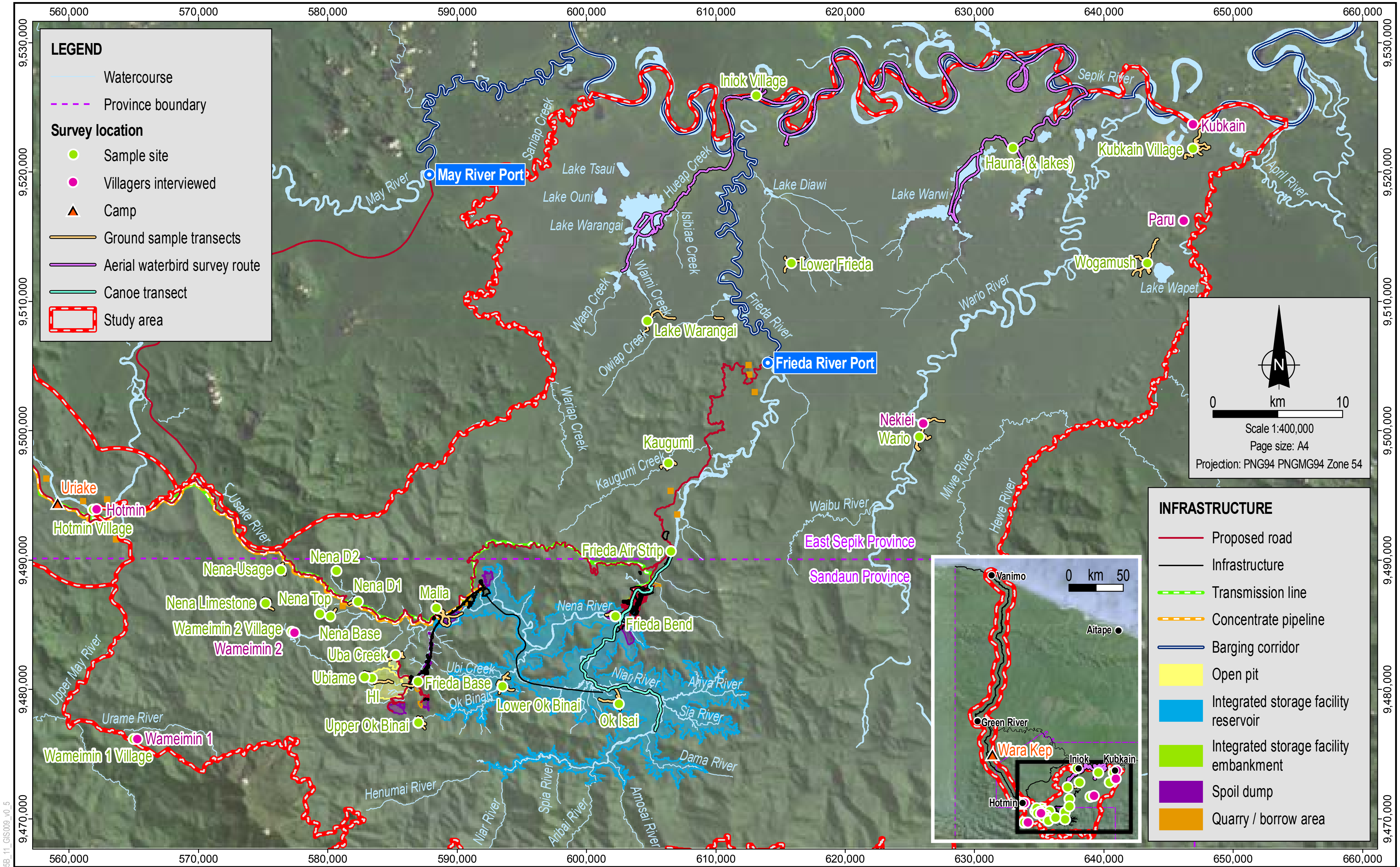
To this end, the assessment focuses on an area 660,571 ha in size, termed hereafter the terrestrial biodiversity study area and shown in Figure 7.14. The terrestrial biodiversity study area is broken into two areas. The first focusses on the mine, FRHEP and downstream areas and is bounded to the north by the Sepik River, to the west by the Saniap, Usake and Upper May rivers, to the east by the Wogamush, Hewe, Miwe and Tau rivers, and to the south by the 1,500 m ASL contour [1]. The second focusses on the infrastructure corridor bounded by a 5 km buffer (i.e., a 10 km corridor).

7.1.7 Flora

Context

The upper Sepik River basin has historically been an area critical to botanical documentation in PNG. The first floristic (as well as other biological taxa) investigation was undertaken by the German Augusta Fluss Expedition of 1912 to 1913, which collected a total of 6,639 plant specimens with several hundred type specimens (i.e., new species) being documented. This botanical collection was destroyed in the 1943 fire at the Berlin Herbarium during WWII, effectively erasing the primary basis for the identification of numerous plant species. The Hunstein District (encompassing Ambunti and the April River) was a focus of the Augusta Fluss Expedition and received considerably more exploration attention than the Frieda River area.

[1] Note that some sampling sites referred to in this document are known by a different name in Appendix 8a. The site names in question are (with Appendix 8a names in brackets): Uba Creek Site (Koki Site); Lower Frieda Site (East Sepik Site); Frieda River Airstrip Site (Frieda Strip Site); Iniok Village Site (Iniok Site); Lake Warangai Site (Warangai South Site); Kubkain Village Site (Kubkain Site), Lower Ok Binai Site (Ok Binai 1 Site).



Source:
Survey locations, tracks and study areas from Francis Crome.
Iinfrastructure, roads and tenements from FRL.
Villages, topographic features, watercourses and water bodies from FRL and Coffey.
Landsat satellite imagery from FRL (capture date unknown).
Hillshade DEM from SRTM.

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Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.14_GIS

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Terrestrial biodiversity study area and survey locations

Figure No: 7.14

Nonetheless, the May River was a principal venue for the expedition during a nine-day transit to the Frieda River area. The most productive part during this survey was an ascent of Mt. Pentecost, between the present May River station and the village of Hotmin.

Since the Augusta Fluss Expedition, there have been a number of surveys in the region including several collections taken from the May River by A. Bellamy in 1984 and D.G. Frodin in 1992. Although many locations visited by the Augusta Fluss Expedition and others are outside the terrestrial biodiversity study area, the exploration results from historical localities are relevant to an understanding of floristic distributions through the upper Sepik basin, particularly with regards to the probable occurrences of Sepik plants beyond their presently-documented limits.

Survey Methods

Given the lack of botanical information for the terrestrial biodiversity study area, vegetation and flora was investigated at 20 sites during five field surveys between November 2009 and March 2011 and two sites in November and December 2017. Study localities consisted of a base camp with an improvised network of access tracks into surrounding habitats. Botanical collections and forest observations were undertaken around these camps in accordance with the procedures described in Appendix 8a and 8b. Locality names, geographic coordinates, elevations, survey dates and survey duration are also provided in Appendix 8a and 8b.

Flora surveys were based on the sampling procedures used in other rapid assessments. Conforming to modern botanical surveys, vascular plants (i.e., ferns, gymnosperms, angiosperms) were recorded by collecting plant specimen (i.e., a sample of leaves, flowers, or fruiting parts) or recording the species by sight for common, easily recognised species. Particular attention was given to plants of probable conservation interest.

The surveys were one of the most labour-intensive botanical inventories undertaken in modern New Guinean research, totalling almost 2,000 hours of active surveying. More species were recorded and collected than for any comparable operation in PNG’s post-Independence period, exceeding even the combined results from previously unexplored areas on the Papuan karst. This coverage has contributed to the broader knowledge of PNG terrestrial biodiversity.

Flora

Floristic Diversity

The botanical survey in the mine area recorded a total of 1,478 specimen numbers in replicate sets. Of these, there were 184 vascular plant families, 735 genera and at least 1,354 morphospecies (i.e., a species distinguished from others only by its morphology). In addition to the physical collections, the survey included over 500 taxa enumerated by sight recognition. More than 1,350 morphospecies were documented, although an exact tally was not possible due to the lack of diagnostic structures (e.g., flowers and fruits) of many plants. A total of 447 species were recorded from two sites in the southern infrastructure corridor. Here, while the two sites shared a number of similarities, there was significantly reduced diversity in comparison to other areas of the terrestrial biodiversity study area and more broadly. This was a somewhat unexpected result, and is a likely reflection of limited productivity and availability of water.

The results indicate a high floristic diversity in the terrestrial biodiversity study area and accentuate the difficulties of developing a comprehensive understanding of this flora. Taxonomic counts according to the principal categories of vascular plants are provided in Table 7.5. Numbers in parentheses represent counts from the two sites surveyed in 2017 in the southern infrastructure corridor.

Table 7.5 Survey results by vascular plant category

	Ferns	Gymnosperms	Monocots	Dicots	Totals
Families	28 (20)	5 (3)	30 (22)	121 (83)	185 (128)
Genera	90 (37)	10 (3)	140 (78)	495 (232)	735 (350)
Species	209 (54)	14 (3)	207 (87)	924 (303)	1,354 (447)

The floristic-tectonic affinities of the Sepik flora are primarily to the west (i.e., the Indonesian province of West Papua), a region with a botanical documentation coverage of less than 30% of PNG. The poor knowledge base in the western half of New Guinea (i.e., West Papua) is likely to exaggerate the level of apparent endemism in the Sepik flora by masking the actual range of plants. However, a substantial number of new floristic discoveries were made during the surveys, including:

- Two genera undescribed but previously recorded elsewhere.
- 23 species new to science or undescribed (three of which have previously been recorded elsewhere).
- Two genera not previously recorded on the island of New Guinea.
- Three species distributional records for PNG (i.e., species not previously recorded in PNG).
- Four rediscoveries of plants known only from type specimens destroyed during WWII.
- Three range extensions for species previously known only from type localities.
- 17 range extensions of taxonomically significant plants.

Of the genera and species that are undescribed or new to science, two are known from a single site, 11 from two sites and 12 from three or more sites within the terrestrial biodiversity study area. Five of the taxa, including two genera, have been recorded outside the area by earlier surveys of the Hunstein District. All botanical discoveries were located in the hill and montane zones of the area. Half of the new or undescribed plants (12 of 25) were seen only in the PNG Forest Inventory and Mapping System (FIMS) vegetation type Hill Forest (Hm), 11 were found in both Hill Forest (Hm) and Coniferous Lower Montane Forest (Lc), one was found only in Lower Montane Forest (L) and one was found in both Hm and Lowland forest on plains and fans. There were no discoveries in the Lowland Zone (Fri/Fsw/Po/Wsw) vegetation. The majority of the botanical discoveries (14 of 25) are concentrated from the Melastomataceae, Myrsinaceae, and Rubiaceae families.

Table 7.6 provides a summary of the most important botanical discoveries, collated by site and forest class. Since the time of the field surveys, seven of the previously undescribed species have now been described scientifically (see Takeuchi, 2012, 2013, 2014a, 2014b; Takeuchi and Arifiani, In Press; Cámara-Leret et al., 2013; Chaowasku, 2015). Appendix 8b and 8c provide a description of all the changes to botanical nomenclature including those species that have been described.

Table 7.6 Occurrence of vascular plant species new to science or undescribed at sample sites

Taxon	Family	FIMS Code	Sites												Total
			Frieda Bend	Malia	Nena D1	Upper Ok Binai	Nena-Usage	Uba Creek	Nena D2	HI	Nena Base	Nena Limestone	Uriake	Wara Kep	
Species New to Science or Undescribed															
Phyllanthera sp. nov.	Apocynaceae	Hm & L	x	-	-	-	-	x	-	x	-	-	-	-	3
Diospyros sp. nov.	Ebenaceae	L & Lc	-	-	-	-	-	-	-	x	-	x	-	-	2
Glochidion sp. nov.	Phyllanthaceae	Hm & L	-	-	-	-	-	-	-	x	x	-	-	-	2
Archidendron sp. nov.	Fabaceae	Hm	-	-	x	-	-	-	-		x	-	-	-	2
Catanthera sp. nov.	Melastomataceae	Hm & L	-	-	-	-	-	x	x	x	x	-	-	-	4
Creochiton sp. nov.	Melastomataceae	Hm, L, & Lc	-	-	-	-	-	-	-		x	x	-	-	2
Medinilla sp. nov. A	Melastomataceae	Hm, L, & Lc	x	-	-	-	-	x	-	x	x	x	-	-	5
Medinilla sp. nov. B	Melastomataceae	Hm & L	-	-	-	-	-	x	-	x	-	-	-	-	2
Medinilla sp. nov. C	Melastomataceae	Hm & L	-	-	-	-	-	x	-	x	x	-	-	-	3
Chisocheton sp. nov.	Meliaceae	Hm	x	-	x	x	x	-	-	-	-	-	-	-	4
Kibara sp. nov.	Monimiaceae	Hm & L	-	-	-	-	x	x	-	x	-	-	-	-	3
Ardisia sp. nov. A	Myrsinaceae	Hm	-	-	-	-		-	-	-	x	-	-	-	1
Ardisia sp. nov. B	Myrsinaceae	Hm	-	-	-	-	x	-	-	-	-	x	-	-	2
Discocalyx sp. nov.	Myrsinaceae	Hm	x	x	-	x	x	-	-	-	-	-	-	-	4
Helicia sp. nov.	Proteaceae	Hm & L	-	-	-	-	-	-	-	x	x	-	-	-	2
Psychotria sp. nov.	Rubiaceae	Hm & Ps	-	-	-	-	-	-	-	-	-	-	x	x	2
Psychotria sp. nov. A	Rubiaceae	Hm	-	x	-	x	-	-	x	-	-	-	-	-	3

Table 7.6 Occurrence of vascular plant species new to science or undescribed at sample sites (cont'd)

Taxon	Family	FIMS Code	Sites												Total
			Frieda Bend	Malia	Nena D1	Upper Ok Binai	Nena-Usage	Koki	Nena D2	HI	Nena Bas	Nena Limestone	Uriake	Wara Kep	
Species New to Science or Undescribed (cont'd)															
Psychotria sp. nov. B	Rubiaceae	Hm & L	-	x	-	-	-	-	-	x	x	-	-	-	3
Timonius sp. nov.	Rubiaceae	Hm	x	x	-	-	-	-	-	-	-	-	-	-	2
Zygogynum sp. nov.	Winteraceae	Hm	-	-	x	-	x	-	x	-	-	-	-	-	3
Undescribed Species Previously Discovered Outside the terrestrial biodiversity study area															
Genus (undescribed)	Annonaceae	Hm	x	x	-	x	-	-	-		-	-	-	-	3
Genus (undescribed)	Melastomataceae	Hm & L	x		-	x	-	-	-	x	-	-	-	-	3
Cyrtandra sp. (undescribed)	Gesneriaceae	Hm	-	x	x	-	-	-	-		-	-	-	-	2
Psychotria sp. (undescribed)	Rubiaceae	Hm	x		-	x	-	-	-		-	-	-	-	2
Beccariella sp. (undescribed)	Sapotaceae	Hm	-	x	-	-	-	-	-		-	-	-	-	1
Total	**-**	**-**	**8**	**7**	**4**	**6**	**5**	**6**	**3**	**11**	**8**	**4**	**1**	**1**	**-**

FIMS code categories: Hm = Hill Forest, L = Lower Montane Forest, Lc = Coniferous Lower Montane Forest, Ps = Lowland Forest on Plains and Fans.

Source: Appendix 8a and 8b.

Terrestrial Flora of Conservation Significance

The International Union for Conservation for Nature (IUCN) red list was the principal source used to assess conservation significance for flora and fauna. The IUCN red list uses a set of criteria to evaluate the extinction risk of biological species.

A total of 16 flora taxa listed as threatened or near threatened on the IUCN red list were recorded during surveys for the Project. These include one Critically Endangered, one Endangered, seven Vulnerable and seven Near Threatened. The Least Concern category was excluded from this assessment, because they do not meet the criteria for threatened or near threatened status. Vascular flora listed as being of conservation significance in the terrestrial biodiversity study area are provided in Table 7.7, along with the vegetation community in which they are found. A Critically Endangered moss (*Schistochila undulatifolia*) was previously recorded from a single locality at 800 m ASL (near the Nena deposit) within the terrestrial biodiversity study area.

Table 7.7 Flora listed as of conservation concern in the terrestrial biodiversity study area

Family	Taxon	FIMS Vegetation Type	IUCN Status
Araucariaceae	*Agathis labillardierei*	Hm	NT
Cunoniaceae	*Ceratopetalum succirubrum*	Hm, L	VU
Cycadaceae	*Cycas rumphii*	Wsw and Fsw, Fri, Po	NT
Dipterocarpaceae	*Anisoptera thurifera*	Hm	VU
Fabaceae	*Intsia bijuga*	Fri, Hm, Po	VU
Fabaceae	*Pterocarpus indicus*	Fri, Hm, Po	VU
Meliaceae	*Aglaia agglomerata*	Hm	NT
Meliaceae	*Aglaia euryanthera*	Hm	NT
Meliaceae	*Aglaia rimosa*	Hm	NT
Meliaceae	*Aglaia subcuprea*	Hm, Po	NT
Myristicaceae	*Horsfieldia ampliformis*	L, Lc	VU
Myristicaceae	*Horsfieldia sepikensis*	Hm, Po	VU
Myristicaceae	*Myristica buchneriana*	Hm	VU
Myristicaceae	*Myristica globosa*	Hm	NT
Rutaceae	*Flindersia pimenteliana*	Hm	EN
Rutaceae	*Halfordia papuana*	Hm, L	CE

IUCN Categories: CE = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened.

Invasive and Introduced Vascular Plant Species

One feature of the terrestrial biodiversity study area was predominant lack of invasive weed species, with the exception being along the northern portion of the infrastructure corridor.

The presence of introduced and invasive species encountered during the surveys was directly correlated to human presence and infrastructure. At Iniok, the environment has been substantially impacted by introduced species and was essentially an altered anthropogenic landscape. Introduced and invasive floras were similarly recorded at Wario, Wogamush and Kubkain Village sites, as a result of proximity to villages and major pedestrian tracks. Nena Base Site had significant levels of floristic disturbance (at least 26 introduced and/or adventive species), but these were confined to the facilities and adjacent areas. In other places where exploration drilling and clearing for helipads has occurred, introduced species were documented. The invasive capacities of these exotic species was considered to be low (Appendix 8a).

Within the infrastructure corridor there has been substantial modifications to the vegetation as a result of human settlements and forestry activities adjacent to the existing road from Vanimo to Green River. Areas of subsistence gardens within the alluvial environment along the May River is densely populated with alien weed species (at least 33 exotic species identified). These species are limited to cultivated areas, evidently unable to establish themselves within nearby environments.

While not specifically surveyed, the presence of invasive weeds are likely to occur along the northern areas of the infrastructure corridor, particularly near oil palm plantations and villages.

For a list of the introduced species recorded in the terrestrial biodiversity study area, see Appendix 8.

Vegetation Communities

Vegetation communities were mapped based on the PNG Forest Inventory and Mapping System (FIMS) (Saunders, 1993a, b; Hammermaster and Saunders, 1995). While the underlying FIMS system is effective for large-scale use, detailed ground truthing frequently uncovers anomalies in the FIMS categories.

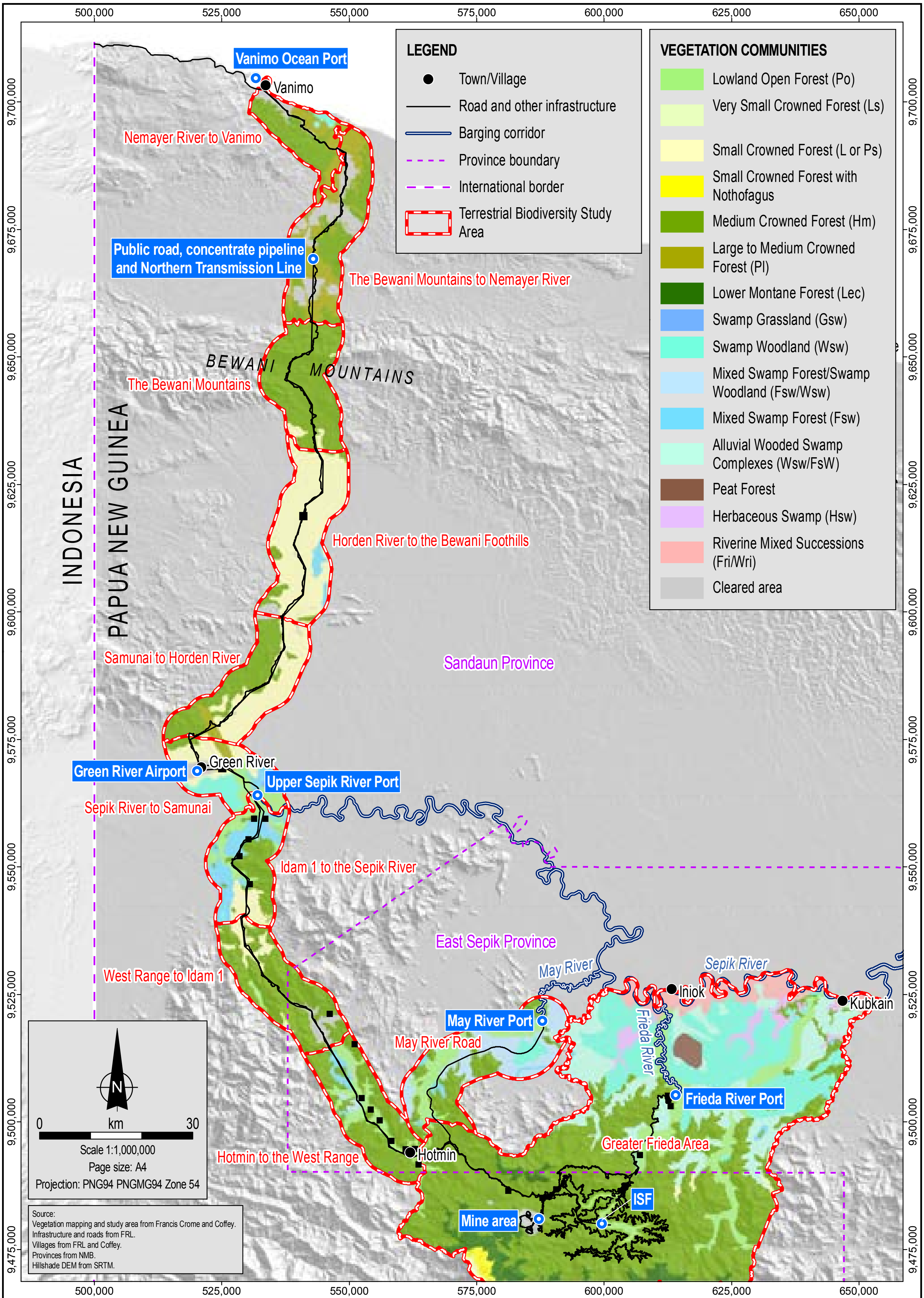
Vegetation communities within the terrestrial biodiversity study area were refined based on the botanical investigations described above, use of high resolution and Lidar imagery and helicopter reconnaissance. A total of 15 types were recorded based on FIMS categories and mapped in Figure 7.15 and Figure 7.16. Short descriptions of vegetation types and formations are provided in Table 7.8.

In addition, one forest type, Peat Forest, is a new formation previously undocumented in PNG at the time of the survey and is thus uncoded under the FIMS. There were also areas of anthropic disturbance, i.e., areas cleared of vegetation. Montane Forest has been described and is referred to in subsequent analysis, although was not specifically surveyed during field surveys.

Hill and Montane Vegetation

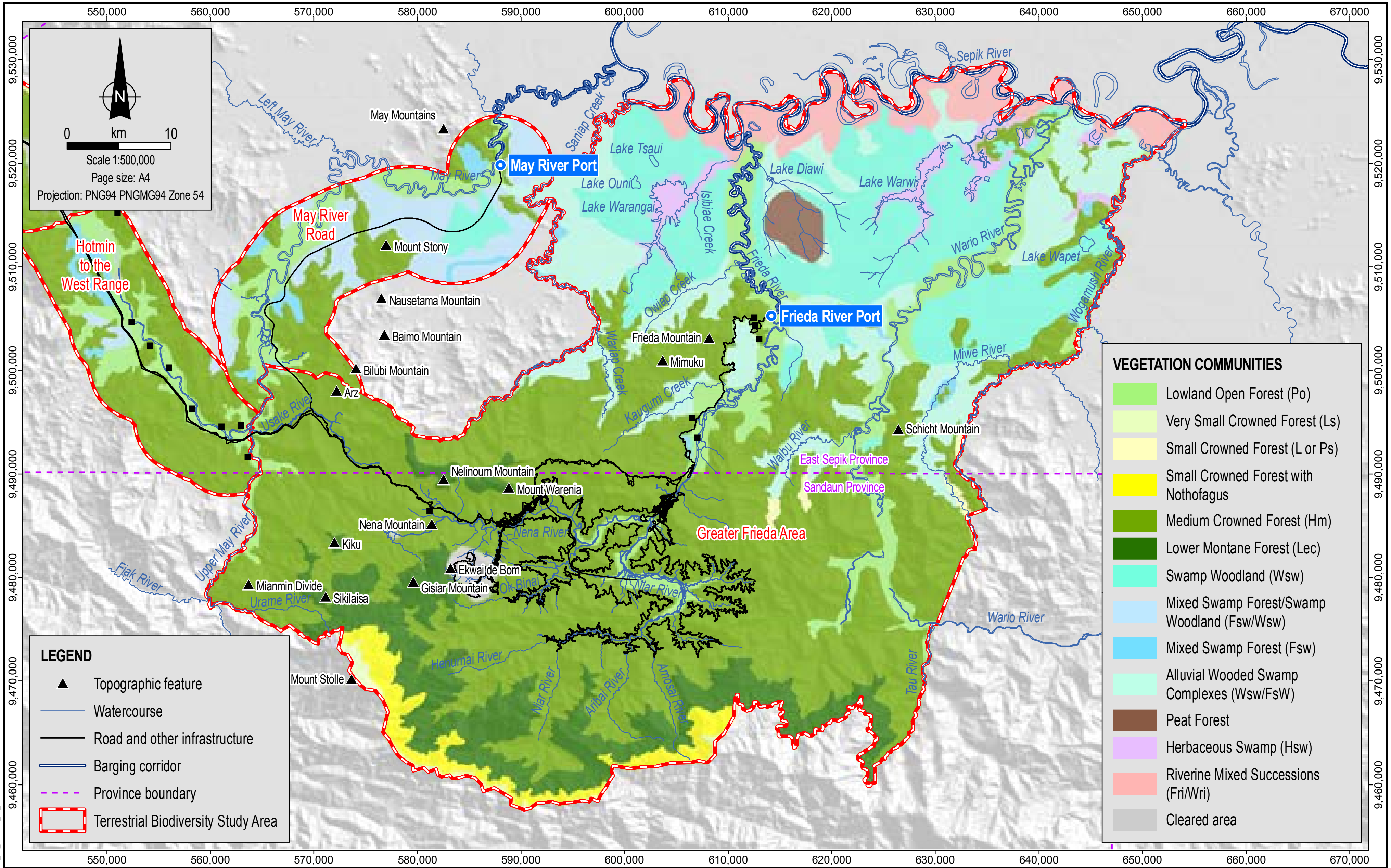
Lower Montane Forest and Coniferous Lower Montane Forest communities occurred at Nena Limestone and Horse-Ivaal (HI) Sites. This was clearly demonstrated by the heavy epiphyte loads on trees, the reduction in tree statures and crown size and the species composition. The presence of this community at elevations below 1,000 m ASL is far lower than the usual elevation range for such formations. This peculiarity may have been caused by exceptionally high rainfalls on specialised substrates.

Hill Forest communities within the terrestrial biodiversity study area occur along riverbeds, which are steeper and narrower than for lowland rivers. Heliophytic species (plants that thrive in bright sunlight) characteristic of the lowlands are thus excluded. Evidence of flood surges along these upland channels is provided by the presence of rheophytic specialists (plants that grow in running water). The adjacent forest supports a diverse community of endemic flora, which contrasts with the lowland plains where vegetation is predominantly composed of a repeating assemblage of cosmopolitan plants.



MXD Reference: 11575B_11_GIS028_v0_4

coffey A TETRA TECH COMPANY	Date: 31.08.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.15_GIS	Frieda River Limited / Sepik Development Project	FRIEDA RIVER	Vegetation communities of the terrestrial biodiversity study area	Figure No: 7.15



MXD Reference: 11575B_11_GIS026_v0_4

Source:
Vegetation mapping and study area from Francis Crome and Coffey.
Infrastructure, roads and tenements from FRL.
Villages, topographic features, watercourses and water bodies from FRL and Coffey.
Provinces from NMB.
Hillshade DEM from SRTM.

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Date: 31.08.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.16_GIS

Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Vegetation communities of the terrestrial biodiversity study area - Greater Frieda Area

Figure No: 7.16

Vegetation composition in the hill and montane zones is primarily driven by the creation of forest gaps. Gaps are created from mortality of large trees either by natural senescence, insect attack, disease, wind or mechanical damage from other falling trees. Small canopy gaps range from tens to several hundred square metres in area. In response, seedlings and saplings that have remained quiescent in the shady understorey are ‘released’ and grow up to fill the gap. Root suckering is also a common source of regeneration.

The presence of soil (i.e., layers of mineral constituents of variable thicknesses derived from weathering and erosion of parent rock materials) is important in determining the vegetation composition of regenerating forest gaps. For example, where a tree has fallen over and the root ball displaced from the ground, there will be a small area of mineral soil allowing colonisation by pioneer species adapted to sunny mineral soil conditions. As the gap size increases by, for example, wind throws during storms, landslides, logging or mechanical clearing, the area of substrate exposed to sunlight, disturbed or reduced to mineral soil and available for colonisation by pioneer and early secondary species increases and secondary forests result.

Large areas of disturbances result from landslides, fires and intensive logging, with consequent removal of large portions of forest canopy. Subsequent regeneration occurs through successional processes from pioneer through secondary stages to mature forest. PNG has large areas subject to catastrophic dynamics produced by landslides, as shown by the vegetation at Nena D2 sample site.

Fire is another feature that can impact rainforest dynamics, particularly during drought years. The most recent significant fire in the PNG Highlands was in late 1997 following an extended period of drought, but this did not impact the terrestrial biodiversity study area.

Lowland Vegetation

Sepik lowland forests were found to consist of a series of successionally related environments, whose communities (i.e., Lowland Forest, Peat Forest, Riverine Mixed Successions, Swamp Forest formations) form a gradient in community physiognomy (structural and physical characteristics). These swampland habitats also merge into lacustrine off-river waterbodies (i.e., Herbaceous Swamp) vegetation. The wetland biome does not exhibit a specific forest type, but rather forms a continuum of principal components. As such, it is often difficult to draw discrete lines between communities owing to structural overlap.

In general, the amount of increasing progressive persistence of standing water results in the following characteristics of lowland vegetation communities:

- Reduced diversity.
- Shorter tree height.
- Limited crown-forms.
- Elimination of macrophyllous taxa (plants with long or large leaves).
- Simplified structure community usually involving disappearance of the middle layers.

Table 7.8 Vegetation communities in terrestrial biodiversity study area

Formation	Vegetation type (FIMS code)	Survey Locations	Description
Montane Forest	Small crowned forest (L) (Plates 7.14, 7.15)	Nena Limestone Site and HI Site	Dense to almost closed forest 20 to 30 m high where ferns and epiphytes are common. Trees tend to be thin, and oaks (*Castanopis* and *Lithocarpus*) are common or dominant. This includes small crowned lower montane forest with conifers (L±c). Coniferous Lower Montane Forests were seen only in mossy crestline habitats near 1,000 m ASL elevation. These communities are dominated by gondwanic gymnosperms.
	Small crowned forest with *Nothofagus* (LN)	Not recorded during surveys, but mapped based on FIMs	Small crowned forest with *Nothofagus* dominant.
	Very small crowned forest (Ls)	Not recorded during surveys, but mapped based on FIMs	This is very small crowned forest (“elfin” forest) and alpine grassland complexes. It is between 5 to 15 m in height, with thin crooked stems and no emergents.
Hill Forest	Medium crowned forest (Hm) (Plate 7.16)	All sites except Nena Limestone, Kaugumi, Lower Frieda, Iniok Village and Wario	Hill Forest is the most extensive vegetation in the terrestrial biodiversity study area, comprising most of the environments examined by botanical survey. This forest has a canopy 25 to 30 m high with emergents up to 40 m. Hill Forest communities are contiguous with Fri and Po forests at the lower elevations (starting at about 50 m) and with the L type (montane) = forests at the higher elevation near 1,000 m ASL.
Lowland Forest	Large to medium crowned forest (Pl)	Not recorded during surveys, but mapped based on FIMs	Tall well-developed lowland rainforest 30 to 35 m high with emergents to 50 m, an irregular canopy and small to large gaps.
	Open forest (Po) (Plates 7.17, 7.18)	Frieda Bend Site, Ok Isai Site, Wario Site	The canopy is approximately 30 m high and consists of small- and medium-crowned trees with scattered emergent trees (especially of *Octomeles sumatrana*) up to 40 m in height. The canopy profile is generally uneven with numerous gaps and the presence of at least two canopy layers. The most frequently seen genera are *Artocarpus, Cananga, Ficus, Intsia, Nauclea, Octomeles, Planchonia, Teijsmanniodendron*, and *Vitex*. A variety of palms occur and climbing rattans are common. In low-lying areas, sago palm stands develop and, where they have the opportunity, broad-leaved trees can reach great sizes (greater than 100 cm diameter at breast height (dbh)).

Table 7.8 Vegetation communities in terrestrial biodiversity study area (cont'd)

Formation	Vegetation type (FIMS code)	Survey Locations	Description
Lowland Forest (cont'd)	Small crowned forest (Ps)	Wara Kep Site	The dominant canopy genera were *Instia, Maniltoa*, *Pometia*, Terminalia and *Vatica*. Periodically flooded forest floors were generally vacant of herbaceous vegetation apart from localised occurrences, and instead were commonly populated by woody shrubs. Common climbers identified in edge aspects included *Faradaya splendida, Flagellaria indica and Fredycinetia* species. Forest with a dense canopy of small crowned trees (25 to 30 m) high usually on floodplains with poorly drained or gravelly soils.
Peat Forest	Peat forest (Plate 7.19)	Lower Frieda Site	At the time of the survey, this was a newly discovered forest type for PNG but was well known in Malesia and is developed on a peat dome with a stilted water table higher than the ground surface of surrounding, non-peat communities. It has since been found elsewhere in PNG, in Western Province. It is stunted forest with extremely low floristic diversity and endemism with a preponderance of pole-stem trees with poor crown development and small leaves. A particular feature is the lack of many plant families missing from situations where they would normally be expected to occur. It can be described as a stunted forest developed on a peat dome with extremely low floristic diversity with a preponderance of pole-stem trees with poor crown development and small leaves.
Swamp Forest	Mixed swamp forest (Fsw) (Plate 7.20)	Kaugumi Site, Wario Site, Wogamush Site, Kubkain Village Site	Mixed swamp forest in the terrestrial biodiversity study area has an even canopy. *Metroxylon sagu* forms a distinct, second tier beneath the limited overstorey. Most of the ground surface is covered by pools of standing water with masses of ascending pneumatophores, indicative of a fluctuating water table. Generally consists of low forest between 20 and 30 m in height with a patchy generally even height canopy, and usually with a dense understory of sago. The water table where this type develops fluctuates greatly, sometimes daily.
	Swamp woodland (Wsw)		Swamp woodlands are usually dominated by sago but have populations of *Horsfieldia* cf. *sylvestris, Intsia bijuga, Kleinhovia hospita, Nauclea orientalis, Pangium edule, Pometia pinnata,* and *Sterculia ampla/ macrophylla*, either as emergents or intermixed with sago at the same height. A dense tall layer of sago or pandanus with scattered trees over a ground layer of sedges, ferns, grass or bare ground. It is permanently inundated.

Table 7.8 Vegetation communities in terrestrial biodiversity study area (cont'd)

Formation	Vegetation type (FIMS code)	Survey Locations	Description
Swamp Forest (cont'd)	Mixed swamp forest/swamp woodland (Fsw/Wsw)	Kaugumi Site, Wario Site, Wogamush Site, Kubkain Village Site (cont'd)	These are complexes of mixed swamp forest and swamp woodlands.
	Alluvial wooded swamp complexes (Wsw/FsW)		
Successions	Riverine mixed successions (Fri/Wri) (Plate 7.21)	Frieda Bend Site and Iniok Village Site	Riverine Mixed Successions occur along the braided river channels. This community typically begins with tussock grasses colonising the outwash gravel of the river. Woody species are next to colonise the stabilised landform and form even-aged forest stands of similar height. In time, short-statured, woody colonisers are replaced by larger trees. With the development of a taller forest community, an understorey with gingers and large terrestrial ferns develop. On the forest margins (e.g., riverfronts) vines proliferate. Stream-course changes regularly cause this community to fragment, reverse or accelerate the vegetation sequence.
Off-river waterbodies	Herbaceous swamp (Hsw) (Plate 7.22)	Iniok Village Site and Kubkain Village Site	Herbaceous swamps occur either as discrete lacustrine habitats (e.g., Lake Warangai) or as stranded oxbows and backswamps from former meanders. The Hsw swamp is a monocot-dominant association composed primarily of amphiphytes. Such communities typically include clump-forming or stoloniferous taxa and representatives from the characteristic wetland genera (*Carex, Eleocharis, Lipocarpha, Schoenus, and Scirpus*). Grasses are prominently represented by *Hymenachne amplexicaulis* and *Leersia hexandra*.
	Swamp grassland (Gsw)	Not recorded during surveys, but mapped based on FIMs	Flooded grasslands with sedges and reeds.
Cleared Area	Cleared Area (O)	All sites with varying degrees, some little at all	Areas of anthropogenic clearance, e.g., large landslides.

Plate 7.14
Lower Montane Forest (L)

Plate 7.15
Coniferous Lower Montane Forest (Lc) on crestline. Conifers dominate the emergent canopy

Plate 7.16
Species-rich Hill Forest (Hm) with typical uneven, colourful and multi-storied canopies

Plate 7.17
Low Open Forest (PO) canopy

Plate 7.18
Low Open Forest (PO) understory

Plate 7.19
Peat Forest recorded at the Lower Frieda Site

W. Takeuchi

Plate 7.20
An example of Mixed Swamp Forest (Fsw)

W. Takeuchi

Plate 7.21
Riverine mixed succession in relation to stream-cutting and riverbank displacement. Active erosion indicated by steep-sided banks (A). Active siltation on the opposing, aggradational side, characterised by gradually sloping ground being built up by sedimentation (B)

W. Takeuchi

Plate 7.22
Herbaceous Swamp (Hsw)

The hydrology in the lowland zone is the major driver determining vegetation dynamics. Essentially, the lowland zone is a vast floodplain and one of the most complex systems to understand, particularly given the limited existing information concerning the ecological processes that relate hydrology to vegetation dynamics in the Sepik River catchment. Available qualitative information (Johns et al., 2007; Paijmans, 1976) provides a basic picture of vegetation relative to water depth and duration of wet season flooding, and can be extrapolated to the terrestrial biodiversity study area as follows:

- In areas free of flooding, Lowland Open Forest (Po) mostly occurs in Mixed Swamp Forest (Fsw) and Swamp Woodland (Wsw). These communities can also tolerate flooding for some time in shallow swamps where the watertable is at or near the surface for part of the year.
- Where high-energy river flows last for extended periods, Riverine Mixed Successions (Fri/ Wri) are a permanent feature.
- Swamp Woodland (Wsw) occurs where flooding is not too deep and water lies stagnant. As water depth increases, it merges into Herbaceous Swamp (Hsw) and flooded grasslands and eventually into permanent open lakes. Sago occurs throughout these formations and its occurrence can vary from scattered palms in the understory to dense monocultures.
- Peat Forest occurs on raised peat lenses where the watertable is stilted and is maintained by a degree of isolation from normal overbank flows of nutrient-rich river water.

7.1.8 Fauna

In order to gain a more detailed understanding of fauna communities within the terrestrial biodiversity study area, detailed surveys were undertaken of a variety of vertebrate and invertebrate taxa over a range of habitats, geographies and elevations. The surveys focused on mammals, birds, amphibians, reptiles, butterflies and odonates (i.e., dragonflies and damselflies).

The focus of the following characterisation of terrestrial fauna is on the mine and FRHEP areas and downstream habitats. The 2017 surveys were completed in the southern extent of the infrastructure corridor, which were supplemented with existing information.

Between 2009 to 2011, a series of terrestrial biodiversity surveys were completed over four campaigns focussing on the mine, FRHEP and downstream areas in a range of habitats, geographies and elevations. These included 16 purpose-built bush camps where surveys were completed over at least five days (see Figure 7.14). A further eight sites were surveyed more briefly from overnight fly camps, flyovers or day trips. Additional data was also obtained from hunters at seven villages.

In 2017, terrestrial biodiversity surveys were completed from two purpose-built bush camps over more than five days in areas adjacent to the proposed infrastructure corridor (see Figure 7.14). A shorter boat survey of the lower reaches of the Idam River, as well as interviews with hunters from two villages were also completed.

Surveys were based on rapid assessment sampling procedures, and particular attention was given to fauna of conservation concern. Description of the methods used for each taxanomic group are described in the following sections with further detail provided in Appendix 8a and 8b.

Mammals

Context

The island of New Guinea hosts an exceptionally diverse mammal fauna with very high levels of endemism at both the genus and species level. This endemism is most pronounced for monotremes, marsupials and rodents, and, to a lesser extent, bats.

Discovery of completely new species is still relatively commonplace in New Guinean mammal research, especially when surveys are conducted in previously under-investigated areas. Furthermore, many groups of New Guinean mammals remain poorly studied and new sampling often invites revision of previous collections.

There have been a number of mammal surveys in the broader region. These include survey work undertaken in the 1960s in the East Sepik Province by CSIRO, in the West Sepik lowlands and the north coastal ranges (Torricelli and Bewani mountains) in the mid-1980s to early 1990s by Flannery and others, in the vicinity of Telefomin by various workers from the American Museum of Natural History, Bernice P. Bishop Museum, the Australian Museum and the PNG National Museum, in the Schrader Range (Western Highland Province) in the 1960s and 1970s by Bulmer and others, and in the Mamberamo River Basin of Indonesian West Papua in the last few decades. Recent work at the Mekil Research Station near Mt Stolle has produced some of the most detailed ecological studies conducted thus far on New Guinean mammals. This body of previous work allows for development of a robust biogeographic framework for northern New Guinea and provides a meaningful context for the study at a regional and local scale (see Appendix 8a for details).

Survey Methods

In order to gain a more detailed understanding of mammal communities within the terrestrial biodiversity study area, detailed surveys for mammals were undertaken over four trips at 22 sites located in a range of habitats, geographies and elevations (see Figure 7.14). A variety of field methods were used with the general goal of detecting the greatest number of species. Survey methods included:

- Trapping for non-volant (i.e., non-flying) mammals using various types of traps, mostly suited to capture small non-volant mammals with body weight less than 1 kg; some larger cage traps were also deployed (8,039 ground traps and 177 cage traps).
- Camera-trapping for non-volant mammals (617 days).
- Daytime patrols looking for signs and traces of mammal activity and for diurnal non-volant mammals.
- Night patrols with spotlights for nocturnal non-volant mammals (224.5 hours).
- Interviews with experienced local hunters, both at villages and casually among field assistants employed by FRL but sourced from local villages.
- Examination of mammal remains kept in villages as hunting ‘trophies’ and of captive live animals held as pets.
- Searches for caves that might contain colonies of bats and/or predator prey remains.
- Setting of mist nets for bats (over 69,000 hours).
- Setting of harp traps for bats (83 harp trap nights).

- Setting of AnaBat electronic bat echolocation call detectors (170 night sessions).

Mammal Diversity

A biogeographic analysis of the mammal fauna of the northern foothills and lowlands of New Guinea was undertaken, based on knowledge of the complex geological and environmental history of the terrestrial biodiversity study area. This allowed prediction of the current distribution pattern of mammal fauna and the generation of a candidate mammals list, with separate predictions for each of the lowland zone, the hill zone and the montane zone. For each zone, individual species were rated as likely to occur, possible to occur or unlikely to occur.

During the initial assessment of mammals for the Project (Appendix 8a), a list of candidate mammals was produced based on geographic and ecological features and included 140 mammal species, including three monotremes, 36 marsupials, 40 rodents, 60 bats and the feral pig. The highest number of species (114) was predicted for the hill zone, with a reduction at lower (84) and higher elevations (50). When non-volant mammals were considered separately from bats, the lowland zone was predicted to have lower diversity (37) compared with either the hill zone (60) or the montane zone (42). The pattern for bats was reversed with the lowland and hill zones both with high diversity predicted (47 and 54 species, respectively) and much lower diversity predicted for the montane zone (eight). The predicted high diversity of the hill zone is attributed to the intersection of two contrasting trends, resulting in relatively high predicted diversity for each of non-volant mammals and bats. With the inclusion of the infrastructure corridor to the Project, a range of additional mammals endemic to the North Coastal Ranges were added to the list of candidate mammals.

A total of 70 mammal species were documented during the survey (and a selection is shown in plates 7.23 to 7.25) with 16 being only partially identified (i.e., unassigned unique echolocation calls). A further 64 species of mammal could occur in the terrestrial biodiversity study area. A full list of the species recorded is presented in Appendix 8a and 8b. The number of species recorded at each of the major sampling zones and the family they belong to is provided in Table 7.9. Species that were not recorded during the study but have a moderate or strong likelihood of occurrence based on their distribution and habitat preferences are indicated in brackets.

Table 7.9 Occurrence of mammal species recorded at each sampling zone in the terrestrial biodiversity study area

Family	Lowland Zone	Hill Zone
Non-volant (ground dwelling) mammals		
Echidnas - Tachyglossidae	-	1
Carnivorous marsupials - Dasyuridae	(3)	3 (2)
Bandicoots - Peramelidae	3(1)	5
Cuscuses, and brushtail possums - Phalangeridae	3(1)	6
Ringtail possums - Pseudocheiridae	(1)	1(4)
Striped and gliding possums - Petauridae	(2)	2(2)
Feather-tailed gliding possums - Acrobatidae	1	(1)
Wallabies, tree-kangaroos, pademelons - Macropodidae	2	5(2)
Rats and mice - Muridae	5 (9)	11 (20)
Pigs - Suidae	1	1

Table 7.9 Occurrence of mammal species recorded at each sampling zone in the terrestrial biodiversity study area (cont'd)

Family	Lowland Zone	Hill Zone
Bats		
Sac-winged or sheath-tailed bats - Emballonuridae	3(3)	3(2)
Leaf-nosed Bats - Hipposideridae	7 (3)	8(2)
Flying foxes - Pteropodidae	11 (3)	11 (3)
Horseshoe bats - Rhinolophidae	1(1)	1(3)
Vesper bats - Vespertilionidae	6(7)	7(7)
Free-tailed bats - Mollosidae	(2)	(2)
Total	43 (36)	65 (50)

Five taxonomically undescribed mammal species were recorded, these being one marsupial, two rodents and two bats:

- A long-footed tree mouse (*Lorentzimys* sp.).
- A large tree mouse (*Pogonomys* cf. loriae).
- A feather-tailed possum (*Distoechurus* sp.) (Plate 7.26).
- Two tube-nosed fruit bats (*Nyctimene* spp.).

The two rodent species may represent entirely new discoveries and their status outside the terrestrial biodiversity study area is unknown; the other species are represented in prior collections from other localities in PNG but have not been taxonomically described. All five are likely to occur more widely in the northern foothills and lowlands of New Guinea.

With the exception of the five newly recognised mammal species, the inventory produced by the survey is a strict subset of the candidate mammal list produced from the biogeographic analysis. Three other groups of mammals were also recorded in the terrestrial biodiversity study area that are unresolved taxonomically, i.e., scientists are currently reviewing their taxonomy and there are likely to be changes at the species and genus groupings.

Mammalian Community Patterns

Based on the extensive surveys between 2009 and 2011 (Appendix 8a), there were clear differences between the mammalian communities of the lowland zone and hill zone. In the lowland zone, 43 species were confirmed to be present and another 36 species were likely to occur. In the hill zone, 65 species were confirmed to be present and another 50 species were likely to occur. There were 36 species confirmed to be present in both the lowland zone and the hill zone.

The survey results suggest some altitudinal differentiation within the mammal fauna, with the maximum species turnover probably occurring around 400 to 500 m ASL. Capture records of the small nectar- and fruit-eating pteropodid bats provide evidence of altitudinal zonation in the mammal fauna of the terrestrial biodiversity study area. Three pteropodid species appear to be restricted to the lowland zone. Four others show higher abundance in this zone and extend only to lower elevations within the hill zone. In addition, two species appear to be restricted to the hill zone.

Plate 7.23

White-striped wallaby (*Dorcopsis hageni*) captured by camera trap at the Upper Ok Binai Site

Plate 7.24

A lowland ringtail possum (*Pseudochirops cupreus*) located during a night transect at Nena Base Site

Plate 7.25

Common spiny bandicoot (*Echymipera kalubu*) recorded at Uba Creek Site

Plate 7.26

An undescribed species of feather-tailed possum, *Distoechurus* sp, photographed at Iniok Village Site

Survey results of insectivorous bats showed a wide range of richness values across the full elevational range sampled; however, maximum richness does shows a slight decline with increasing elevation, from 12 species at low elevation sites (28 to 185 m ASL) to 10 species at mid-elevations (281 to 596 m ASL) and eight species at the highest elevation sample sites (737 to 1036 m ASL). The majority of non-volant mammal species produced too few records to support any conclusions regarding either altitudinal distribution or patterns of habitat usage.

A dominant feature of the survey was the low contact (observation or trapping) rates for all groups of non-volant mammals and the moderate to high capture rates for bats, particularly the small nectar- and fruit-eating pteropodid bats. These community characteristics were hypothesised to be primarily due to:

- Low productivity of palatable fruits within the forest canopy.
- High densities of leaf-eating insects at all levels in the understorey and canopy, providing highly effective competition for any mammal species that might feed on young leaves or shoots.
- High diversity and abundance of Hymenoptera (e.g., large stinging ants) that may predate on small non-volant mammals, especially rodent young that must be left unattended in burrows or nests while the mother forages.
- Competition for scarce arboreal food resources from fruit-eating bats.
- Regular inundation by floodwaters in parts of the terrestrial biodiversity study area lowland zone, causing a significant reduction in population densities of terrestrial species during the inundation periods.

The relative abundance of the various small nectar- and fruit-eating pteropodid bats varied considerably among the sampling sites of the terrestrial biodiversity study area. The most commonly caught pteropodids were various blossom bats (*Syconycteris* spp. and *Macroglossus minimus*) and tube-nosed bats (*Paranyctimene* spp. and *Nyctimene* spp.). These groups are so abundant that they must play a central role in many aspects of forest ecology, including pollination, seed dispersal and nutrient cycling.

Large roosting congregations of flying foxes (*Pteropus* spp.) were reported by informants and one of these was observed and photographed from the air in November 2010. This congregation involved tens of thousands of great flying foxes (*Pteropus neohibernicus*). Based on their size, mobility and sheer numbers, these bats are acknowledged to play significant roles in pollination and seed dispersal within forest communities.

Birds

Context

More than 800 bird species have been recorded in New Guinea, of which some 330 (approximately 41%) are endemic to the island. The region supports most of the world’s species of birds-of-paradise (Corvidae: Paradisaeini), bowerbirds (Ptilorhynchidae), ‘Australasian’ robins (Petroicidae), cassowaries (Casuariidae) and owlet-nightjars (Aegothelidae), and is the only place in which berrypeckers and longbills (Melanocharitidae) and pitohuis are found.

Despite the diversity and high public profile of New Guinea’s unique birdlife, and the high global conservation value of its tropical forests, relatively little is known of the distribution and ecology of avifauna across much of the island. Biological exploration has been limited by logistical constraints, weather, difficult terrain and/or law and order issues such that available information remains ad hoc. Consequently, many regions have not been surveyed for the better part of a century or remain entirely unexplored.

Despite being one of the better-studied vertebrate taxa in PNG, almost no bird surveys have been conducted within the terrestrial biodiversity study area itself and recent data was lacking. The most relevant studies were conducted during the Augusta Fluss Expedition of 1912 to 1913, which focused on the Hunstein Range. Elsewhere along the Central Cordillera, ornithologists have worked at the nearby Mekil Biological Research Station on Mount Stolle compiling a basic species inventory, and detailed investigations into the behaviour and ecology of select species have also been conducted at that station. Further south-west, and on the southern slopes of the Central Cordillera, ornithological surveys have been conducted around the Tabubil and Ok Tedi valley areas, south-eastern slopes of the Star Mountains and the south-western slopes of the Hindenburg Range. Other researchers have worked on the Hunstein Range, an isolated range lying north of the Central Cordillera and some 55 km east of the terrestrial biodiversity study area. A number of ornithologists have also travelled along the Sepik River, some of whom have collected or published their records. In the Bewani Mountains, north of the Sepik River, bird surveys have been conducted by Jared Diamond (Diamond 1969; Diamond and Terborgh 1968) and on neighbouring north coastal ranges (the Toricelli and Prince Alexander Mountains) also by Diamond (Diamond 1967, 1969; Diamond and Terborgh 1968) and Hulme (1977). The northern coastal range has been defined under the PNG Conservation Needs Assessment in 1993 as ‘major terrestrial unknowns’ (Swartzendruber 1993).

Collectively, this body of previous work in the general region provides the study with a robust context for the avifauna of northern New Guinea at a regional and local scale. In addition, detailed bird surveys were conducted at 23 sites between October 2010 and March 2011 and 2 sites between November and December 2017 (see Figure 7.14). Data from these surveys were supplemented with observations made at various locations during reconnaissance of the Project area prior to the surveys and a shorter expeditionary visit at Idam 1 village during the 2017 survey. Survey sites were positioned to cover a representative sample of the elevations and the habitats present throughout the terrestrial biodiversity study area.

Survey Methods

Survey methods included transect searches (582.75 hours), mist-netting (140,419 mist-net meter-hours), digital recordings (537 minutes), automated sound recorders (327 hours) (only during the 2017 survey), call playbacks, camera traps (3,616.5 hours) (only during the 2017 survey) and interviews with local hunters. These techniques were combined to maximise completeness of the bird species inventory and the likelihood of locating rare and threatened taxa in the time available. A detailed description of study methods is provided in Appendix 8a and 8b.

Bird Diversity

A total of 224 bird species from 44 families was recorded in the terrestrial biodiversity study area (and a selection is shown in plates 7.27 to 7.29). An additional 208 species of birds could occur including 123 land birds and 50 waterbirds. A full list of the species recorded is presented in Appendix 8a and 8b. In the lowland zone, a total of 168 species were recorded, of which 62 were exclusively recorded in this zone. In the hill and montane zones, a total of 159 species were recorded, of which 52 were exclusively recorded in this zone. The highest number of species was recorded at Uriake (105), Iniok Village Site (93), Wara Kep (91), Wario Site (90), Nena Base Site (87), Kaugumi Site (84), Upper Ok Binai Site (81), Malia Site (80), Frieda Bend Site (76), Ok Isai Site (73) and Hauna (and lakes) Site (72).

Of the 224 species recorded, more than one third were found at only one survey site (50 species; 22.7%) or two survey sites (36 species; 16.4%). Forty-two species (19.1%) were recorded at 12 or more survey sites (>50%). There were 24 species that were recorded at 15 or more sites. The four most widespread species were Blyth's hornbill (*Aceros plicatus*), black-capped lorry (*Lorius lorry*), rainbow lorikeet (*Trichoglossus haematodus*) and banded imperial-pigeon (*Ducula zoeae*).

Most of the birds recorded in the terrestrial biodiversity study area were resident breeding species (204 of 220; 92.7%). There were, however, 12 migratory species recorded that occur in New Guinea only as non-breeding migrants, five species recorded only as migrants (but that may also breed in New Guinea) and nine breeding residents with numbers seasonally augmented by non-breeding visitors. The names and migratory status of these species are provided in Table 7.10.

Table 7.10 Migratory bird species recorded in the terrestrial biodiversity study area

Common Name	Species Name	Migratory Status
Dollarbird	*Eurystomus orientalis*	BR+M
Sacred kingfisher	*Todirhamphus sanctus*	M
Buff-breasted paradise-kingfisher	*Tanysiptera sylvia*	M
Rainbow bee-eater	*Merops ornatus*	M
Oriental (/Himalayan) cuckoo	*Cuculus optatus(/saturatus)*	M
Brush cuckoo	*Cacomantis variolosus*	BR+M
Channel-billed cuckoo	*Scythrops novaehollandiae*	M
White-throated needletail	*Hirundapus caudacutus*	M
Common sandpiper	*Actitis hypoleucos*	M
Wader sp. [Sharp-tailed sandpiper]	*Calidris acuminate*	M
Whiskered tern	*Chlidonias hybridus*	M
Little pied cormorant	*Phalacrocorax melanoleucos*	BR+M
Little black cormorant	*Phalacrocorax sulcirostris*	BR+M
Great cormorant	*Phalacrocorax carbo*	V
Pied heron	*Ardea picata*	M (+BR?)
Little egret	*Egretta garzetta*	M (+BR?)
Great egret	*Ardea alba*	BR+M
Intermediate egret	*Mesophoyx intermedia*	M (+BR?)
Yellow (/little) bittern	*Ixobrychus sinensis(/minutus)*	M (+BR?)
Spangled drongo	*Dicrurus bracteatus*	BR+M
Satin flycatcher	*Myiagra cyanoleuca*	M
Grey wagtail	*Motacilla cinerea*	M
Pacific black duck	*Anas superciliosa*	BR+M
Australasian darter	*Anhunga novaehollandiae*	BR+M
Pacific koel	*Eudynamys orientalis*	BR+M
Channel-billed cuckoo	*Scythrops novaehollandiae*	M (+BR?)

Migratory status: M – species that occur in New Guinea only as non-breeding migrants; BR+M – breeding residents with populations seasonally augmented by non-breeding visitors; V – rarely recorded non-breeding vagrants; M(+BR?) – non-breeding migrants with possible breeding populations in New Guinea.

A total of 23 species of waterbirds were positively identified. These species are most diverse in the lowland sections of the terrestrial biodiversity study area located on or near the Sepik River floodplain. Of these, only the gull-billed tern (*Gelochelidon nilotica*) is likely to be a regular visitor;

little tern (*Sterna albifrons)*, hardhead (*Aythya australis)*, Australian pelican (*Pelecanus conspicillatus*), royal spoonbill (*Platalea regia)*, glossy and Australian ibis (*Plegadis falcinellus, Threskiornis molucca*) may occur only rarely, most likely during periods of severe drought in Australia.

Nearly half of the bird species recorded in the terrestrial biodiversity study area (102 of 224, 46.4%) are found only in New Guinea and its satellite islands. This represents more than one third (~37%) of the 275 or so species that are endemic to the region. A total of 26 of the species recorded are restricted to the island of New Guinea.

It is likely that additional bird species are present in the terrestrial biodiversity study area, but not detected during surveys. These include species that are nomadic in response to seasonal changes in food availability and others that are genuinely rare and/or inconspicuous (such as nocturnal predators), while variability in detection possibility (for instance due to limited vocalisations outside the breeding period) may also have contributed to non-detection of species. Consequently, the potential for additional (unrecorded) species within the terrestrial biodiversity study area was assessed using a conservative approach considering the broadest range of distributional and elevational records available for each species.

Based on bird surveys between 2009 and 2011(see Chapter 4 of Appendix 8a), 73 additional montane species may occur within the upper Frieda River catchment (see Appendix 8a). None of these are normally found below 1,000 m ASL and are therefore only likely to occur in the montane zone. Moreover, nearly half of the montane species (32 of 73) are not normally found below 1,500 m ASL, the upper elevational limit of the terrestrial biodiversity study area, though their presence cannot be ruled out as they have, at least occasionally, been recorded at lower elevations. Eighty-five additional species may occur in the lowland zone of the Frieda River catchment, more than half of which (44 species) are not expected to occur in the hill or montane zones. A further 50 bird species were identified as potentially occurring in the infrastructure corridor between the mine area and Vanimo (see Appendix 8c). These are likely to include a range of coastal species.

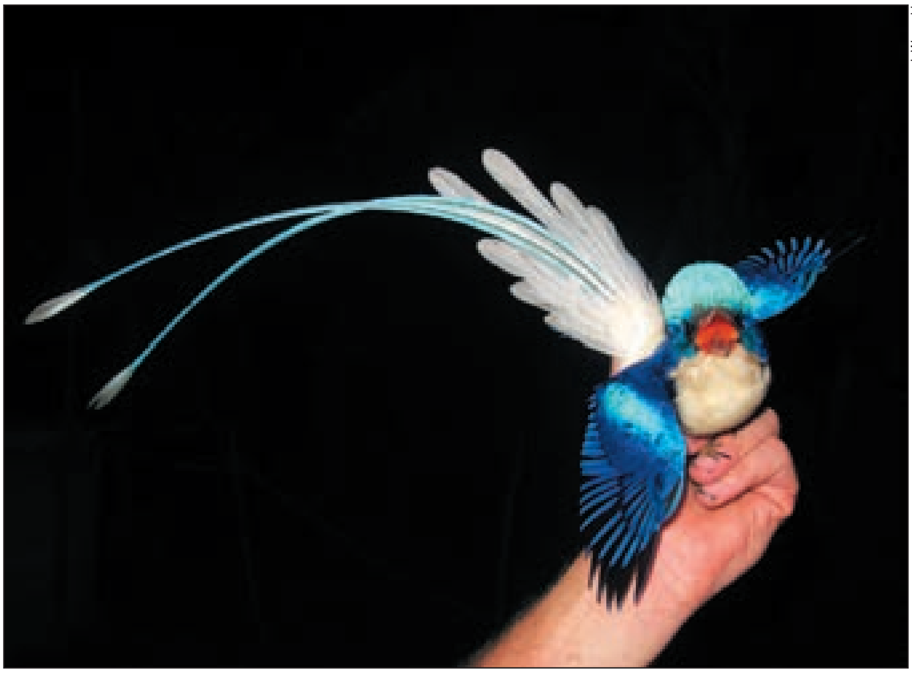
The freshwater wetlands of the Sepik River basin support important resident waterbird populations and a suite of migratory species. While wetland birds were a major component of the observed avifauna around Iniok Village Site and Hauna (and lakes) Site, a number of additional species are likely to occur. Additional resident waterbird species may include kingfishers, crakes and rails, ducks, grebes, herons and the comb-crested jacana.

No new or otherwise undescribed species or subspecies were definitively recorded during the surveys.

Bird Community Patterns

Birds respond to a wide variety of environmental variables, including broad-scale habitat changes (e.g., forest, wetlands, open and disturbed areas), elevation, seasonal changes in food availability (e.g., flowers, fruit) and a suite of more subtle ecological signals, including fine-scale changes in forest structure and floristics.

From a regional perspective, the terrestrial biodiversity study area incorporates part of two distinct avifaunal regions: the hills and lower mountains of the Central Cordillera (hill and montane zones) and the north Papuan lowlands (lowland zone). The terrestrial biodiversity study area is situated more or less in the centre of an approximately 1,200 km long interface between these two extensive areas. Most of these areas, and their zones of intersection, still support significant tracts



I. Woxvold

Plate 7.27
Common paradise kingfisher
(*Tanysiptera galatea*)

I. Woxvold

Plate 7.28
Coroneted fruit-dove
(*Gallicolumba rufigula*)

I. Woxvold

Plate 7.29
Papuan hanging-parrot
(*Loriculus aurantiifrons*)

of remote and intact habitat. Within the hill and montane zones, there was further separation between mid-elevation sites and upland sites.

At a finer scale, a number of site-pairs yielded similar bird communities, most notably the Malia–Upper Ok Binai sites, Ok Isai–Kaugumi sites, Wario–Wogamush sites, Frieda Base–Nena D1 sites and the Nena Base–Nena Limestone sites. The most distinctive bird communities were recorded at HI Site/Ubiame Site, Lower Frieda Site and Iniok Village Site.

Upper- elevation Hill Zone and Montane Zone

The upper-elevation hill and montane zone sites comprised the Nena Base Site, Nena Limestone Site and HI Site/Ubiame Site. The clustering of these sites in terms of bird community structure, and their distinction from communities recorded elsewhere, can be largely explained by the higher elevations surveyed. While Hill Forest was still a major habitat component at Nena Base Site and HI Site, all sites (with Nena Limestone Site and Ubiame Site exclusively) supported tracts of lower Montane Forest. Accordingly, several birds recorded only at one or more of these sites are exclusively or strongly associated with upper Hill Forest and/or lower Montane Forest. Conversely, a suite of species common at other hill zone locations were absent from these sites, including red-cheeked parrot, wompoo fruit-dove, streak-headed honeyeater, black and hooded butcherbirds, Boyer’s cuckooshrike, and spot-winged and hooded monarchs.

Mid-elevation Hill Zone

Hill Forest and lower Montane Forest within the terrestrial biodiversity study area supported a number of forest-dependent bird species that did not extend to habitats in the lowland zone. Of the 52 species recorded only in the hill and montane zones, more than three quarters (40 species; 76.9%) are forest-dependent residents. Mid-elevation bird assemblages of Malia, Upper Ok Binai, Nena D1, Frieda Base and Uba Creek sites showed a degree of similarity attributable to habitat and overlap of elevation.

Lowland Zone and Lower Nena and Niar River Catchments

Sites in the lowland zone and lower Nena and Niar River catchments (Frieda Bend Site and Ok Isai Site) showed similarities in bird community structure. Although the Ok Isai Site was technically part of the hill zone, and in spite of the presence of Hill Forest at both Frieda Bend and Ok Isai sites, this is attributable to the lower elevations surveyed at these sites (65 to 150 m ASL) and the predominance of habitats more closely allied with those surveyed at other sites in the lowland zone, including broad, mid-reach stretches of the Nena and Niar rivers, associated riverine successions (including tall grasses, scrub and secondary vegetation in various stages of regrowth) and Lowland Open Forest.

There were relatively few birds restricted to lowland zone forest habitats, with most species also likely to occur in Hill Forest. Of the 62 species recorded only in the lowland zone, only 12 (19.4%) are residents dependent on mature forest habitats. Among these, at least two that are resident in the lowland zone’s Swampy Forests are likely to be restricted to these habitats, i.e., the New Guinea flightless rail and the twelve-wired bird-of-paradise. Other birds more or less restricted to forests of the lowland zone may also be present in Hill Forest, as shown by the northern cassowary, albeit in lower numbers.

The remaining species recorded only in the lowland zone are dependent on rivers and wetlands and/or open and disturbed habitats. While many of these also occur at higher elevations elsewhere in New Guinea, the distribution of these habitats within the terrestrial biodiversity study area is currently heavily skewed towards the lowland zone.

Reptiles and Amphibians

Context

New Guinea has an exceptionally diverse herpetofauna (i.e., reptiles and amphibians), with the total number of frog and reptile species currently exceeding 600. This number is predicted to increase substantially due to taxonomic revisions and exploration of remote regions that continue to reveal numerous new species.

Historically, herpetofauna surveys in PNG have focused on the southern slopes of the Central Cordillera in Southern Highlands and Gulf Provinces, in high montane regions of the central mountains, and in Milne Bay Province. Herpetofauna diversity on the northern slopes of PNG's Central Cordillera remains poorly studied.

The 1938 to 1939 Archbold expedition undertook intensive biological surveys at sites in the lowlands of the Mamberamo River basin and was one of the few expeditions to obtain herpetological material from the northern foothills of the Central Cordillera. In the last decade, the herpetofauna of the Mamberamo River basin and Foya Mountains in adjacent West Papua Province, Indonesia, has also been the subject of recent study. Given the continuity of habitats and lack of major biogeographic barriers along the northern face of the Central Cordillera and between the Mamberamo and Sepik river basins, many of the taxa documented from the Mamberamo River basin lowlands and foothills would be expected to also occur in the Sepik River catchment of northern PNG.

Given the paucity of information of herpetofauna in the region, field surveys have been undertaken which have been the first comprehensive surveys of herpetofauna in the region. Surveys for frogs and reptiles were undertaken at 17 sites between 2009 and 2011 and two sites between November and December 2017 covering a range of habitat, elevations and geographies in the terrestrial biodiversity study area. An additional overnight boat-based survey was also carried out in 2017 within the terrestrial biodiversity study area.

At each site intensive searches for frogs and reptiles were conducted (totalling 1,556.25 hours) along trails established for this purpose. During the day, searches focused on heliothermic (basking) reptiles along trails through forest, clearings, and on-stream banks. Nocturnal reptiles, including geckos, were detected by walking along forest trails at night with a headlamp.

Frogs were sampled at night by conducting visual-encounter and aural surveys along streams, and in and around small ponds. Waterbodies examined included seepages, small closed canopy streams, larger streams and small forest pools. Because a large proportion of New Guinean frogs have life cycles that are independent of free-standing water, extensive visual and aural searches along trails in forest away from water were also conducted. Whenever possible, the advertisement calls of frogs were recorded, as they are an important diagnostic character that greatly assists with species identification. A full description of survey methods is given in Appendix 8a.

Frog Diversity

The terrestrial biodiversity study area is rich in frogs with 60 species recorded and at least another 27 species having the potential to occur. A full list of the species recorded during field surveys is presented in Appendix 8a and 8b.

Frog diversity varied among sites with a maximum of 35 species at Nena Base Site and a minimum of seven species at East Sepik Site and Idam River (overnight survey location) (and a selection is presented in plates 7.30 to 7.35). Previous studies of frog diversity have indicated a positive correlation with elevation; however, the influence of elevation on results obtained in the current study was less clear. While there was a positive correlation between elevation and species diversity, search effort was also found to positively correlate to frog diversity recorded at each site.

Apart from altitudinal effects and search effort, seasonal effects – most notably weather conditions – appeared to play an important role determining the numbers of frog species documented. For example, frog activity, as indicated by calling intensity and encounter rates, was substantially lower during the February 2010 survey than it had been in November and December 2009, and was exceptionally low during May and June 2010 even after sporadic heavy rains. It is likely that more species occur than were recorded at the Uriake Site (18 species), the Wara Kep Site (18 species), Frieda Bend Site (12 species), Kaugumi Site (11 species), Lower Frieda Site (seven species), Iniok Village Site (nine species) and Kubkain Village Site (eight species).

Despite these variables, total frog diversity is broadly consistent with that known from other sites in the Sepik River basin, and is dominated by the families Microhylidae (egg-brooding frogs) and Hylidae (treefrogs).

At least 26 species of frogs documented in the terrestrial biodiversity study area were either new to science or undescribed at the time of the surveys. An unusually high proportion (~70%) of these new or undescribed species are from the family Microhylidae (egg-brooding frogs). A small undescribed species of the Microhylidae genus *Austrochaperina* is known only from streams at Upper Ok Binai and Lower Ok Binai sites. Frogs from the family Hylidae (treefrogs) are also highly represented in the number of new species identified, nine out of 26. Five of these nine new or undescribed treefrog species are habitat specialists requiring clear, torrential rocky streams for reproduction. New or undescribed species recorded during the surveys include:

- Nine tree frogs belonging to the *Litoria* genus.
- Four species belonging to the *Austrochaperina* genus.
- Three species belonging to the *Choerophryne* genus.
- Four species belonging to the *Hylophorbus* genus.
- Four species belonging to the *Oreophryne* genus.
- Two species belonging to the *Xenorhina* genus.

Since the time of the initial field surveys eight species have been described and named scientifically (see Kraus, 2013: Kraus and Allison, 2009; Iannella et al., 2016). Details of the taxonomic nomenclature is provided in Appendix 8c.

The discovery of new species at any site in PNG is not unexpected, but the large number of undescribed species discovered in the current surveys is somewhat unusual. This reflects the fact that few studies have been conducted anywhere on the northern slopes of the Central Cordillera and greater effort has been involved in the current surveys compared to other studies. It is extremely likely, given the extensive areas of apparently suitable habitat available, that most of the species reported here have broad distributions in the foothills of the Central Cordillera.

Frog Community Patterns

The frog diversity documented in the terrestrial biodiversity study area was found to be broadly consistent with that known from other sites in the Sepik Basin, and is dominated by the families Microhylidae (egg-brooding frogs) and Hylidae (treefrogs). For example, Austin et al. (2008) reported 33 frog species from at a site in the upper Sepik Basin, and Dahl et al. (2009) reported a total of 44 species from five sites in the north-coast lowlands.

S. Richards

Plate 7.30
Family Ceratobatrachidae
(Platymantis papuaensis)

S. Richards

Plate 7.31
Family Hylidae
(Litoria leucova)

S. Richards

Plate 7.32
Family Hylidae
(Nyctimystes fluviatilis)

Plate 7.33
Family Microhylidae
(Oreophryne biroi)

Plate 7.34
Family Ranidae
(Limnonectes grunniens)

Plate 7.35
Family Ranidae
(Rana cf grisea)

There was a high proportion of treefrogs (Hylidae) recorded in the terrestrial biodiversity study area. This is likely to reflect the presence of a greater diversity of aquatic habitats in the hill zone than is available in the lowland zone, particularly fast-flowing streams. Large swamps and permanent forest pools were not encountered in the hill zone, except at the lower margins of the Ok Isai Site, and the significance of the small forest pools at Frieda Bend Site for frog reproduction was difficult to assess due to the low frog activity at the time of the survey. However, small, isolated forest pools are likely to be significant habitats for at least some treefrogs in the hill zone.

In contrast to the hill zone, the frog fauna of the lowland zone was dominated by common, widespread species. The exception was the documentation of a small microhylid frog of the genus *Oreophryne* that was found only in the Peat Forest at Lower Frieda Site, the poorly known but widespread treefrog *Litoria purpureolata*, and a potentially undescribed *Callulops* found at Wario and Wogamush sites. Only three other species were found in the lowland zone but not in the hill zone.

Reptile Diversity

The reptile fauna documented during surveys was relatively low with 46 species recorded (and a selection is shown in plates 7.36 to 7.38). A full list of the species recorded during field surveys is presented in Appendix 8a and 8b. Diversity ranged from three to 17 species. The low diversity at HI Site and Idam River Site was not surprising because the weather was cold and raining during most of the survey period at HI Site, conditions that greatly reduce reptile activity and the short amount of time spent at Idam River.

There was no correlation between reptile diversity and survey effort, or between reptile diversity and elevation. Numerically, the fauna was dominated by the widespread and abundant skinks *Emoia obscura* and *E. pallidiceps* (within the 2009-2010 sites), *E. caeruleocada, E. jakati* and *E. kordoana* (within 2017 survey sites) the agamid (dragon) lizard (*Hypsilurus modestus)*, the gecko *Cyrtodactylus sermowaiensis* and the brown tree snake (*Boiga irregularis*). With the exceptions of undescribed geckos of the genus *Lepidodactylus* and *Gehyra*, possibly new species in each of the gecko genus *Cyrtodactylus*, the skink genus *Emoia*, and identification of the widespread but IUCN Vulnerable variegated giant softshell turtle (*Pelochelys signifera*) at the Idam River Site, the reptile fauna was dominated by common, widespread species known from other sites outside the terrestrial biodiversity study area.

Although snake diversity was generally low, three notable species were reported: the green tree python (*Morelia viridis*) at Malia and Wario sites, the amethistine python (*Morelia amethistina*) at Malia Site, Ok Isai Site and Lower Frieda Site, and a D'Albertis python (*Leiopython albertisii*) at Kaugumi Site. Freshwater turtles (*Elseya schultzei*) were found in a small tributary of the Frieda River at Frieda Bend Site. Although none of these species were identified in the 2017 survey locations, they are likely to occur within the infrastructure corridor. Both freshwater and saltwater crocodiles were documented in the vicinity of Iniok Site. Turtles and crocodiles are discussed more fully in Section 7.2.6.

Five species of reptiles recorded are potentially new or undescribed species; these include *Hypsilurus* sp, *Cyrtodactylus* sp., *Emoia* sp, *Gehyra cf brevipalmata* and *Nactus cf muilticarinatus*. In addition, a single small, slender gecko of the genus *Lepidodactylus* was collected in forest regrowth on the ridge at Kubkain Village Site and appears to represent an undescribed species. Since the time of surveys, the giant bent-toed gecko (*Cyrtodactylus novaeguineae*) has been

S. Richards

Plate 7.36
Family Agamidae
(Hypsilurus cf dilophus)

S. Richards

Plate 7.37
Family Gekkonidae
(Cyrtodactylus novaeguineae)

S. Richards

Plate 7.38
Family Pythonidae
(Morelia viridis)

described as *Cyrtodactylus rex* (Oliver et al., 2016) while *Hypsilurus* sp. 1 was subsequently recorded as *Hypsilurus magnus*.

Reptile Community Patterns

Unlike the frogs for which the hill zone provides specific habitats for an assemblage of species so far not known from elsewhere on the Sepik Plain, most of the reptile species documented in the hill zone are known to occur not only in the lowland zone, but also elsewhere in the lowland forests of New Guinea.

It was clear that there is little distinction between the reptile communities of the hill zone and those of the lowland zone, and that most species occurring in the terrestrial biodiversity study area are common, widespread species with broad habitat tolerances.

Reptile species of conservation concern that were documented, or likely to occur, in the terrestrial biodiversity study area are discussed later in this section.

Butterflies

Context

Nearly 1,000 butterfly species are known to occur in New Guinea, of which approximately 840 have been recorded in PNG. A characteristic of the New Guinean butterfly fauna is the high level of endemism, including some spectacular radiations of closely related species (i.e., the process of speciation and adaptation of a variety of species exhibiting different morphological and physiological traits to exploit a range of divergent environments). New Guinea is also recognised as the home to the world's largest butterflies, the birdwings (*Ornithoptera Boisduval*).

Previous surveys of butterflies (order Lepidoptera) in the region have been limited and have focused on the coastal plains and ranges. The terrestrial biodiversity study area is of particular interest since it hosts a combination of intact Hill Forest (Hm) and Lowland Open Forest (Po) and Alluvial Wooded Swamp Complexes (Wsw/FsW).

Butterfly surveys were undertaken at 17 sites within the mine and FRHEP areas and downstream in a range of habitats, geographies and elevations. Surveys totalling 646 hours were carried out along transects, some of which were pre-cut while others were constructed ad hoc. Other transects were designed to follow natural features, e.g., along streams and ridges. In particular, males of many butterfly species will congregate at the tops of hills or in open areas above fast-flowing streams, so such habitats were a focus during the surveys.

Long-handled nets were employed to collect specimens of the more elusive arboreal canopy-dwelling species. Visual searches as well as baits (urine and fruit) and paper lures (totalling over 1,146 traps) were also used as survey methods. A detailed description of the methods employed is provided in Appendix 8a.

Butterfly Diversity

In total, 359 butterfly species were recorded during field surveys (and a selection is shown in plates 7.39 to 7.41). A full list of the species recorded during field surveys is presented in Appendix 8a. Such a compilation surpasses the total number of butterflies recorded from any other survey in New Guinea and is the first major butterfly survey of this biologically poorly known region. The species/effort curve for all sites approaches an asymptote, implying that the majority of species occurring in the terrestrial biodiversity study area were documented.

The best represented butterfly families were Lycaenidae, with 138 (38.4%) species, and Nymphalidae with 98 (27.3%) species. This is close to the proportions of each family across New

Guinea. Representatives of all butterfly subfamilies known from PNG were recorded during the surveys.

A significant number of species, particularly in the subfamily Lycaeninae, were recorded only from single sites. 50% of all butterfly species recorded at Ubiame Site and 16.7% at HI Site were located nowhere else during the surveys.

Nine distinct unidentified taxa were recorded during the surveys of the terrestrial biodiversity study area and these may represent species new to science[2]. Descriptions of these species are provided in Appendix 8a, with genus (and family) provided below:

- *Chaetocneme* ?sp. nov. (Hesperiidae).
- *Sabera* ?sp. nov. 1 (Hesperiidae).
- *Sabera* ?sp. nov. 2 (Hesperiidae).
- *Kobrona* ?sp. nov. (Hesperiidae).
- *Philiris* ?sp. nov. (Lycaenidae).
- *Candalides* ?sp. nov. (Lycaenidae).
- *Taenaris* ?sp. nov. (Nymphalidae).
- *Mycalesis* ?sp. nov. 1 (Nymphalidae).
- *Mycalesis* ?sp. nov. 2 (Nymphalidae).

A further six species (cf) are close to described species and slight differences can probably be attributed to geographical variation. A further three species were not identified with certainty due to specimens being in exceedingly poor condition, not captured, or within complexes of very closely related species.

Since the time of field surveys *Philiris sp. nov.* was described and named scientifically as *Philiris bubalisatina* (Müller, 2014b) and *Mycalesis sp. nov. 1.* was described and named scientifically as *Mycalesis woxvoldi* (Müller, 2014a).

Butterfly Community Patterns

Despite their apparent mobility, butterflies are generally localised to particular environments. Butterfly composition and diversity is generally constrained less by FIMS forest types than the successional status of the vegetation, which is directly related to the presence or absence of their particular food plants and the particular microclimates that prevail.

The highest numbers of butterfly species were documented in mature forest and lightly disturbed forest. In total, 246 species (68.5% of all species recorded) and 249 species (69.4%) were found in mature forest and lightly disturbed forest, respectively. There were 76 species (21.2%) considered to be restricted to closed canopy forest. Only 33 species (9.2%) of the total 359 were potential inhabitants of grasslands. No species appeared restricted to riparian forest, but males of many species commonly used this habitat for territories and flight paths.

A negative relationship exists between butterfly diversity and elevation. Lowland sites had the greatest diversity (with the exception of Nena Base Site) while sites above RL 600 m had substantially fewer species.

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[2] 'sp nov.' refers to a species new to science; 'sp' indicates that the information available precludes positive identification; 'cf' indicates that the species in question appears most similar to the taxon listed; '?' following a species name indicates that the identification to species level is only tentative but the species is probably new to science.

C. Müller

Plate 7.39
The green-spotted triangle
(*Graphium agamemnon*)
a common butterfly throughout
the Indo-Pacific tropics

C. Müller

Plate 7.40
The larva of *Atrophaneura polydorus*
on its foodplant, *Aristolochia* sp.
(Family: *Aristolochiaceae*)

C. Müller

Plate 7.41
The peacock jewel
(*Hypochrysops pythias*)

Males of many butterfly species commonly used the tops of steep, jungle-clad hills to establish territories in which to seek females with which to mate. These sites are not necessarily the areas in which the butterflies breed, but are important in the conservation of species that are rare, or in such low densities within the forest that such meeting points facilitate pairing. As such, sites located near hilltops produced a high diversity of butterflies.

Each survey site was accorded a butterfly endemicity score. Endemism is most pronounced at Ubiame Site and HI Site, followed by the low elevation sites Frieda Airstrip Site, Frieda Base Site and Wogamush Site (Figure 7.14). However, there does not appear to be any direct overall correlation between endemism and elevation, since both Iniok Village Site and Kubkain Village Site (both in the terrestrial biodiversity study area lowland zone) scored relatively high levels of endemism.

Butterfly species of conservation concern that were documented or that are likely to occur in the area are discussed later in this section.

Odonates

Context

With more than 400 described species, the dragonflies and damselflies (Odonata) of New Guinea are a diverse and colourful component of the region’s biodiversity. Given their moderate size, relative ease of identification and a complex life cycle that includes an aquatic larva and terrestrial, flying adult stage, odonates are considered to be useful indicators of environmental change. Despite this ease of identification, the odonate fauna of New Guinea remains substantially undocumented.

The northern lowlands of New Guinea between the Central Cordillera and the north coast are known to have an exceptionally diverse odonate fauna, with more than 200 described species occurring in the region. Most knowledge about this fauna is based on material collected in the Indonesian province of West Papua, mainly by the 1938 to 1939 Archbold Expedition and a number of private collectors.

Given the paucity of information of Odonata regionally and their utility as environmental indicators, a field survey was undertaken; this was the first comprehensive survey of odonates in the region.

Odonate surveys were undertaken at 22 sites over a variety of terrains that support a wide range of habitats in the terrestrial biodiversity study area. At each site, intensive searches (totalling over 1,150 hours) were conducted for adult dragonflies and damselflies along and around all available waterbodies, during the morning, on sunny afternoons and in the evenings. Waterbodies examined included seepages, small closed-canopy streams, larger streams and small forest pools. Additional surveys were conducted along forest trails and in clearings, especially helipads. Specimens were captured with large insect nets, fixed in acetone and stored in glassine envelopes (see Appendix 8a and 8b).

Odonate Diversity

A total of 116 odonate species (64 damselflies and 52 dragonflies) were documented at 22 sites in the terrestrial biodiversity study area (and a selection of these is shown in plates 7.42 to 7.44). A full list of the species recorded during field surveys is presented in Appendix 8a and 8b. The odonates of the hill zone were dominated by species inhabiting small forest streams while the lowland zone was dominated by species breeding in ponds and other large waterbodies.

Odonate diversity was highest at Ok Isai Site (46 species), Camp 1 (infrastructure corridor section 3) (44 species) Wara Kep Site (43 species), Lower Ok Binai Site (40 species), Camp 2 (infrastructure corridor sections 2 and 2A) (40 species) and was also extremely high at Kaugumi Site (39 species) and Uriake Site (39 species), Nena Base Site (38 species) and Frieda Bend Site (37 species).

Diversity appeared to be influenced by aquatic habitat heterogeneity. The Ok Isai Site, Lower Ok Binai Site and Frieda Bend Site included microhabitats typical of both hill zone and lowland zone forests, and this diversity of local microhabitats contributed to the high species diversity documented at these sites.

The discovery of new odonate species at any site in PNG is not unexpected and at least 17 new species or undescribed species were documented during the surveys.

Species that are new to science or undescribed include:

- *Hylaeargia* sp. nov. – an undescribed stream-dwelling damselfly.
- *Gynacantha* sp. nov. – a large crepuscular dragonfly (primarily active during dawn and dusk).
- At least one, and possibly all four species, belonging to the *Argiolestes* genus.
- At least three species belonging to the *Drepanosticta* genus.
- Two species belonging to the *Paramecocnemis* genus.
- At least three species belonging to the *Nososticta* genus.
- Two species of damselflies belonging to the *Metagrion* genus.

Since the time of field surveys ten of the species new to science or undescribed listed above have been named scientifically (see Orr et al., 2012; Theischinger and Richards 2012a, b; Theischinger and Richards 2013a, b, c; and Theischinger and Richards 2014). For details of these taxanomic revisions see Appendix 8b.

Odonate Community Patterns

The odonate fauna of the hill zone was exceptionally diverse with 116 species recorded, and this probably represents the most species-rich assemblage documented on New Guinea to date. The hill zone fauna is dominated by species requiring clear, flowing stream environments for reproduction. These habitats were present at all sites in this zone. In addition, small forest pools and swampy habitats, typical of lowland forests provide many breeding sites for odonate species. A small assemblage of species appears to be less dependent of water bodies on the forest floor. These species were generally encountered randomly in the forest and were not associated with streams or ponds.

Odonate diversity in the lowland zone was moderately high, with a total of 87 species recorded, comprising 44 damselflies and 43 dragonflies. The lowland fauna documented tended to be dominated by common and widespread species. Nearly 45% (20 species) of the damselfly species found in the terrestrial biodiversity study area hill zone were not found in the lowland zone. In contrast, only 16% of damselfly species found in the lowland zone were restricted to this zone.

Conservation Significant Terrestrial Fauna Species

As defined in the terrestrial biodiversity impact assessment (Appendix 8c), fauna species were assessed as conservation significant if they were:

- Listed as Critically Endangered, Endangered, Vulnerable, or Near Threatened on the IUCN Red List.

Plate 7.42
Damselfly *(Neurobasis ianthinipennis)*

Plate 7.43
Dragon fly *(Huonia epinephele)*

Plate 7.44
Dragon fly *(Protorthemis coronata)*

- Listed as protected under the PNG *Fauna (Protection and Control) Act 1966* (the PNG Fauna Act).
- Migratory including birds that migrate from the northern hemisphere.
- Endemic or with a restricted distribution.
- Culturally important.

During the surveys a total of five threatened or protected mammal species (either on the IUCN red list or PNG Fauna Act) were confirmed present within the terrestrial biodiversity study area. This includes the Critically Endangered black spotted cuscus (*Spilocuscus rufoniger*) and Vulnerable eastern long-beaked echidna (*Zaglossus bartoni*). A further 15 have the potential to occur (either low, moderate or high likelihood) (Table 7.11) including six that are Critically Endangered, three that are Endangered, two that are Vulnerable and four that are Near Threatened.

In total 29 bird species that are Threatened or Protected (either on the IUCN red list or PNG Fauna Act) were recorded within the terrestrial biodiversity study area, most of which occur fairly widely across New Guinea, are known from widely-scattered localities across the island, or have a broad distribution across its northern lowland forests.

Twenty-four additional species may also potentially occur in the terrestrial biodiversity study area. These include two species listed by IUCN as Endangered (far eastern curlew, *Numenius madagascariensis* and great knot, *Calidris tenuirostris*) one species listed by the IUCN as Vulnerable (Salvadori's teal, *Salvadorina waigiuensis*), eleven species listed by the IUCN as Near Threatened, and nine species listed under the PNG Fauna Act. These additional conservation significant species are listed in Table 7.11.

The conservation of Palaearctic waders (i.e., species that breed in the Palearctic ecozone that includes Europe, northern Asia, northern Africa, and the northern and central parts of the Arabian Peninsula) and their habitats is a focus of international concern, since many of the species are in decline. Each year these birds travel between their northern hemisphere breeding grounds and wintering areas in Australia and New Zealand. The energy required for migration comes primarily from fat stored at wintering grounds and stopover points. Consequently, disruptions to their foraging behaviour and/or habitat can have serious consequences for their survival. The terrestrial biodiversity study area, situated in the southern half of the East Asian-Australasian Flyway, includes suitable foraging habitat as exposed mudflats, vegetated swamps and shallow edges to lakes and rivers.

Most of the migratory waders recorded prefer coastal or subcoastal, tidal wetland habitats and therefore are likely to be most prevalent in subcoastal wetlands of the lower Sepik River basin. The species most common in the middle and upper Sepik River basin are the pacific golden plover (*Pluvialis fulva*) and the sharp-tailed sandpiper (*Calidris acuminate*). Others recorded from the floodplains of the Sepik and Ramu rivers include black-tailed and bar-tailed godwits (*Limosa* and *L. lapponica*), whimbrel (*Numenius phaeopus*), marsh and wood sandpipers (*Tringa stagnatilis* and *T. glareola*), grey-tailed tattler (*Heteroscelus brevipes*), red-necked stint (*Calidris ruficollis*) and Latham's and Swinhoe's snipe (*Gallinago hardwickii* and *G. megala*).

Seven of the frog species documented in the terrestrial biodiversity study area and a further 13 species that potentially occur within the study area are listed as Data Deficient by the IUCN due to their small known geographic ranges and poorly understood population status. None of these species are listed under the PNG Fauna Act.

Seventeen of the reptile species documented in the terrestrial biodiversity study area have been assessed by the IUCN; 16 are listed as Least Concern, while one aquatic species, the New Guinea soft-shelled turtle (*Pelochelys signifera)* is listed as Vulnerable. This species was recorded at the Idam River Site. Boelen's python (*Morelia boeleni*) may occur in the upper portions of the terrestrial biodiversity study area (and is known to occur at higher elevations on Mt Stolle to the south of the terrestrial biodiversity study area). This species is protected under the PNG Fauna Act, has a distribution restricted predominantly to montane New Guinea, and occurs at elevations as low as 1,000 m ASL.

Four butterfly (birdwings) species of conservation significance were either confirmed or are likely to occur in the terrestrial biodiversity study area and are listed (one as Near Threatened and one as Endangered) under the IUCN Red List and are protected under the PNG Fauna Act (Table 7.11).

In addition, a total of 43 butterfly taxa were assessed as being biogeographically significant based on their range and abundance. These included taxa known from only the original type series or from exceedingly few specimens and/or species not previously recorded from PNG or at least not from the Sepik Provinces. A description of each of these species is provided in Appendix 8a.

Thirty-three odonate species of some significance were confirmed during these surveys. Most of these species occur across both hill and lowland zones, with only seven species restricted to one zone. Of these, six are poorly known, Data Deficient damselfly species. All are species described from the Indonesian Province of West Papua and their occurrence in the terrestrial biodiversity study area extends their known distributions significantly to the east, except for *Nososticta nigrifrons* which has been identified at a number of sites in PNG since 1996. One dragonfly species (*Bironides teuchestes*) from Malia Site (Figure 7.14) in the lowland zone is listed by IUCN as Vulnerable and was previously known only from three sites in the vicinity of Jayapura and the Cyclops Mountains in north-eastern West Papua Province, Indonesia.

Table 7.11 Threatened or Protected fauna either recorded or having the potential to occur in the terrestrial biodiversity study area

Common name	Species name	IUCN	PNG Fauna Act	Likelihood of occurrence	Location within the Study Area
Mammals					
Black spotted cuscus (Plate 7.45)	*Spilocuscus rufoniger*	CE	P	Present	Trophy jaw of species recorded in the Hill Zone of the Frieda River catchment.
Sir David’s long-beaked echidna	*Zaglossus attenboroughi*	CE	P	Low	Low likelihood of occurrence across the terrestrial biodiversity study area excluding the northern coastal plain.
Eastern long-beaked echinda	*Zaglossus bartoni*	VU	P	Present	Confirmed present in the Hill Zone of the Frieda River catchment
Telefomin cuscus	*Phalanger matanim*	CE	-	Low	Low likelihood of occurrence in the Hill Zone of the Frieda River catchment
Tenkile	*Dendrolagus scottae*	CE	P	Moderate	Moderate likelihood of occurrence in the Bewani Mountains
Waimang	*Dendrolagus pulcherrimus*	CE	P	Low	Low likelihood of occurrence in the Bewani Mountains
Goodfellow’s tree kangaroo	*Dendrolagus goodfellowi*	EN	P	High	High likelihood of occurrence in Hill Zone of the Frieda River catchment
New Guinea pademelon	*Thylogale browni*	VU	-	Present	Confirmed present in Hill and Lowland Zones of the Frieda River catchment
Western montane tree kangaroo	*Dendrolagus notatus*	EN	P	High	High likelihood of occurrence in Montane Zone of the Frieda River catchment
Small mountain dorcopsis	*Dorcopsulus* sp.	NT	-	Present	Confirmed present in the Hill Zone of the Frieda River catchment
New Guinean quoll	*Dasyurus albopunctatus*	NT	-	Present	Confirmed present in Hill and Lowland Zones of the Frieda River catchment
Bulmer’s fruit bat	*Aproteles bulmerae*	CE	P	Low	Low likelihood of occurrence in the Hill Zone of the Frieda River catchment
Plush-coated ringtail possum	*Pseudochirops corinnae*	NT	-	High	High likelihood of occurrence in the Hill Zone of the Frieda River catchment
Bruijn’s pogonomelomys	*Pogonomelomys bruijni*	NT	-	Low	Low likelihood of occurrence in the Lowland Zone of the Frieda River catchment
D'Albertis's ringtail possum	*Pseudochirops albertisii*	NT	-	High	High likelihood of occurrence in the Bewani Mountains

Table 7.11 Threatened or Protected fauna either recorded or having the potential to occur in the terrestrial biodiversity study area (cont'd)

Common name	Species name	IUCN	PNG Fauna Act	Likelihood of occurrence	Location within the Study Area
Mammals (cont'd)					
Grizzled tree kangaroo	*Dendrolagus inustus*	VU	P	High	High likelihood of occurrence in the Bewani Mountains
Champion's tree mouse	*Pogonomys championi*	NT	-	Low	Low likelihood of occurrence in the Hill and Lowland zones of the Frieda River catchment
Northern glider	*Petaurus abidi*	CE	-	Low	Low likelihood of occurrence in the Bewani Mountains
Northern water rat	*Paraleptomys rufilatus*	EN	-	Low	Low likelihood of occurrence in the Bewani Mountains
Hill's leaf-nosed bat	*Hipposideros edwardshilli*	VU	-	High	High likelihood of occurrence in the Bewani Mountains
Birds					
Great knot	*Calidris tenuirostris*	EN	-	Moderate	Moderate likelihood of occurrence near Vanimo
Far eastern curlew	*Numenius madagascariensis*	EN	-	Moderate	Moderate likelihood of occurrence near Vanimo
Salvadori's teal	*Salvadorina waigiuensis*	VU	-	High	High likelihood of occurrence in Hill Zone within Frieda River catchment
Pesquet's parrot	*Psittrichas fulgidus*	VU	-	Present	Confirmed present in Hill Zone within Frieda River catchment
Papuan eagle	*Harpyopsis novaeguineae*	VU	-	Present	Confirmed present in Frieda River catchment and southern section of infrastastucture corridor
Victoria crowned pigeon (Plate 7.46)	*Goura victoria*	NT	-	Present	Confirmed present in Frieda River catchment and southern section of infrastastucture corridor
Pale-billed sicklebill	*Drepanornis bruijnii*	NT	P	Moderate	Moderate likelihood of occurrence in infrastructure corridor between Idam and Samunai
Yellow-breasted satinbird	*Loboparadisea sericea*	NT	P	Present	Confirmed within the infrastructure corridor between the West Range and Idam 1
Doria's goshawk	*Megatriorchis doriae*	NT	-	Present	Confirmed present within Hill Zone of Frieda River catchment
Gurney's eagle	*Aquila gurneyi*	NT	-	High	High likelihood of occurrence to occur throughout the Project area

Table 7.11 Threatened or Protected fauna either recorded or having the potential to occur in the terrestrial biodiversity study area (cont'd)

Common name	Species name	IUCN	PNG Fauna Act	Likelihood of occurrence	Location within the Study Area
Birds (cont'd)					
Forest bittern	*Zonerodius heliosylus*	NT	-	Present	Confirmed present in the Hill Zone of Frieda River catchment
Blue-black kingfisher	*Todiramphus nigrocyaneus*	NT	-	Present	Confirmed present within the Lowland Zone of the Frieda River catchment
Banded yellow robin	*Poecilodryas placens*	NT	-	High	High likelihood of occurrence in Frieda River catchment and southern section of the infrastructure corridor
Beach stone-curlew	*Esacus magnirostris*	NT	-	High	High likelihood of occurrence near Vanimo
Bar-tailed godwit	*Limosa lapponica*	NT	-	High	High likelihood of occurrence throughout the Project area
Black-tailed godwit	*Limosa limosa*	NT	-	High	High likelihood of occurrence throughout the terrestrial biodiversity study area
Red knot	*Calidris canutus*	NT	-	Moderate	Moderate likelihood of occurrence near Vanimo
Curlew sandpiper	*Calidris ferruginea*	NT	-	High	High likelihood of occurrence throughout the terrestrial biodiversity study area
Red-necked stint	*Calidris ruficollis*	NT	-	High	High likelihood of occurrence throughout the terrestrial biodiversity study area
Asian dowitcher	*Limnodromus semipalmatus*	NT	-	Moderate	Moderate likelihood of occurrence near Vanimo
Grey-tailed tattler	*Tringa brevipes*	NT	-	High	High likelihood of occurrence throughout the terrestrial biodiversity study area
Loria's satinbird	*Cnemophilus loriae*	LC	P	Moderate	Moderate likelihood of occurrence in the Hill Zone of the Frieda River catchment
Glossy-mantled manucode	*Manucodia ater*	LC	P	Present	Confirmed present within the Lowland Zone of the Frieda River catchment and between Hotmin and the West Range of the infrastructure corridor
Jobi manucode	*Manucodia jobiensis*	LC	P	Present	Confirmed present within the Lowland Zone of the Frieda River catchment and between Hotmin and the West Range of the infrastructure corridor

Table 7.11 Threatened or Protected fauna either recorded or having the potential to occur in the terrestrial biodiversity study area (cont'd)

Common name	Species name	IUCN	PNG Fauna Act	Likelihood of occurrence	Location within the Study Area
Birds (cont'd)					
Crinkle-collared /Jobi manucode	*Manucodia chalybatus8*	LC	P	Present	Confirmed present within the Frieda River catchment
Trumpet manucode	*Phonygammus keraudrenii*	LC	P	High	High likelihood of occurrence throughout the terrestrial biodiversity study area
Short-tailed paradigalla	*Paradigalla brevicauda*	LC	P	Low	Low likelihood of occurrence within the Hill Zone of the Frieda River catchment
Queen Carola's parotia	*Parotia carolae*	LC	P	Present	Confirmed present in the Hill Zone of the Frieda River catchment
King of saxony bird-of-paradise	*Pteridophora alberti*	LC	P	Low	Low likelihood of occurrence in the Hill Zone of the Frieda River catchment
Superb bird-of-paradise	*Lophorina superba*	LC	P	Present	Confirmed present in the infrastructure corridor between the West Range and Idam 1
Magnificent riflebird	*Ptiloris magnificus*	LC	P	Present	Confirmed present in the Frieda River catchment Hill Zone
Black sicklebill	*Epimachus fastosus*	LC	P	Moderate	Moderate likelihood of occurrence in the Frieda River catchment Hill Zone
Black-billed sicklebill	*Drepanornis albertisi*	LC	P	High	High likelihood of occurrence in Frieda River catchment Hill Zone
Magnificent bird-of-paradise (Plate 7.47)	*Diphyllodes magnificus*	LC	P	Present	Confirmed present in the Frieda River catchment Hill Zone and the infrastructure corridor between the West Range and Idam 1
King bird-of-paradise	*Cicinnurus regius*	LC	P	Present	Confirmed present in the Frieda River catchment and the infrastructure corridor between Hotmin and the West Range
Twelve-wired bird-of-paradise	*Seleucidis melanoleucus*	LC	P	Present	Confirmed present the Frieda River catchment Lowland Zone and the infrastructure corridor between Hotmin and Idam 1
Lesser bird-of-paradise	*Paradisaea minor*	LC	P	Present	Confirmed present in the Frieda River catchment and the infrastructure corridor between Hotmin to Idam 1

Table 7.11 Threatened or Protected fauna either recorded or having the potential to occur in the terrestrial biodiversity study area (cont'd)

Common name	Species name	IUCN	PNG Fauna Act	Likelihood of occurrence	Location within the Study Area
Birds (cont'd)					
Palm cockatoo	*Probosciger aterrimus*	LC	P	Present	Confirmed present in the Frieda River catchment and the infrastructure corridor between Hotmin to Idam 1
Blyth's hornbill	*Rhyticeros plicatus*	LC	P	Present	Confirmed present in the Frieda River catchment and the infrastructure corridor between Hotmin to Idam 1
Great egret	*Ardea alba*	-	P	Present	Confirmed present in the Frieda River catchment Lowland Zone and infrastructure corridor between Hotmin to Idam 1
Intermediate egret	*Ardea intermedia*	-	P	Present	Confirmed present in the Frieda River catchment Lowland Zone
Little egret	*Egretta garzetta*	-	P	Present	Confirmed present in the Frieda River catchment Lowland Zone and in the infrastructure corridor between Hotmin and the West Range
Butterflies					
Ornithoptère méridional	*Ornithoptera meridionalis*	EN	P	Present	Recorded in the Lowland Zone of the Frieda River catchment
Chimaera birdwing	*Ornithoptera chimaera*	NT	-	High	High likelihood throughout the Project area
Goliath birdwing	*Ornithoptera goliath*	LC	P	Present	Recorded in the Lowland Zone of the Frieda River catchment
Butterfly of paradise (Plate 7.48)	*Ornithoptera paradisea*	LC	P	Present	Recorded in the Lowland Zone of the Frieda River catchment
Reptiles					
Boelen's python	*Morelia boeleni*	NE	P	High	High likelihood in the Frieda River catchment in the Montane Zone
Dragonflies					
Dragonfly	*Bironides teuchestes*	VU	P	Present	Confirmed present in Frieda River catchment Hill Zone.

IUCN Categories: CE = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, DD = Data Deficient, LC = Least Concern.

PNG Fauna Act Categories: P = Protected.


S. Richards

Plate 7.45
A lower jaw of the black-spotted cuscus (*Spilocuscus rufoniger*) photographed at Wario Site


I. Woxvold

Plate 7.46
Victoria crowned-pigeon (*Goura victoria*)


M.Sale

Plate 7.47
Magnificent bird-of-paradise (*Cicinnurus magnificus*) recorded at the HI Site


C. Müller

Plate 7.48
Butterfly of paradise (*Ornithoptera paradisea*) recorded during field surveys

7.1.9 Noise

Background noise levels in the Project area, with the exception of Vanimo, are likely to be typical of other rural PNG environments given the remoteness of the area from major industrial sources. As reported in the assessment undertaken by SLR (Appendix 10), most sensitive receivers (villages) are typically located in rural, mountainous and riverine areas. Noise monitoring undertaken elsewhere in PNG at locations with similar terrain and rural setting showed that the ambient background noise was dominated by natural sources, including insects, wind noise in foliage, birds, and rainfall, together with typical anthropogenic noise from village activities including domestic animals. SLR concluded that high insect noise levels are a common feature of the ambient environment all year round. This is due to the tropical weather resulting in little variation in temperature from season to season and, while the prevalence and activity of individual insect species may vary slightly throughout the year, there is generally a consistently high level of insect activity all year round. Based on this existing noise monitoring data, the following ambient background noise levels at sensitive receivers have been adopted for the Project:

- Day (7:00 am to 6:00 pm): 30 to 43 a-weighted decibels (dBA).
- Evening (6:00 pm to 10:00 pm): 40 to 49 dBA.
- Night (10:00 pm to 7:00 am): 34 to 46 dBA.

The ambient noise levels in the villages along the infrastructure corridor adjacent to the existing Vanimo to Green River road is expected to be influenced by the noise of cars, public motor vehicles (PMVs) and trucks travelling along the road.

Ambient noise levels in Vanimo are expected to be higher than the rest of the Project area due to existing industrial and commercial activities including logging barge loading and existing port operations. The background noise levels in the villages adjacent to the Vanimo Ocean Port (Wesdeco and Cis Point) has not been monitored but is influenced by the proximity to Vanimo town, and the noise from logging barge loading in the bay.

7.1.10 Air Quality

Given the general remoteness of the Project area from major industrial sources, background concentrations of gaseous air pollutants, such as sulphur dioxide and nitrogen oxides, can be expected to be negligible. As reported in the study undertaken by SLR (Appendix 11), background concentrations of suspended particulate matter are also expected to be low given the high rainfall, low wind speeds and well-vegetated nature of the area. Elevated particulate levels would only be expected to occur during events such as a volcanic eruption (which may be significant on a regional scale) or bushfire (which, depending on size, may be significant on either a regional or local scale). Locally elevated particulate concentrations may also occur around villages in the lowlands and along the Sepik River due to emissions from cooking fires, or in those villages along the infrastructure corridor adjacent to the existing Vanimo to Green River road due to passing traffic.

The air quality in the villages adjacent to the Vanimo Ocean Port (Wesdeco and Cis Point) is influenced by the proximity to Vanimo town and activity at the port.

For the purposes of the air quality assessment, emissions generated by the Project were conservatively assumed to be released into an essentially undisturbed environment.

7.1.11 Greenhouse Gas Emissions

Total greenhouse gas (GHG) emissions for PNG in 2013, including land use change and forestry (LUCF), were estimated to have totalled 70,855 kilotonne (kt) carbon dioxide equivalent (CO_2-e) (FAO, 2017). Approximately 77% of these emissions are associated with LUCF emissions, such as deforestation of primary or secondary forest and selective logging.

7.2 Aquatic Environment

Watercourses within and downstream of the mine area and FRHEP area (see Figure 7.2) are the primary focus of the discussion in the following sections as most of the historical data has been collected in these areas and they are likely to be subject to the greatest impact as a result of the Project. Watercourses intersecting the infrastructure corridor between the mine area and Vanimo on the north coast of PNG (within Usake/May, Idam and Horden river catchments) are characterised at a higher level. These descriptions are commensurate with the anticipated duration and intensity of Project activities in each of the respective areas.

7.2.1 Hydrology and Drainage

This section provides a summary of the hydrology of the Project area described in Appendix 6a. Watercourses in and downstream of the mine and FRHEP area can be categorised according to elevation or physical definitions as follows (Appendix 7a):

- Upland creeks: all creeks above 150 m ASL, and those dominated by cascades, rapids, waterfalls or regular riffles.
- Upland rivers: all rivers above 150 m ASL. These rivers are high-gradient watercourses with moderate to high flows.
- Mid-catchment rivers: rivers below 150 m ASL. These are steep to broad valleys with semi-confirmed channel with areas of floodplain comprising runs, riffles, pools and rapids.
- Lowland rivers: located on the Sepik River floodplain. These comprise broad or shallow valley rivers, or floodplain with generally slower flows.
- Lakes and off-river waterbodies (ORWBs).

The mine and FRHEP area is located in the upper Sepik River basin in the foothills of the Central Highlands of PNG, where maximum elevations are about 1,500 m ASL and vegetation is dominated by thick tropical rainforest. Average stream gradients in the upper reaches of the rivers are very steep, being in excess of 350 m/km, with streambeds confined by valley slopes (Appendix 5). These upland streams characteristically have rocky streambeds with medium and large boulders and typically fast-flowing clear waters (Plate 7.49), although turbidity temporarily increases during high-flow events and downstream of landslips. Levels of suspended solids are otherwise generally low, typical of undisturbed forested catchments. Channel profiles showing gradients of key rivers in the mine and FRHEP area are shown in Appendix 5.

Streams including the lower Nena and Niar rivers and Ok Binai are mid-catchment rivers with medium gradient profile, ranging from approximately 10 to 20 m/km, and partly confined channels (Plate 7.50). These streams characteristically have wide, straight to partly meandering channels, moderate sediment loading and cobblestone/gravel streambeds and banks.

Along the lower Frieda River, gradients reduce significantly to around 0.5 m/km and the river channel widens and becomes extremely sinuous, showing strong meandering behaviour (Plate 7.51). Water quality is generally turbid due to the higher loads of suspended sediment. The overbank flow areas next to the lower Frieda River are also relatively flat, becoming inundated during large flood events, and are characteristically swampy with areas of shallow standing water. The Frieda River within the Sepik floodplains (and other lowland rivers, including the Sepik River itself) is highly dynamic with frequent shifts in the main channel path that result in the formation of oxbow lakes (Plate 7.52).

At the confluence of the Frieda and Sepik rivers, the elevation of the riverbed is around 20 m ASL. The Sepik River flows east into the Bismarck Sea approximately 400 km downstream of this confluence and the resultant average river gradient along the Sepik River reduces further to around 0.02 m/km (Appendix 5). This variation in channel gradients from the upper reaches of the Project disturbance area, down the Frieda River and, ultimately, along the Sepik River has a considerable impact on the sediment transport capacities within the river system.

As shown on Figure 7.17, west of the Frieda/Sepik confluence there are a number of tributaries of the Sepik River that either flow from the south (Usake/May and Idam rivers), from the north (Horden, North and Yellow rivers) or from the west (Hauser and October rivers). Some of these rivers are described below.

The Usake River, shown in Plate 7.53, flows north into the May River, which meets the Sepik River approximately 14 km (direct, or 30 river kilometres) upstream of the Frieda and Sepik river confluence. Both the Usake and May rivers are mid-catchment rivers and sites sampled within the Usake/May River catchment ranged from approximately 60 to 120 m ASL.

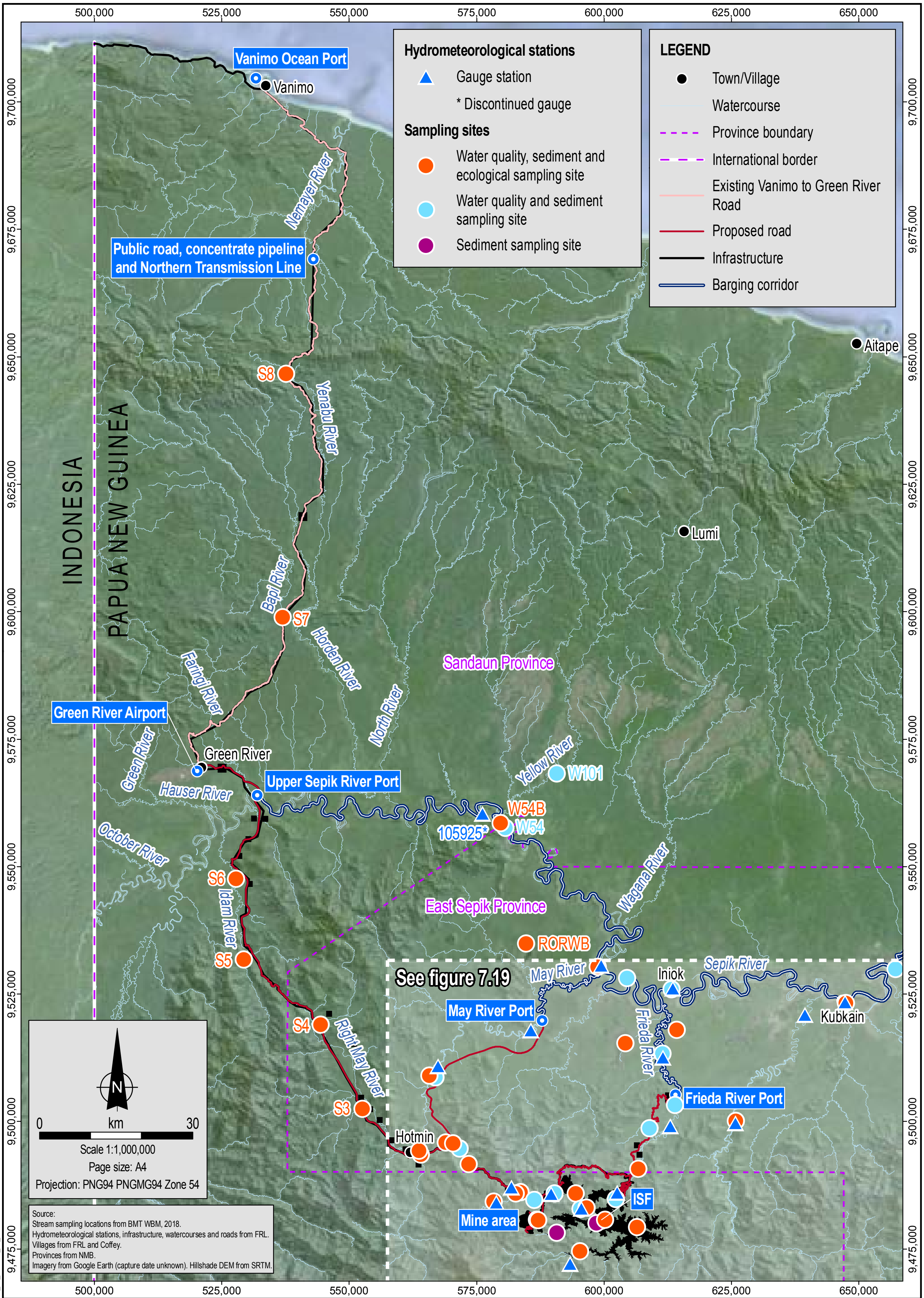
The Idam River, which flows north to meet the Sepik River, is classified as a mid-catchment river towards its headwaters and becomes a lowland river further downstream (Plate 7.54). Elevation at the survey sites within the Idam River catchment ranged from 59 to 105 m ASL.

The Horden River, along with the Yellow and North rivers, flows from the north in a southerly direction to meet the Sepik River. An area known as Stonepass on the Horden River (Plate 7.55), at an elevation of 88 m ASL, is classified as a mid-catchment river, is used as a docking point for villagers' vessels arriving via the Sepik River or coming via the road from Vanimo.

Both the October and Hauser rivers originate in West Papua and cross the border west of Green River Station to meet the Sepik River south of the station (Boyce, 1992).

Nena River

The Nena River headwaters rise near Nena Mountain and then the river flows in an easterly direction for about 35 km to its junction with the Niar River, where it becomes the Frieda River. The Nena River catchment area upstream of its junction with the Niar River is approximately 410 km^2. The upper reaches of the river are steep, with a substratum comprised of bedrock and large boulders and cobbles interspersed with areas of gravel and coarse sand. Water is fast flowing and clear. Further downstream, near the junction with Ok Binai, the gradient flattens and the river exhibits the characteristics of a mid-catchment stream, having straight to partly meandering channels, cobblestone/gravel streambeds and banks and increased sediment loading. High levels of turbidity occur in the lower reaches following rain events, with possible sources of fine sediment being erosion and scouring of exposed soils from natural landslips in the catchment, active and abandoned exploration drilling pads, river bank erosion from high flows and reworking of settled bed sediments. Uba Creek is a tributary of the Nena River upstream of the Nena River's confluence with Ubai Creek.



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Stream sampling locations along the infrastructure corridor

Figure No: 7.17

SKM

Plate 7.49
Upper reach of the Nena River

Coffey

Plate 7.50
Niar River at the confluence with Isai Creek

SKM

Plate 7.51
Braided reach of the lower Frieda River

SKM

Plate 7.52
Oxbow lake formation in the lower Frieda River

Plate 7.53
Middle Reach of the Usake River (Site S1)

Plate 7.54
Upper Idam River (Site S5)

Plate 7.55
Horden River at Stonepass (Site S7)

Ubai Creek

Ubai Creek, with a catchment area of 27 km^2, is about 10 km in length from its headwaters near the Koki deposit to the Nena River. The creek flows along a narrow, incised channel through a steep valley and has steep banks and rocky beds with large boulders. Flows during and following the frequent rainfall events have high energy and high velocity, limiting the build-up of loose sediment or vegetation in the streambed.

Ok Binai

Ok Binai, with a catchment area of approximately 67 km^2, is approximately 20 km in length from its headwaters south of the HITEK deposits to its junction with the Nena River. It also flows through a steep valley and characteristically has high energy and high-velocity flows during the frequent storm events.

Niar River

The Niar River has a catchment area of about 600 km^2 and is about 85 km in length from its headwaters to its junction with the Nena River, where it becomes the Frieda River. Tributary streams of the Niar River include Isai Creek and Ariya, Sia, Dama, Amosai and Alibai rivers, which flow into the reach of the Niar River. Other large tributaries further upstream include the Bloime and Henumai rivers.

The upper reaches of the Niar River flow through a relatively steep valley. Downstream of the junction with the Amosai River (southwest of Wabia village), the Niar River floodplain widens to several kilometres. The river in this area ranges from less than 100 m up to 800 m in width, and is extensively braided (see Plate 7.50).

Frieda River

The Frieda River is approximately 70 km in length from the junction of the Niar and Nena rivers to its confluence with the Sepik River. The total area of the Frieda River catchment is about 1,470 km^2, with about 1,050 km^2 of this area being above the confluence with the Nena and Niar rivers (Appendix 6).

The upper and middle reaches of the river flow through relatively steep valleys for approximately 30 km until the edge of the mountain range near Frieda Mountain. It then becomes a lowland river, meandering through the Sepik River floodplain and exhibiting strong braiding behaviour. Constant avulsion of the main channel has resulted in the formation of numerous oxbow lakes along its banks. In this region, water is generally turbid due to the high levels of suspended sediment, with deposition occurring if stream velocities are low. Alluvial ridges occur along the margins of the river because of sediment deposition.

Flood events in the Frieda River and tributaries typically have fast response times with floodwaters rising and falling very quickly, i.e., within a few hours. This contrasts to the flood characteristics of the Sepik River, which has slow response times with floodwaters rising and falling over days or weeks, as shown in the hydrographs for the two rivers presented in Figure 7.18. These differences reflect the relative size and steepness of the catchments.

The river valley of the upper Frieda River is deeply incised and negligible overbank flooding occurs in this area. Flooding on the lower Frieda River is more primarily influenced by the Sepik River, rather than flows from the Frieda River catchment, with the water level of the Sepik River influencing the Frieda River for approximately 30 km upstream of the confluence of the two rivers.

The largest ORWB hydraulically connected to the Frieda River is Lake Warangai (Plate 7.56), which is also connected to the Sepik River via several channels, with the main outflow channel to the Sepik River being Hueap Creek (Figure 7.19). Water within the lake occasionally receives overland flow from the Sepik and Frieda rivers and flow reversal from the Sepik River along Hueap Creek. Inflows to the smaller Lake Diawi to the east of the Frieda River would also similarly be supplemented by flow reversal from the Frieda River.

Sepik River

The Sepik River has a drainage basin of approximately 78,000 km^2 and is the longest river in PNG, having a total length of around 1,100 km. The river drains the Central Cordillera of PNG, including areas above 3,500 m ASL. The upper catchment is characterised by steep mountainous areas while the lower catchment consists of lowland swampy floodplains. The Sepik River meanders through a wide floodplain in the centre of the basin. The main channel of the river has been, and will continue to be, subject to small- and large-scale alignment changes or lateral migration that results in the formation of oxbow lakes (see Plate 7.52).

At Iniok, immediately downstream of the confluence of the Frieda River and Sepik River (Plate 7.57), the catchment area is approximately 25,200 km^2. The width of the Sepik River near Iniok is approximately 400 to 500 m and water depth ranges from about 8 to 14 m. From Iniok, the Sepik River is about 500 km in length to its mouth.

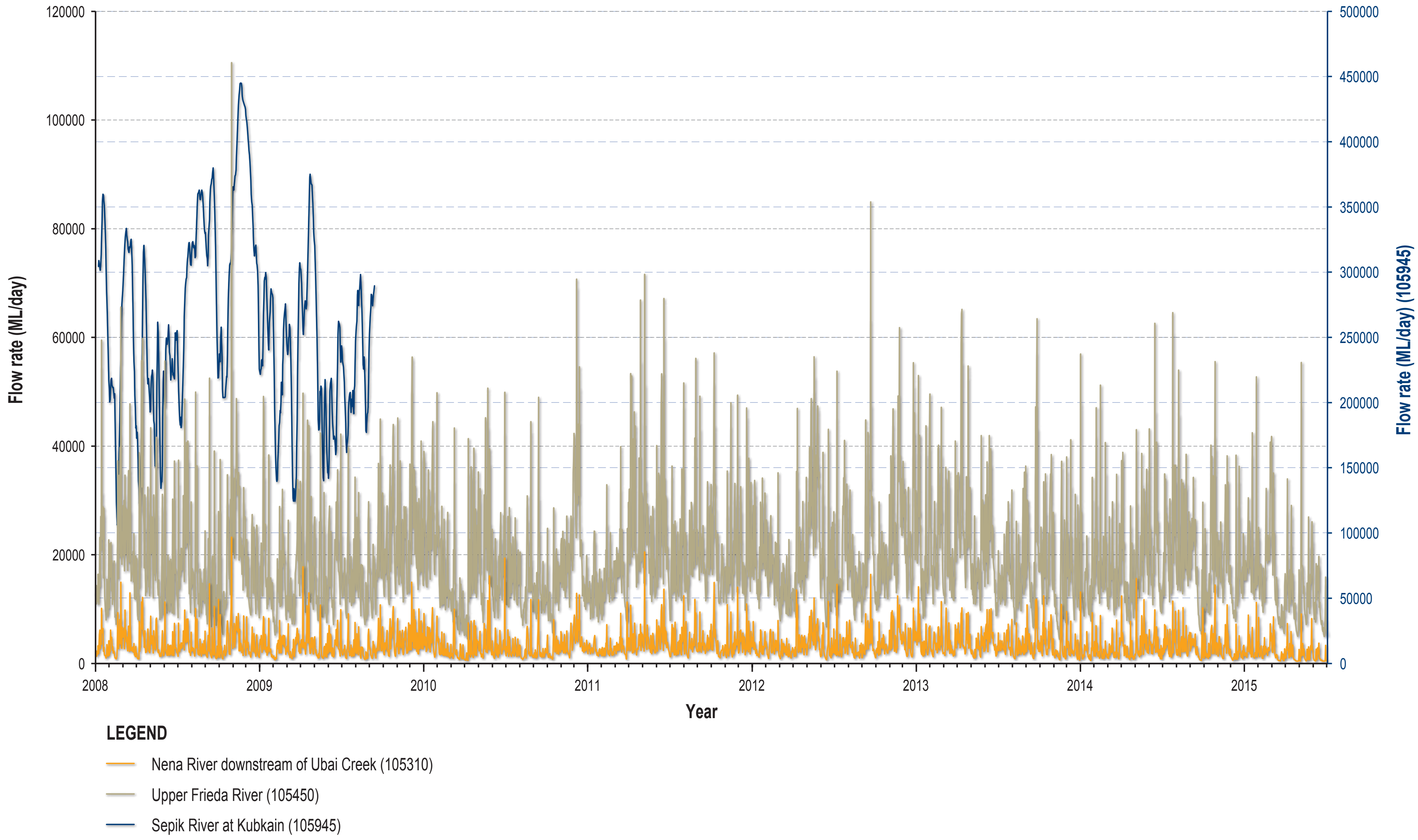
Silt and clay sedimentation occurs along the main river channel during flooding, giving rise to river banks generally lying 2 to 3 m above normal flow levels. Away from the river, the ground surface grades gently down to broad peaty swamps, often with sago palms. Little deposition of silt or clay appears to be occurring in these swamps, with only organic matter slowly building up. This has resulted in the occurrence of very immature peat to depths of up to at least 30 m (Douglas Partners, 2010).

ORWBs on the Sepik River floodplains are fed from the surrounding catchment areas and through small channels connecting to the Sepik River, through which water may flow in or out. These channels may be permanently or intermittently connected to the Sepik River, depending on the elevation, terrain, local geology and the profile of the channels. Connectivity is expected to vary with season, with higher levels of connectivity occurring during the wet season from December to March and during flood events.

The largest ORWB associated with the Sepik River floodplain is the Chambri Lake system, located southeast of Pagwi (east of Kubkain), which consists of a large central lake and a series of smaller interconnected lakes of varying sizes. The central lake has a surface area of approximately 150 km^2 and is about 3 km south from the Sepik River, with which it is connected by a number of channels. Given the number and large size of these channels, it is thought that the lake has a permanent connection to the Sepik River, with flow less likely to be affected by seasonality than is the case for the smaller waterbodies. Flood events would, however, remain an important source of water, providing regular flushing events through the lake system and surrounding floodplain.

Stream Flows

Stream flow monitoring has been undertaken at various gauging stations in the mine and FRHEP area and surrounds from 1995 to 1999 and from 2008 to 2015, with additional data available at limited locations from the 1970s and 1980s. Further details of this monitoring are provided in Appendix 6. Figure 7.19 shows the locations of gauging stations in the Project area. Tables 7.12 and 7.13 show stream flow statistics for the combined periods 1994 to 1999 and 2008 to 2015, as



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Source:
FRL, 2016

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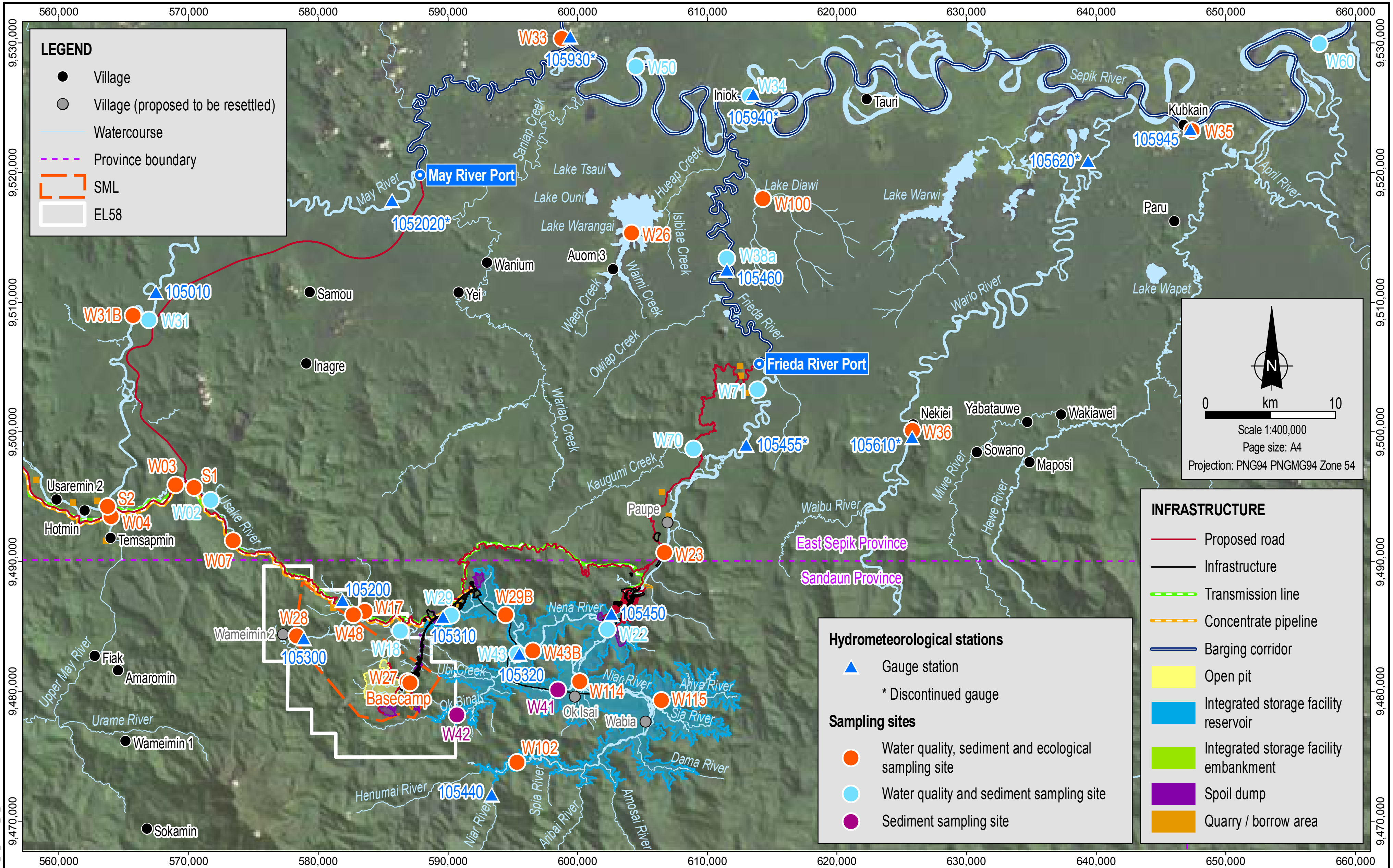
Hydrographs for Frieda and Sepik rivers

Figure No: 7.18



MXD Reference: 11575B_11_GIS006_v0_6

Source:
Stream sampling locations from BMT WBM, 2018.
Hydrometeorological stations, infrastructure, roads and tenements from FRL.
Villages, topographic features, watercourses and water bodies from FRL and Coffey.
Provinces from NMB.
Landsat satellite imagery from FRL (capture date unknown). Hillshade DEM from SRTM.

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Stream sampling locations in the mine and FRHEP area

Figure No: 7.19

FRL

Plate 7.56
Lake Warangai

FRL

Plate 7.57
Sepik River at its confluence with the Frieda River (foreground)

well as historical records for two sites. Flow duration curves for the Nena River below Ubai Creek (Site 105310), Frieda River below Nena River junction (Site 105450) and the Sepik River at Kubkain (Site 105945) are shown in Figure 7.20. A gauging station on the Sepik River upstream of the May River junction (Site 105930) recorded a daily mean flow of 134,735 megalitres per day (ML/day), with a range of between 44,470 ML/day and 263,331 ML/day.

Table 7.12 Daily percentile stream flow

Gauging Station Number	Location	Catchment Area (km^2)	Percentile Flow (ML/day)*		
			10th	50th	90th
105200	Yok Creek	1.5	5	14	43
105320	Ok Binai	69	431	946	1,933
105300	Nena River u/s of Nena gorge	99	649	1,399	3,164
105310	Nena River d/s of Ubai Creek	200	1,202	2,699	6,518
105450†	Upper Frieda River	1,032	9,596	16,872	32,429
105610	Wario River u/s of Nekei	1,668	10,380	16,708	43,291
105930	Sepik River u/s of May River	20,000	73,119	126,294	198,853
105940	Sepik River at Iniok	25,200	111,921	192,686	310,642
105945	Sepik River at Kubkain	30,983	127,940	260,656	378,167
105950§	Sepik River at Ambunti	40,900	180,617	312,704	439,438

* Percentile flow is the flow below which the indicated percentage of observations fall.

† Historical record also includes 1981 to 1999.

§ Historical record also includes 1970 to 1992.

Table 7.13 Daily stream flow statistics*

Gauging Station Number	Location	Daily Mean Flow (ML/day)												Annual Daily Mean	Annual Daily Min	Annual Daily Max
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
GS105200	Yok Creek	20	22	21	22	18	20	18	18	22	22	20	22	20	2	226
GS105300	Nena River u/s of Nena gorge	1,660	2,016	1,915	1,960	1,553	1,576	1,695	1,570	1,731	1,731	1,490	1,684	1,711	195	11,183
GS105310	Nena River d/s of Ubai Creek	3,290	4,048	3,804	3,878	3,116	3,202	3,212	3,223	3,371	3,482	3,133	3,415	3,466	542	23,239
GS105320	Ok Binai	1,083	1,303	1,099	1,271	1,193	1,044	1,221	805	986	1,128	910	1,201	1,099	226	5,641
GS105450†	Upper Frieda River	19,474	22,168	21,590	21,109	18,545	17,954	18,248	18,901	18,143	19,822	17,974	18,312	19,280	3,190	110,588
GS105610	Wario River u/s of Nekei	24,575	26,682	21,130	28,607	23,715	22,450	21,580	17,745	23,280	27,060	18,638	17,630	22,723	3,482	136,948
GS105930	Sepik River u/s of May River	170,077	184,207	186,384	145,093	140,144	111,939	99,255	116,710	93,271	97,422	120,142	154,357	134,735	44,470	263,331
GS105940	Sepik River at Iniok	186,727	239,306	244,604	268,876	253,048	176,765	156,339	122,626	193,780	194,403	200,926	221,418	204,586	61,090	390,880

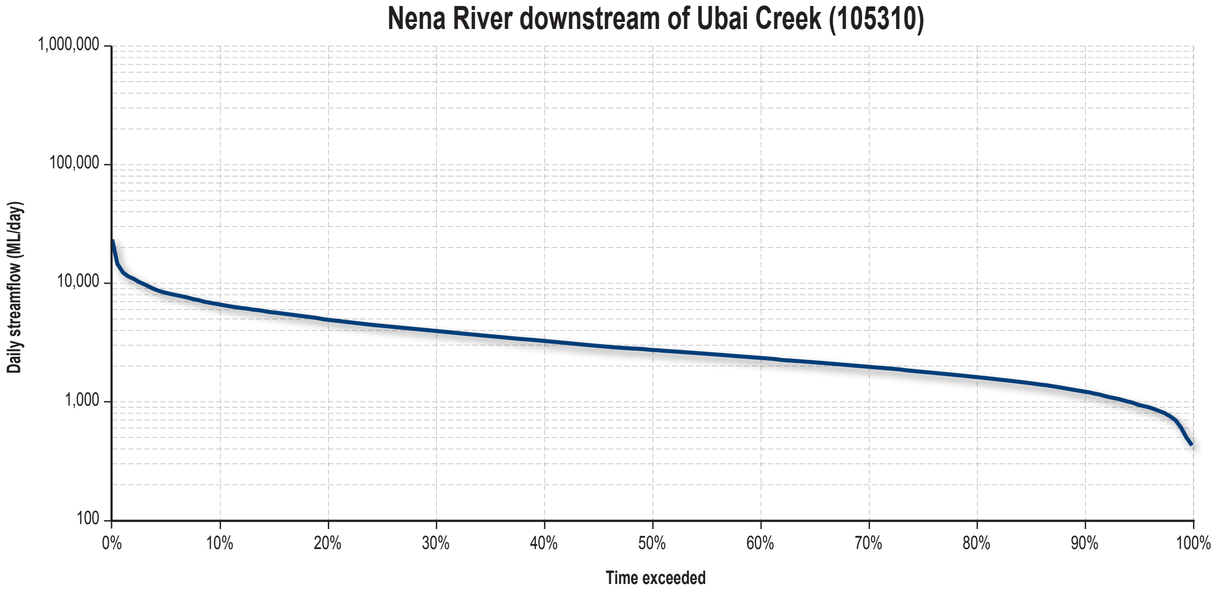
Table 7.13 Daily stream flow statistics* (cont'd)

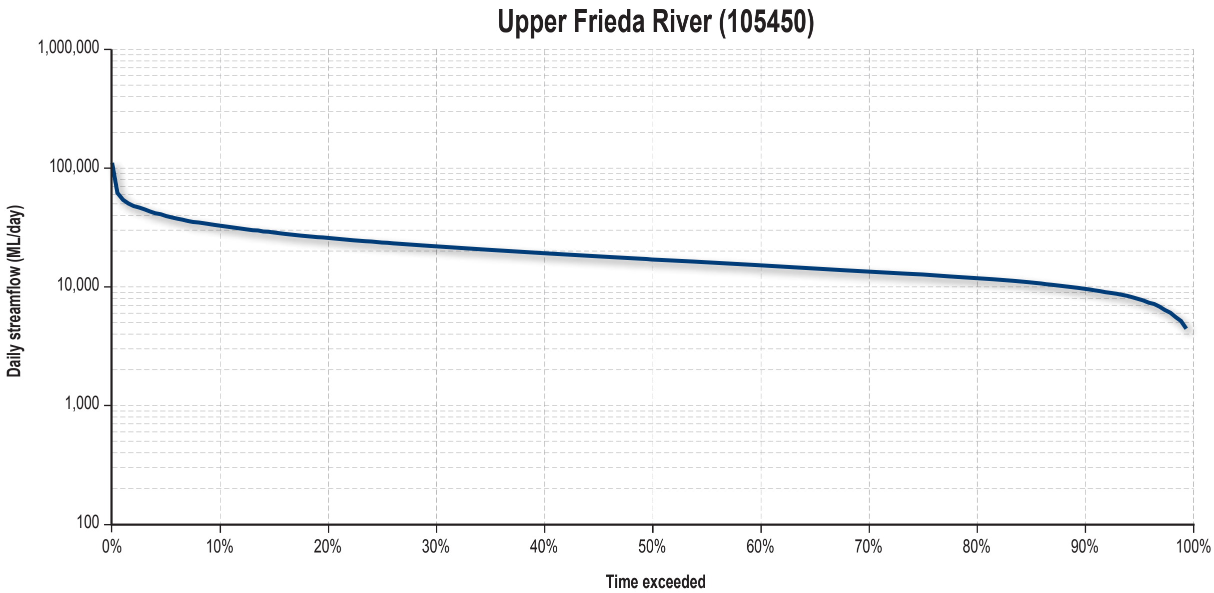
Gauging Station Number	Location	Daily Mean Flow (ML/day)												Annual Daily Mean	Annual Daily Min	Annual Daily Max
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
GS105945	Sepik River at Kubkain	291,350	346,691	393,332	375,693	286,771	209,566	218,233	222,506	186,055	204,517	241,625	274,126	288,460	110,099	520,320
GS105950§	Sepik River at Ambunti	346,509	363,994	399,950	418,173	358,891	291,960	258,845	226,114	235,360	274,657	300,140	306,960	314,802	80,760	772,315

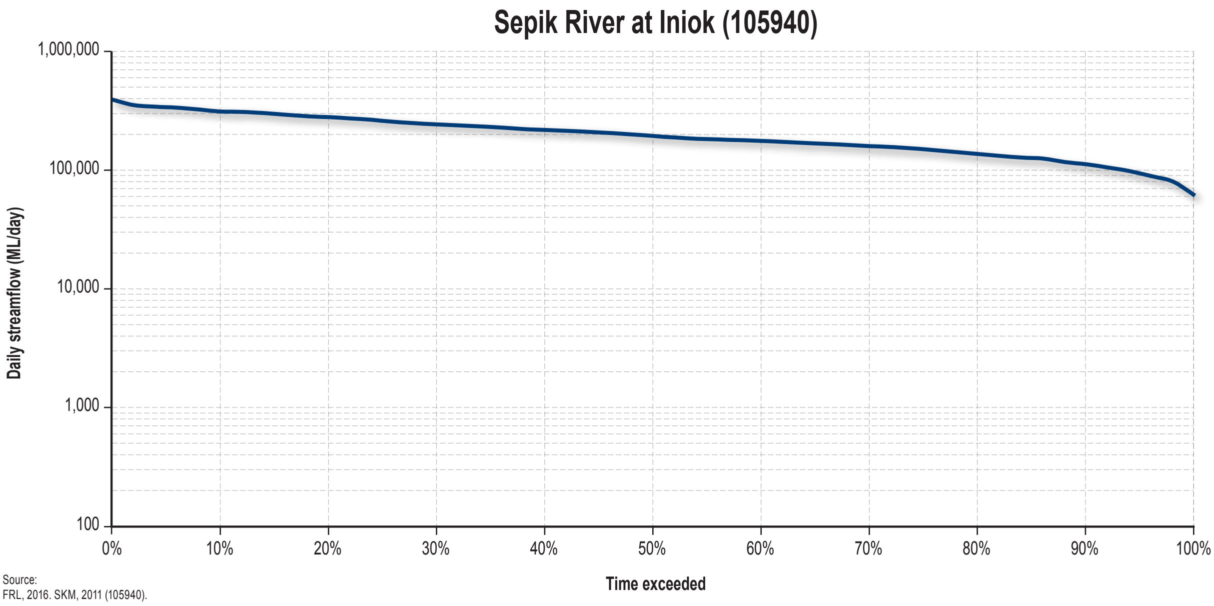
* Statistics shown for selected gauging stations with adequate flow records.

† Historical record also includes 1981 to 1999.

§ Historical record also includes 1970 to 1992.







Source:
FRL, 2016. SKM, 2011 (105940).

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Flow duration curves for Nena, Frieda and Sepik rivers

Figure No: 7.20

7.2.2 Sediment Loads and Sediment Transport

Total suspended solids (TSS) were measured during the 1990s at a series of gauging stations downstream of the proposed HITEK open-pit. This included rising stage samplers and grab and depth-integrated sampling. These data are described in Appendix 5. Stream discharge measurements were also undertaken at a number of the sites allowing the relationship between TSS concentrations and stream discharge to be determined. These relationships are shown in Figure 7.21 for the Nena River below Ubai Creek (Site 105310), Frieda River below Nena River junction (i.e., Upper Frieda River) (Site 105450) and the Sepik River at Kubkain (Site 105945). The TSS-discharge relationships have a stronger correlation for the Sepik River and the Frieda River for flows less than approximately 700 m^3/s, while the Nena River correlation is relatively weak.

Based on these relationships, the existing average annual sediment loss from various catchments in the mine and FRHEP area was calculated by Golder Associates (Appendix 5). The estimated average annual sediment loss in the vicinity of the mine under existing conditions is estimated to be around 6 to 11 t/ha/year in Ok Binai and the Nena River, respectively. The estimated existing average annual sediment loss in the Upper Frieda River is higher at around 17 t/ha/year, indicating that losses from the Niar River catchment are some 20 t/ha/year, which is around double that of the Nena River catchment. The reasons for this are not clear but may be reflective of potential landslips and increased sediment transport from disturbances caused by vegetation clearing associated with the villages of Ok Isai and Wabia in the Niar River catchment.

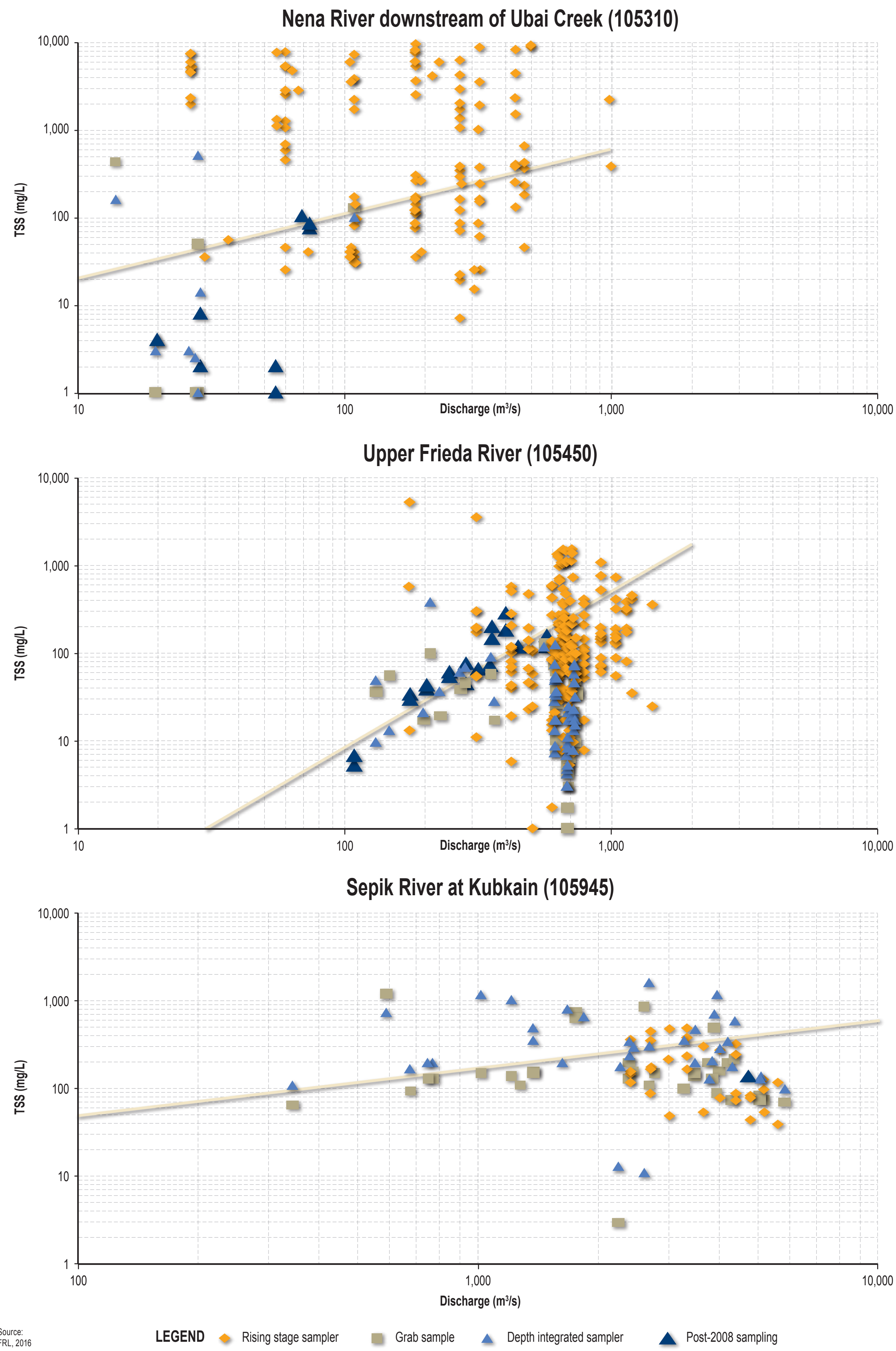
For the Sepik River, the existing average annual sediment loss is about 8 to 9 t/ha/year. This is not dissimilar to average natural catchment sediment yield estimates of 14 t/ha/year for the Sepik River basin based on an annual loss of 85 Mt/year by Kineke et al. (2000) (as cited in Appendix 5) and assuming an overall basin area of around 78,000 km^2.

Overall, the Frieda River catchment currently contributes minimal suspended sediment loads (and flow volumes) to the Sepik River, being about 5% of that contributed from the upper Sepik River (Appendix 5). Suspended sediment in the Sepik River comprises extremely fine silts and clays, which have very low settling velocities. Even though flow velocities in the Sepik River are not generally high at around 1 to 1.5 m/s, it is likely that most of the extremely fine silts and clays are transported the length of the Sepik River and discharged into the Bismarck Sea, with no substantial deposition before this discharge.

Almost all flow is conveyed within the river channel, for both the lower Frieda and Sepik rivers. Even during large floods resulting in overbank flow, the volume of sediment deposited on the floodplains is estimated to be less than 1% of the total sediment load being transported (Appendix 5).

7.2.3 Stream Water and Sediment Characteristics

A water quality and sediment sampling program was undertaken, as detailed in Appendix 7a, consisting of 13 sampling events conducted between September 2007 and October 2010 by Hydrobiology and nine sampling events undertaken between April 2011 and November 2017 by BMT WBM. The study area included the Usake/May, Idam, Horden, Nena/Niar/Frieda, Wario and Sepik rivers, with sampling undertaken at a total of 44 sites all the way down to the mouth of the Sepik River. Sampling locations in the vicinity of the mine and FRHEP area in the Nena/Niar/Frieda and Sepik rivers are shown in Figure 7.18 and sampling locations in the vicinity of the infrastructure corridor between the mine site and Vanimo are shown in Figure 7.17. Two



coffey A TETRA TECH COMPANY	Date: 31.08.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.21_GRA	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Graphs of relationships between TSS and stream discharge	Figure No: 7.21

copper complexing capacity studies were also undertaken in September 2015 and in November 2017 during which water samples were collected from Ekwai Creek and the Nena, Frieda and Sepik rivers.

Turbidity and Total Suspended Solids

Water quality monitoring shows that existing turbidity is highly variable in the mine, FRHEP and infrastructure corridor areas as a result of the high rainfall and landslips in steeper terrain. In upland creeks and rivers, average turbidity is lower than in mid-catchment and lowland rivers (Figure 7.22). The greatest variation in turbidity in upland creeks and rivers throughout the sampling period was found in Ubai Creek (at the basecamp site), which ranged from 0 to 1,586 nephelometric turbidity unit (NTU) (in February 2010), and Ekwai Creek (Site W27), which ranged from 0 to 97 NTU (in April and July 2008, respectively). Ubai Creek was noted as having highly variable turbidity during the surveys and is potentially draining unstable landforms upstream, such as areas of landslip.

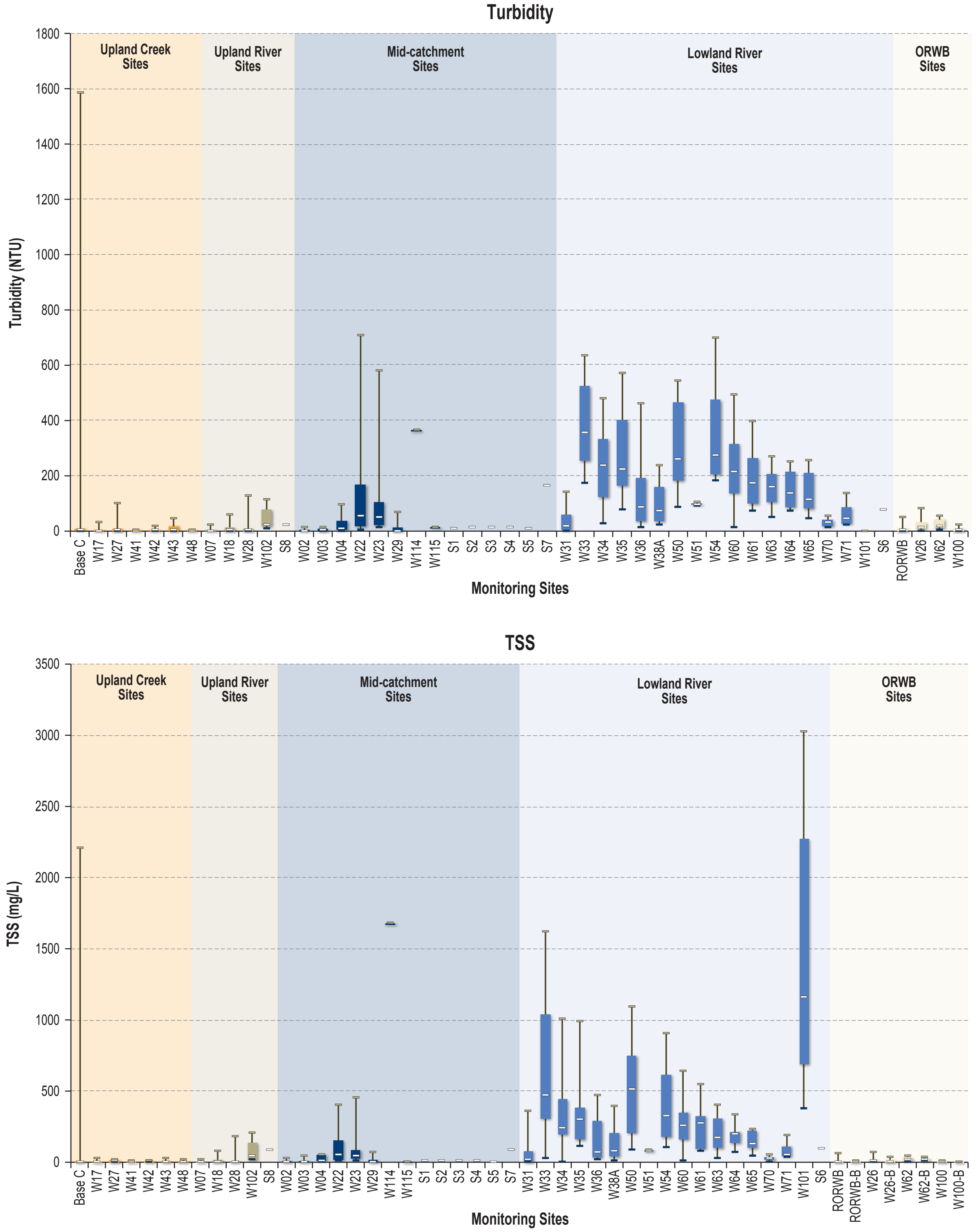
Turbidity and TSS levels are highly variable in mid-catchment and lowland rivers. This natural variation is illustrated by sampling in the Niar River (Site W22) during a relatively low-flow period in July 2008 when turbidity and TSS levels were 39 NTU and 32 mg/L, respectively, compared to a high-flow period in February 2010 when turbidity and TSS levels were 707 NTU and 389 mg/L, respectively.

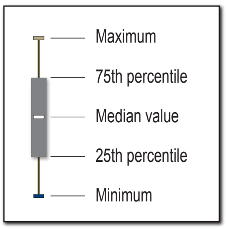
In the lower Nena River (Site W29), TSS levels varied between 1 and 72 mg/L with an average concentration of 14 mg/L. Turbidity at this site varied between 0 and 67 NTU with an average of 10 NTU. Further downstream in the Frieda River near Paupe (Site W23), TSS concentrations ranged between 8 and 449 mg/L (median 47 mg/L) while turbidity ranged between 11 and 578 NTU (median 48 NTU). As to be expected, there was less variability in Lake Warangai (Site W26), where TSS levels ranged between 2 and 72 mg/L (median 10 mg/L) and turbidity ranged between 0 and 79 NTU (median 11 NTU).

Levels of turbidity and TSS increased in the Sepik River, with monitoring showing the following:

- Sepik River upstream of junction with the May River (Site W33):
  - Turbidity ranged between 174 and 636 NTU (median 355 NTU).
  - TSS ranged between 31 and 1,620 mg/L (median 473 mg/L).
- Sepik River at Iniok (Site W34):
  - Turbidity ranged between 115 and 477 NTU (median 235 NTU).
  - TSS ranged between 5 and 1,010 mg/L (median 239 mg/L).
- Sepik River at Kubkain (Site W35):
  - Turbidity ranged between 74 and 569 NTU (median 223 NTU).
  - TSS ranged between 112 and 992 mg/L (median 298 mg/L).

Turbidity and TSS at sites in the vicinity of the infrastructure corridor, most of which were classified as mid-catchment rivers, were variable across the sites, ranging from 6.5 NTU for turbidity and 4 mg/L TSS in the upper Idam River (Site S5) to 165 NTU for turbity and 90 mg/L TSS in the Horden River at Stonepass (Site S7). In the upper May River (Site W31), median turbidity was 14.6 NTU and ranged from 3.1 to 140 NTU. TSS ranged from 2 to 355 mg/L with a median TSS of 18 mg/L.





Note:
A single black horizontal bar (the median) represents a single sampling event only (i.e., no statistical range available).

Source:
BMT WBM, 2018

AI Reference: 11575_11_GRA025.ai_4

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Date: 31.08.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.22_GRA

Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Box and whisker plots of turbidity and TSS measurements

Figure No: 7.22

General Water Quality Parameters

The pH of upland creeks and rivers was typically between pH 7 and 8, except for Ekwai Creek (Site W27) where pH ranged from pH 3.6 to 4.5. This acidity is attributed to the natural occurrence of acid and metalliferous drainage (AMD) at this location, which is the area of mineralisation where the mine will be developed. The pH of mid-catchment and lowland rivers was also generally in the range of pH 7 to 8. The pH of Lake Warangai (site W26) was highly variable but tended to be acidic, with pH ranging between 3.8 and 8.4 (median pH 6.3). Lower pH readings, along with lower recorded concentrations of dissolved oxygen, are common in ORWBs in the study area.

Dissolved oxygen levels were at or close to saturation at the majority of sites in the study area with the exception of the ORWBs and the lower Sepik River. These lower concentrations are possibly attributable to inputs from ORWBs and swamp areas, which typically have low dissolved oxygen levels due to high levels of organic matter inputs and reduced flow rates and associated mixing. The ORWBs can be deeply coloured as a result of tannins leaching from vegetation decaying in the water, which results in transparent acidic water (NDPI, 2011 as cited in Appendix 7a).

Alkalinity measurements showed there to be a low to moderate amount of buffering capacity (i.e., alkalinity) available in most of the sampled creeks and rivers. The notable exception was Ekwai Creek (Site W27), which had no buffering capacity at all, and Lake Warangai (Site W26), which had little alkalinity (average 7 mg $CaCO_3$/L). Otherwise, alkalinity was generally about 20 to 40 mg $CaCO_3$/L in upland and mid-catchment streams, increasing to about 50 to 70 mg $CaCO_3$/L in the Sepik River.

The dominant major ions were calcium and carbonate, reflecting the influence of limestone within the catchment. However, water hardness was low with monitoring results showing the following:

- Lower Nena River (Site W29) — median hardness of 23 mg/L.
- Niar River (Site W22) — median hardness of 40 mg/L.
- Frieda River near Paupe (Site W23) — median hardness of 35 mg/L.
- Upper May River (Site W31) — median hardness of 30 mg/L.
- Sepik River at Iniok (Site W34) — median hardness of 58 mg/L.
- Sepik River at Kubkain (Site W35) — median hardness of 57 mg/L.

Conductivity in the creeks and rivers was relatively low, with all measurements being less than 300 µS/cm. Dissolved organic carbon (DOC) and total organic carbon (TOC) concentrations in the Project area streams were similar, indicating that most of the organic carbon is present in the dissolved form. Concentrations were up to about 3 mg/L with slightly higher levels in lowland rivers and ORWBs than at other riverine/creek sites.

Available nutrient (ammonia, nitrate/nitrite, filterable reactive phosphorus) concentrations were generally low throughout Project area streams, which is typical of streams in PNG.

Metals

Concentrations of metals in the Project area streams were generally low, except in Ekwai Creek (Site W27) where the occurrence of naturally occurring AMD has resulted in an elevation of dissolved metals. Otherwise, where detected, metal concentrations were predominantly associated with the particulate fraction, with total metal concentrations increasing with the level of TSS.

A summary of maximum dissolved metals concentrations measured in selected Project area streams is presented in Table 7.14, with all data (including results for total metal concentrations) for all sampling events presented in Appendix 7a. Dissolved metal concentrations were compared against various water quality guidelines including:

- Ambient water quality guidelines:
  - Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002, which are legally enforceable water quality criteria in PNG under the Environment Act.
  - Water quality criteria for freshwater aquatic life, as described in the PNG Environmental Code of Practice for the Mining Industry (OEC, 2000). Compliance with this code is voluntary.
  - Australian and New Zealand guidelines for freshwater aquatic ecosystem protection (95% species protection level) (ANZECC/ARMCANZ, 2000).
- Drinking water guidelines:
  - PNG Public Health (Drinking Water) Regulation, Schedule 2, 1984.
  - Raw drinking water quality criteria described in OEC (2000).
  - World Health Organisation (WHO) drinking water guidelines (2017).

Selected naturally occurring exceedances of ANZECC/ARMCANZ (2000) freshwater aquatic ecosystem protection guidelines, which are generally the most stringent of all the above water quality guidelines, occurred at the following locations:

- Ubai Creek (Basecamp): aluminium (maximum concentration), cadmium (maximum concentration) and copper (minimum concentration).
- Ekwai Creek (Site W27): aluminium (20 percentile concentration), cadmium (maximum concentration), copper (20 percentile concentration) and zinc (20 percentile concentration).
- Upper Nena River upstream of Ubai Creek (Site W28): aluminium (maximum concentration), copper (maximum concentration) and zinc (maximum concentration).
- Lower Nena River downstream of Ubai Creek (Site W29): aluminium (median concentration), cadmium (maximum concentration), copper (minimum concentration) and zinc (maximum concentration).
- Niar River (Site W22): aluminium (maximum concentration), copper (maximum concentration) and zinc (maximum concentration).
- Frieda River near Paupe (Site W23): copper (maximum concentration) and zinc (80 percentile concentration).
- Lake Warangai (Site W26): aluminium (20 percentile concentration), cadmium (maximum concentration), copper (80 percentile concentration) and zinc (80 percentile concentration).
- Sepik River at Iniok (Site W34): cadmium (marginal maximum concentration exceedance) copper (marginal maximum concentration exceedance) and zinc (80 percentile concentration).
- Sepik River at Kubkain (Site W35): aluminium (maximum concentration), cadmium (maximum concentration marginally exceeds the guideline), copper (maximum concentration marginally exceeds the guideline) and zinc (80 percentile concentration).

- Abei River (Site S2), Uriake River (Site S3) (Usake/May River catchment) and upper Idam River (Site S5) (Idam River catchment): silver concentrations exceeded the ANZECC/ARMCANZ (2000) guideline value (0.0005 mg/L).

Dissolved metals concentrations were generally below drinking water guidelines with the following exceptions associated with exceedances (maximum recorded concentrations) of the raw drinking water criteria in the PNG Environmental Code of Practice for the Mining Industry (OEC, 2000) of:

- Aluminium: Nena River (W18), Ekwai Creek (W27), Sepik River upstream of May River junction (W33) and Ok Isai (W41).
- Iron: Nena River (W18), Sepik River (W60, W61, W63, W64 and W65) and at Kaugumi Creek (W70).
- Manganese: Sepik River (W33, W61, W63 and W64).

Table 7.14 Maximum dissolved metal concentrations at selected locations (mg/L)

Location	Site	Silver	Aluminium	Arsenic	Cadmium	Cobalt	Chromium	Copper	Iron	Mercury	Manganese	Lead	Nickel	Selenium	Zinc
Ekwai Creek	W27	<0.001	0.73	<0.001	0.0005	0.002	<0.001	0.087	0.2	<0.0001	0.068	<0.001	0.002	<0.01	0.139
Upper Nena River	W28	<0.001	0.074	<0.001	0.0002	<0.001	<0.001	0.003	0.07	<0.0001	0.01	<0.001	0.004	<0.01	<0.005
Lower Nena River	W29	<0.001	0.1	0.002	0.0006	<0.001	<0.001	0.007	0.13	<0.0001	0.01	<0.001	0.002	<0.01	0.027
Niar River	W22	<0.001	0.08	<0.001	0.0002	<0.001	<0.001	0.003	0.12	<0.0001	0.033	<0.001	0.003	<0.01	0.024
Frieda River near Paupe	W23	<0.001	0.05	<0.001	0.0002	<0.001	<0.001	0.002	0.13	<0.0001	0.012	<0.001	0.004	<0.01	0.02
Lake Warangai	W26	<0.001	0.16	<0.001	0.0007	0.002	0.002	0.002	0.73	<0.0001	0.052	<0.001	0.002	<0.01	0.091
Upper May River	W31	<0.001	0.04	<0.001	0.0004	<0.001	<0.001	0.002	0.19	<0.0001	0.082	<0.001	0.004	<0.01	0.006
Sepik River at Iniok	W34	<0.001	0.05	0.002	0.0003	0.001	<0.001	0.002	0.25	<0.0001	0.036	<0.001	0.001	<0.01	0.038
Sepik River at Kubkain	W35	<0.001	0.06	<0.001	0.0005	<0.001	<0.001	0.002	0.38	<0.0001	0.091	<0.001	0.002	<0.01	0.045
Water Quality Guidelines															
PNG aquatic life[a]		0.0001	-	0.05	0.00066	0.00024	0.01	0.0065	1.0	0.0001	-	0.0013	0.056	0.005	0.18
PNG Schedule 1[b]		0.05	_	0.05	0.01			1	1	0.0002	0.5	0.005	1	0.01	5
ANZECC/ARMCANZ trigger value[c]		0.00005	0.055	0.013	0.0002	-	-	0.0014	-	0.00006[d]	1.9	0.0034	0.011	0.005[d]	0.008
PNG raw drinking water[e]		0.1	0.2	0.007	0.002	-	0.05	1.0	0.3	0.001	0.1	0.01	0.02	0.01	3.0

Table 7.14 Maximum dissolved metal concentrations at selected locations (mg/L) (cont'd)

Location	Site	Silver	Aluminium	Arsenic	Cadmium	Cobalt	Chromium	Copper	Iron	Mercury	Manganese	Lead	Nickel	Selenium	Zinc

Water Quality Guidelines (cont'd)														
PNG Schedule 2[f]	0.05	_	0.05	0.01	_	-	1.5[f]	1[f]	0.001	0.5[f]	0.1	-	0.01	15[f]
WHO (2017)[h]	-	-	0.01[i]	0.003	_	0.05[i]	2	-	0.006	-	0.01[i]	0.07	0.04[i]	-

a OEC (2000). Hardness dependent values (for Cd, Cu, Pb, Ni and Zn) based on hardness of <50 mg $CaCO_3$/L.

b Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002.

c ANZECC/ARMCANZ (2000) trigger value for the protection of 95% of freshwater aquatic species. Hardness dependent values (for Cd, Cu, Pb, Ni and Zn) based on hardness of 30 mg CaCO3/L.
d Protection of 99% of species adopted for slightly to moderately disturbed systems due to the potential for bioaccumulation (ANZECC/ARMCANZ, 2000).
e Raw drinking water quality criteria described in OEC (2000).
f PNG Public Health (Drinking Water) Regulation, Schedule 2, 1984.
g Aesthetically-based value.
h World Health Organisation (WHO) drinking water guidelines (2017).
i Provisional guideline value.

Copper Complexing Capacity

In 2015 and 2017, surface water samples were collected from Ekwai Creek and the Nena, Frieda and Sepik rivers as part of a study to determine the natural capacity of the watercourses in the mine and FRHEP area to form strongly-bound complexes with dissolved metals, thereby making them less bioavailable (i.e., less toxic) to aquatic biota than labile metal ions (i.e., free unbound metal ions in solution). The study focussed on copper complexing capacity based on the naturally-occurring copper mineralisation in the mine area. The following parameters were measured:

- Total copper.
- Dissolved copper.
- Labile copper.
- Copper complexing capacity.

Key factors that can influence copper complexing capacity are dissolved organic carbon (DOC) and pH, as follows:

- **DOC**. DOC can form complexes with dissolved copper, therefore higher concentrations of DOC means there is more DOC available to form complexes with the dissolved copper. This reduces the copper's availability and therefore toxicity to aquatic biota.
- **pH**. Typically, as pH increases, copper complexing also increases. Therefore, in neutral or alkaline waterbodies, it is more likely that dissolved copper will be bound with dissolved organic carbon if it is present.

Other variables affecting copper complexing capacity include composition of the organic matter (i.e., binding affinity), conductivity, hardness, concentration of major ions and temperature.

The results showed that the dissolved copper concentrations ranged from 0.39 micrograms per litre (µg/L) at the Nena River gauging station to 64.4 µg/L at Ekwai Creek (Table 7.15). The high dissolved copper concentration measured in Ekwai Creek in 2017 was associated with an acidic pH of 4.6, indicative of the occurrence of natural AMD reported previously at this site. The dissolved copper concentration typically comprised up to 10% labile copper, with the exception of Ekwai Creek which reported 36% labile copper in 2015 and 70% labile copper in 2017. The copper complexing capacity ranged from 4.1 to 30.9 µg/L, with the lowest level measured at Ekwai Creek and the highest recorded in the lower Nena River.

These results generally indicate that in the upland rivers and creeks, there is less natural capacity for the watercourses to bind copper, which is also somewhat reflected by the lower concentrations of DOC in upland streams compared to mid-catchment and lowland rivers. In some cases, however, a high copper complexing capacity was measured with a correspondingly low or moderate concentration of DOC. For example, sites in the Nena River (NR-GS and W29) and the Frieda River (W23) recorded relatively high copper complexing capacities (ranging from 24.7 to 30.0 µg/L) with moderate DOC concentrations (ranging from 1.58 to 2.63 mg/L). Furthermore, higher DOC does not necessarily dictate the highest complexing capacity as is the case with the Sepik River at Iniok (W34). This indicates that DOC is only a partial contributor to complexing capacity, with the possibility of other non-DOC ligands contributing to increased complexing capacity in some cases and the potential that some DOC species are less efficient at binding copper than others (as may be the case with Site W34 in the Sepik River).

Measurements of copper complexing capacity in the lower Frieda River (19.3 µg/L on average) and the Sepik River (22.2 µg/L on average) ranged between 11 and 25 µg/L, which suggests that most, if not all, of the dissolved fraction of copper is bound with organic carbon and thereby is not bioavailable (and therefore not toxic) to aquatic biota. This was supported by the concentrations of labile copper in the Frieda and Sepik rivers, which were below the detection limit at most sites and, where they were detected, they were at low concentrations (between 0.1 and 0.14 µg/L). Furthermore, given that there is an excess of complexing capacity at these sites, an increase in the dissolved copper concentration up to the complexing capacity would likely be organically bound thereby reducing its toxicity to aquatic biota.

Waterbodies with acidic pH have a reduced capacity to organically bind dissolved copper regardless of DOC concentrations and other variables. Examples of this include ORWB's such as Lake Diawi (Site W100) and Lake Kiawi (Site RORWB), which are located on the Sepik River floodplain upstream of the river's confluence with the May River, as well as at Site W27 in the Ekwai Creek, where low pHs have been recorded (although not observed in the 2015 data in Table 7.15, possibly due to natural fluctuations) and where AMD is known to naturally occur. Concentrations of DOC in Ekwai Creek range from 0.5 to 5 mg/L, which is lower than DOC concentrations in Lake Diawi, which range from 14 to 26 mg/L. Therefore, the labile copper concentration is likely to form a greater proportion of dissolved copper at these locations and would therefore be more bioavailable to aquatic biota.

Table 7.15 Copper complexing capacity results

Site location	Sample ID	Date	pH	Dissolved Cu (µg/L)	Chelex-labile Cu (µg/L)	Chelex-labile (%)	Cu complexing capacity (µg/L)	DOC (mg/L)
Ekwai Creek upstream of Ubai River Junction	W27	2015	7.2	4.7	1.7	36	8	-
		2017	4.6	64.4	45.4	70	4	0.93
Nena River gauging station	NR-GS	2015	7.1	0.52	0.03	5	21	-
		2017	7.6	0.39	<0.008	none detected	26	2.05
Lower Nena	W29	2015	6.9	4.2	0.42	10	23	-
		2017	7.3	2.4	<0.008	none detected	31	2.63
Frieda River downstream of the Airstrip	W23	2015	7.5	1.0	<0.02	none detected	14	-
		2017	7.6	2.1	<0.008	none detected	25	1.58
Frieda River downstream	W71	2017	7.6	0.45	<0.008	none detected	12	0.70
Lower Frieda River	W38a	2015	7.0	1.4	0.14	10	25	-
		2017	7.5	0.7	<0.008	none detected	21	1.64
Sepik at Iniok	W34	2015	7.4	1.7	0.10	6	20	-
		2017	7.5	1.5	<0.008	none detected	24	4.06

Copper Adsorption Capacity

In 2017, copper adsorption measurements were performed on water samples collected from the Frieda and Sepik rivers (at W23, W34, W38A and W71) to determine the ability of the naturally present suspended particulate matter in the water to reduce dissolved copper concentrations via adsorption onto suspended particulate matter, known as adsorption capacity. These tests were completed by spiking unfiltered sample waters with a mixture of dissolved copper at concentrations of 0, 5, 10, 20 and 50 µg/L and measuring the proportion of copper removed from solution by adsorption onto the suspended particulate matter. Using this data, partition coefficients (Kd) were derived to characterise the adsorption affinity[3] of the copper for the suspended particulate matter, where a higher Kd value suggest a higher the adsorption affinity. The results for the 5 and 50 µg/L spike test are shown in Table 7.16. The data for the full range of spike tests is provided in Appendix 7a.

For water samples taken from the Frieda River, the proportion of copper removed from the dissolved phase ranged from 46 to 85%, with the highest proportion being measured in the middle Frieda River (Site W71). This site had a correspondingly high adsorption affinity (Kd) of 121 litres/gram of suspended particulate matter (measured as TSS) (L/g).

As the spiked concentration increased, the percentage of copper removed through adsorption also increased, indicating that the adsorption sites on the suspended particulate matter (i.e., TSS) were not becoming saturated with copper at higher spike concentrations.

There is an approximate exponential relationship between TSS and Kd; however, this can be influenced by other factors such as TSS composition and aggregation of TSS at higher concentrations, resulting in reduced numbers of binding sites. This may be an explanation for a low Kd value (10.5 L/g) for the Sepik River sample, with the highest TSS concentration of 275 mg/L. While the adsorption affinity (Kd) of the Sepik River sample is low (i.e., the binding sites per gram of TSS is lower), the higher TSS concentrations are likely to reduce dissolved copper concentrations more overall.

Table 7.16 Copper adsorption capacity results (2017)

Site location	Sample ID	Spike concentration (µg/L)	Losses via adsorption (%)	TSS (mg/L)	Kd (L/g)
Frieda River downstream of the Airstrip	W23	5	46	55	37.9
		50	65		
Frieda River downstream	W71	5	67	57	121
		50	85		
Lower Frieda River	W38a	5	49	40	57.5
		50	67		
Sepik at Iniok	W34	5	50	275	10.5
		50	71		

[3] Adsorption affinity, Kd, refers to the strength and efficiency of the binding interaction between dissolved copper ions and suspended particulate matter (measured as TSS).

Sediment Quality

Analyses were undertaken of sediment particle size distribution of the whole sediment sample and metals in the less than 2,000 μm and less than 63 μm particle size fractions of the samples. The less than 2,000 μm size fraction is considered to represent 'whole sediment' to which organisms are exposed whereas the less than 63 μm size fraction represents the silt/clay particle size range. This latter size fraction tends to contain higher concentrations of metals due to the greater surface area compared to coarser particles, and allows normalisation between sites and sampling occasions based on particle size.

Notwithstanding that sampling focused on collection of finer-grained sediment at each site, i.e., it may not be representative of the whole stream bed composition, the following observations were made from particle size analyses:

- Lowland rivers and ORWBs typically contain a higher proportion of silts and clays (between 40 to 95%).
- Bed sediments of upland streams are typically dominated by coarser fractions, i.e., sands and gravels.

Comparison of metal concentrations in sediment was undertaken against Australian and New Zealand interim sediment quality guidelines (ISQGs) described in ANZECC/ARMCANZ (2000) and updated in Simpson et al. (2013). The updated 2013 sediment guidelines describe two guideline values:

- Guideline Value, the concentration below which ecotoxicological effects probably do not occur.
- SQG-high, the concentration above which ecotoxicological effects could occur.

The guideline values for metals/metalloids in ANZECC/ARMCANZ (2000) and Simpson et al. (2013) are the same except for silver which is 4 mg/kg in Simpson et al. (2013) and 3.7 mg/kg in ANZECC/ARMCANZ (2000).

Exceedance of the Guideline Value does not necessarily mean that adverse biological effects will occur in the sediments but rather provides a trigger for further investigation to assess the environmental risk associated with the exceedance.

In terms of sediment quality in Project area streams, noteworthy findings are:

- With several exceptions, the silts and clays fraction (i.e., <63 μm) typically had the highest metal/metalloid concentrations.
- Median metal/metalloids concentrations of copper and nickel exceeded the SQG-high guideline value. Nickel exceeded the SQG-high at most sites.
- Median copper concentrations exceeded the SQG-high at the Basecamp site, and was above the Guideline Value at most upland creeks and rivers and mid-catchment rivers in the Project area. Lower concentrations were generally measured in sediment from the Sepik River and ORWBs. Maximum copper concentrations exceeded SQG-high concentrations at Ekwai Creek (Site W27) and the Lower Frieda River (Site W38A).
- Median chromium concentrations exceeded the Guideline Value at most upland creek and mid-catchment sites.
- There were occasional exceedances of the Guideline Value for median silver, arsenic, mercury, lead, antimony and zinc, mostly in upland creeks and mid-catchment rivers.

Notwithstanding the heterogeneity typically observed in sediments, concentrations of metals were generally similar at the various sites sampled.

Similarly, total nitrogen and total phosphorus concentrations were generally comparable at the limited number of locations where these measurements were undertaken, being about 200 mg/kg total nitrogen and about 350 mg/kg total phosphorus. Organic carbon concentrations in sediments were low, with concentrations less than 0.2% at the five sites where this parameter was measured.

7.2.4 Aquatic Habitats

This section describes the aquatic habitats of the Project area, based on the results from six aquatic habitat assessment events conducted by Hydrobiology in November 2008 to January 2009 and August 2010, and BMT WBM in June/July 2011, December 2011, June 2012, December 2012, April 2013 and November 2017 as described in Appendix 7a. The study area included the Usake/May, Frieda/Nena, Wario and Sepik floodplain catchments all the way to the mouth of the Sepik River. In 2017, sampling took place at eight new sites within the Usake/May, Idam and Horden river catchments in the vicinity of the infrastructure corridor between the mine and Vanimo.

Within these catchments, watercourses comprise different habitat types according to elevation or physical definitions as described in Section 7.2.1, i.e., upland creeks, upland rivers, mid-catchment rivers, lowland rivers and lakes, and ORWBs.

Aquatic habitat assessments were undertaken at sites that were representative of each of the water body types present in the Project area. Figure 7.17 and Figure 7.18 shows most sampling sites with the exception of sites along on the Sepik River downstream of the April River, which can be seen in Appendix 7a. The method for habitat assessment in the 2008 to 2010 surveys included completing a series of proformas that quantified various physical and biological components of in-stream habitat. The data for each of the aquatic habitats are summarised in Table 7.17. The 2011 survey was conducted based on a semi-quantitative sampling method and the 2012, 2013 and 2017 aquatic habitat surveys were conducted based on a modified version of the AusRivAS sampling protocol (Appendix 7a). All surveys, regardless of method, assessed a standard set of parameters including waterbody type, stream condition/integrity, substrate type, percent cover of woody debris, aquatic macrophytes, riparian cover, water depths, wetted widths and various other structural micro habitat characteristics. Physical aquatic habitat differences at the regional scale in the Project area were greater than differences between sites located within similar catchment units and river types, as expected for an area that spans a broad range of altitude and geological formations.

With the exception of Ekwai Creek (Site W27), where sedimentation was observed (which may be due to drilling activities upstream in the catchment), there was no indication of existing mineral exploration-related impacts to the physical aquatic habitat. There was some evidence of naturally occurring AMD-related impacts on aquatic habitat at the upland creek sites W27 and W48, and artisanal mining has been noted in the Ok Binai and Niar river catchments with likely localised sedimentation and water quality impacts.

An important finding of the baseline study was that the upper and middle reaches of the Sepik River catchment had high aquatic habitat integrity and conservation value, most likely because these areas are sparsely populated. However, the composition of the fish community within the Sepik River catchment, particularly in the middle reaches of the Sepik River, has been significantly changed as a result of introduced non-native species.

Table 7.17 Key physical aquatic habitat characteristics

Ecosystem type	Sites	Habitat characteristics
Upland creeks	Basecamp, W27, W48, W102, W41, W43	• Substrate predominantly gravel, cobbles and boulders intermixed with coarse sands. • High gradient. • Low turbidity and high dissolved oxygen. • Tens of metres wide, depths <2 metres. • Lotic/run, riffle, rapid, cascade, waterfall and pool habitat. • Variable riparian shading (low to high dependant of riparian zone).
Upland rivers	W18, W28, S8	• Substrate predominantly gravel, cobbles and boulders intermixed with coarse sands. • High gradient. • Low turbidity and high dissolved oxygen. • Tens of metres wide, depths <5 metres. • Lotic/run, riffle, rapid, cascade, waterfall and pool habitat. • Low riparian shading.
Mid-catchment rivers	W23, S1, S2, S3, S4, S5, S7	• Substrate comprising of a matrix of sands, gravel and cobbles. • Moderate gradient. • Variable turbidity. • Tens to hundreds of metres wide, depths <5 metres. • Lotic/run, riffle, pool and rapid habitat. • Very low riparian shading.
Lowland rivers	W70, W71 W38a, W33 W50, W34 W35, W60 W61, W63, W64, W22, W23, W36, W65, S6	• Mix of vegetation and land use types (cleared/native forest). • Broad or shallow valley or floodplain. • Flat moderately sloped banks. • Riparian zone comprised of trees, shrubs and grasses. Grasses typically dominant cover category at most sites. • Substrates dominated by clays, silts and fine grain sand. • Wetted channel width of tens to hundreds of metres. • Very low riparian shading. • Mostly nil or slight trailing vegetation. • Turbid water clarity.
Off-river waterbodies (ORWBs)	RORWB* W100 W26	• Native wetland and grassland vegetation. • Flat banks. • High riparian vegetation coverage, mostly trees <10 m height. • Substrate material comprised mostly of fine particles (clays, silts and organic matter). • Lake dimensions (size and depth) vary according to season and flow levels. • Low riparian shading. • Mostly nil or slight trailing vegetation. • Moderate macrophyte coverage. • Low water clarity. • Anaerobic/anoxic odours.

* Reference off-river water body.

7.2.5 Aquatic Flora

The aquatic flora of the clear-water upland rivers and creeks is typically dominated by diatoms, periphyton and benthic algae, with larger submerged macrophytes being limited or absent. In the turbid rivers and streams, there is more limited aquatic flora and no macrophytes. In the lakes and ORWBs, marginal, submergent and floating aquatic types of aquatic flora occur, as well as diatoms, periphyton and benthic algae (Plates 7.58, 7.59 and 7.60).

Appendix 7a lists the native and non-native aquatic flora species that are known to occur in the Sepik River catchment. No significant beds of native aquatic flora species were observed at any of the sites during sampling, despite the extensive list of species that has been reported in the catchment, particularly at sites visited during the surveys. For example, Chambri Lake (Site W62)

BMT WBM

Plate 7.58
Aquatic flora in an off-river water body in the study area (Site RORWB)

BMT WBM

Plate 7.59
Aquatic flora at Chambri Lake (Site W62)

BMT WBM

Plate 7.60
Aquatic flora at Lake Diawi (Site W100)

has been reported as having extensive floating macrophytes (Osborne, 1989) but, at the time of sampling in October 2010, water levels were extremely low and no significant macrophytes were observed. Sampling events post-2010 also revealed a lack of macrophytes at this location. The sparseness of native macrophytes at Site W62, the remaining ORWBs and the main channel sites may be attributed to the influence of non-native fish species, as discussed in Section 7.2.6.

Non-native aquatic flora species have been observed throughout the lower catchment, including *Ipomoea aquatica* (Gowep, 2008), which is a semi-aquatic plant known as water spinach, the water hyacinth, *Eichhornia crassipes* (Gowep, 2008; Osborne, 1989) and the floating weed *Salvinia molesta* (Osborne, 1989; Petr, 2000), infestations of which can block waterways from light penetration and boat traffic. *S. molesta* has historically been a major issue within the Sepik–Ramu floodplain, particularly during the late 1970s and early 1980s, although biological control has greatly reduced its impact since then (Osborne, 1989). *E. crassipes* has reportedly been prominent throughout the Sepik floodplain waterways (Osborne, 1989). Large floating beds of *E. crassipes* were observed on the Sepik River near Angoram and Ambunti during the 2010 sampling event as well as subsequent sampling events, otherwise the non-native species were not prevalent during the surveys.

7.2.6 Aquatic Fauna

This section describes the aquatic fauna of the study area (which includes the Project area and surrounding streams and rivers), based on the results described in Appendix 7a. The study area included the Idam/Horden, Usake/May, Frieda/Nena, Wario and Sepik floodplain catchments all the way to the mouth of the Sepik River. Figures 7.18 and 7.25 show the location of most aquatic fauna sampling sites with the exception of sites along the Sepik River downstream of the April River, which can be seen in Appendix 7a.

Macroinvertebrates

The aquatic macroinvertebrate surveys were undertaken by Hydrobiology in 2008, 2009 and 2010, and by BMT WBM in 2011 and 2017. The macroinvertebrate sampling in the 2011 and 2017 surveys used some different methods to those in the 2008 to 2010 surveys. The main differences were the number of sample replicates between the two studies (five in the Hydrobiology study and three in the BMT WBM study) and that the earlier Hydrobiology study supplemented riffle sampling by sampling pool and run habitats, whereas the BMT WBM study sampled edge habitat. While all the results between the studies are not directly comparable, the results of riffle sampling provide a comparable dataset.

Insect larvae and nymphs form the dominant macroinvertebrate communities in the clear, well-oxygenated upland rivers and streams where riverbeds are characterised by coarse gravel or stony substrata. Macroinvertebrates in the upland creeks and rivers were quantitatively sampled by standard kick-net sampling technique in riffle habitats and by sweep-net sampling in pools and runs in the mid-catchment and lowland rivers, where riffles could not be sampled.

Macroinvertebrate taxa can be sensitive to changes in type and abundance of food resources, substrate stability and sedimentation, and for these reasons are used as indicators for monitoring the ecological health of waterways. Certain orders of macroinvertebrates such as Plecoptera, Ephemeroptera and Trichoptera (referred to as PET taxa) are considered to be among the most sensitive to pollution (Fjellheim and Raddum, 1992; Greenberger et al., 2003; Hodkinson and Jackson, 2005). Plecopterans, for example, are particularly sensitive to organic pollution, industrial effluent and heated water, but also have some sensitivity to increased TSS and sediment load, and are thus useful as indicators of ecosystem health (Bunn and Smith, 2002; DERM, 2007). Relative abundance and richness of PET taxa were considered in addition to overall macroinvertebrate abundance and richness. Identification of macroinvertebrate taxa was assigned to family level, which allows calculation of richness to be determined and is not hampered by the poorly known taxonomic definition of PNG aquatic insect fauna.

During the 2008, 2009 and 2010 surveys, 96 macroinvertebrate taxa from ten orders and 64 families were collected in riffle and composite sweep samples (combined) in the mine and FRHEP area. Of these taxa, 38 were PET taxa from 25 families. The other main orders were coleopterans (eight families and 11 taxa), hemipterans (eight families and 11 taxa) and dipterans (11 families and 21 taxa), and these were important components of overall taxon richness. In just the riffle samples, a total of 79 aquatic macroinvertebrate taxa were collected, of which 32 were PET taxa. Summary statistics are given in tables 7.16 and 7.17 for the riffle and sweep samples respectively. The riffle similarity index (S) values for between-habitat comparisons (upland creek and mid-catchment river) of PET taxon richness and total richness were moderate to high (0.50 to 0.70 for 2008/2009 and 2010), but relatively low for the 2009 sampling event (0.25 to 0.44) (Table 7.18). For the sweep samples, similarity index (S) values for between-site comparisons for upland creek sites, mid-catchment river sites and lowland river/floodplain habitat sites ranged between 0 and 0.5, indicating very low or no similarity in taxon composition of catches between sites within each habitat for the two survey periods (Table 7.19).

During the 2011 and 2017 surveys, 68 macroinvertebrates taxa from 21 orders were collected in the Project area in kick-sampling of riffle habitats and sweep samples of edge habitats (combined). The 2011 and 2017 surveys surveyed a greater amount of edge habitats compared to more riffle habitats sampled in the 2008 to 2010 surveys. The most abundant family recorded in the 2011 and 2017 surveys were Veliidae water bugs. Across all the surveys, Chironominae midge larvae were the most abundant taxa. Six taxa were recorded exclusively in December 2011, five taxa were recorded exclusively in June 2011 and 14 taxa were recorded exclusively in November 2017. The remaining 43 taxa were recorded in all three sampling events. In June 2011, a total of 48 taxa and 1,473 individuals were recorded from 67 samples, compared to 39 taxa and 2,206 individuals from 60 samples collected in December 2011 and 49 taxa and 5,286 individuals from 45 samples in November 2017.

A total of 12 PET taxa were recorded in the study area, of which three were Ephemeroptera, with Leptophlebiidae the most abundant and Baetidae the most commonly occurring family. The other main orders were coleopterans (10 taxa), hemipterans (nine taxa) and dipterans (eight taxa), and these were important components of overall taxonomic richness.

Table 7.18 Summary of relative taxon richness and abundance[4] of PET and non-PET macroinvertebrates and similarity indices values for riffle samples in upland and mid-catchment creeks and rivers

Survey	Total PET taxa	Total all taxa	% PET taxa	Total PET numbers	Total all numbers	% PET numbers
2008/2009	13	32	40.6	304	583	52.1
2009	14	35	40.0	67	289	23.2
2010	22	48	45.8	473	663	71.3
June 2011*	8	33	24.2	204	653	31.2
December 2011*	9	29	31.0	177	700	25.3
November 2017*	8	34	24	1458	2,733	53

* Results from 2008 to 2010 are not directly comparable to the 2011/2017 data given the different sampling techniques used.
PET = Plecoptera + Ephemeroptera + Trichoptera.

[4] Richness is the number of taxa; abundance is the number of individuals.

Table 7.19 Summary of relative taxon richness and abundance of PET and non-PET macroinvertebrates and similarity indices values for composite sweep samples in upland, mid-catchment and lowland creeks and rivers

Survey*	Total PET taxa	Total all taxa	% PET taxa	Total PET numbers	Total all numbers	% PET numbers
2008/2009	7	21	33.3	29	82	35.4
2009	15	33	45.4	30	114	26.3
June 2011†	8	48	16.7	277	1473	18.8
December 2011†	9	39	23.1	342	2206	15.5
November 2017†	8	44	18	259	2553	10

* Note: 2010 sampling results not included due to limited number of samples collected.

† Results from 2008 to 2010 are not directly comparable to the 2011/2017 data given the different sampling techniques used.

PET = *Plecoptera + Ephemeroptera + Trichoptera.*

The 2008 to 2010 surveys found that macroinvertebrates were generally more diverse in clear upland creeks and rivers than in the mid-catchment and lowland rivers and ORWBs. During the 2011 and 2017 surveys, consistent with patterns in overall taxa richness, most upland sites had higher PET taxa richness than the mid-catchment and lowland rivers and ORWBs. This is typical of PNG freshwater systems and may be due to the greater variety of available habitats and ample food resources, such as high plant material input from the dense riparian vegetation typical of upland creeks and rivers in the mine and FRHEP area. Upland rivers and creeks have high gradients and structural diversity with generally clear, fast-flowing waters (with episodic turbidity), often with cascades as well as riffles, runs and pools. Many of the taxa at the upland river sites were associated with fast-flowing creeks and rocky substrates, and were filter feeders or have delicate external gills. These taxa are generally considered to be sensitive to sediment, although they appear able, at least in the short term, to tolerate episodic elevated turbidity.

Among the mid-catchment rivers, there was considerable variability in riffle macroinvertebrate abundance and richness during the 2008 to 2010 surveys. The macroinvertebrate taxa present in mid-catchment rivers comprised fewer PET taxa than upland creeks and rivers. For example, some stoneflies (nemourids) and net-spinning caddisflies (hydropsychids) were less abundant in the mid-catchment rivers than the upper creeks and rivers. In addition, four species of mayfly (family Baetidae, which comprises species with delicate external gill filaments that can be sensitive to sediment) were recorded for the upper creeks and rivers, while just one species was recorded in mid-catchment rivers.

The 2011 species richness at upland river, mid-catchment and lowland river sites differed significantly compared to in November 2017. This is not unexpected based on the geographical separation of the sites sampled in 2017 in the vicinity of the infrastructure corridor from the sites sampled in the 2011 surveys in the mine and FRHEP area. Species richness in the 2017 survey was similar between the sites sampled during that survey.

In the ORWBs, there was relatively low macroinvertebrate abundance and richness recorded in the 2008 to 2010 surveys, likely due to reduced habitat diversity and sediment conditions in these reaches. Lowland rivers and ORWBs were dominated by non-biting midges (Chironomidae), which tend to be generalist feeders. Other taxa that were present in very low numbers included one species of dragonfly larvae (Libellulidae), the true bugs (Notonectidae), pygmy backswimmers (Pleidae) and riffle bugs (Veliidae), and five PET taxa, comprising three ephemeropteran taxa and two trichopteran taxa. During 2011, there was little consistent difference in taxon richness compared to other ecosystem types, but greater variability in taxon richness among sites and over time.

In all survey periods, the proportion of combined PET taxa to the total macroinvertebrate community was similar in upland creeks and mid-catchment rivers, but these taxa were less common in lowland rivers and ORWBs, probably due to naturally higher TSS and sediment loads in these areas.

Natural AMD appeared to have affected water quality at Ekwai Creek (Site W27) where pH was less than 5 (see Section 7.2.3). Macroinvertebrate abundance was low at this site relative to most other upland creeks, and exposure to acidified waters was likely to have had both direct and indirect impacts on aquatic fauna, including macroinvertebrates, potentially by damage to gills and exoskeletons or shells from the low pH (Dudgeon, 1999).

Fish and Macrocrustaceans

Fish and macrocrustaceans were sampled in the mine and FRHEP area in 2008, 2009 and 2010 (Appendix 7a). Eight additional sites were surveyed in 2017 along the proposed infrastructure corridor from the mine to the ocean port at Vanimo. Figures 7.18, 7.25 and Appendix 7a show the locations of the fish and macrocrustacean sampling sites (biological sampling sites). Methods used to sample fish and macrocrustaceans included electrofishing, electroseining, bait trapping, netting and hydroacoustic sampling. Electrofishing (both back-pack and boat based) and electroseining (in shallow fast creeks) were the most effective methods of sampling in the shallow clear upland creeks and rivers. Electrofishing in the wider, deeper, mid-catchment and lowland rivers and ORWBs was limited by the range of the generated electric field. Bait trapping and netting (panel nets and gill nets) were therefore carried out in these habitats. Hydroacoustic sampling was also used for providing estimates of standing fish stock, biomass and distribution in the ORWBs.

Fish

Prior to the present surveys, existing information on the freshwater fish of the Sepik River catchment was from studies by Allen and Coates (1990), who conducted surveys of the freshwater fishes of the Sepik River between 1978 and 1985, and Shearman (1999). The dominant families included the catfish (Ariidae and Plotosidae), rainbow fishes (Melanotaeniidae), gudgeons (Eleotrididae) and gobies (Gobiidae). Many of the species were restricted to either the intermontane trough comprised of the Markham, Ramu, Sepik and Mamberamo catchments or to the Sepik and Ramu rivers, which connect after flooding rains, particularly during summer months, forming the Sepik-Ramu River system.

Prior to 1960, three non-native species were also present in the Sepik-Ramu River system: the eastern gambusia (*Gambusia (affinis) holbrooki*), introduced for mosquito control; the Mozambique tilapia (*Oreochromis (Tilapia) mossambicus*); and the European carp (*Cyprinus carpio*), imported for aquaculture development. Tilapia (Plate 7.61) and carp were accidentally released from aquaculture facilities and rapidly spread through the mid- and lower reaches of the Sepik-Ramu River system, including floodplain habitat (Coates, 1985; Coates and Ulaiwi, 1995). Between 1990 and 1997, more non-native species were introduced into the lower and middle Sepik River and ORWBs on the floodplain as part of the Sepik River Stock Enhancement (SRSEP) and FISHAID programs. The aim of the FISHAID project was to enhance the sources of protein for people in these catchments and to generate income.

The deliberate introductions were conducted with reference to the International Council for the Exploration of the Sea and the European Inland Fisheries Advisory Commission code of practice for the introduction and transfer of aquatic organisms (Coates, 1993; Kolkolo, 2003) to ensure that selection of species occurred via a reviewed process that minimised the risk of adverse environmental consequences.

Overall, the FISHAID and SRSEP projects culminated in the release of eight species of African, Asian and South American fish into selected creeks, rivers and oxbow lakes throughout the Sepik-Ramu River system. The following species were stocked in the lower Sepik River and associated floodplain habitat:

- Java carp (*Barbonymus gonionotus*).
- Sabálo, known throughout the Sepik River catchment as rubber mouth or Emily's fish (*Prochilodus argenteus*).
- Pacu, known throughout the Sepik River catchment as the bolkata (*Piaractus brachypomus*).
- Rendall's tilapia (*Tilapia rendalli*).

The following three species were released into the upper catchment of the Ramu River:

- Snow trout (*Schizothorax richardsonii*).
- Golden mahseer (*Tor putitora*).
- Chocolate (or copper) mahseer (*Neolissochilus hexagonolepis*).

The giant gouramy (*Osphronemus goramy*), which was introduced to southern PNG prior to the FISHAID project, was stocked in a single remote lake in the Ramu catchment.

In addition to these species, the walking catfish (*Clarias batrachus*) has also been introduced into New Guinea in the Lake Sentani region and has subsequently spread by human translocation and natural dispersal.

A number of coordinated investigations on the impact of the introductions to native fish fauna have indicated some significant declines in native species abundance and richness, particularly in tributaries and ORWBs.

During the three characterisation sampling surveys conducted in 2008, 2008/2009 and 2010, 33 native and seven non-native fish species were collected from upland creeks and rivers, mid-catchment and lowland rivers and ORWBs in the Sepik River catchment. Approximately 40% of the known fish fauna within the study area were observed in the characterisation study. Non-native species were recorded throughout the study area and dominated catches in the lowland rivers and ORWBs, and comprised 75% of the total number of individuals in ORWBs.

A total of 35 freshwater fish species (28 native and seven non-native) were recorded during the 2011 sampling events and a total of 10 species were recorded in 2017 (9 native and one non-native). Non-native species dominated the catch during both of the 2011 events, comprising 50 to 80% of individuals captured, although they only comprised 20 to 40% of the species captured. The most abundant species overall was the non-native Java carp (*Barbonymus gonionotus*), comprising 44% and 32% of individuals collected in June and December, respectively. In 2017 at sites sampled along the infrastructure corridor, 99% of the individuals captured were native species. The dominance of native species during the November 2017 survey reflects the habitat types surveyed, with native species tending to dominate the communities within the upland to mid-catchment sites (compared to lowland rivers and ORWBs).

Over the three survey campaigns, and including previous literature, 60 native species and nine non-native species have been reported in the Sepik River catchment.

Lowland rivers, mid-catchment rivers and ORWBs had a relatively similar proportion of native versus non-native species. No non-native species were collected from upstream habitats.

Site summaries for native and non-native species abundance during the 2008 to 2010 sampling surveys are presented in Figure 7.23.

Site summaries for native and non-native species abundance during the 2011 and 2017 sampling surveys are presented in Figure 7.24. The proportional representation of native fish such as *Oxyeleotris heterodon*, *Ophieleotris aporos* and ariid catfish (*Brustiarius nox, Brustiarius solidus, Potamosilurus velutinus* and *Sciades utarus*) was found to be substantially lower in lowland rivers compared to the last major fish survey in the mid-1980s.

To date, nine species of non-native fish have been recorded in the study area, with the majority of species introduced for improving fish stocks for human consumption. The most abundant non-native species are:

- Rubber mouth (*Prochilodus argenteus*).
- Java carp (*Barbonymus gonionotus*).
- Pacu (*Piaractus brachypomus*).
- European carp (*Cyprinus carpio*).

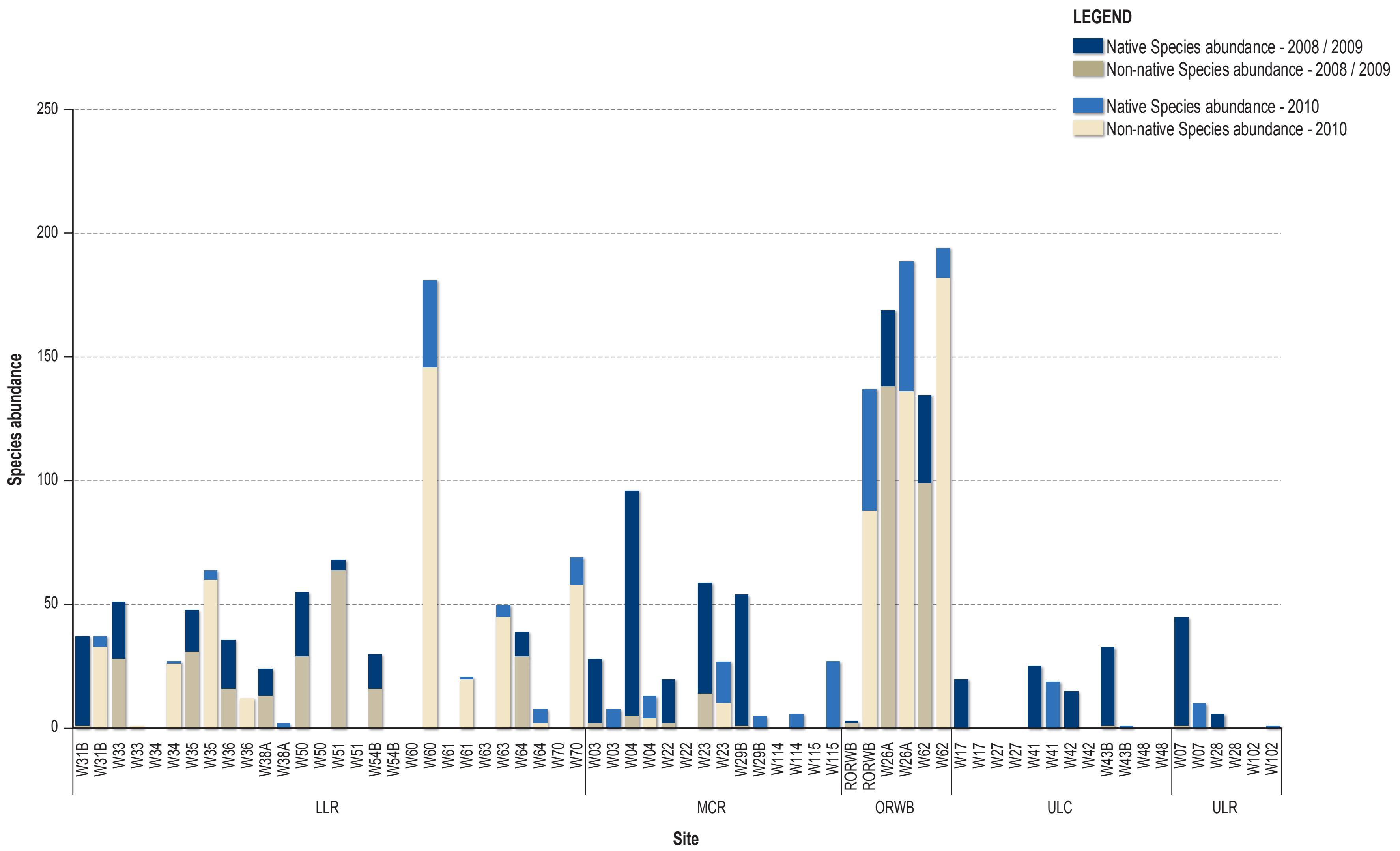
Carp modify their environment (disturbing the sediments, which results in increased turbidity and habitat simplification) to suit their conditions, often resulting in sub-optimal conditions for native species.

Figures 7.25 and 7.26, presenting species richness in the 2008 to 2010 surveys and 2011 and 2017 surveys, respectively, show a decreasing trend in species richness with increasing elevation and decreasing catchment area, following the general pattern for fish river diversity. A similar decrease in native species abundance was also observed. This decrease in richness and abundance also includes the introduced species, which may be due to lower water temperatures or barriers to upstream movement such as steep, fast flowing channels and waterfalls in the upstream areas. Species introduced as part of the FISHAID project to inhabit cooler water of mid-catchment and upland habitats, such as the golden mahseer (*Tor putitora*), chocolate mahseer (*Neolissochilus hexagonolepis*) and snow trout (*Schizothorax richardsonii*), were not collected within the Project area.

Hydroacoustic sampling in the ORWBs at Site W26 (Lake Warangai) and Reference ORWB (ROWRB) enabled the visualisation of the distribution of fish biomass in these water bodies and a quantitative estimate of fish biomass per unit area. Average fish biomass in Lake Warangai and RORWB was similar and unevenly distributed in the lakes, with high-density aggregations occurring in patches. The information is mainly of use for ongoing monitoring.

Species of Conservation Significance

Seventeen species of fish that have been reported in the Sepik River are of conservation significance, due either to their assessment as threatened or potentially threatened species or because of their restricted range (endemism). Three species previously reported in the Sepik River are listed in the IUCN red list: the spinach pipefish (*Microphis spinachioides*), assessed as Data Deficient; the freshwater gudgeon (*Eleotris aquadulcis*), listed as Near Threatened; and the common sawfish (*Pristis pristis*, formerly *Pristis microdon*), listed as Critically Endangered (IUCN, 2016). Neither the spinach pipefish nor the sawfish were collected during the 2008 to 2010, 2011 or 2017 sampling events. However, the freshwater gudgeon was caught at two locations; within an ORWB (W39); and a location upstream of the confluence of the Sepik and Frieda rivers during the early 2009 surveys.



Source:
BMT WBM, 2016

coffey
A TETRA TECH COMPANY

Date:	29.08.2018
Project:	754-ENAUABTF11575B
File Name:	11575_11_F07.23_GRA

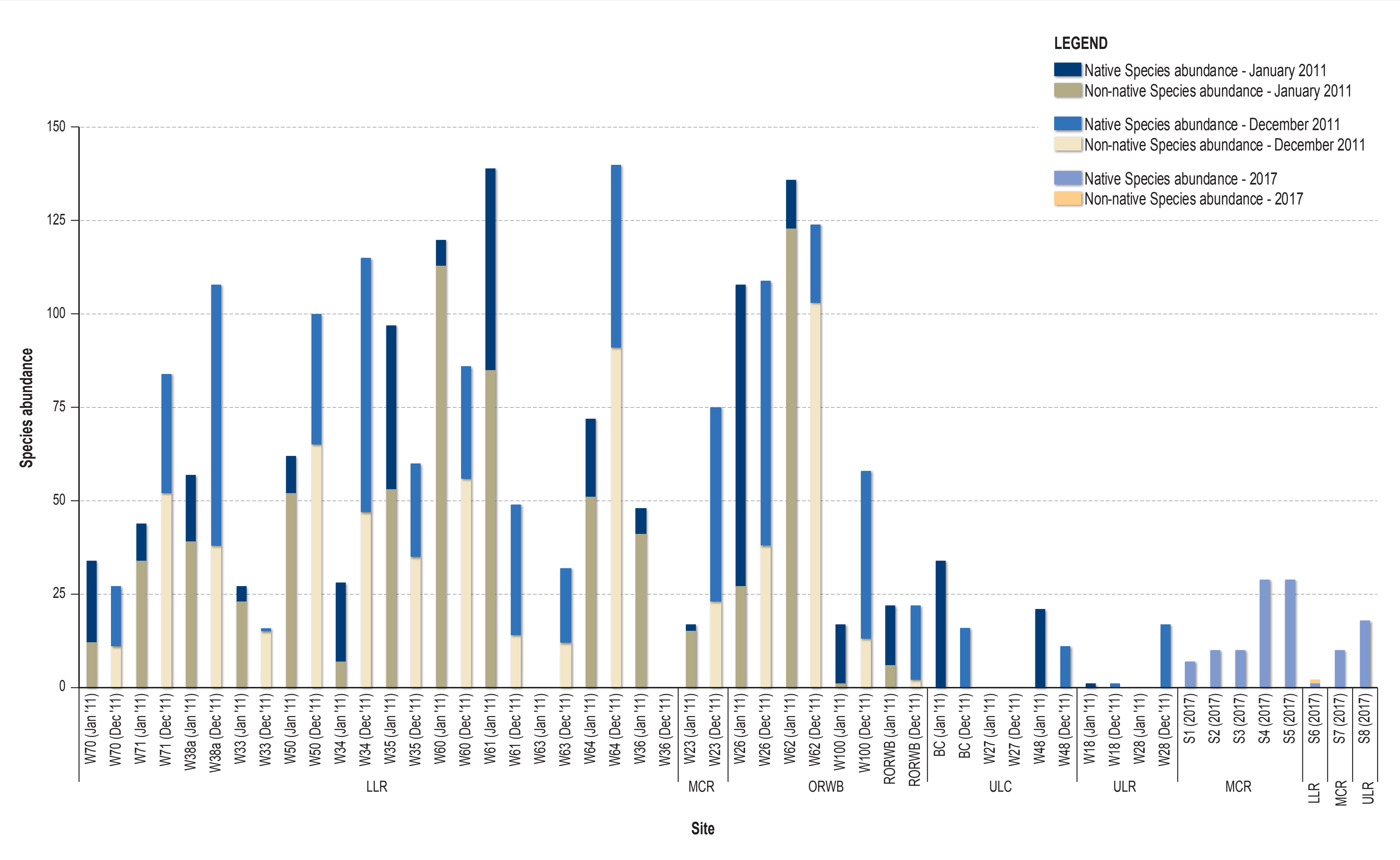
Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Native and non-native fish species abundance per site sampled in the Sepik River key catchment habitat types (2008 – 2010)

Figure No: 7.23



Source:
BMT WBM, 2018

coffey
A TETRA TECH COMPANY

Date: 29.08.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.24_GRA

Frieda River Limited

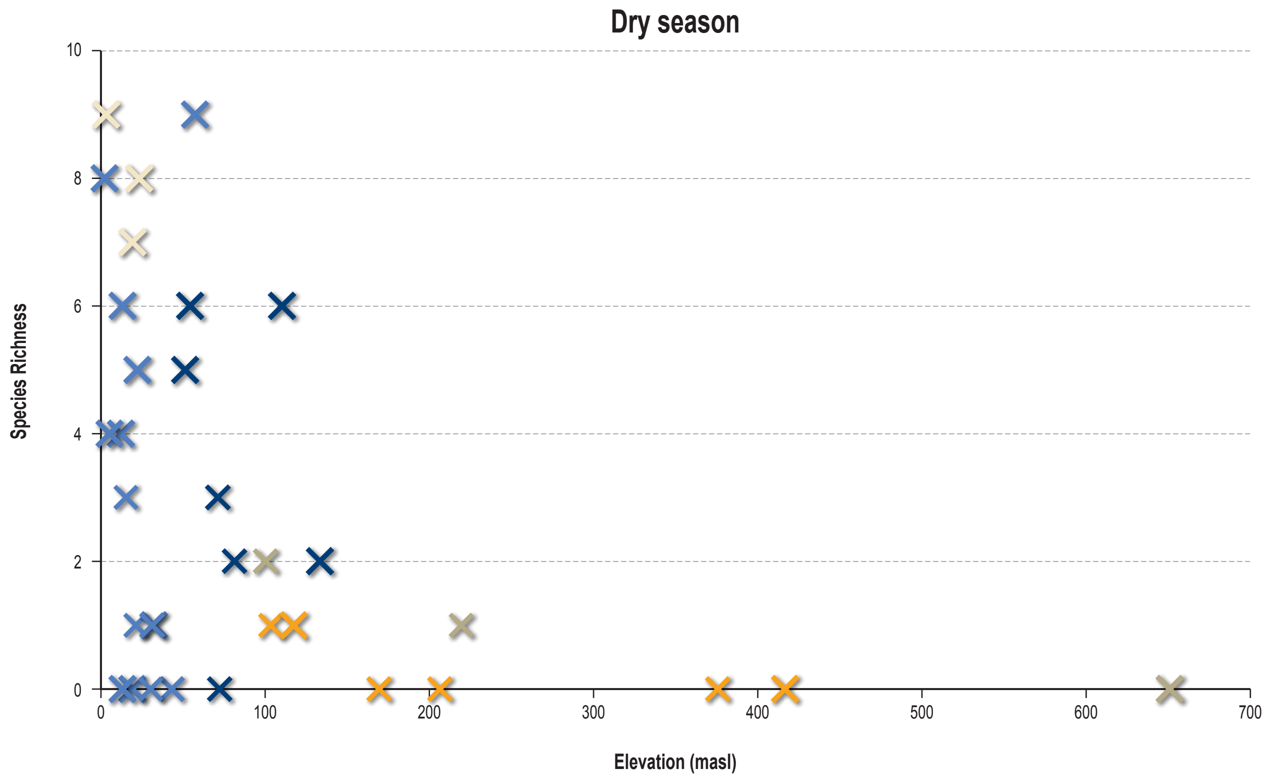
Sepik Development Project

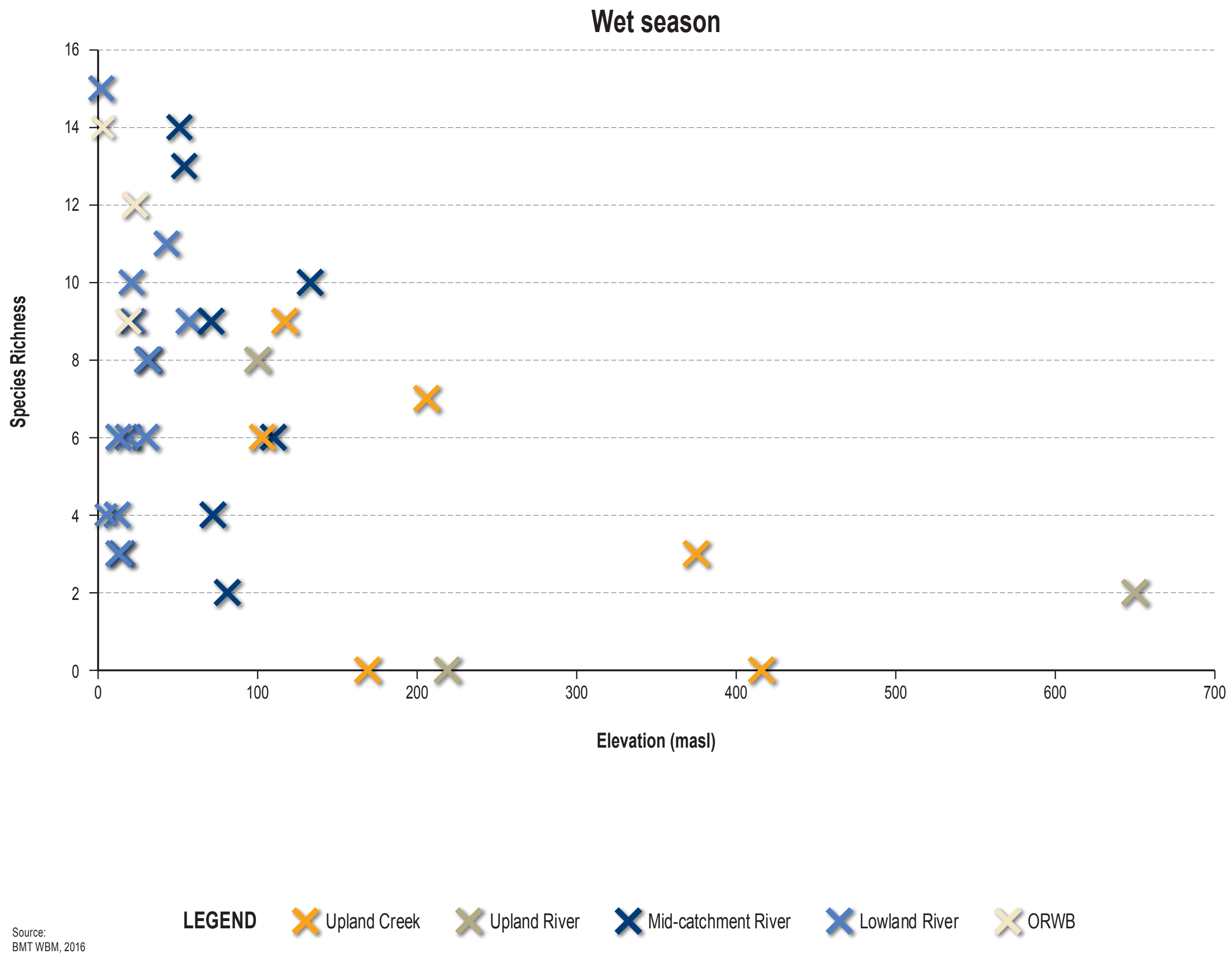
FRIEDA RIVER

Native and non-native fish species abundance per site sampled in the Sepik River key catchment habitat types (2011 and 2017)

Figure No: 7.24

AI Reference: 11575_11_GRA018.ai_3

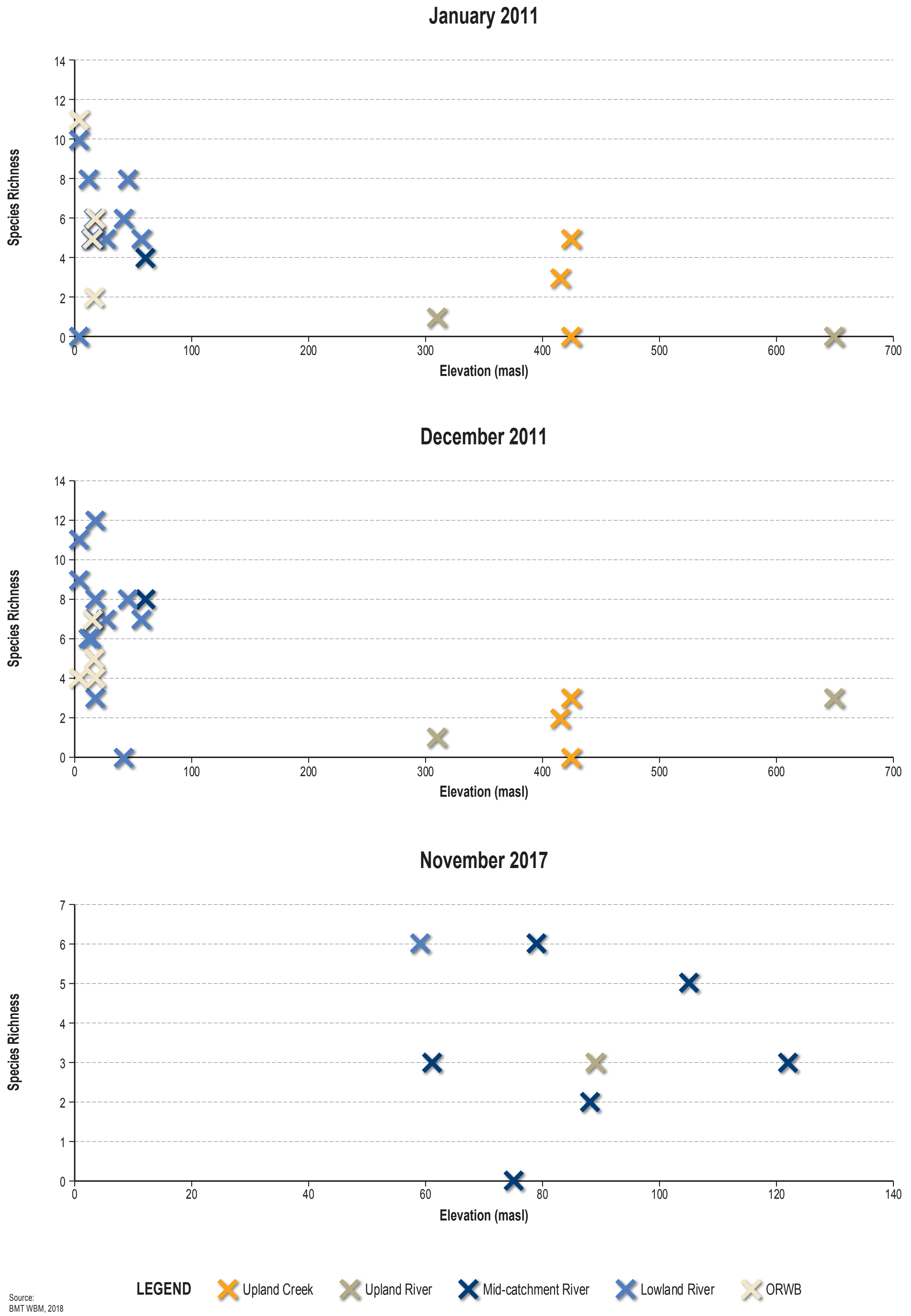




Source:
BMT WBM, 2016

coffey A TETRA TECH COMPANY	Date: 29.08.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.25_GRA	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Changes in fish species richness per site for key catchment habitat types in the Sepik River catchment (2008 – 2010)	Figure No: 7.25

AI Reference: 11575_11_GRA023.ai_2



Source:
BMT WBM, 2018

coffey A TETRA TECH COMPANY	Date: 29.08.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.26_GRA	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Changes in fish species richness per site for key catchment habitat types in the Sepik River catchment (2011 and 2017)	Figure No: 7.26

AI Reference: 11575_11_GRA020.ai_2

The common sawfish is unlikely to inhabit the Project area, as this species favours large turbid rivers away from its typical inshore and estuarine habitat. It is likely to occur in the downstream reaches of the Sepik River.

The presence of the spinach pipefish and the freshwater gudgeon is possible in the study area. The former species may occur in ORWBs in the study area while the latter species is mainly found in oxbow lakes, only in the Sepik-Ramu River system.

A further 15 species of fish have also been recorded that are either endemic to northern New Guinea or locally endemic to the Sepik-Ramu River system. Thirteen of these species were recorded in one or more of the 2008 to 2010, 2011 or 2017 survey events.

Other Aquatic Fauna

In addition to the fish, two New Guinea-endemic species of freshwater turtles are known to occur in the Sepik-Ramu River system: the Northern New Guinea giant softshell turtle (*Pelochelys signifera*) and Schultze's snapping turtle *(Elseya schultzei).*

Schultze's snapping turtle, listed as Least Concern under IUCN, was observed in a small tributary of the Frieda River (Frieda Bend Site). It was also reported as being abundant at a number of sites in the study area by villagers in 2011.

Northern New Guinea giant softshell turtle (*Pelochelys signifera*) is listed as Vulnerable under IUCN. This species was not observed during the aquatic sampling events. However, during the terrestrial biodiversity surveys in 2017 a carapace (turtle hard upper shell) was observed in a hunting hut on the Idam River and a juvenile was shown to the survey team by the villagers from Idam 1. It was also reported as being abundant at a number of sites in the study area by villagers in 2011. The species favours main channel and off-river ecosystem types.

Two crocodiles, the freshwater crocodile (*Crocodylus novaeguineae*), and the saltwater crocodile (*C. porosus*), occur in the Sepik River system. While neither species is listed as threatened by the IUCN, both are of local conservation significance and are listed by CITES (Appendix II). The freshwater crocodile, while relatively common, is endemic to New Guinea and therefore has a restricted distribution. The saltwater crocodile occurs throughout the Indo-Pacific, from India to Southeast Asia, Australasia and tropical Pacific islands, although it has recently experienced major declines in nesting activity in some parts of its range. Within the middle-upper Sepik River region, Sine (2010) reports that, based on helicopter surveys of the Sepik River wetlands, monitoring data for the period 1981 to 2007 for *C. novaeguineae* and 1982 to 2010 for *C. porosus* 'clearly depicts a steady increasing nesting trend for both species'. Nest counts range from 71 in 1992 to 132 in 2007 for *C. noveaguineae*, and from 30 in 1983 to 97 in 2010 for *C. porosus*.

C. porosus was recorded at three locations (in the lower May River and in the lower Sepik River near Timbunge and Angoram) during the 2008 to 2010 surveys, but was not observed during the 2011 or 2017 surveys. *C. novaeguineae* was not observed during any of the surveys.

Crocodiles, especially the saltwater crocodile, are important to the local economy and a number of documents sourced from Mainland Holdings Ltd in Lae, PNG, discuss the commercial significance of the crocodile egg harvest. They are also of great cultural and religious significance to people in the Sepik region. The crocodile is a key totemic animal symbolising strength and power and plays a central role in male initiation ceremonies (Simmons, 2010).

The main recent threats to the local population have been over-collection of eggs and live animals, hunting and habitat loss (Shearman, 1999; Cox et al., 2006; Solmu, 2009; Sine, 2010). Another threat may be loss of nesting habitat (bank and floating vegetation) potentially from grazing by introduced herbivorous fish, as noted by Solmu (2009). If this is the case, the establishment of populations of the introduced herbivorous Java carp and the detritivorous Emily's fish could further reduce this nesting habitat and threaten breeding success of the crocodiles. Following the FISHAID introductions, extensive areas of submerged and floating mat vegetation in Sepik floodplain habitats have disappeared. According to Sine (2010), the continued loss of this habitat is a potential threat to crocodile egg production and recruitment throughout the Sepik River, with grazing by non-native herbivorous fishes on interlocking root systems of floating vegetation mats resulting in these mats breaking up and being swept downstream.

Aquatic Biota Tissue Metal Concentration

Tissue samples were taken from species that were found to be widespread in the study area, easily collected and determined to be a common food source of the local people, during the 2008 to 2010, 2011 and 2017 sampling campaigns. These included fourteen species of native fish (*Brustiarius solidus, Brustiarius nox, Sciades uterus, Neoarius coatesi, Potamosilurus coatesi, Potamosilurus velutinus, Glossamia gjellerupi* (Plate 7.62)*, Oxyeleotris heterodon, Chilatherina sp., Melanotaenia affinis, Zenachopterus kampeni, Arius spp., Glossogobius koragensis* and *Giuris margaritacea*), two prawns (*Macrobrachium* sp. and *Macrobrachium mammillodactylus*) and three non-native species (*Barbonymus gonionotus, Piaractus brachypomus* and *Prochilodus argenteus*).

Where possible, tissue samples were taken from up to five specimens of each species per site. Hind body samples were taken from smaller fish specimens and flesh (dorsal muscle), gill and liver samples were taken from larger fish specimens, where possible.

Sample sites were grouped by catchment unit and river type. Metal concentrations in tissues were compared against generally expected levels (GELs) as documented in ANZFA (2001) and human health protection guideline values (i.e., maximum levels as documented in FSANZ (2015)) for fish and prawns, in order to provide some context.

The Food Standards Australia New Zealand guide (FSANZ, 2015) helps to identify a range of contaminant levels (i.e., GELs) that would normally be expected in particular foods. GELs are guideline values based on analysis of a large number of samples of the edible portions fish/ macro-crustaceans (and other foods not relevant to this study). GELs describe both median and the 90th percentile of results. For the purposes of this study, comparisons of 90th percentile values were used. The Australia New Zealand Food Authority (ANZFA, 2001) document specifies the maximum levels (MLs) of contaminants and natural toxicants permitted in the foods listed in the standard. In comparison to GELs, MLs are levels above which an unacceptable risk to human health is perceived. MLs are set for lead, arsenic and mercury, whereas GELs are available for antimony, copper, selenium and zinc in a variety of aquatic biota tissue types.

The United States Food and Drug Administration (US FDA, 2013) food code and associated Fish and Fishery Products Hazards and Controls Guidance (US FDA, 2011) and Food and Agriculture Organisation of the United Nations and World Health Organisation (FAO and WHO, 2006) Codex standards for the protection of human health have also been consulted.

Generally expected levels (ANZFA, 2001; FSANZ, 2015 and FAO and WHO, 2006) for metals were exceeded at the following sites in 2008 to 2010 (see figures 7.15 and 7.17, and Appendix 7a for locations):

- W64 (Sepik at Angoram 2008) – one *Barbonymus gonionotus* flesh sample (3.4 mg/kg) was found to be above the selenium GEL (2 mg/kg).

- RORWB (Reference ORWB 2010) – one *Brustiarius solidus* flesh sample (18 mg/kg) was found to be above the zinc GEL (15 mg/kg).
- W33 (Sepik River Upstream of May River Junction 2008) – one *Sciades utarus* flesh sample (34 mg/kg) was found to be above the zinc GEL (15 mg/kg).
- W26 (Lake Warangai) – mercury concentrations (0.84 mg/kg) were higher than ANZFA food standards/WHOFAO Codex standards (0.5 mg/kg) in the flesh of one specimen of *Brustiarius nox*.
- W35 (Sepik at Kubkain) – mercury concentrations were higher than ANZFA food standards/WHOFAO Codex standards (0.5 mg/kg) in the flesh of one specimen of *Potamosilurus velutinus*.

Human health guidelines and GELs (ANZFA, 2001; FSANZ, 2015; US FDA, 2013; FAO and WHO, 2006) for metals were exceeded at the following sites in 2011 and 2017:

- Copper concentrations exceeded ANZFA food standards (2 mg/kg) in three gill tissue samples of *Barbonymus gonionotus* (two samples in mid-river and one from the Sepik River).
- Mercury concentrations of one flesh sample at a lowland site in the Sepik River equalled the ANZFA food standards/WHO and FAO Codex standards (0.5 mg/kg) and one fish hind body sample at Site S2 (Upper May River at Hotmin Mission) exceeded the guidelines.
- Lead concentrations exceeded WHO and FAO Codex standards (0.3 mg/kg) but lower than ANZFA food standards (0.5 mg/kg) in one gill tissue sample from each of the Sepik and Frieda rivers.
- The majority of sites had concentrations of zinc in fish tissue samples over the ANZFA food standards (15 mg/kg). Zinc concentrations in Ariidae catfish gills also exceeded the ANZFA food standards of 15 mg/kg. The highest zinc concentrations were recorded in lowland sites.

Tissues from fish and macrocrustaceans collected at all other sites were below the human health guidelines and GELs. The detection of mercury concentrations in fish flesh above guideline values in a small number of samples does not necessarily constitute a human health risk, as this risk can only be assessed by studying overall dietary exposure of the local population to mercury.

Macrocrustaceans

During the 2008, 2009 and 2010 surveys, fifteen species of freshwater prawns from two families were collected. These consisted of nine *Macrobrachium* species (Plate 7.63), with juvenile *Macrobrachium* assigned to '*Macrobrachium* sp. (juv.)', and six *Caridina* spp. (Atyidae).

The majority of species and individuals were collected from lowland rivers (seven *Macrobrachium* species, comprising 52% of total abundance) and mid-catchment rivers (six species comprising 27% of total abundance) with decreasing species richness and abundance with increasing elevation. Only four species (one *Macrobrachium* sp. and three *Caridina* spp.) were reported from upland rivers and creeks, representing only 17% of total abundance. *Macrobrachium mammilodactylus*, *M. equidens, M. rosenbergii* and *M. weberi* were found only in lowland rivers, reflecting a preference for lowland environments.

BMT WBM

Plate 7.61

Nile tilapia (Oreochromis niloticus) captured in the Sepik River at Angoram (Site W64)

BMT WBM

Plate 7.62

Gjellerups mouth almighty (*Glossamia gjellerupi*) captured from Kaugumi Creek (Site W70)

BMT WBM

Plate 7.63

Macrocrustacean (*Macrobrachium rosenbergii*) captured from Lake Warangai (Site W26)

During the 2011 and 2017 surveys, seven macrocrustacean species from three families were collected during the three sampling events. Species were dominated by freshwater prawns (*Palaemonidae*, *Macrobrachium* spp.), with additional small numbers of the freshwater crab (Holthuisana sp.) and freshwater shrimp (*Atyidae*, *Caradinia* sp.).

Similar to the 2008, 2009 and 2010 surveys, the majority of macrocrustacean species were collected from lowland rivers (76% of total abundance) and species richness decreased with elevation.

7.2.7 Nearshore Marine

This section describes the physical and biological characteristics of the nearshore marine environment at the proposed location of the Vanimo Ocean Port, located on the north coast of mainland PNG, and is based on the results of a nearshore marine characterisation study completed by BMT WBM (Appendix 12a). The objectives of the survey, undertaken in November 2017, were to: characterise the nearshore marine environment, including identification of any critical or sensitive habitats; characterise the existing water and sediment quality; and describe existing metal/metalloid concentrations in the tissues of selected aquatic fauna species.

The nearshore marine characterisation survey involved habitat mapping using remote sensing and ground-truthing, baited remote underwater video (BRUV), water quality and sediment quality sampling at sites in Dakriro Bay, fish tissue metal analysis and gathering anecdotal information from the community.

The nearshore marine study area at Dakriro Bay included the nearshore marine and coastal areas shown in Figure 7.27. These areas contain intertidal, tidal, shallow marine and reef zones. Plates 7.64, 7.65 and 7.66 show representative areas in Dakriro Bay.

Background

Dakriro Bay is a natural ebayment between two peninsulas on which Lido Village (to the west) and Cis Point (to the east) are located. The peninsulas comprise accreted coralline[5] and fluvial[6] sediment and the coastline in the bay consists of fringing coral reefs and sandy beaches. The fringing reefs include a reef flat (the zone found closest to the shore), a crest (the highest part of the reef) and a reef slope (the area of reef that is the farthest away from the shore) as shown in Figure 7.28. The shoreline profiles of all beaches surveyed are gradual and lack any significant dune formations. The bathymetry gently slopes downgradient from the shoreline to the centre of the harbour, which has a maximum depth of approximately 50 m. With the exception of the fringing reefs, there were no coral reefs charted within Dakriro Bay.

Based on the collected data and field observations, reefs throughout the study area appear to be heavily affected by anthropogenic activities, with stressors including thermal bleaching, sea-level rise, over-fishing, physical damage, rubbish and low water quality as a result of stormwater and deforestation. The eastern side of the harbour is used extensively by logging companies and commercial fishing fleets as an anchorage and port.

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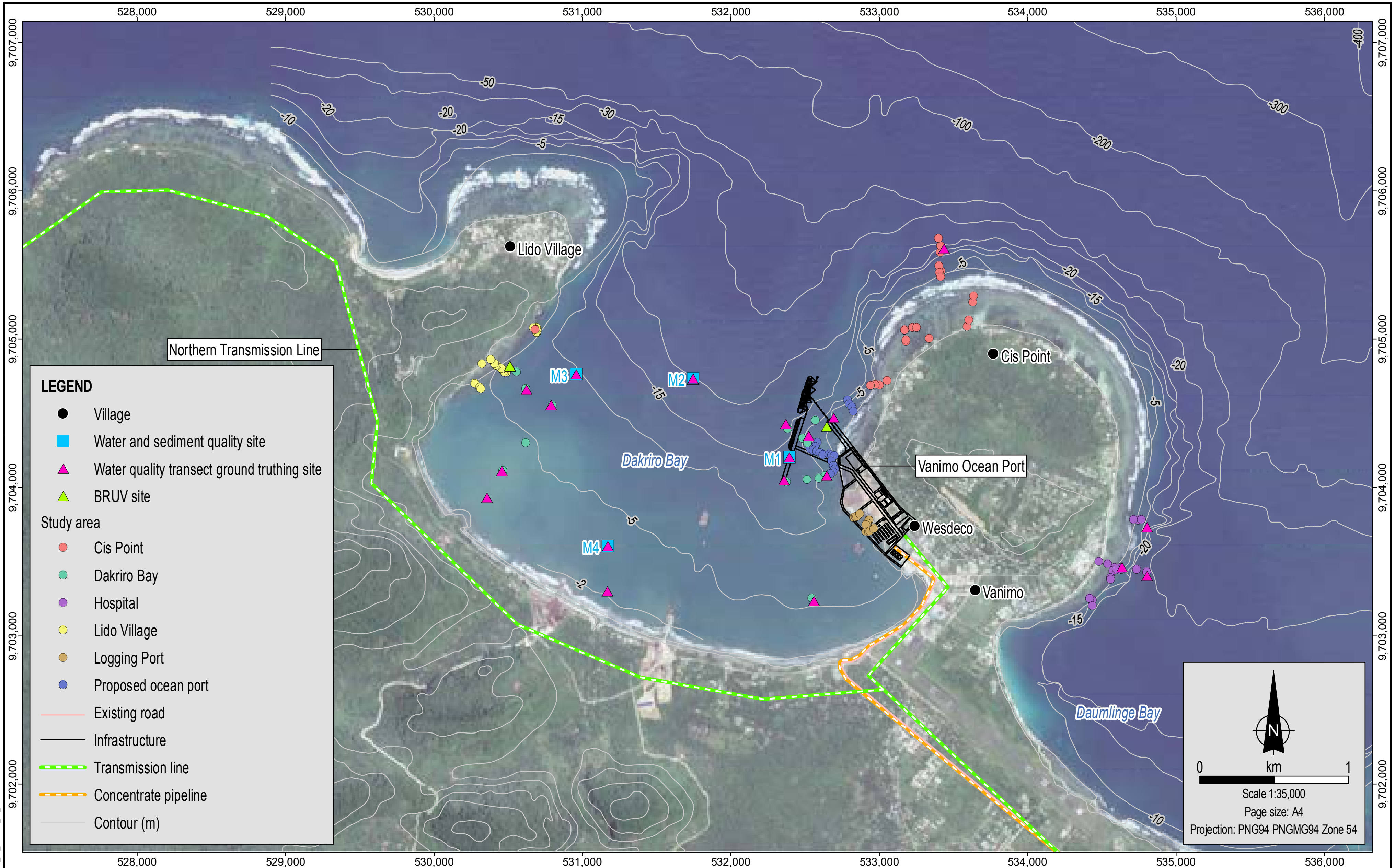
[5] Sediments derived from coral reefs that has accumulated in an area.

[6] Sediments transported and deposited by rivers.



Source:
Neashore marine data from BMT WBM.
Infrastructure and roads from FRL.
Villages from FRL and Coffey.
Imagery from Google Earth (DigitalGlobe captured 14 December 2014).

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Vanimo nearshore marine sampling sites

Figure No: 7.27

Coffey

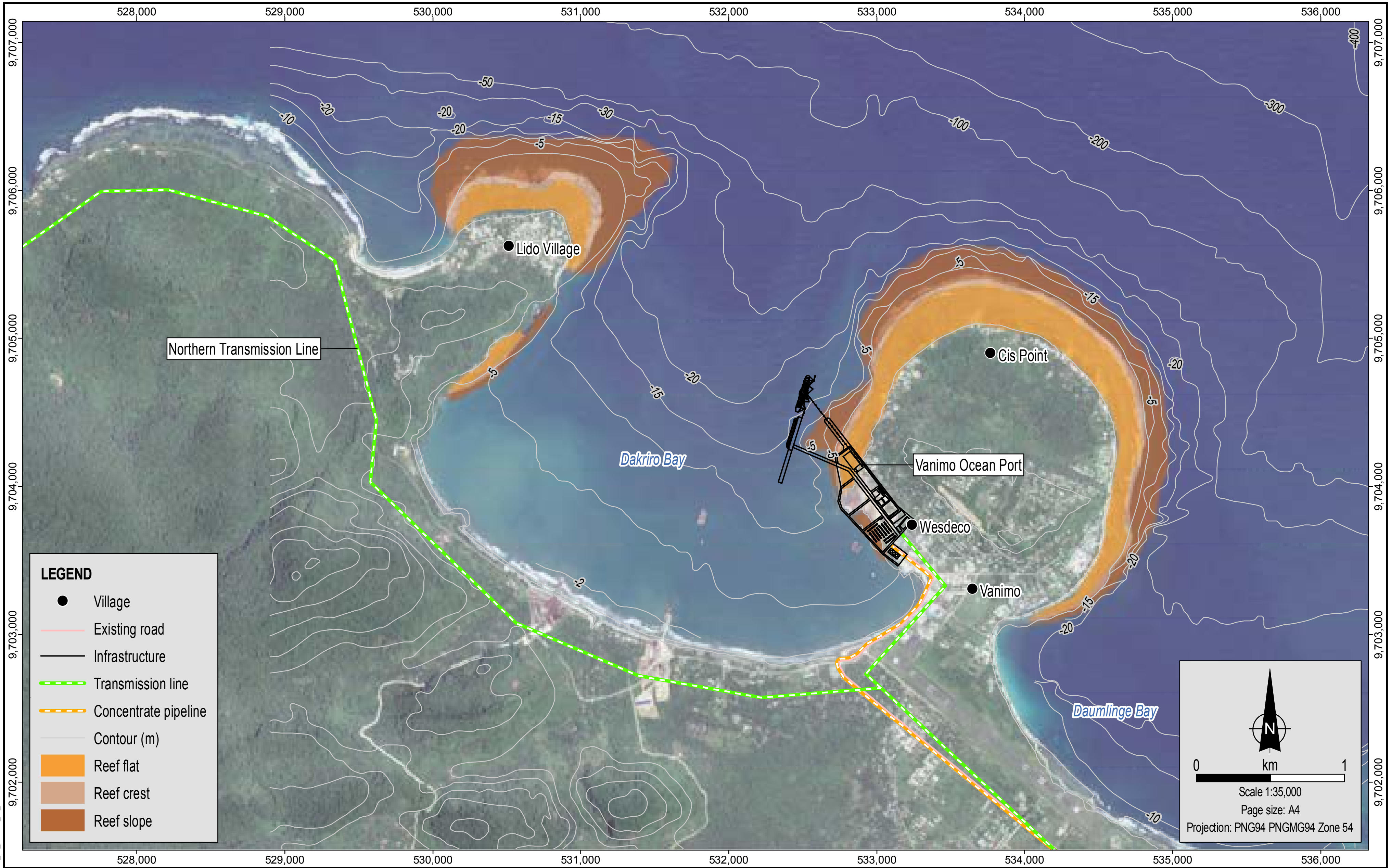
Plate 7.64
View of Dakriro Bay from Cis Point

Coffey

Plate 7.65
Shoreline adjacent to Wesdeco

BMT WBM

Plate 7.66
Rubbish along the shoreline at Vanimo



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Bathymetry and reef zones in the nearshore marine study area

Figure No: **7.28**

The mouth of the Nemayer River, located 16 km to the east of Vanimo, is the nearest large source of fluvial sediment to Dakriro Bay. While wet-season plumes at the time of the survey did not visually extend to Vanimo, longshore drift associated with predominantly easterly winds, north-easterly swells and westerly currents offshore are likely to transport some of this sediment into Dakriro Bay. Dakriro Bay also receives freshwater, sediment and pollutants from several small tributaries and open drains from Vanimo town centre.

The primary wave energy comes from either the north or north-east, with the largest and most consistent waves arriving from the north-east. Mean significant wave height varies between 1 to 1.5 m, with occasional mean significant wave height increasing to 1.5 to 2.5 m. Vanimo is frequented by surf tourists, primarily between November to March. Surfing generally occurs at four locations including the north-west peninsula of Dakriro Bay, the town beach, north of Cis Point and at the section of reef within the ocean port footprint. The shoreline near the Wesdeco settlement and proposed ocean port location, logging port area and near the hospital (sites labelled as ‘Hospital’ on the east side of Cis Point in Figure 7.27) appears to be eroding in places due to large wave action and high tidal events.

Fishing activities in the nearshore marine study area include artisanal fishing (for direct consumption), local fishing (for sale at the market) and commercial fishing. Fishing activities are described in further detail in Section 7.3.7.

Water Quality

Surface water quality samples, for laboratory analysis, were collected at the beginning of the north-west monsoon (wet) season from four sites within Dakriro Bay (Site M1 to Site M4), as shown in Figure 7.27. *In situ* data at each site was also recorded. The *in situ* and laboratory water quality results for selected parameters are shown in Table 7.20. Exceedances of PNG ambient marine water quality standards are shown in bold text.

Table 7.20 Nearshore marine water quality for selected parameters

Parameter	Units	Survey sites				PNG Schedule 1*	ANZECC/ ARMCANZ Trigger Value†
		M1	M2	M3	M4		
In situ parameters							
Temperature	°C	29.7	29.9	29.7	29.9	-	-
Electrical conductivity	µS/cm	52,302	52,618	52,118	52,152	-	-
Salinity	Ppt	34.3	34.5	34.2	34.2	-	-
pH	-	8.17	8.21	8.18	8.18	no alteration	-
Turbidity	NTU	1.5	0.8	2.3	3.3	no alteration	
Dissolved oxygen	% sat	93.9	98.1	97.5	97.9	>25	-
TSS	mg/L	6.0	6.2	6.1	6.1	-	-
Dissolved metals/metalloids							
Aluminium	mg/L	<0.005	<0.005	<0.005	<0.005	-	-
Arsenic	mg/L	0.0013	0.0015	0.0013	0.0012	0.05	-
Barium	mg/L	0.004	0.005	0.004	0.005	1	-

Table 7.20 Nearshore marine water quality for selected parameters (cont'd)

Parameter	Units	Survey sites				PNG Schedule 1*	ANZECC/ ARMCANZ Trigger Value†
		M1	M2	M3	M4		
Dissolved metals/metalloids (cont'd)							
Boron	mg/L	**4.32**	**3.5**	**4.28**	**3.99**	2	-
Cadmium	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	0.001	0.0007
Chromium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	0.01	0.0044
Cobalt	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.001
Copper	mg/L	<0.001	<0.001	<0.001	<0.001	0.03	0.0013
Iron	mg/L	<0.005	<0.005	<0.005	<0.005	1	-
Mercury	mg/L	<0.00004	<0.00004	<0.00004	<0.00004	0.0002	0.0001
Manganese	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	2	-
Nickel	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	1	0.007
Lead	mg/L	<0.0002	<0.0002	<0.0002	<0.0002	0.004	0.0044
Selenium	mg/L	0.003	0.003	0.004	0.003	0.01	-
Silver	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	0.05	0.0014
Tin	mg/L	<0.005	<0.005	<0.005	<0.005	0.0005	-
Vanadium	mg/L	0.0016	0.0018	0.0017	0.0016	-	0.1
Zinc	mg/L	<0.005	<0.005	<0.005	<0.005	5	0.015

* Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002.

† ANZECC/ARMCANZ (2000) trigger value for the protection of 95% of marine aquatic species.

Surface water quality was typical of marine waters and similar across sampling sites, characterised by warm waters (~30°C) with low concentrations of suspended sediments (TSS of 1 to 5 mg/L and turbidity of 0.8 to 3.3 NTU), nutrients and metals/metalloids. Hydrocarbons were not detected. The pH was consistently alkaline (8.2) across all sites and through the water column. Dissolved oxygen concentrations were between 93% and 98% saturated, and between 6.0 mg/L and 6.1 mg/L.

The conductivity of around 52 mS/cm and salinity of around 34 ppt were typical of marine waters.

Total and dissolved metal/metalloid concentrations were generally consistent among survey sites, except for site M4 near the coastal foreshore which contained higher concentrations of total metals associated with a higher TSS concentration. These concentrations were generally below the PNG water quality criteria for aquatic life protection from Schedule 1 of the Environment (Water Quality Criteria) Regulation 2002 and ANZECC/ARMCANZ (2000) ambient guidelines for marine waters. The exception to this was dissolved concentrations of boron at all locations (ranging from 4.15 to 5.38 mg/L), which exceeded the PNG water quality criteria for marine aquatic life protection of 2 mg/L. However, this boron concentration range is similar to that reported in the literature for background concentrations in seawater. ANZECC/ARMCANZ (2000) reports a background seawater boron concentration of about 5.1 mg/L and Emsley (1991) provides a seawater abundance concentration of 4.41 mg/L.

Nutrient concentrations were below detection limits with the exception of ammonia detected at concentrations of 0.02 to 0.11 mg/L. These concentrations were below the ANZECC/ARMCANZ (2000) guideline values.

Sediment Quality

Sediment samples were collected at sites M1 to M4 (Figure 7.27) using a Van Veen grab sampler and subsequently laboratory analysed for:

- Particle size distribution.
- Total metals/metalloids.
- Nutrients – i.e., total nitrogen, oxidised nitrogen, ammonia, filterable reactive phosphorus and total phosphorus.
- Total organic carbon.
- Total petroleum hydrocarbons, total recoverable hydrocarbons, polynuclear aromatic hydrocarbons and BTEXN (benzene, toluene, ethylbenzene, xylenes and naphthalene).

The sediment substrates adjacent to the proposed ocean port (Site M1) and Lido Village (Site M3) consisted predominately of unconsolidated sediments of sands and muds (particle size 0.006 to 2.0 mm). Muds and clays (particle size <60 µm) were found in the middle of Dakriro Bay (Site M2) and coastal foreshore (Site M4) survey sites.

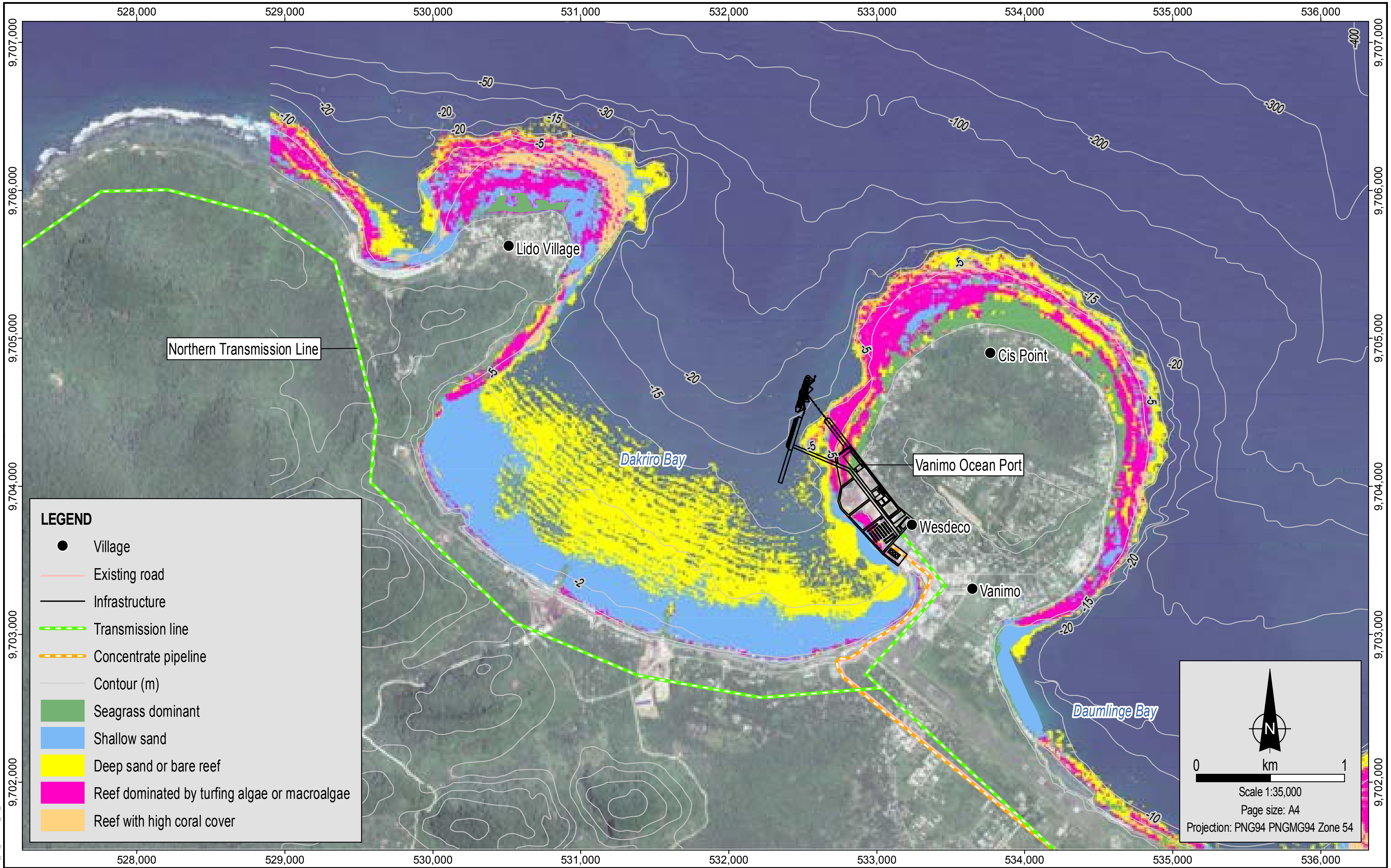
Metal and metalloid concentrations were below Australian and New Zealand ISQGs (Simpson et al*,* 2013) (see Section 7.2.3 for a description of the guidelines) with the exception of nickel at sites M2, M3 and M4. Nickel concentrations at sites M2 and M3 (42.6 and 22.5 mg/kg respectively) were above the Guideline Value of 21 mg/kg and concentrations at site M4 (56.2 mg/kg) exceeded the SQG-high guideline of 52 mg/kg. Metal and metalloid concentrations including boron, antimony, cadmium and silver were reported below the detection limit for all sites.

Total nitrogen and ammonia concentrations ranged from 300 to 880 mg/kg and 3 to 8 mg/kg, respectively. Nitrogen species including nitrite, nitrate and nitrogen oxides below the detection limit at all sites with the exception of Site M3. Total phosphorus concentrations ranged from 354 to 498 mg/kg.

Marine Habitats

To characterise biological habitats of Dakriro Bay’s nearshore environment, six transect area surveys (approximately 5 m linear transects) were undertaken using remote sensing (habitat mapping), BRUV and ground-truthing (see Figure 7.27). The depth of the transect survey areas varied from extremely shallow (1.5 m or less) through to 20 m water depth.

Marine habitats within the study area consisted of sandy beaches, subtidal sands, fringing coral reefs and seagrass meadows. Shallow water habitats as identified by multispectral satellite data are as shown in Figure 7.29. These habitats were also groundtruthed to confirm the habitat types and condition. Fringing coral reefs were covered by a mixture of unconsolidated sediments (including sand, rubble and mud), seagrasses and macroalgae over the reef flats, with substrate cover dominated by macroalgae, turfing algae and coral down the reef slopes.



Source:
Neashore marine data from BMT WBM.
Infrastructure and roads from FRL.
Villages from FRL and Coffey.
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Marine habitats in the nearshore marine study area

Figure No: 7.29

MXD Reference: 11575B_11_GIS016_v0_3

Table 7.21 provides a brief summary of the six transect areas, their key features and habitat values. Each of the marine habitat types determined from both the remote sensing and groundtruthing are discussed further detail below.

Table 7.21 Summary of transect area key features

Survey Area	Approximate depth	Average coral cover (%)	Generic richness	Key features and habitat values
Proposed ocean port	5 m to 10 m	13	20	This area contained fringing reefs at a depth of 5 to 10 m along a seabed of mostly sandy unconsolidated sediments. The area endures high-tide and large wave activity with shallow and deep sand in areas. One location on the reef slope contained very high coral cover, representing a large coral outcrop, but was generally low and had an overall average cover of almost 13% on the reef slope and crest. Very few fish were observed in the Wesdeco/ocean port area.
Logging port	5 to 10 m	13	15	Little coral was present at this site, with one small colony observed on rubble near the port. The area consisted primarily of turf, sargassum and seagrass. The reef south of the logging port had an average coral cover of approximately 13% and an overall richness of 15 genera, but with up to eight genera observed at individual transects in this area. Few fish were sighted at this location apart from some anemonefish, very occasional small damsels and wrasses, and one large unicorn fish (*Naso unicornis*).
Cis Point	Up to 20 m	5	15	This area comprised mostly of seagrass and sargassum and had the lowest coral cover of 5%. While the reef was extensive, the reef substrate was covered with non-living coral cover due to a heavy covering of turf algae and macroalgae. Dense seagrass communities including *Thalassia hemprichii, Halodule uninervis, Cymodocea serrulata* and *C. rotundata* existed on the reef flat. Low numbers and diversity of fish were present. Several portions of this area have experienced significant disturbance and seagrass communities at this location were not in good condition. Plate 7.67 shows an example of the coral community near this location.
Hospital (east side of peninsula)	Up to 20 m	17	22	The reef crest and slope in this area had an average coral cover of 17%, and coral richness of 22 genera (the highest coral richness in the study area). This location had the highest abundance and the largest fish, including moderate to small wrasses (Labridae), snappers (Lutjanidae), surgeonfishes (Acanthuridae), butterflyfish, damselfish and a green sea turtle.

Table 7.21 Summary of transect area key features (cont'd)

Survey Area	Approximate depth	Average coral cover (%)	Generic richness	Key features and habitat values
Lido Village	5 m to 10 m	25	15	This area is primarily covered by coral, seagrass and turf. The reef at Lido Village had the highest average coral cover of almost 25% with a generic coral richness of 15. Anecdotal evidence based on conversations with provincial government officials and local fishermen indicated some of the best reef in the harbour, in terms of coral cover and fish abundance, is present to the north of this area.
Dakriro Bay	20 m	<1	1	This area (near Site M2) contained unconsolidated sediments of shallow sand to a depth of 5 m and deep sand to a depth of 20 m. The sands appeared to become muddier towards the central harbour. This area is below the photic zone for the survival of coral reefs, thereby recording very little coral cover and a generic richness of one. There is the possibility of non-photosynthetic rubble/soft coral patches existing beyond the 30-m depth contour. Muddy sands may support a range of flatfishes, rays, and inshore schooling species such as mullet and herring.

Unconsolidated Sediments

Unconsolidated sediments (loose accumulations of material), shown as deep sand or bare reef categories on Figure 7.29, were distributed throughout the harbour. These consisted of:

- Sands and muds, with fine fractions appearing more prevalent near drains, river mouths and the central harbour.
- Calcium carbonate sands over reef flats and at the base of the reef slope.

Intertidal unconsolidated sediments were littered with rubbish, with the highest concentrations observed near open drains entering the harbour adjacent to the outdoor market and supermarket. No burrows were observed at any of the beaches, reef flats or base of the reefs, indicating that the unconsolidated sediments are unlikely to support much infauna. The unconsolidated sediment area was not reported to constitute significant fishing habitat by local fishermen, apart from occasionally finding rock lobsters beneath stray logs. Sea urchins, sea stars and sea cucumbers were the dominant fauna found on unconsolidated sediments on the reef flats.

Coral Communities

Coral communities within Dakriro Bay have been highly altered by anthropogenic activities, with stressors including thermal bleaching, over-fishing, physical damage, rubbish, and low water quality as a result of stormwater and deforestation. Some areas of high reef cover, representing higher ecological value, are located north of Cis Point and north of Lido Village, where depth gradually increases from the reef crest down to 20 m (see Figure 7.29).

Most of the reef habitat in the study area contained some coral (in some areas up to 25%), but the areas were dominated by seagrasses, macroalgae and turfing substrates. Coral communities found in small lagoons, depressions and pools included *Goniastrea, Porites lobata* and *P. latistella.* Fringing reefs exposed to high wave energy action with a well-established reef crest (such as at Lido Point and north of Cis Point) were composed of a dense covering of *Turbinaria* algae, which is an alga that is heavily calcified (Plate 7.68).

The most extensive reef areas were found north of Cis Point and north of Lido Point, although the reef areas north of Cis Point had little living coral cover. The reef flat is also widest at these locations becoming narrower towards the harbour. The waters of these areas are low in turbidity and sediment, providing conditions for corals to proliferate to greater depths. Reef slopes typically contained the highest cover of living coral.

Towards the southern limits of these reefs inside the harbour, the shallow areas (5 m or less) containing coral or algal substrate became unconsolidated habitat. This was attributed to wave energy and proximity to stormwater outlets within this area.

Macroalgal Communities

Macroalgal communities were highly abundant and most dominant near the reef crest and along the reef flat throughout the study area. Species of *Sargassum, Halimeda* and *Padina* dominated the reef flat, *Turbinaria* dominated the wave break areas (reef crest) and large fleshy macroalgae species, such as *Halimeda,* and cementing forms such as crustose coralline algae, were more dominant on the reef slope.

Seagrass Communities

Seagrass communities, an example of which is shown in Plate 7.69, were present on most of the reef flats within the study area. The dominant species of seagrasses include: *Thalassia hemprichii*, *Halodule uninervis*, *Cymodocea serrulata* and *C. rotundata* and smaller patches of *Halophila ovalis*, *Syringodium isoetifolium* and *Enhalus acoroides*. *E. acoroides* tended to be found in established, dense meadows on the reef flat, or in more turbid parts of the harbour that experience less wave energy. Most seagrass were in good health with the exception of the reef flat north of Cis Point where the area has been disturbed.

Invasive Species

While a survey of introduced marine species was not specifically conducted, during benthic surveys, none of the following large invasive species known from tropical northern Australia were observed: *Plumularia setacea*, (plume hydroid), *Perna viridis* (Asian green mussel), *Mytilopsis sallei* (blackstriped mussel), *Megabalanus tintinnabulum* (tital acron barnacle), *Hydroides sanctaecrucis* (tubeworm), or *Caulerpa taxifolia*.

Marine Fauna

A summary of the fish communities and threatened marine species that could occur in the study area is provided below.

Fish Communities

Fish communities were seldomly observed during the field survey, and fish size and abundance was much lower in comparison to other fringing reefs in other locations in PNG. This reduced fish abundance is attributed to the area being highly overfished. The areas with the observed least abundance included near the ocean port and the logging port (some anemonefish, very occasional small damsels and wrasses, and one large unicorn fish (*Naso unicornis*)). Areas with the highest abundance of fish were observed at Lido Village and adjacent to the hospital. The species observed in these more abundant areas included small butterflyfish, bannerfish, damselfish, wrasses (Labridae) snappers (Lutjanidae), and surgeonfishes (Acanthuridae).

Plate 7.67
Coral community near Cis Point

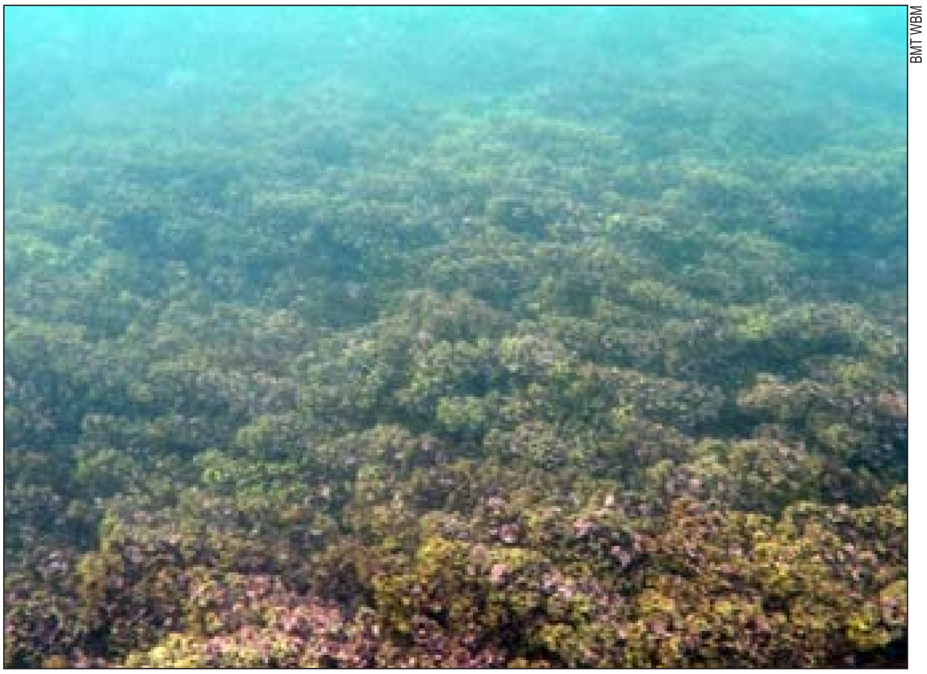


Plate 7.68
Thick rope-like macroalgae (*Turbinaria* spp.)

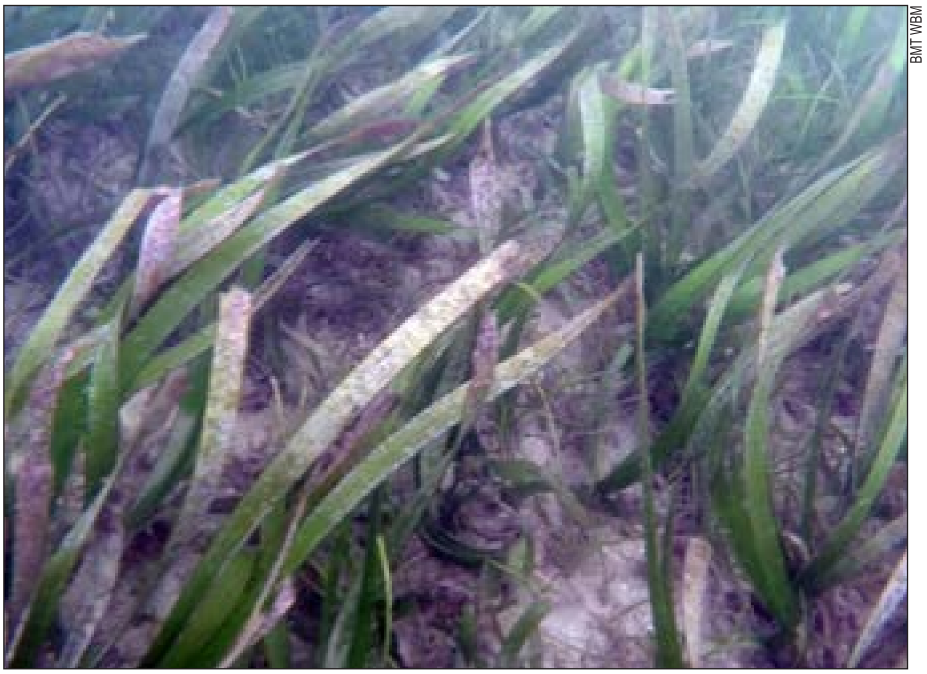


Plate 7.69
Seagrass community of Dakriro Bay (*Enhalus acoroides*)

Threatened Marine Species

The list of IUCN species and their status that could occur in the study area are detailed in Table 7.22. These species have ranges and habitats that overlap with the study area. Two green sea turtles, *Chelonia mydas* (classified as Endangered in the IUCN red list) were observed during the survey: one was observed 12 m offshore in Daumlinge Bay, south of the hospital; the other was seen directly in front of the logging port. Other marine turtle species, including loggerheads, leatherback, olive-Ridley turtles, and Hawksbill turtles, have ranges and habitats overlapping the study area, but were not observed during the survey. The beaches in the study area do not support turtle nesting habitat as those adjacent to the fringing reefs are not high enough above sea level, and the beaches without fringing reefs are not wide or high enough.

Table 7.22 Threatened marine aquatic fauna species on the IUCN Red List that could occur in the study area and surrounds

Common Name	Species	Category*
Hawksbill turtle	*Eretmochelys imbricate*	Critically Endangered
Leatherback turtle	*Dermochelys coriacea*	Vulnerable
Green turtle†	*Chelonia mydas*	Endangered
Loggerhead turtle	*Caretta caretta*	Vulnerable
Olive Ridley turtle	*Lepidochelys olivacea*	Vulnerable
Flatback turtle	*Natator depressus*	Data Deficient
Dugong	*Dugong dugon*	Vulnerable
Whale shark	*Rhincodon typus*	Vulnerable
Pygmy sperm whale	*Kogia breviceps*	Data Deficient
Dwarf sperm whale	*Kogia sima*	Data deficient
Sperm whale	*Physeter macrocephalus*	Vulnerable
Blainville's beaked whale	*Mesoplodon densirostris*	Data Deficient
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*	Data Deficient
Short-finned pilot whale	*Globicephala macrorhynchus*	Data Deficient
Pygmy killer whale	*Feresa attenuate*	Data Deficient
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Bryde's whale	*Balaenoptera edeni*	Data Deficient
Indo-pacific beaked whale	*Indopacetus pacificus*	Data Deficient
Spinner dolphin	*Stenella longirostris*	Data Deficient
Indo-pacific bottlenose dolphin	*Tursiops aduncus*	Data Deficient
Giant clam	*Tridacna gigas*	Vulnerable

* Category definitions as of 1 December 2015.
† This species was observed in the study area.

Metals and Metalloids in Fish Tissue

Fish collection was successful in locations where the largest and most abundant fish were observed, such as the reef in front of Vanimo hospital. Ten fish specimens collected by local fisherman along this reef were analysed for metal and metalloid concentrations in fish tissue. Collected specimens included surgeonfish, trigger fish (*Rhinecanthus verrucosus*), goatfish (Mullidae) and small wire-netting cod (*Epinephelus merra*).

The results of the analyses indicated that:

- The zinc concentration in one fish tissue sample, *Rhinecanthus verrucosus* (Blackpatch Triggerfish) at site Reef 4, exceeded the ANZFA GEL (15 mg/kg).
- Arsenic concentrations in four fish tissue samples (blackpatch triggerfish (*Rhinecanthus Verrucosus*) at sites Reef 3 and Reef 4, Palelipped surgeonfish (*Acanthurus Leucocheilus*) at site Reef 6, and goatfish (*Parupeneus crassilabrus*) at site Reef 9) exceeded the ANZFA ML guideline value of 2 mg/kg.
- Other metals and metalloids were recorded in concentrations below the ANZFA ML and ANZFA GEL.
- Aluminium concentrations were highly variable (ranging from <0.5 mg/kg to 338.4 mg/kg).
- Concentrations of copper, lead and selenium were detected in all fish tissue samples and silver and antimony concentrations were typically detected at concentrations close to the detection limit or below the detection limit.

Attempts were made by local fishermen to catch fish along the reefs situated in front of the proposed ocean port and the logging port for the purposes of metal/metalloid analysis. However, the fishing was unsuccessful. This is consistent with the history of overfishing in Dakriro Bay, the fact that fishing practices do not target waters in Dakriro Bay and the observed lack of healthy coral reef habitat to support diverse fish communities.

7.3 Socio-economic Environment

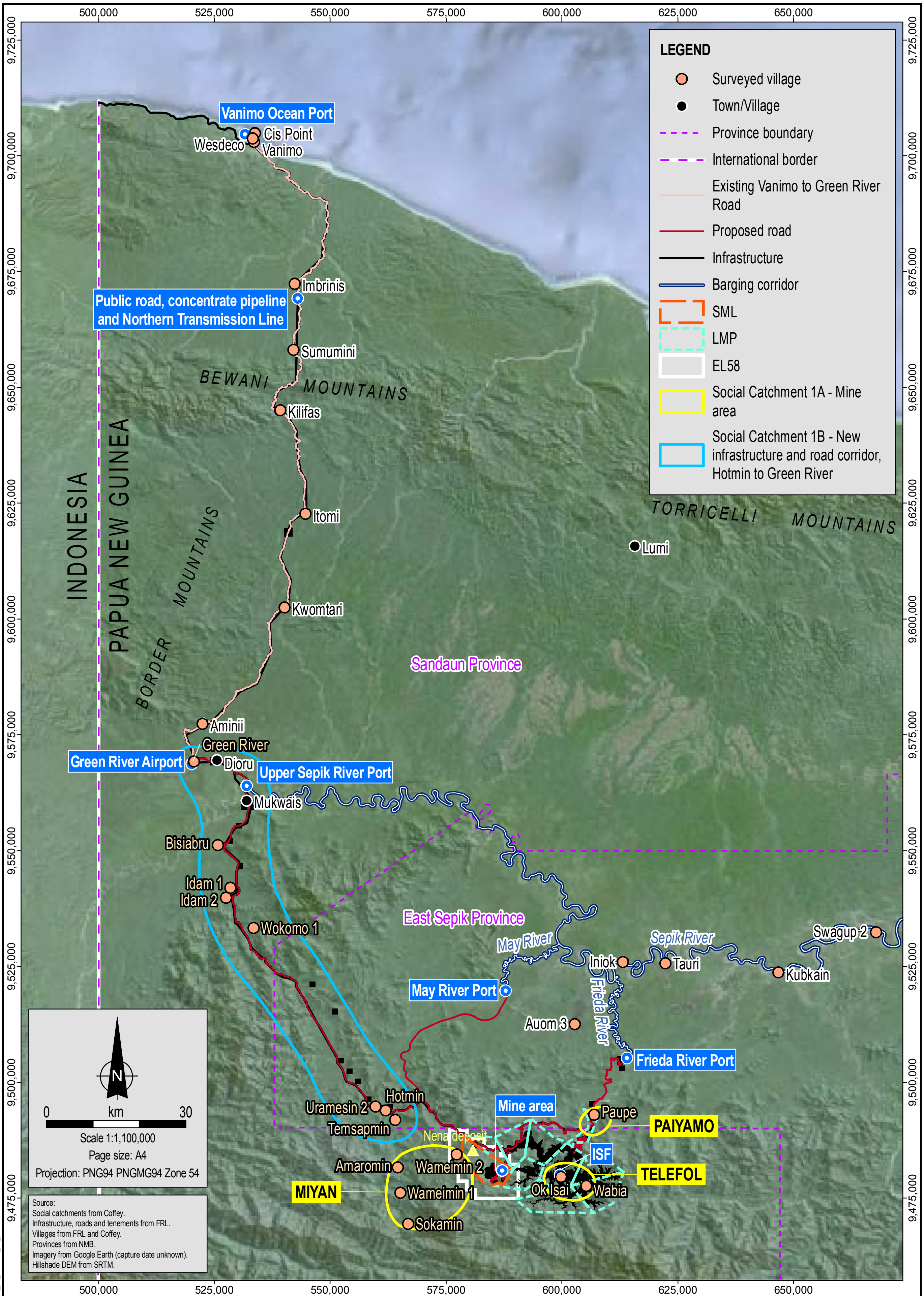
This section provides a summary of the socio-economic environment of the Project area. It is based on the Social Impact Assessment (Appendix 13), which includes the Cultural Heritage Baseline and Impact Assessment and the Baseline Health, Diet and Nutrition Survey Report.

7.3.1 Social Catchments

The communities associated with the mine and FRHEP area, infrastructure corridor, Vanimo Ocean Port, and Sepik River Corridor have been categorised by social catchment areas that have been defined through consideration of location (including watershed boundaries and proximity to the mine area), the type of Project activity that may potentially occur in proximity to villages in the catchment, and language group or cultural affinity of the villages in the catchment area.

The social catchments comprise:

- Social Catchment 1A: Mine and FRHEP area (Figure 7.30).
- Social Catchment 1B: New infrastructure and road corridor, Hotmin to Green River (Figure 7.30).
- Social Catchment 1C: Existing infrastructure and road corridor, Green River to Vanimo (Figure 7.31).
- Social Catchment 1D: Vanimo Ocean Port (Figure 7.31).
- Social Catchment 2: Sepik River Corridor (Figure 7.32).
- Social Catchment 3: Sandaun and East Sepik Provinces (Figure 7.32).



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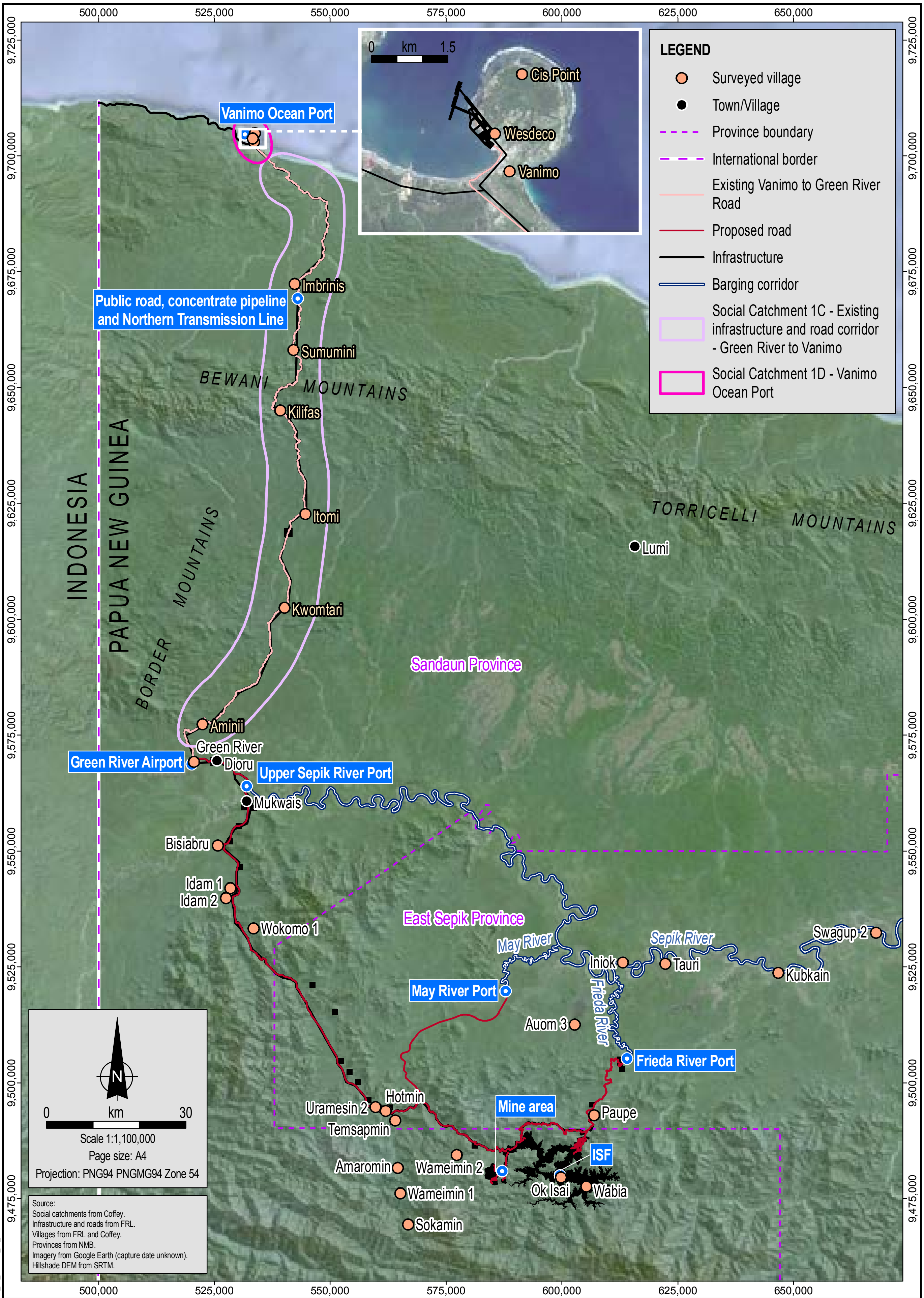
coffey A TETRA TECH COMPANY	Date: 04.10.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.30_GIS	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Social Impact Assessment catchments 1A and 1B	Figure No: 7.30



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Date: 03.10.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.31_GIS

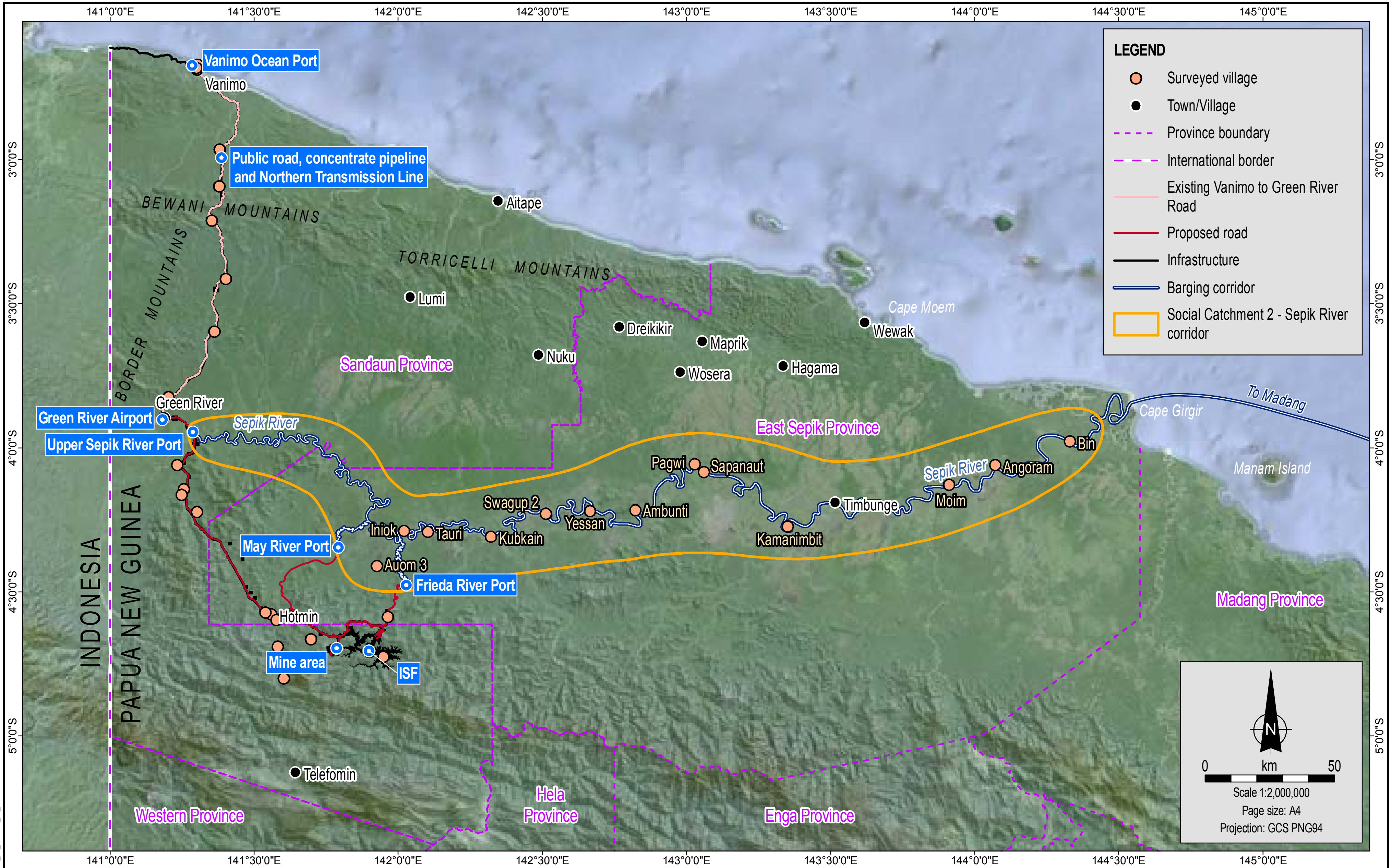
Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Social Impact Assessment catchments 1C and 1D

Figure No: 7.31



Source:
Social catchments from Coffey.
Infrastructure and roads from FRL. Villages from FRL and Coffey.
Provinces from NMB.
Imagery from Google Earth (capture date unknown).
Hillshade DEM from SRTM.

coffey A TETRA TECH COMPANY

Date: 03.10.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.32_GIS

Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Social Impact Assessment catchments 2 and 3

Figure No: 7.32

MXD Reference: 11575B_11_GIS012_v0_4

Table 7.23 lists communities characterised within each catchment area.

Table 7.23 Communities included in the characterisation study

Language group	Community	Local-level government	District	Province
Social Catchment 1A: Mine and FRHEP area				
Miyan	Amaromin	Telefomin Rural	Telefomin	Sandaun
	Sokamin	Telefomin Rural	Telefomin	Sandaun
	Wameimin 1	Telefomin Rural	Telefomin	Sandaun
	Wameimin 2	Telefomin Rural	Telefomin	Sandaun
Telefol	Ok Isai	Telefomin Rural	Telefomin	Sandaun
	Wabia	Telefomin Rural	Telefomin	Sandaun
Paiyamo	Paupe	Tunap/Hunstein	Ambunti-Dreikikir	East Sepik
Social Catchment 1B: New infrastructure and road corridor, Hotmin to Green River				
	Uramesin 2	Tunap/Hustein Rural	Ambunti/Drekikir	East Sepik
	Temsapmin	Tunap/Hustein Rural	Ambunti/Drekikir	East Sepik
	Hotmin	Tunap/Hustein Rural	Ambunti/Drekikir	East Sepik
	Idam 1	Green River Rural	Vanimo/Green River	Sandaun
	Idam 2	Green River Rural	Vanimo/Green River	Sandaun
	Wokomo 1	Green River Rural	Vanimo/Green River	Sandaun
	Bisiabru	Green River Rural	Vanimo/Green River	Sandaun
	Green River	Green River Rural	Vanimo/Green River	Sandaun
Social Catchment 1C: Existing infrastructure and road corridor, Green River to Vanimo				
	Amini	Green River Rural	Vanimo/Green River	Sandaun
	Kwomtari	Amanab Rural	Vanimo/Green River	Sandaun
	Itomi	Amanab Rural	Vanimo/Green River	Sandaun
	Kilifas	Walsa Rural	Vanimo/Green River	Sandaun
	Sumumini	Bewani/Wutung Onei Rural	Vanimo/Green River	Sandaun
	Imbrinis	Bewani/Wutung Onei Rural	Vanimo/Green River	Sandaun
Social Catchment 1D: Vanimo Ocean Port				
	Wesdeco	Vanimo Urban	Vanimo Green River District	Sandaun
	Cis Point	Vanimo Urban	Vanimo Green River District	Sandaun

Table 7.23 Communities included in the characterisation study (cont'd)

Language group	Community	Local-level government	District	Province
Social Catchment 2: Sepik River corridor				
	Auom 3	Tunap/Hustein Rural	Ambunti-Dreikikir	East Sepik
	Iniok	Tunap/Hustein Rural	Ambunti-Dreikikir	East Sepik
	Kubkain	Ambunti Rural	Ambunti-Dreikikir	East Sepik
	Tauri	Ambunti Rural	Ambunti-Dreikikir	East Sepik
	Swagup	Ambunti Rural	Ambunti-Dreikikir	East Sepik
	Yessan	Ambunti Rural	Ambunti-Dreikikir	East Sepik
	Ambunti	Ambunti Rural	Ambunti-Dreikikir	East Sepik
	Pagwi	Gawi Rural	Wosera-Gawi	East Sepik
	Sapanaut	Gawi Rural	Wosera-Gawi	East Sepik
	Moim	Angoram/Middle Sepik	Angoram	East Sepik
	Kamanimbit	Angoram/Middle Sepik	Angoram	East Sepik
	Angoram	Angoram/Middle Sepik	Angoram	East Sepik
	Bin	Marienberg Rural	Angoram	East Sepik

The following sections outline socio-economic data collection and then describe each social catchment based on survey results. Greater detail has been provided for social catchments within the Project area and immediate surrounds, i.e., social catchments 1A, 1B, 1C, 1D and 2. Where appropriate, characterisations of social catchments have been grouped to avoid repetition of information.

7.3.2 Social Values

Social values are regarded as qualities of the social environment that are conducive to individual well-being now and into the future, and for which community stakeholders have a high regard. Each social value is characterised by a range of indicators, and is associated with a range of stakeholders who have an interest in the value within the social catchment.

Social values for social catchments were identified through the following process:

- Collection and analysis of primary data gathered through field surveys.
- Analysis of secondary information including the extensive body of research previously conducted in the social catchments.
- A workshop with social and other technical specialists from FRL and Coffey.
- Workshops with landowners in Social Catchment 1A, who are located close to mine site infrastructure or Project activities, held at Frieda River in October 2015.

This process resulted in the articulation of six social values, comprised of two for each category of: Livelihoods; Culture; and Personal and Community Well-being (Table 7.24). Communities within each social catchment have been characterised in the context of these categories and social values, to enable an appreciation of the social values that may be affected by the Project.

Table 7.24 Social values within the Project area

Category 1 - Livelihoods		Category 2 - Culture		Category 3 - Personal and community well-being	
Social value 1	**Social value 2**	**Social value 3**	**Social value 4**	**Social value 5**	**Social value 6**
The capacity to support subsistence livelihoods	Opportunities for participation in the cash economy	An enduring ability to sustain individual and group cultural identity and traditions including connection to ancestors	An enduring ability to maintain customary rights to land access and resource use	An environment amenable to personal and family health, education, safety and security	The availability of services supportive of personal health, education, safety and security

Social values can change and sometimes do so rapidly, as has been observed with key local stakeholders in the Sepik Development Project, where they themselves have initiated quite radical change in relatively recent times, and continue at present to experience the consequences of such change. Therefore caution is warranted in assigning too much weight to expressions of values, for example values centered on culture and traditional leadership which may well evolve during the life of the Project.

7.3.3 Socio-economic Data Collection

Socio-economic data has been collected using a range of methods including:

- Review of socio-economic and cultural studies undertaken in the 1995 to 1996 period including:
  - Gardner, D. (1996) Nena Project Socio-economic Impact Assessment-Cultural Impacts.
  - Subada Consulting (1996) Community Directory Nena Project Area.
- Analysis of population census, household surveys and village surveys undertaken by Coffey in 2009 to 2010, 2015 and 2017.
- Review of village health baseline surveys undertaken by the Centre for Environmental Health in 2010.
- Review of key informant interviews and focus group workshops carried out in the mine area and the new and existing road and infrastructure corridor catchments.
- Review of cultural heritage studies and archaeological surveys undertaken in 2010 and 2015 by Monash University and by Andrew Long and Associates (in 2016 and 2018).
- Discussions with village women's focus groups in the mine area, new and existing infrastructure and road corridors and the Sepik River corridor, and social value workshops with village leaders from the mine area in 2015.
- Review of secondary information sourced from national, provincial and district level government agencies reports and plans.

Surveys conducted between 2009 and 2017 throughout the Project area encompassed additional villages to those that now define the study area. This additional contextual information is drawn on where appropriate in the characterisation, but specific information on these additional villages has not been included.

Details of the surveys within the study area are provided below and Table 7.25 shows the specific studies undertaken in each community.

Secondary information sources, including documentation published by agencies of the PNG Government, universities and non-governmental organisations, were drawn upon to characterise the host provinces and the nation.

Table 7.25 Survey coverage of villages within social catchments

Village	2009 to 2011 Socio-economic survey (census, household and village)	2015 Socio-economic survey (census, household and village)	2010 Health baseline survey	2010 Cultural heritage survey	2016 Cultural heritage survey (targeted sites)	2015 Village leader social values workshops	2017 Socio-economic survey (household and village)	2017 Focus group / key informant interview
Social Catchment 1A – Mine and FRHEP area								
Amaromin	✓	✓	✓	✓	✓	✓		
Sokamin	✓	✓				✓		
Wameimin 1	✓	✓	✓	✓		✓		
Wameimin 2	✓	✓	✓	✓	✓	✓	Village only	✓
Ok Isai	✓	✓	✓	✓	✓	✓	Village only	✓
Wabia	✓	✓	✓	✓	✓	✓	Village only	
Paupe	✓	✓	✓	✓	✓	✓	Village only	
Social Catchment 1B – New road and infrastructure corridor, Hotmin to Green River								
Uramesin 2							Village only	
Temsapmin							Village only	
Hotmin							✓	✓
Idam 1							✓	✓
Idam 2							✓	
Wokomo 1							✓	
Bisiabru							Village only	✓
Green River								✓
Social Catchment 1C – Existing road and infrastructure corridor, Green River to Vanimo								
Amini							Village only	
Kwomtari							Village only	

Table 7.25 Survey coverage of villages within social catchments (cont'd)

Village	2009 to 2011 Socio-economic survey (census, household and village)	2015 Socio-economic survey (census, household and village)	2010 Health baseline survey	2010 Cultural heritage survey	2016 Cultural heritage survey (targeted sites)	2015 Village leader social values workshops	2017 Socio-economic survey (household and village	2017 Focus group / key informant interview
Social Catchment 1C – Existing road and infrastructure corridor, Green River to Vanimo (cont'd)								
Itomi							Village only	
Kilifas							Village only	✓
Sumumini							Village only	
Imbrinis							Village only	
Social Catchment 1D – Vanimo Ocean Port								
Wesdeco							Village only	
Cis Point							Village only	
Social Catchment 2 – Sepik River corridor								
Auom 3	✓	✓	✓	✓				
Iniok	✓	✓	✓	✓		✓		
Kubkain	✓	✓	✓	✓				
Tauri				✓				
Swagup	Village survey only							
Yessan			✓					
Ambunti	Village survey only							
Pagwi	Village survey only	Village and limited household survey						
Sapanaut			✓					
Moim	Village survey only							
Kamanimbit	Village survey only							
Angoram	Village survey only							
Bin	Village survey only							

Social Catchments 1A, 1B, 1C and 1D

Characterisation of mine and FRHEP area, the new and existing infrastructure and road corridor, Vanimo Ocean Port and Sepik River corridor communities was compiled using a range of existing secondary sources as well as the:

- Twenty-seven-day program of primary socio-economic data collection across 20 communities within the mine area and the former infrastructure corridor (east of Frieda River) in 2009.
- Twenty-day program of primary baseline environmental health data collection at selected locations in the mine area and former Frieda River infrastructure and road corridor communities by the Centre for Environmental Health (CEH, 2018) in 2010 (Appendix 13).

  Twenty-one-day program of primary archaeological and cultural heritage data collection at selected locations in the mine area, and former Frieda River infrastructure and road corridor communities by Monash University in 2010. Results of this program were updated via desktop studies in 2015 by Denham and Hitchcock (2015).
- Twenty-day program of primary socio-economic data collection across 17 communities within the mine area, former road corridor and Sepik River (east of Frieda River) in 2015.
- Fourteen-day program of verifying targeted archaeological and cultural heritage sites located in the mine area, and former Frieda River infrastructure and Sepik River port communities by Andrew Long and Associates (ALA) in 2016 and 2018 (Appendix 13).
- Sixteen-day program of primary socio-economic data collection across 19 communities within the mine area, new and existing road infrastructure corridor and Vanimo Ocean Port catchments in 2017.

Social Catchment 2

The characterisation of the Sepik River corridor was compiled using a range of existing secondary sources as well as the:

- Seven-day program of primary baseline health data collection at selected locations along the Sepik River corridor by the CEH in 2010 (Appendix 13).
- Seven-day program of primary socio-economic data collection at selected locations along the Sepik River corridor in 2011.
- Fifteen-day program of primary socio-economic data collection across 11 communities within the Sepik River corridor in 2015.

Social Catchment 3

The baseline characterisation of PNG and Sandaun and East Sepik provinces was compiled primarily from a range of secondary sources as well as feedback from the:

- Four-day Joint Provincial Development Workshop held in Aitape in October 2009 with representatives from Sandaun and East Sepik provincial administrations and attended by Coffey.
- Four-day program of primary data collection (interviews) with members of the Sandaun and East Sepik provincial administrations in March 2010.
- Quarterly Joint Provincial Consultative Committee meetings held with key staff of both provincial governments.

The views and concerns of people (including men, women and children) within each village surveyed were compiled from both consultation and data collection. Community feedback has also informed the stakeholder engagement plan (see Chapter 4).

The following sections describe the social environment for Social Catchment 1A (Section 7.3.4), Social Catchment 1B and 1C (Section 7.3.5), Social Catchment 1D (Section 7.3.6), Social Catchment 2 (Section 7.3.7) and Social Catchment 3 (Section 7.3.8).

7.3.4 Social Catchment 1A: Mine and FRHEP Area

In the mine and FRHEP area there are three social sub-catchments of villages either within or near (15 to 20 km) the proposed mine footprint, or downstream of the ISF embankment on the Frieda River (see Figure 7.30). These social sub-catchments consist of the Miyan, Telefol and Paiyamo sub-catchments.

Location

The location of each social sub-catchment in relation to government administrative boundaries (Local Level Government (LLG), District and Province) is shown in Table 7.26.

Table 7.26 Mine area government administrative boundaries

Social sub-catchment	LLG	District	Province
Miyan	Telefomin Rural	Telefomin	Sandaun
Telefol	Telefomin Rural	Telefomin	Sandaun
Paiyamo	Tunap/Hunstein	Ambunti-Dreikikir	East Sepik

The Miyan social sub-catchment is located to the west of the proposed open-pit. Three villages (Sokamin, Wameimin 1 and Amaromin) are approximately 20 km west to south-west of the mine area, and situated within catchments of the Upper May River. The fourth village (Wameimin 2) is located approximately 7 km north-west of the proposed open-pit on the Upper Nena River, approximately 11 km upstream of the western extent of the proposed ISF reservoir. The village of Fiak, located approximately 2 km west of Amaromin, is not within the Miyan social sub-catchment due to the residents generally not being landowners of the area within the proposed SML and LMP areas.

The terrain within the social sub-catchment area is rugged and mountainous, with access via walking tracks only. From Sokamin, access to the nearest administrative centre (Mianmin) is via a two-day walk to the south; from Amaromin, following a walk to Fiak there is canoe travel available to Hotmin and the Sepik River. From Wameimin 2, residents walk to the headwaters of the Usake River from where canoe travel downstream to Hotmin and the Sepik River is available.

The Telefol social sub-catchment is located to the east of the HITEK deposits. It consists of two villages (Ok Isai and Wabia) that are approximately 15 and 20 km respectively in a direct line from the proposed open-pit, and within the footprint of the ISF reservoir, and situated within catchments of the Niar River. The terrain within this social sub-catchment area is rugged and mountainous, though both villages have airstrips (suitable for light aircraft up to Twin Otter size) and are accessible via canoe from the Frieda and Sepik rivers.

The Paiyamo social sub-catchment consists of one village (Paupe) located primarily on the left bank of the Frieda River, 2.5 km north of the Frieda River airstrip and approximately 25 km from the HITEK deposits, 7 km downstream of the ISF embankment and 12 km downstream of the confluence of the Nena River and Ok Binai.

Population and Demographics

The total population of the mine area at the end of 2017 (the most recent data collected by FRL) was approximately 2,000 persons, with an annual growth of around 60 persons per year. Population characteristics of the mine area are shown in Table 7.27.

The population of the mine and FRHEP area was skewed toward younger age groups, however there were also a reasonable number of older persons as shown in Table 7.28. This is compared to the national average of 2.6% of the population aged 65 years and over (NSO, 2015a).

Observations on population change during the three-year period from 2014 to 2017 compared to the prior five years include:

- Wameimin 2 and Paupe have the highest rates of population growth among the mine area social catchment villages.
- Wameimin 1, Sokamin, Ok Isai and Wabia showed a slower rate of population growth; Amaromin showed a decrease in population growth.
- The most significant increase in the rate of annual population growth rate was at Wameimin 2 (1.5% to 6.3%).
- The most significant decrease in the rate of annual population growth rate was at Amaromin (4.3% to -1.4%).

The number of men per 100 women (gender ratios) for the villages are shown in Table 7.29. The most obvious feature of this data is the higher gender ratio for the Miyan and Paiyamo villages in comparison to the Telefol villages. The reason for this difference is not known. The gender ratio for the Telefomin Rural District at the time of the 2011 census was 104 (NSO, 2014).

Table 7.27 Social Catchment 1A population data

Village	Population				Number of households				Annual growth rate (%)				Household occupancy (persons per household)		
	1996*	2009†	2014§	2017**	1996*	2009†	2014§	2017**	1996 to 2009	2009 to 2014	2014 to 2017	Telefomin Rural District 2000§§ to 2011 Census††	2009/2010 Momase rural††	2014	2017
Amaromin	n.a.	116	143	137	n.a.	25	29	27	n.a.	4.3	-1.4	2.4	6.7	4.9	5.1
Sokamin	201	256	332	360	25	39	55	57	1.9	5.3	2.7	2.4	6.7	6.0	6.3
Wameimin2	77	151	163	196	14	26	32	33	5.3	1.5	6.3	2.4	6.7	5.1	5.9
Wameimin1	81	144	171	188	16	23	27	32	4.5	3.5	3.2	2.4	6.7	6.3	5.9
Miyan sub-total	359	667	809	881	n.a.	113	143	149	4.9	3.9	2.9	2.4	6.7	5.5	5.9
Ok Isai	175	348	413	465	21	38	46	60	5.4	3.5	4.0	2.4	6.7	9.0	7.8
Wabia	177	319	369	393	17	45	61	63	4.6	3.0	2.1	2.4	6.7	6.0	6.2
Telefol sub-total	352	667	782	858	38	83	107	123	5.0	3.2	3.1	2.4	6.7	7.5	7.0
Paupe	105	163	222	262	18	22	28	38	3.4	6.4	5.7	2.4	6.7	7.9	6.9
Total	816	1,497	1,813	2,001	n.a.	218	278	310	-	-	-	-	-	-	-

n.a.: not available.

* 1996 Subada Consulting survey.

† Coffey 2009 survey.

§ 2014 FRL census.

** 2017 FRL census.

†† NSO, 2014.

§§ NSO, 2000.

Table 7.28 Population age distribution in villages within the mine and FRHEP area

Village	Total Population	Number and percentage of population under 15	Number and percentage of population over 60
Amaromin	137	57 – 41.9%	6 – 4.4%
Sokamin	360	146 – 41.6%	9 – 2.6%
Wameimin 1	188	79 – 42.0%	10 – 5.3%
Wameimin 2	196	73 – 38.4%	10 – 5.3%
Ok Isai	465	189 – 41.9%	18 – 4.0%
Wabia	393	146 – 38.0%	18 – 4.7%
Paupe	262	107 – 44.8%	12 – 5.0%
Total	**2,001**	**797 – 39.8%**	**83 – 4.1%**

Source: Data from December 2017 FRL census.

Table 7.29 Village gender ratios (number of men per 100 women)

Village	Gender ratio (2014)	Gender ratio (2017)
Miyan social sub-catchment		
Amaromin	119	121
Sokamin	110	112
Wameimin 1	118	109
Wameimin 2	120	120
Telefol social sub-catchment		
Ok Isai	92	97
Wabia	100	92
Paiyamo social sub-catchment		
Paupe	116	101

Source: 2014 and 2017 FRL census.

Livelihoods (Social Values 1 and 2)

Information on agricultural subsistence livelihood activity is drawn from the CEH health baseline survey (Appendix 13), and the household surveys undertaken by Coffey in 2015 which replicated the nutritional elements of the CEH health baseline survey. Information on cash economy activity has been derived from the 2015 household and village surveys.

Natural Capital / Subsistence Activity

The 2010 surveys concluded that all communities in the area derived most of their food and income through land and water use, largely practicing subsistence activities of gardening, farming of animals and crops, hunting and fishing. Food surveys in 2015 indicated that food preferences were unchanged. Labour requirements for gardens following initial clearing were not high but did need to be continuous.

Gardening was a pivotal part of life in all villages and was undertaken by all household members, but most often by women. The most common crops grown included banana, corn and taro. Cash crops were uncommon in the area. The number of gardens that each household maintained varied from one to five and ranged from small vegetable patches located close to houses to large gardens located in the bush some distance (up to four hours travel) away from villages. Typically, the gardens would contain inter-plantings of pitpit, pumpkin, cucumbers, cabbages, tomatoes, beans, onions, peanuts and greens. Many respondents reported having a regular supply of food from their gardens, which reflected the variety of crops grown and the practice of staggering different crops throughout the year. While some garden produce was sold and traded, these events were generally intermittent given the lack of access to markets.

Infrequent hunting was an important supplementary source of protein. Hunting was undertaken largely by men and target prey included wild pig, cassowary, bird, bandicoot, cuscus, possum and, in the more mountainous areas, tree kangaroo.

Water for drinking, cooking and washing was mainly sourced from unprotected surface waterbodies including rivers, creeks, springs and streams, with communal or household water tanks supplied by rainfall present in some villages, although water availability through this method was seasonal. Domestic water sources in the mine and infrastructure area were of variable quality and many, particularly tanks, appeared likely subject to faecal contamination. Some villages had received support in the past for basic reticulated systems including water tanks. CEH noted that without maintenance, tanks posed a risk of becoming microbiological traps and a source of childhood diarrhoea, a major avenue for morbidity in infants.

The use of household pit latrines varied between villages with sanitary wastes being sometimes discharged to the surrounding environment; solid waste disposal was, at best, disorganised. At Amaromin, only a small proportion of the households had pit toilets, possibly due to an elevated groundwater level, with most human waste being disposed to the nearby river. Data from the 2009 household surveys indicated that waste disposal methods differed for households within a village and individuals in Amaromin, Sokamin, and Wameimin 1 reported using their own, rather than a communal, designated rubbish dump.

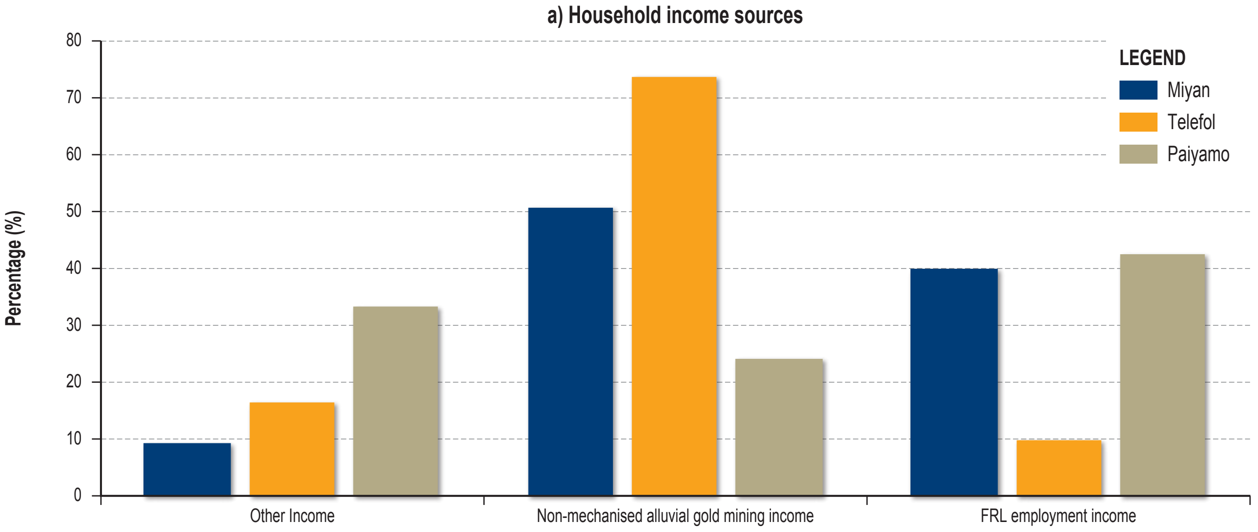
Cash Economy Activity

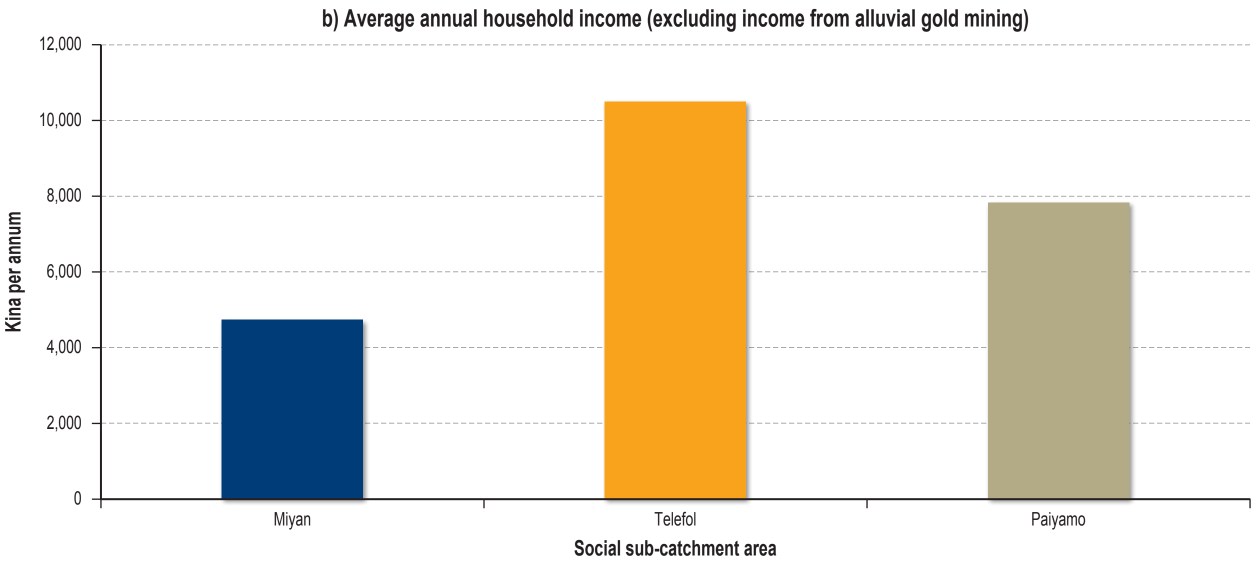
Social Catchment 1A is characterised by remoteness and the general absence of a market economy. Data on household income and expenditure derived from the 2015 household survey gives some insight into the sources, levels and uses for cash in this area and its surrounds.

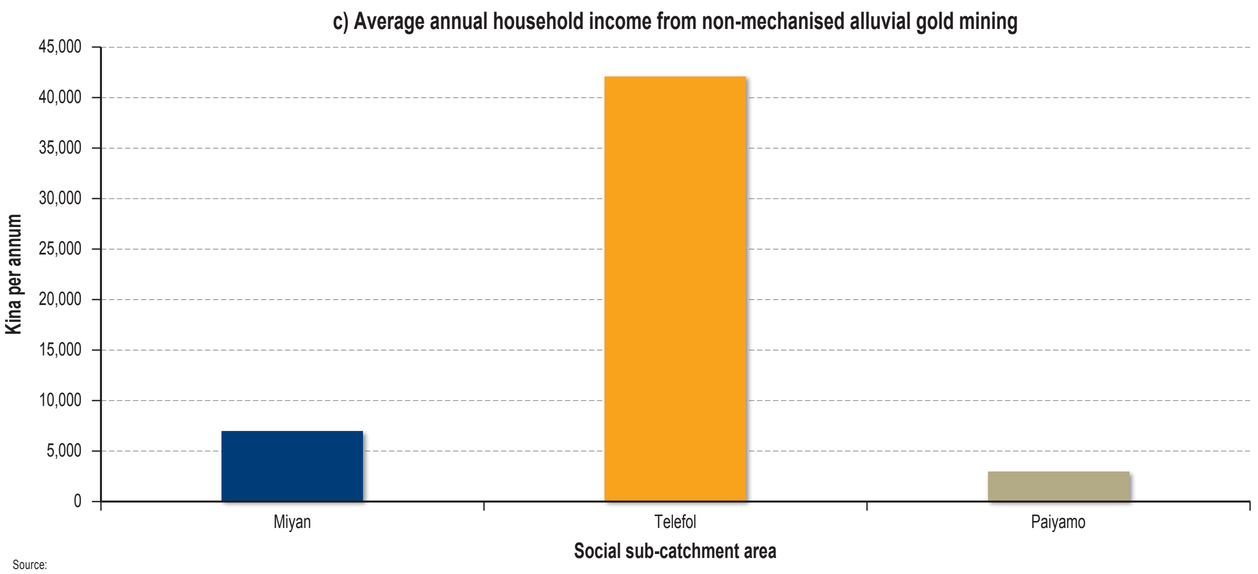
Income

The relative importance of principal income sources for each social sub-catchment area is shown in Figure 7.33. For the Miyan villages, alluvial gold mining, particularly at Wameimin 2, and FRL employment were most important as isolation precludes almost any other cash generating activity. For Paiyamo (Paupe), its location enables a range of income-generating activities to be undertaken including canoe transport services to and from the Sepik River, trading in produce such as vegetables and fish to neighbouring Telefol villages that have a higher disposable income from alluvial gold mining, and the trading of eaglewood. Ok Isai and Wabia are located very close to the alluvial gold areas and are the biggest miners of alluvial gold. FRL related employment for Paiyamo was most important and closely associated with the supply of labour for nearby Frieda River airstrip operations.

For the Telefol villages, selling gold from alluvial mining generated income for 90% of families within Ok Isai and Wabia (Finlayson, 2014), which also stimulated the operation of trade stores in the village, with approximately five in Ok Isai and two in Wabia. Employment with FRL was least important for Telefol villages due to the higher returns to labour available through alluvial mining.







Source:
Coffey 2015 household survey

AI Reference: 11575_11_GRA033.ai_4

coffey A TETRA TECH COMPANY	Date: 29.08.2018 Project: 754-ENAUABTF11575B File Name: 11575_11_F07.33_GRA	Frieda River Limited Sepik Development Project	FRIEDA RIVER	Mine area average household income	Figure No: 7.33

An alluvial mining survey undertaken for the Project in 2014 (Finlayson, 2014) identified that small scale mining included the use of surface dredges, panning, locally-made sluice boxes, diving for gold with goggles and manually searching for gold under rocks or in small areas of accumulated sand or gravel. It was estimated that almost 600 people engaged in alluvial mining within Social Catchment 1A including 27 dredge operators and 128 dredge workers from Ok Isai and Wabia. Alluvial gold production levels varied substantially, however it was estimated that individual dredges produced approximately 30 grams of gold per day. Dredge workers are generally provided with certain days in which they can keep any gold found, as a form of payment. Other methods of alluvial mining typically produced between one and two grams of gold per day for residents.

Expenditure

The summary figures shown in Figure 7.34 indicate that the higher incomes of the Telefol villages has enabled significant expenditure on store goods and the highest level of expenditure on transport; both villages have operational airstrips and air travel was provided by the Missionary Aviation Fellowship. Store goods are increasing in significance for the Paiyamo social sub-catchment, possibly due to the higher levels of income from FRL related employment and ease of access compared with planting and protecting gardens.

All villages incurred expenditure from sending children away to attend high school and, often, primary school. The higher level of expenditure in Telefol villages (Figure 7.34) on education may indicate the use of more expensive air transport to convey students to school. Expenditure on durable items (Figure 7.34) highlights the importance that villagers attach to household lighting through the purchase of solar battery and light packs (Table 7.30).

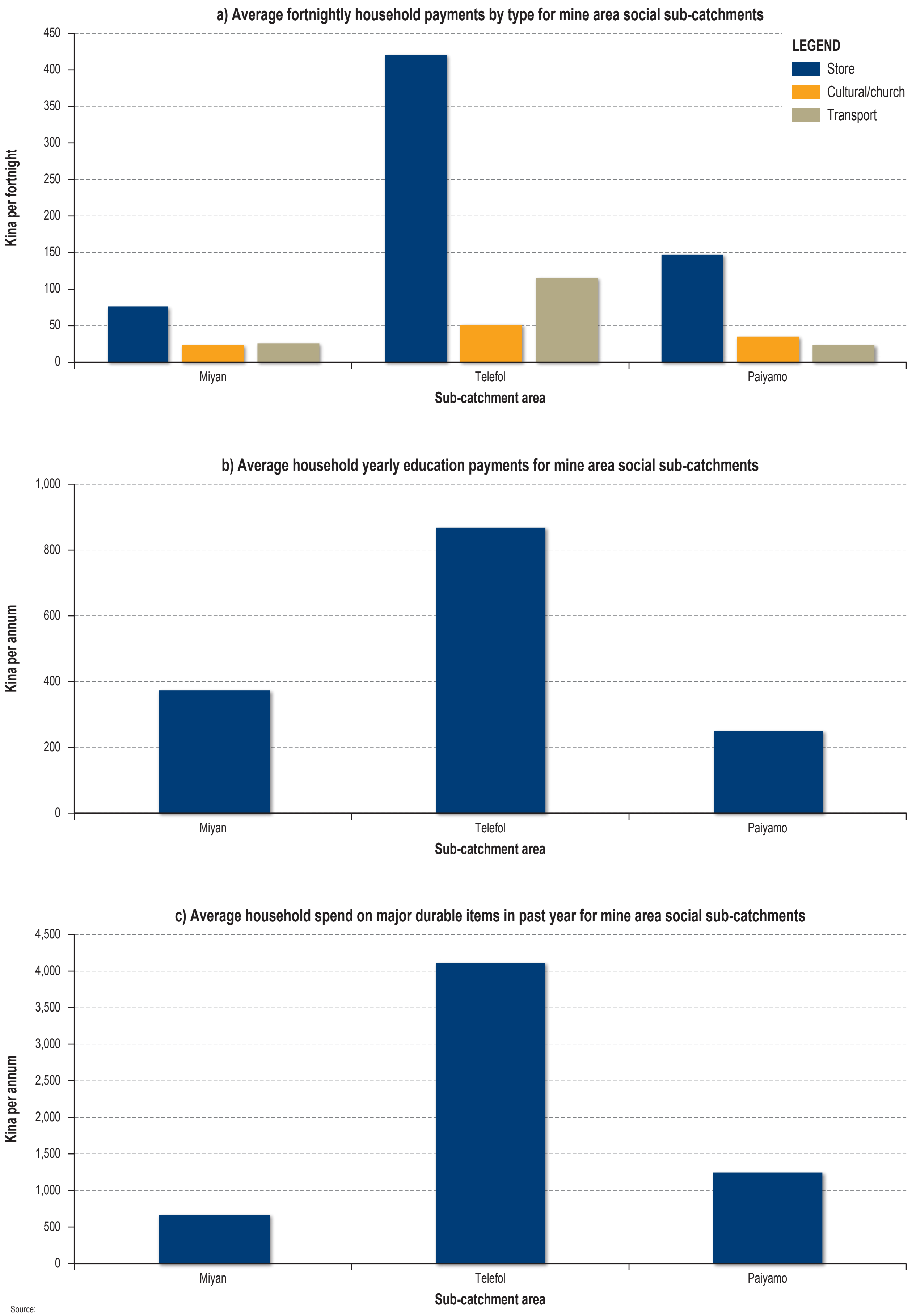
Table 7.30 Type and number of durable items purchased in the previous 12 months

Village	**Type of goods**				
	Solar lights	**Generator**	**Gold dredge**	**Outboard motor**	**Building materials**
Amaromin			1		
Sokamin	5				
Wameimin 2	4				
Wameimin 1	5	1			
Ok Isai	2	1	1	3	
Wabia		1	1	1	1
Paupe	3			1	
Total	19	3	3	5	1

Source: Coffey household survey 2015.

Status of Social Values 1 and 2 within Social Catchment 1A

Summary statements of the status of social values (SV) 1 and 2 within Social Catchment 1A are provided below.



Source:
Coffey 2015 household survey

AI Reference: 11575_11_GRA032.ai_3

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A TETRA TECH COMPANY

Date: 29.08.2018
Project: 754-ENAUABTF11575B
File Name: 11575_11_F07.34_GRA

Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Average household expenditure for mine area social sub-catchment

Figure No: 7.34

SV1 - The capacity to support subsistence livelihoods

Gardner (1996) asserted that 'the communities in the mine area retain a viable subsistence base and functioning social systems'. Twenty years on it is apparent through the investigations made that this statement remains valid for all social sub-catchments in the mine area, notwithstanding that the Telefol villages have established livelihoods based primarily on income derived from alluvial gold mining. The Miyan and Paiyamo subsistence bases appear to be robust, with the Paiyamo exploiting opportunities for income generation through the provision of transport and labour as they become available.

SV2 - Opportunities for participation in the cash economy

Opportunities for participation in the cash economy were extremely limited, apart from alluvial gold production and the supply of labour and services to FRL on an intermittent basis. The availability of better infrastructure (principally roads) would improve accessibility, however this may not increase opportunities due to the remoteness of the area which reinforces dependence on FRL.

Culture (Social Values 3 and 4)

The Miyan and Telefol live on the northern extremity of land occupied by the Mountain Ok or Min cultures. Traditionally, their lifestyle was characterised by frequent settlement shifts, long fallow one-crop gardens dominated by taro, and a dependence upon hunting rather than domestically produced protein. Gardner (1996) asserts that this lifestyle, coupled with large land areas and significant adverse health effects experienced in settlements at lower elevations, meant that 'personnel, rather than land, were the crucial resource, and that competition for people, rather than for land, was a key element of social 'progress''. In precontact times the northern expansion of the Mountain Ok was a response to expansionary pressures due to population growth in the central valleys around Ifitaman, and resulted in the displacement of groups like the Owininga and upper Sepik peoples from the valleys (such as the Usage River valley). In colonial times the expansion of the Miyan people northward can also be attributed to the pressure that was placed on them by Telefomin. Hence, life was characterised by continual raiding.

The Mountain Ok speakers had evolved a complex understanding of their origins based upon an interlocking series of creation sagas, focused on a legendary ancestor, Afek. Their social organisation and values were grounded in these sagas.

In simplified terms, the Min and Miyan had values focused on:

- A series of ancestral stories based on Afek and her deeds.
- A bilateral descent system.
- No clans as such but rather groups tied together by their common residence.
- A complex male initiation system.
- Leadership based on progress through that initiation system.
- Access to land through both male and female lines.
- Village and satellite garden residences.

Toward the end of the colonial period, and stimulated by Baptist mission influence, there was a significant social change as Afek's stories were supplanted by Bible stories, and men's houses were torn down and initiation schedules abandoned. One consequence of this was that traditional leadership systems were also overthrown. While this helps to explain why the influence of both local Baptist pastors and local government councillors is more than usually evident in the region, neither group has the legitimacy-granted-by-tradition which empowered the pre-existing set of social values. There is some indication that in the broader region to the south of the mine area, social values are themselves still in a re-formative stage following the earlier abandonment of Afek stories. Consequently, caution is warranted in assigning too much weight to expressions of those values centered on culture and traditional leadership which may well evolve in different ways during the life of the Project.

The Paiyamo are the smallest cultural group in the mine area, largely residing in one village, Paupe, and are more closely related to groups of the Wario River system to the east and Duranmin to the south, where there are genealogical connections. Paiyamo also have close relations with the residents of Auom (sharing resources between Lake Warangai and the Frieda River) and Iniok. Historically, the Paiyamo were significantly impacted by the Telefol annexation of the upper Frieda River, and 'have managed to maintain their population in recent decades by persuading outsiders to join them through offers of marriage and/or access to resources' (Gardner, 1996).

Land Ownership

The issue of land ownership, and the associated delineation of land boundaries, of the land required for the Project has been the subject of numerous investigations over the decades of Project exploration and development studies. As boundaries tended to move over time depending on the relative strengths of competing groups, the issue of historical ownership of the Frieda mineral deposit has been subject to on-going contestation between the Miyan and Telefol groups. While there have been a number of past agreements, an Agreement under the *Land Dispute Settlement Act 1975* was signed on 12 January 2015 between the Telefol and Miyan landowning groups establishing criteria for membership of the landowning groups and the sharing of royalties for the HITEK and Nena mineral deposits.

Governance

Telefomin District (Sandaun Province) is divided administratively and politically into four LLGs and 82 ward areas for governance and service delivery purposes. The Miyan and Telefol social sub-catchments are part of the Telefomin Rural LLG area while the Paiyamo (Paupe) are part of the Tunap/Hunstein LLG in East Sepik Province. The political leadership for districts comprise an elected member of the National Parliament, a president and a councillor representing each ward in the district. During community surveys, awareness of the identity of ward councillors among communities in the mine and infrastructure area was variable and tended to depend on whether the ward councillor was resident in the village or not, and even that did not guarantee that the rest of the residents knew who the elected person at the time was. Representation and contribution to decision-making from ward to LLG or district was perceived to be low in all cases, matched with lack of capacity at LLG level to engage in planning processes or implement planning decisions.

Table 7.31 indicates governance infrastructure and law and order services and facilities at each community.

Table 7.31 Governance, law and order summary by village

Community	Governance	Infrastructure	Formal police	Auxiliary police
Amaromin	Village councillor; village committee of elders	None	None	1
Sokamin	Village councillor; village council	None	None	1

Table 7.31 Governance, law and order summary by village (cont'd)

Community	Governance	Infrastructure	Formal police	Auxiliary police
Wameimin 1	Village councillor	None	None	None
Wameimin 2	Village councillor; committee of elders	None	None	None
Ok Isai	Village councillor; village magistrate	None	None	2
Wabia	Village councillor; village magistrate	None	None	None
Paupe	Village councillor; sub-group leader	None	None	None

Religious and Traditional Practice Adherence

As reported by Gardner et al. (1996), while all cultural groups in the mine area have changed with the coming of Christianity,

> *…old knowledge has not completely gone and people still think about the way they used to do things. People are especially concerned about the success of their gardens and the health of their children and sometimes the old ways are thought to be powerful in these important matters. All groups retain fundamental ideas about how the world can be affected by spirits and by human beings who have the knowledge.*

The Baptist Church (initially through the Australian Baptist Missionary Society, now through the Baptist Union of PNG) has been present in the Telefomin area for over 50 years and has had a significant influence on events in the area, delivering many services, such as maternal and child health, that have improved livelihoods. The Baptist Church presence also provides an important network of links between dispersed congregations through regular meetings of pastors and women's groups.

Survey data presented in Table 7.32 indicates mainstream Christian denominations in the mine area villages. All pastors were local men, except for the pastor at Wameimin 1 who was from Yawe. All villages with a church indicated strong attendance at services except for Paupe where attendance was said to be weak.

Table 7.32 Mainstream Faith indicators

Village	Religion	Dedicated church building?	Resident pastor?	Frequency of service	Attendance at services
Amaromin	Baptist	x	x	Nil	Nil
Sokamin	Baptist	✓	✓	Weekly	Strong
Wameimin 1	Baptist	✓	✓	Weekly	Strong
Wameimin 2	Baptist	✓	✓	Weekly	Strong
Ok Isai	Baptist, New Guinea Revival	✓	✓	Weekly	Strong
Wabia	Baptist	✓	✓	Weekly	Strong
Paupe	Baptist	✓	✓	Weekly	Weak

Source: Coffey survey 2015 and Coffey village survey 2017.

Archaeology and Cultural Heritage

Project EIS studies included a detailed preliminary assessment of archaeology and cultural heritage by Denham and Hitchcock (2015) and a subsequent targeted cultural heritage survey by

ALA (Appendix 13). Table 7.33 indicates the number of sites recorded for the mine and FRHEP area.

Table 7.33 Number of archaeological and cultural heritage sites recorded for the mine and FRHEP area during the field investigations, by language group

Language Group	Number of sites
Miyan	66
Telefol	142
Paiyamo	43
Total	251

Source: ALA, 2018 (Appendix 13).

The Paiyamo indicated that the most significant sites were landforms associated with various masalai spirits (who regulate the Paiyamo world-order), ossuaries containing the bones of ancestors, and mountains that house the spirits of the dead. Certain episodes associated with the period of ‘marking the landscape’ have particular relevance to Miyanmin cultural heritage sites recorded particularly regarding the ancestors named Wanyea and Oiyap, with complex interwoven nature between itineraries of ‘real’ figures (e.g., Oiyap) and ‘fictive’ or semi-mythical figures (e.g., Dimoson) ‘with the latter acting as a foundation for the former’. The Telefol had the greatest number and density of cultural sites compared to any other group, with sites of greatest significance being ossuaries and some masalai places.

Status of Social Values 3 and 4 within Social Catchment 1A

Summary statements of the status of social values 3 and 4 within Social Catchment 1A are provided below.

SV3 - An enduring ability to sustain cultural identity and traditions including connection to ancestors

Cultural knowledge among the current generation of adults was strong, though accompanied by an acknowledgement that elements of culture have been evolving since initial contact with the Australian colonial administration, and that they will continue to evolve, possibly at a higher rate, should the Project proceed. There was a common sentiment expressed that it is the responsibility of parents to ensure that important elements of tradition and ancestral connection are passed on to the next generation.

SV4 - An enduring ability to maintain customary rights to land access and resource use

Land custodianship in accordance with customary precepts for access and resource use was reasonably strong in 2015, partly supported by the isolation and difficulty of access and travel within the area. There was recognition that, in the event of the Project proceeding, there would inevitably be pressure for in-migration from outsiders and distant relatives that will require State and private support to manage.

Personal and Community Well-being (Social Values 5 and 6)

Hanson et al. (2001) describe people living in Sandaun Province as ‘strongly disadvantaged relative to people in other districts of PNG’ and that people living in Telefomin District:

> *…are extremely disadvantaged relative to people in other districts of PNG. There is no agricultural pressure, land potential is low, access to services is very poor and cash incomes are very low. Child malnutrition is of concern.*

The Telefomin District Development Program Plan (Sandaun, 2014) gives some insight into the delivery of services aimed at ensuring the well-being of residents in the district. It describes the provision of basic health care services as a 'mammoth task' due to the dependence on expensive air transport, and indicates that:

> *…outreach maternal and child health programs are being scaled down to one or two rounds for major health centres…*

It also indicates that education services are:

> *…no different, school materials had to be stranded either in Vanimo or at Telefomin District HQ, as there are no regular flights into the district and even out to the remote parts of the districts for the teachers and materials to be delivered. Most schools in the remote areas of the district are not fully staffed with teachers, as accessibility and other hardships that the teachers are going through makes it difficult for them to live and work there.*

In this situation, the well-being of residents rests in the hands of the communities themselves, and it is unsurprising that they rely on the development and service programs of churches where they are available and in the case of the mine area social catchment, on support that can be provided by FRL.

Infrastructure

The built environment in all mine area villages was typical of remote PNG villages. Houses were generally constructed by the owner and residents working collectively using bush material; however, in Ok Isai and Wabia, where there is substantial income from alluvial mining, persons with carpentry skills were sometimes engaged to build elevated houses of sawn timber framing on steel posts. Roofs in this case were invariably made of corrugated iron, but wall cladding was of natural material, sawn planks or profiled steel sheets (Plate 7.70).

Other public infrastructure was extremely limited and, where it is in place, it is difficult to sustain. Wabia and Ok Isai both have airstrips that are maintained (Plate 7.71). A piped water supply at Amaromin (initially installed by a previous project developer) has been in disrepair for some time. Only two villages, Sokamin and Wabia, had a community meeting hall, and sporting facilities such as playing fields and volleyball courts were rare and, where present, were generally not maintained to a good standard. In Sokamin and Wameimin 1, topography constrains the establishment of playing fields. All villages have helicopter landing areas established by FRL. No village has access to mobile phones; however, all have access to radio communication with the Frieda River Base Camp or church headquarters. Villages at Wabia, Ok Isai and Paupe situated on rivers have access to motorised canoe transport without built landing facilities (Plate 7.72).

Education

Survey data in Table 7.34 shows that the Telefol villagers have attained the highest levels of secondary and tertiary education in Social Catchment 1A (i.e., 8.4% and 10% for Ok Isai and Wabia, respectively).

Table 7.34 Highest education level attainment by village

Village	None (%)	Elementary (%)	Primary (%)	Secondary (%)	Tertiary/ vocational (%)	Unknown (%)
Amaromin	51.7	2.6	19.8	1.7	0	24.1
Sokamin	42.6	10.9	42.2	3.5	0.4	0.4

Table 7.34 Highest education level attainment by village (cont'd)

Village	None (%)	Elementary (%)	Primary (%)	Secondary (%)	Tertiary/ vocational (%)	Unknown (%)
Wameimin 1	44.4	15.3	21.5	1.4	0	17.4
Wameimin 2	45.7	11.9	23.2	4.6	0	14.6
Ok Isai	37.9	1.7	27.6	7.8	0.6	24.4
Wabia	41.7	5.3	24.1	9.7	0.3	18.8
Paupe	65	12.9	17.8	1.2	0	3.1

Source: Coffey household survey 2015.

During the 2009 village surveys, women's groups from all villages highlighted the need for education and training opportunities for adults as well as children, suggesting adult, specifically women's, literacy classes and sewing lessons as useful contributions. In 1995 and 1996 representatives from the Project provided the women of Paupe with sewing machines, materials and training. In October 2009, FRL funded a women's literacy program in Amaromin. Similarly, the women of Ok Isai and Wameimin 2 reported that a women's literacy program was operating within their village, with one course having been completed and more to be run in the future.

Table 7.35 lists the status of education facilities in the mine area villages.

Table 7.35 Education facilities

Community	Current school status
Amaromin	No facility, children walk to Fiak Community School (two hours walk).
Sokamin	Elementary school with local teachers, stationed in the community.
Wameimin 1	Elementary school with semi-permanent classroom built using Community Project Fund. Local teachers stationed in the community.
Wameimin 2	Elementary school with semi-permanent classroom built using Community Project Fund. Local teachers stationed in the community.
Ok Isai	Primary school with three teachers, school operational.
Wabia	Elementary school, one teacher.
Paupe	Elementary school, three teachers.

Source: FRL Community Affairs Department.

Telefomin district has two high schools; Telefomin High School, which is a government agency school and the Oksapmin High School, which is a Church Agency School. The Telefomin district development program plan (Sandaun, 2014) has identified a need to upgrade one of these schools into a secondary school so that it eases burden on parents of the expense of sending their children to other secondary schools in the province. The plan also identified a need for improving the Technical and Vocational Education and Training (TVET) available at Telefomin for those children who do not progress into the academic pathway and who desire to pursue the Skills Development Pathway such as offered by TVET Centres. It proposes to do this by upgrading the current Telefomin Vocational Centre into a TVET Centre to deliver trade skills training.

Coffey

Plate 7.70
Houses at Ok Isai showing use of different construction materials

Coffey

Plate 7.71
Airstrip at Ok Isai

Coffey

Plate 7.72
Canoes at Ok Isai

Health and Nutrition

Table 7.36 shows the reported medical conditions recorded during the 2010 health baseline survey, indicating the significant morbidity due to malaria and intestinal parasites (Appendix 13). The 2015 community surveys reported that fevers due to malaria and upper respiratory tract infections and diarrhoea were the most prominent morbidity factors. The Telefomin district development program plan (Sandaun, 2014) indicated that skin disease was also an important source of morbidity.

Table 7.36 Reported medical conditions in the previous 12 months

Village area and number surveyed	Asthma (%)	Pneumonia (%)	Hypertension (%)	Intestinal parasites (%)	Malaria (%)	Dengue-like fever (%)
Mine and FRHEP area villages (480)	3.1	1.3	4.4	39.0	77.0	-

Source: CEH, 2018.

Table 7.37 lists the status of health facilities in the mine area villages.

Table 7.37 Village health infrastructure and service status

Community	Current status
Amaromin	No facility and nearest aid post is at Fiak (two hours walk).
Sokamin	Community has built a bush material hut to use as an aid post, but it is not gazetted by government. Limited services are delivered by village health volunteers.
Wameimin 1	No facility.
Wameimin 2	Government gazetted aid post.
Ok Isai	Government gazetted aid post.
Wabia	Aid post and Community Health Worker present.
Paupe	Government gazetted aid post.

Source: FRL Community Affairs Department.

Table 7.38 presents a summary of the 2010 CEH survey (Appendix 13) results and compares them with observations made during the 2015 and 2017 surveys.

Table 7.38 2010 health survey results and 2015 and 2017 survey observations

2010 Health survey results*	2015 Village survey observations	2017 Village survey observations
Environmental health		
Reasonably typical for remote low-altitude rural and remote communities in PNG. • For most village households, the results confirm that overcrowding and ventilation were not of health concern. • The majority of village households generally had at least one mosquito net, but insufficient bed nets for all of the family. This is particularly notable at Auom 3 (89%), Wabia (81%) and Iniok (58%). The general practice at these communities appeared to be to reserve the mosquito nets for babies and infants. At all of the villages, none of the bed nets had been treated with pesticides since purchase. • The availability of screens and use of mosquito nets, considering the observed high malaria incidence, does not appear to be effective as a means of vector control. • Overall smoking rate (49%) was markedly higher than that reported both nationally (37%), as measured in the Mt Obree area of Central Province (30%) and in a recent study of inland villages in Madang Province (37%). • Both the socio-economic and health surveys found that alcohol consumption was largely restricted to adolescent and adult males in all of the communities with the exception of Ok Isai where a significant number of females reportedly consume alcohol.	• No significant observable changes. • Kapa roofs: Telefol (64%), Miyan (31%), Paiyamo (5%). • Paupe in most obvious need for improvement in housing. • Piped water supply at Amaromin in disrepair; pit toilets at Wameimin 2 of a higher standard than elsewhere; no overall improvement in water supply; villages clean.	• No significant observable changes. • Iron roofing present on 16 out of 33 houses surveyed in Wameimin 2; 13 out of 45 in Paupe; 28 out of 68 in Wabia and 46 out of 61 in Ok Isai. • Water sourced from tanks, rivers or lakes are said to be in good or satisfactory condition. Treatment of water only occurs in Wabia. • The village surveys generally indicated the need for an upgrade to service facilities and equipment provided by the aid posts.

Table 7.38 2010 health survey results and 2015 and 2017 survey observations (cont'd)

2010 Health survey results	2015 Village survey observations	2017 Village survey observations
Nutrition		
• Nutritional surveys identified significant differences in the range of food consumed and consumption frequencies between the more isolated inland villages and those along the Frieda and Sepik rivers. • Degree of isolation, local environmental conditions and household access to a cash income stream were the main determinants for food diversity and food consumption frequency. • Food insufficiency was invariably either a short-term issue, relating to insufficient taro or other crops planted, unexpected visitors, or was a consequence of large family size (Paupe and Iniok). • 24-hour food recall and food frequency survey indicated: – Tubers supplemented by banana, provided the main carbohydrate source at Amaromin, Ok Isai, Wabia and the Wameimin 1 and 2 villages. – Consumption of rice dominated at the more affluent communities of Ok Isai and Wabia. – More than 50% of the households at Paupe had consumed fresh fish on the previous day. – Tinned fish and tinned meat have almost entirely replaced fresh fish at Ok Isai (90% of households). – The diet at Ok Isai, while still including the traditional consumption of tubers and green vegetables, is largely dominated by store-purchased foods. A similar situation is apparent at Wabia. • Consumption of store foods by household in the other mine area villages, was very low.	• Store food for mine area villages (Wabia, Ok Isai, Paupe) appear to be around 25 to 50% higher than at Pagwi, with price of some items (e.g., cooking oil) up to 100% higher. • No discernible change in food insufficiency. • 2010 Tinned fish and tinned meat have almost entirely replaced fresh fish at Ok Isai (90% of households) 2015 A higher consumption of fresh fish (50% of households). • 2010 Ok Isai diet largely dominated by store-purchased foods 2015 Ok Isai modest decrease in dependency on store foods; Wabia, significant increase in store foods consumed; Paupe and Auom 3 show some intrusion of store foods, with a significant increase in consumption of rice at Paupe.	• No nutrition data collected in 2017.

Table 7.38 2010 health survey results and 2015 and 2017 survey observations (cont'd)

2010 Health survey results	2015 Village survey observations	2017 Village survey observations
Anthropometric measurements		
• Indicated above average nutritional health with little wasting, stunting or underweight in children under five years of age. Little child malnourishment in the first five years of life. Mildly overweight children in all of the age groups are of some significance, but not of health concern. • Comparison of the mean adult values for weight and height suggest that male weights were markedly higher in those communities that are transitional towards urban PNG lifestyles. The villagers at Iniok, Ok Isai and Wabia, by example, were generally more affluent and had better food diversity and food quality. • Small survey of FRL employees (35) at the Frieda River Base Camp indicated that on average, employees were approximately 10 kilograms heavier than their village lifestyle counterparts. • Measurement of blood pressure indicated that there were few hypertensive individuals, as to be expected in a group with very low levels of adult obesity. • Spleen enlargement was typical of communities living in hyperendemic malaria areas of rural and remote PNG. • Prevalence of eye infections was similar to the results reported for a number of other inland village groups, but markedly higher than that observed along the Ramu River system in Madang province. • The prevalence of skin infections varied between villages and on a whole-of-population basis, was somewhat higher than that reported in other recent PNG studies.	• Little observable evidence of obesity, even in camp mess.	• No anthropometric measurements made in 2017.

Table 7.38 2010 health survey results and 2015 and 2017 survey observations (cont'd)

2010 Health survey results	2015 Village survey observations	2017 Village survey observations
Clinical measurements		
• The medical examinations clinically identified four unreported cases of tuberculosis at Wabia (2) and Amaromin (2) confirming that there are pockets of uncontrolled tuberculosis in these communities. Since the examinations involved only 19% and 26.7% of the respective total populations at Wabia and Amaromin, the prevalence is significant. • None of the villages appeared to have an awareness of family planning. Girls marry at very young ages, multiple births are routine and although unconfirmed, there would appear to be unusually high maternal and 0 to 12 months infant mortality. • Blood pressure results were almost universally in the normal to low range, with little difference between the males and females of all age groups. • Only two cases of liver enlargement and no cases of kidney enlargement in any of the villagers examined. • Splenomegaly (spleen enlargement) result (overall 38%; Miyan 18%; Paiyamo 46%; Telefol 47%) very similar to that reported in Madang Province (41%) for mid-altitude rural villagers. • Prevalence of eye infections were somewhat comparable with those reported for rural and remote villages in the remote Fly River region. • Prevalence of skin infections was scabies 0.2%, scalp infections 1.1% sores and tropical ulcers 21.2%, ringworm 18.4% and other skin infections 43.2%. These results were similar to those reported for Western Province lowland communities.	• No clinical measurements made in 2015.	• No clinical measurements made in 2017.
Immunisation rates		
• Villages had widely variable immunisation coverage rates. • On a whole-of-population basis, immunisation coverage was markedly below the average in PNG.	• Immunisation rates were consistent with the PNG average which ranged from 63% to 84% dependant on the specific vaccine.	• Immunisation rates not recorded in 2017.

Table 7.38 2010 health survey results and 2015 and 2017 survey observations (cont'd)

2010 Health survey results	2015 Village survey observations	2017 Village survey observations
General state of health		
• A comparison between villages identified Amaromin (56%), Auom 3 (65%), and Paupe (72%) as reporting the lowest health satisfaction ratings. • Over the previous 12 months the participants from all communities had sought little treatment for medical complaints, other than malaria (77%) and internal parasites (39%). • Self-reported medical complaints indicate a high prevalence of fever associated with malaria and upper respiratory tract infections.	• Main illnesses stated to be fever from malaria and upper respiratory tract infections, followed by diarrhoea.	• Young children in Wameimin 2 and Wabia do not receive regular immunisations. Paupe and Ok Isai do. • Main type of illness for Ok Isai, Wabia and Paupe is diarrhoea, malaria and fever. • Main type of illness for Wameimin 2 is skin infections, malaria and upper respiratory infections.

* Focussing on PNG Department of Health priority health indicators.

Children's Health

Table 7.39 presents survey data as the percentage of children under 71 months of age, falling below two or three standard deviations reference population median value for each of the three indices weight-for-age, height-for-age and weight-for-height. While acknowledging the normal caveats associated with such a small sample, it can be seen that there is little child malnourishment in the first five years of life in mine area villages. The survey results also indicated that there were a number of mildly overweight children in all of the age groups which were of some significance, but not of health concern.

Table 7.39 Anthropometric data of children 12 to 71 months of age (all values %)

Age (months)	Number	Weight-for-age		Height-for-age		Weight-for-height	
		Underweight		Stunting		Wasting	Overweight
		< -3 sd	< -2 sd	< -3 sd	< -2 sd	< -2 sd	< +2 sd
12 – 23	17	0	0	0	5.9	0	5.9
24 – 35	31	0	0	0	3.2	0	6.5
36 – 47	49	0	0	0	2.0	0	2.0
48 – 59	38	0	0	0	2.6	0	5.3
60 – 71	34	0	5.9	0	3.0	3.0	3.0

sd = standard deviation.
Source: CEH, 2018.

The results compare favourably with World Bank anthropometric data for lowland and highland fringe communities in PNG, which although using different criteria nationally, identified a prevalence of stunting in these geographic groups of 35% to 59% (CEH, 2018). The results for wasting in the mine area population is also at the lower end of the values recorded in the World Bank survey of 0 to 14.8% and similar to the prevalence observed in Madang and Morobe provinces in 2007 (0% and 2% respectively). The weight-for-age measure for mine area villages also compares favourably to the 2012 provincial figure of 31% for children under five.

Immunisation of children is supported by FRL in the mine area villages. The status of child immunisation in November 2015 survey is shown in Table 7.40. All children born in 2015 had commenced their immunisation, and the immunisation rate for children 1 to 5 years old was 73%.

Table 7.40 Status of child immunisation

Village (Number children surveyed)	Immunisation status			
	Infant (0 to 12 months) Started (%)	Child (1 to 5 years)		
		Complete (%)	Incomplete or behind schedule (%)	No record (%)
Wamiemin 2 (28)	100	70	22	9
Wamiemin 1 (47)	100	62	38	0
Amaromin (18)	100	100	0	0
Ok Isai (83)	100	59	19	22
Wabia (73)	100	57	22	21
Paupe (47)	100	68	16	16
Mean coverage		73		

Women's Health

The women's focus groups conducted in each village as part of the 2010 socio-economic survey by Coffey sought information specifically about women's health.

In the mine area social catchment, most villages did not have access to any government maternal health services and women delivered their children without medical assistance, relying on FRL's healthcare personnel in the case of serious complications. A number of villages reported to have a village birth attendant present in the village. Some villages reportedly had access to maternal health services outside of the village, but few women utilised these services due to the distance to access the service and the inconvenience of travel when pregnant. Village surveys undertaken by Coffey in 2015 confirmed the 2010 survey results relating to maternal health.

CEH 2018 noted that although unquantified, it appeared that a combination of poor hygiene, multiple births in very young women and the lack of pre- and post-natal support was a major contributor to the high-level of mortality (and evident morbidity) in females aged 15 to 45 years.

Women were largely aware of family planning methods, however, accurate knowledge about family planning and access to contraceptives was variable. The contraceptive pill and injections were reportedly more readily available than condoms. Agreement for the use of contraception was reportedly determined by husbands, many of whom felt that their wife's use of contraception would reflect negatively on their status by resulting in less children (a status of virility), and implying that their wife may be promiscuous.

Traditional birth control methods were said to be used in only a small number of villages surveyed for the socio-economic study. Methods included the ingestion of various herbs and betel nut, and the traditional practice of placing herbs in the mouth of a turtle and releasing it into a stream to prevent pregnancy.

Women's groups from most villages reported that abstinence from sex after childbirth was practiced as a means to allow the mother to recuperate and to prevent another immediate pregnancy. The period of abstinence varied dramatically from village to village with a period of four to six months the most commonly stated duration. In nearly all cases, the abstinence period was at the discretion of husbands, and the women reported that they were often harassed (sometimes physically assaulted) if they tried to withhold sex.

Women in most villages generally maintained the traditional practice of keeping themselves segregated from the rest of the village during menstruation, sometimes by removing themselves altogether for the duration of menstruation, others by segregating themselves only from their husbands by sleeping in the same house but separate beds.

Law and Order

There was no local presence of formal law and order and dispute resolution institutions within Social Catchment 1A, which was consistent with minimal law and order issues being reported. However, surveys by Coffey in 2010 concluded that domestic violence (generally seen as being caused by a failure of wives to fulfil their marital duties) was pervasive across all communities surveyed, as acknowledged by both male and female participants. Alcohol was considered a considerable contributor to crime (from domestic violence and physical abuse through to public nuisance) across almost all communities in the mine area, despite village laws existing in most places banning the consumption of some or all types of alcohol. Amaromin, Wameimin 1, and Wameimin 2 reported only occasional issues as a result of alcohol consumption, with no incidence of drug use or gambling.

Status of Social Values 5 and 6 within Social Catchment 1A

Summary statements of the status of social values 5 and 6 within Social Catchment 1A are provided below.

SV5 - An environment amenable to personal and family health, safety and security

The physical and social environment of mine and FRHEP area communities in 2015 was supportive of health, safety and security, primarily due to remoteness (and consequent minimal contact with outside persons and influences such as alcohol and drugs), continued access to good quality gardening land, forests and rivers, and health services supported by FRL. While elements of these factors in all communities will be vulnerable to proximal development, Paupe has the highest level of vulnerability due to proximity to Project activities.

SV6 - The availability of services supportive of personal health, safety and security

Mine and FRHEP area communities had limited public infrastructure, and in general, were not in receipt of services supportive of personal health, safety and security. This is an area where communities have strongly held views on the need for improvement which they believe will only occur should the Project proceed.

7.3.5 Social Catchments 1B and 1C: New Infrastructure and Road Corridor and Existing Infrastructure and Road Corridor

Social profiles for Social Catchments 1B and 1C have been characterised together to avoid repetition of information that is applicable to both social catchments.

Location

The new infrastructure and road corridor (Social Catchment 1B) encompasses approximately 110 km of the proposed main access route to the mine area and runs from Hotmin north-northwest to Green River. At this point it meets the existing infrastructure and road corridor (Social Catchment 1C). Eight representative villages in Social Catchment 1B were surveyed by Coffey in 2017 and this survey data forms the basis of much of the information on this catchment. These villages include Hotmin, Idam 1, Idam 2, Bisiabru, Wokomo 1, Uramesin 2 and Tempsapin (see Figure 7.30 and Figure 7.31). Hotmin, Uramesin 2 and Tempsapin are located in the Tunap/Hustein Rural LLG of the Ambunti/Dreikikir District of East Sepik Province. Wokomo 1, Idam 1, Idam 2, Bisiabru and Green River are located in the Green River Rural LLG of the Vanimo/Green River District of Sandaun Province. Much of the land that the corridor crosses is customary land belonging to the Abau language group.

The existing infrastructure and road corridor (Social Catchment 1C) runs approximately 190 km north from Green River to Vanimo on the north-west coast of the Sandaun Province. From Green River, the corridor travels along the edge of western hills to Kilifas, across lands generally belonging to various clans of the Kwomtari language group. From Kilifas, the corridor travels across the Bewani Mountains to Sumumini and then onto Imbrinis where it tracks along the Nemayer River to Vanimo. Lands of this section predominantly belong to clans of the Fas language group. Seven representative villages in the catchment were surveyed by Coffey in 2017 and this survey data forms the basis of much of the information on this catchment. The villages surveyed were Amini, Kwomtari, Itomi, Kilifas, Sumumini, Imbrinis and Green River. Amini and Green River are located in the Green River Rural LLG, Kwomtari and Itomi are located in the Amanab Rural LLG, Kilifas is located in the Walsa Rural LLG and Sumumini and Imbrinis are located in the Bewani/Wutung Onei Rural LLG. All seven villages are within the Vanimo/Green River District of Sandaun Province.

Villages in the south of Social Catchment 1C are largely isolated with few settlements spread out along the existing road corridor. As you move further north in the catchment, commercial operations including logging and palm oil plantations increasingly dominate the landscape.

Population and Demographics

Population data has been assembled from a number of sources, including ward level data from the 2011 census (NSO, 2014) and household and village surveys conducted by Coffey in 2017.

New Infrastructure and Road Corridor, Hotmin to Green River

Table 7.41 presents a summary of the population characteristics of each of the villages in Social Catchment 1B. The largest village (based on population) is Idam 1, with 794 inhabitants, followed by Idam 2 with 518 inhabitants. Wokomo 1 had the smallest population, with 65 inhabitants.

Table 7.42 details the age demographics in the catchment. A small percentage of residents within the catchment are over 60 years of age, with the majority between the 15 and 60 years of age.

Table 7.41 Social Catchment 1B population data

Village	Population	Households	Household occupancy	Male	Female	Gender Ratio*
Hotmin	202	44	4.6	110	92	120
Idam 1	794	148	5.4	457	336	136
Idam 2	518	115	4.5	316	259	122
Bisiabru	255	50	5.1	n.a.	n.a.	n.a.
Wokomo 1	65	10	6.5	20	45	44
Uramesin 2	194	38	5.1	n.a.	n.a.	n.a.
Temsapmin	112	22	5.1	n.a.	n.a.	n.a.

n.a.: not available. Population data was not available for Green River.

Source: 2017 Coffey village and household survey and NSO, 2014.

* Number of males per 100 females.

Table 7.42 Social Catchment 1B estimated age demographics

Villages	Percentage of population under 15	Percentage of population over 60
Hotmin, Uramesin 2, Temsapmin	41%*	3%*
Wokomo 1, Idam 2, Idam 1, Bisiabru, Green River	46%†	3%†

* Based on Tunap/Hustein Rural LLG data.

† Based on Green River Rural LLG data.

Source: NSO, 2014.

Existing Infrastructure and Road Corridor, Green River to Vanimo

The population of Vanimo/Green River District grew by an average annual rate of 2.9% between 2000 and 2011, from 50,751 to 69,052 (NSO, 2000 and NSO, 2014). The highest rate of population growth was in the Bewani/Wutung Onei Rural LLG, the closest LLG to the town of Vanimo. At the village level, both Itomi and Imbrinis had substantially higher than average growth rates, 13.5% and 8.2% respectively. This is possibly attributable to in-migration associated with logging activities in the region.

Key population characteristics for Social Catchment 1C are detailed in Table 7.43.

Table 7.43 Social Catchment 1C population data

Village	Population	Households	Household occupancy	Male	Female	Gender Ratio*
Amini	292	39	7.5	150	142	106
Kwomtari	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Itomi	525	77	6.8	287	238	121
Kilifas	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Sumumini	1,010	168	6.0	556	454	122
Imbrinis	939	141	6.7	516	423	122

Source: NSO, 2014.

Table 7.44 details the age demographics in the catchment. Between 44% and 46% of the population are between 20 to 49 years of age.

Table 7.44 Social Catchment 1C estimated age demographics

Villages	Percentage of population under 15	Percentage of population over 60
Amini	46%*	3%*
Kwomtari, Itomi	44%†	4%†
Kilifas	45%§	2%§
Sumumini, Imbrinis	45%**	3%**

* Based on Green River Rural LLG data.
† Based on Amanab Rural LLG data.
§ Based on Walsa Rural LLG data.
** Based on Bewani/Wutung Onei Rural LLG data.
Source: NSO, 2014.

Livelihoods (Social Values 1 and 2)

This section outlines subsistence activity and participation in the cash economy within social catchments 1B and 1C.

Natural Capital / Subsistence Activity

New Infrastructure and Road Corridor, Hotmin to Green River

Villages within Social Catchment 1B predominantly live a subsistence based lifestyle. Food staples include sago, taro, Chinese taro, banana and coconut. Gardening practices are generally of low intensity, with fallow periods in the order of 15 years or greater.

Hunting and fishing are important practices within the catchment for providing a source of protein such as fish and, to a lesser extent, bushmeat and chicken.

There has been little penetration of commercially supplied foods in the catchment, with the consumption of store bought foods infrequent. In Hotmin, the consumption of rice was noted as increasing, along with cassava, banana and sago, while consumption of fresh fish, taro and sweet potato was declining (based on household food surveys conducted by Coffey in 2011 and 2017).

Table 7.45 provides a summary of the most frequently consumed foods in the villages surveyed by Coffey in 2017.

Table 7.45 Food consumption in Social Catchment 1B

Village	Most frequently consumed foods
Hotmin	Taro, banana, sago, fish (in any form), aibika/kumu and other greens.
Wokomo 1	Banana, sago, aibika/kumu and other greens.
Idam 2	Sago, aibika/kuma and other greens.
Idam 1	Banana, sago, aibika/kumu and other greens.

Source: Coffey household surveys 2017.

Four (of 35) households surveyed in 2017 reported food shortages in the past 24 hours. These households were in Hotmin (1), Wokomo 1 (1) and Idam 2 (2).

Water supply in the catchment is generally from untreated natural sources including rivers or natural springs. The quality and reliability of the water supply was considered by most people surveyed as satisfactory or better than satisfactory, with two exceptions: in Bisiabru, where the quality and reliability was considered poor; and in Idam 1, where reliability was considered poor.

Existing Infrastructure and Road Corridor, Green River to Vanimo

The lifestyle of villages in Social Catchment 1C south of the Bewani Mountains is subsistence based. Further north towards Vanimo, subsistence based lifestyle is mixed with a market economy where people buy and sell local produce in roadside stalls.

Food staples in the catchment are sago, banana and taro. Fishing is an important source of food and primarily undertaken for subsistence purposes in the Sepik River and the northern coastline near Vanimo.

Land potential in the Vanimo/Green River District varies. In the foothills of the Bewani Mountains and Border Mountains, land potential is high to very high, yet the steep slopes of these areas limit the land's utility. Land potential is low in the Bewani Mountains due to the steepness of the terrain and low in the plains from the foothills of the Bewani Mountains to the Vanimo coastal plains due to relatively poor soils and frequent flooding.

Water supply in the catchment is from a range of sources including tanks, rivers, springs and bores. The quality of this water varies from poor to good depending on the village. Year-round water supply reliability in villages surveyed by Coffey in 2017 was deemed satisfactory to good in three of the six villages and poor within the remaining three villages.

Cash Economy Activity

New Infrastructure and Road Corridor, Hotmin to Green River

Villages within the catchment are characterised by their remoteness and their low level of participation in the cash economy. Four of the eight villages surveyed had markets (Hotmin, Uramesin 2, Temsapmin and Green River) but restricted access and high transport costs limit the extent that many families can participate in the cash economy.

Income

Seventeen of the 35 households surveyed by Coffey in 2017 reported earning an income in the past fortnight leading up to the survey. Hotmin had the highest level of average household income of surveyed villages in the catchment at PGK1,204. Approximately PGK800 of this is derived from alluvial gold mining, while the remaining PGK400 is sourced from the sale of garden, river and forest products.

While income generated from alluvial gold mining is substantial in Hotmin, only 35% of households surveyed generated an income from it in the two weeks leading up to the 2017 survey. The majority of households (approximately 70%) reported generating an income from the sale of garden, river and forest products.

In Idam 1 there was no evidence of income from gold or cash cropping and there was very little income generated through project related work (e.g., FRL or logging) or work for the government.

Across the catchment, formal employment is minimal, with only seven of the 35 households surveyed reporting to have received income from such sources in the past year. Of those receiving an income from formal employment, the average household income was between PGK200 and PGK300 over the two weeks leading up to the survey.

Figure 7.35 and Figure 7.36 detail the key household income data for Social Catchment 1B (excluding and including alluvial gold).

Expenditure

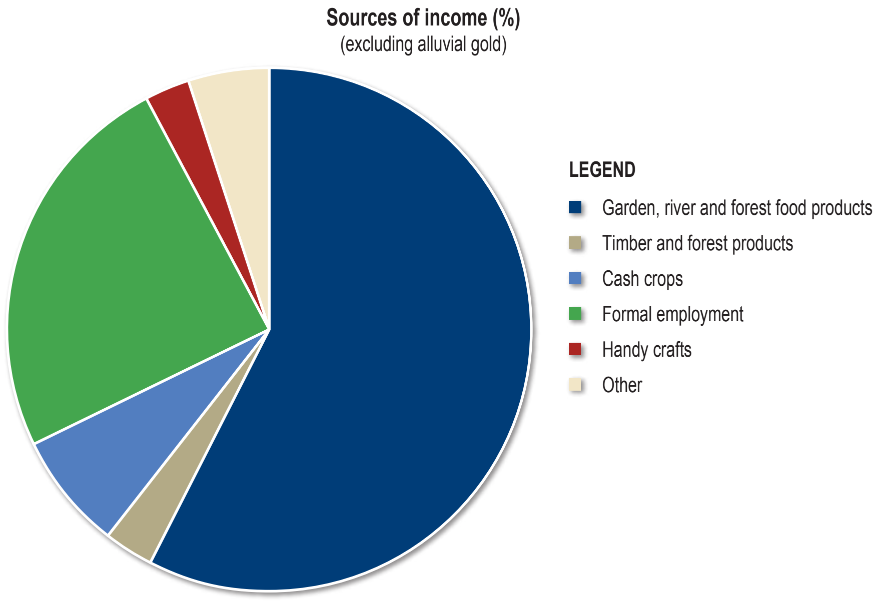
The average fortnightly household expenditure at stores and markets across the catchment is PGK124. Hotmin has the highest average fortnightly household expenditure (PGK157), while households in Idam 1, Idam 2 and Wokomo 1 have an average fortnightly expenditure of PGK42.

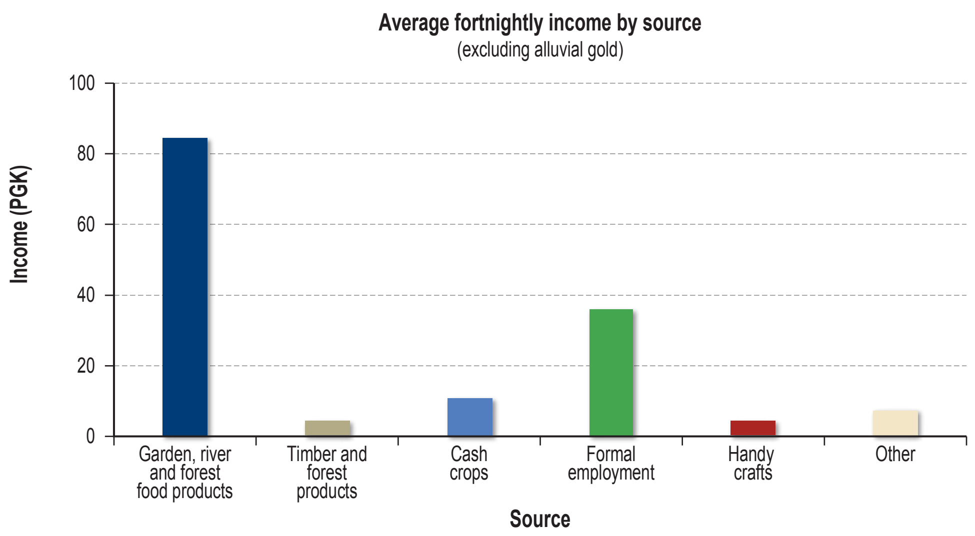
Household expenditure in Hotmin is in the order of PGK2,000 per year on food and other consumables, approximately PGK2,800 per year on education and approximately PGK5,000 per year on transport expenditure. Expenditure on education in Idam 1, Idam 2 and Wokomo 1 is virtually non-existent, at PGK5 per year. Table 7.46 provides further details on household expenditure within the catchment.

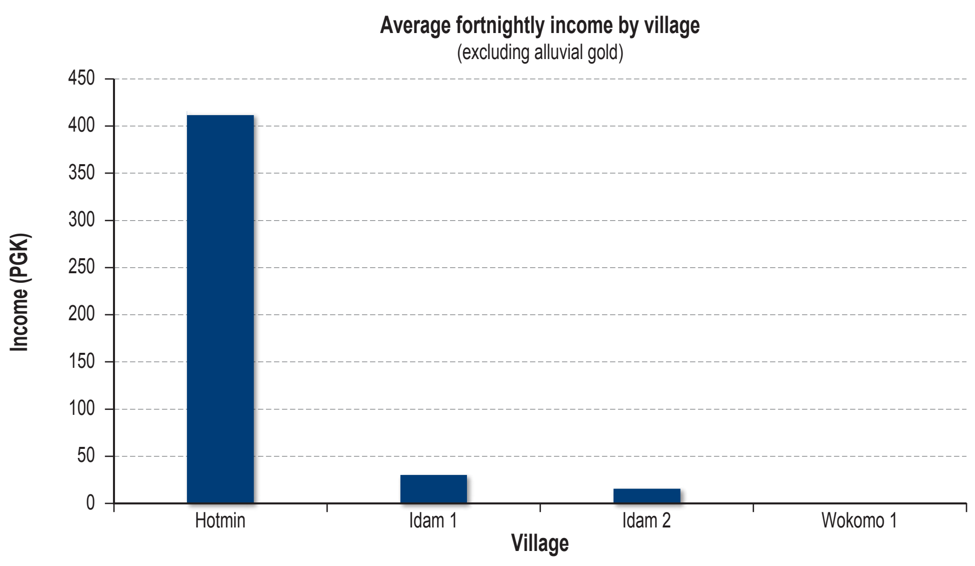
Table 7.46 Average fortnightly household expenditure in Social Catchment 1B villages

Expense category	Average fortnightly expenditure (PGK)	Comments
Purchase from store or market	124*	Most common store bought purchase was food followed by clothing or shoes.
Transport	Airfare: 91 Canoe travel: 22 PMV: 0 Other: 54	Hotmin had the highest transport cost due to airfares out of those villages that reported on transport expenditure. Idam 1 village had the lowest transport cost which likely reflects its closer proximity to Green River than the other villages surveyed enabling a cheaper trip to Vanimo.
Church and cultural	Cash: 1 In-kind: 1 Giving for repaying loans: see comments Other: 1	The offerings given to repay loans were mostly in the form of garden produce.

*Excludes the PGK5,000 that was reportedly spent on fuel by one household in Hotmin which was treated as an anomaly.
Source: Coffey household surveys (2017).

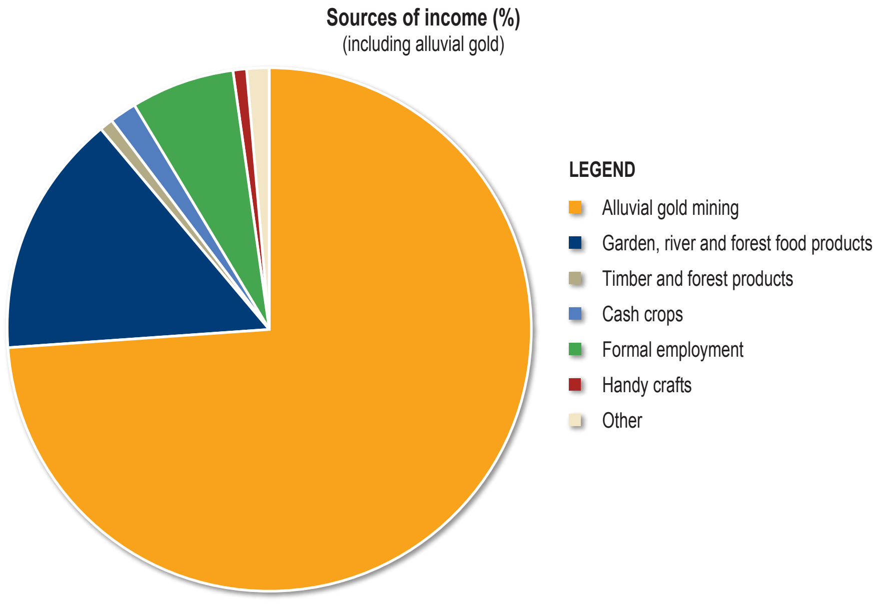


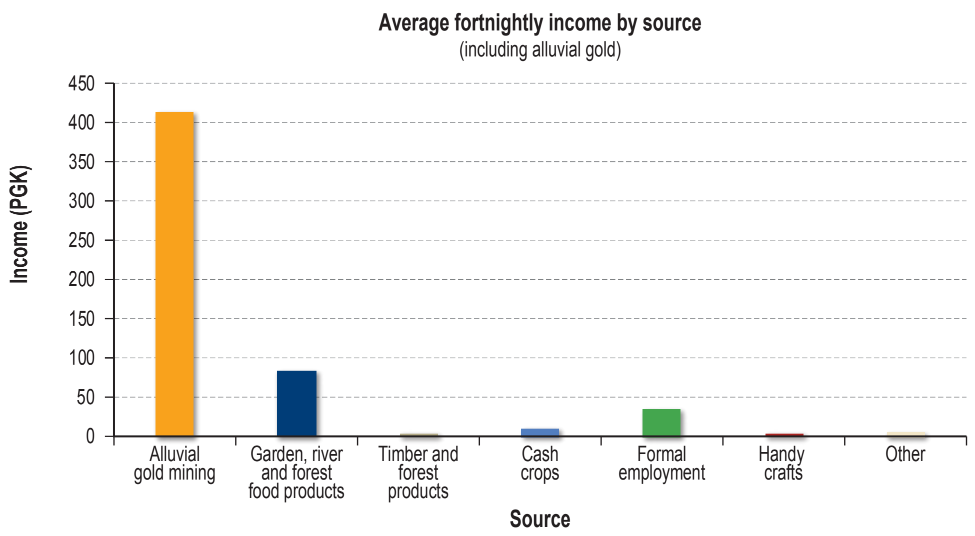


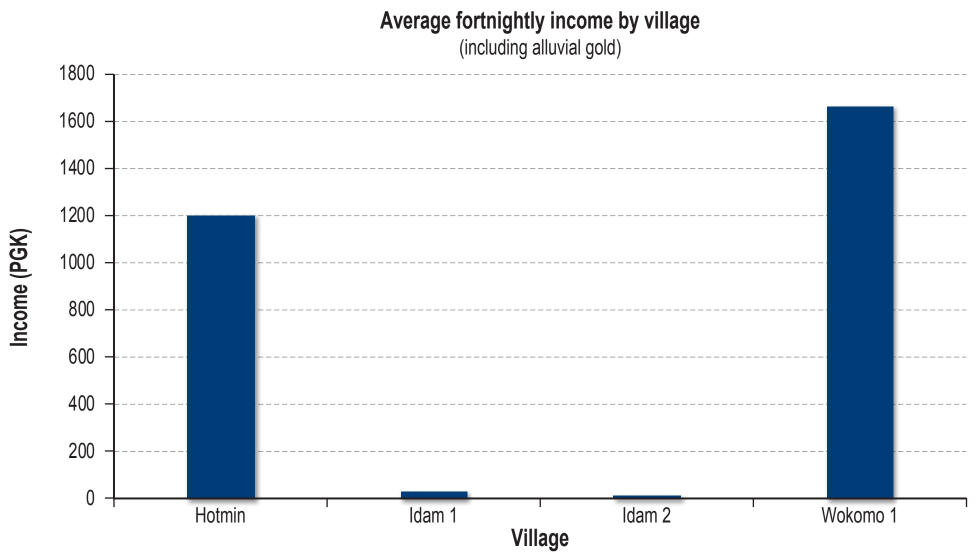


Social Catchment 1B household income data excluding alluvial gold

Figure No: 7.35


Sources of income (%)
(including alluvial gold)
LEGEND
Alluvial gold mining
Garden, river and forest food products
Timber and forest products
Cash crops
Formal employment
Handy crafts
Other


Average fortnightly income by source
(including alluvial gold)
Income (PGK)
450
400
350
300
250
200
150
100
50
0
Alluvial gold mining
Garden, river and forest food products
Timber and forest products
Cash crops
Formal employment
Handy crafts
Other
Source


Average fortnightly income by village
(including alluvial gold)
Income (PGK)
1800
1600
1400
1200
1000
800
600
400
200
0
Hotmin
Idam 1
Idam 2
Wokomo 1
Village

Existing Infrastructure and Road Corridor, Green River to Vanimo

Trade stores were observed in four of the villages surveyed in Social Catchment 1C (Amini, Sumumini, Kilifas and Itomi). Villages in the northern section of the catchment such as Imbrinis have access to roadside markets, and food/trade stores and fuel stations in Vanimo.

Income

The Vanimo/Green River District has a more developed cash economy than other districts within the province (Sandaun Provincial Government, 2013). This is due to the logging operations that take place near Vanimo and Aitape which provide employment opportunities and royalties.

Other sources of income within the catchment include the sale of surplus garden produce and betel nut at markets in Vanimo, work in the forestry and oil palm plantation industry and through the sale of goods at roadside stalls to vehicles that travel between the logging operations and Vanimo. Rubber, once an important cash crop grown in the catchment, has been substantially neglected in recent years.

A review of census data from 2000 and 2011 indicates a slight shift in how people in the catchment earn a wage. In 2000, 8% of the male population received a wage from employment, while in 2011, 13.5% of males received a wage. Only 4% of women received a wage in 2011, compared to 2% in 2000. In 2011, subsistence based employment (i.e., gardening/fishing for own use, helping in family business without pay and housework) was undertaken by 49% of males and 65% of females (NSO, 2014).

Status of Social Values 1 and 2 within Social Catchments 1B and 1C

Summary statements of the status of social values (SV) 1 and 2 within Social Catchment 1B and 1C are provided below.

SV1 – The capacity to support subsistence livelihoods

Subsistence practices play a significant role in the livelihoods of households within social catchments 1B and 1C. Opportunities to support a subsistence livelihood are strong given favourable seasonal conditions. Areas north of the Bewani Mountains in Social Catchment 1C are vulnerable to unfavourable climatic conditions such as flooding and pressure from commercial agricultural operations such as logging and oil palm plantations.

SV2 – Opportunities for participation in the cash economy

Opportunities to participate in the cash economy varies across social catchments 1B and 1C. In Social Catchment 1B opportunities are skewed towards Hotmin in the south, due to greater access to markets. In Social Catchment 1C access is skewed to the north of the Bewani Mountains due to access to markets, food stalls as well as the proximity to the provincial capital Vanimo.

Culture (Social Values 3 and 4)

Culture in social catchments 1B and 1C has been undergoing a process of slow change since initial contact by the Australian administration. Drivers of this change have been the imposition of a foreign system of law and order, labour out-migration to other areas of PNG, marriage outside of traditional norms and the inroads made by Christian missions. As with all Papua New Guineans, culture is underpinned by traditional rights to land access and resource use. In social catchments 1B and 1C there has been no large-scale cash cropping or logging land uses, although logging operations have increased significantly in the past 10 years. While used extensively for fishing and canoe travel, waterways and lakes are subject to minimal outside use for shipping purposes. Population densities are low and there is minimal pressure on resource use, though there are ongoing disputes over land boundaries, a perennial feature of traditional PNG society.

Land Ownership

Access to customary land rights is under pressure from commercial logging operations within Social Catchment 1C (AusAid, 2004). Logging operations have increased in the past 5 to 10 years (Appendix 9) and the potential income streams to be generated from such activities has resulted in people forming sub-clans to claim ownership of resource rich land (Sandaun Provincial Government, 2013).

Governance

Social Catchment 1B is located in both Sandaun and East Sepik provinces and includes two LLGs and two districts, while Social Catchment 1C is located within the Sandaun Province only and includes four LLGs and one district.

Public infrastructure is minimal within the catchment and as is common throughout the province, the majority of LLGs lack adequate facilities and systems to effectively govern.

Religious and Traditional Practice Adherence

Social catchments 1B and 1C sit within one of the most linguistically diverse regions in PNG (SIL-PNG, 2008), the Sandaun Province, with approximately 80 different ethnic and cultural groups. The Vanimo/Green River District alone contains 670 clan groups and 29 language groups (Sandaun Provincial Government, 2013).

There are three traditional language groups within Social Catchment 1B, Miyan, Abuau and Amto and four language groups within Social Catchment 1C, Fas, Kwomtari, Nai, and Baibai. The traditional languages are still used in the communities but there is a slow shift among young people who are more comfortable speaking Tok Pisin. Tok Pisin is widely used in all villages within the catchment and understood by children and adults of all ages.

Communities within social catchments 1B and 1C continue to practice traditional cultural activities while also adopting non-traditional practices into their society. For example, three of the five villages surveyed in Social Catchment 1B (Bisiabru, Idam 1 and Temsapmin) reported to using traditional village birth attendants and either trained village birth attendants or qualified medical officers (Coffey, 2017).

Every village surveyed across the two catchments, apart from Idam 1, has a functioning church building with resident pastors. Attendance to weekly services is stronger within Social Catchment 1B compared to Social Catchment 1C (Table 7.47). More than 50% of the villages surveyed receive some form of support from the Church, ranging from funded community development programs such as canoe and house building to education infrastructure building and the provision of health services.

Table 7.47 Mainstream faith indicators in social catchments 1B and 1C

Village	Religion	Dedicated church building?	Resident pastor?	Frequency of service	Attendance at services
Social Catchment 1B					
Hotmin	Other	Yes	Yes	Weekly	Most people
Uramesin 2	Other	Yes	Yes	Weekly	Many people

Table 7.47 Mainstream faith indicators in social catchments 1B and 1C (cont'd)

Village	Religion	Dedicated church building?	Resident pastor?	Frequency of service	Attendance at services
Social Catchment 1B (cont'd)					
Temsapmin	Other	Yes	Yes	Weekly	Many people
Wokomo 1	Other	Yes	Yes	Weekly	Most people
Idam 2 (Plate 7.73)	Catholic	Yes	Yes	Weekly	Many people
Idam 1	Other	No	Yes	Weekly	Many people
Bisiabru	Other	Yes	Yes	Weekly	Few people
Social Catchment 1C					
Amini	Pentecostal and other	Yes	Yes	Weekly	Few people
Kwomtari	Other	Yes	Yes	Weekly	Most people
Itomi	Other	Yes	Yes	Weekly	Few people
Kilifas	Other	Yes	Yes	Weekly	Many people
Sumumini	Seventh Day Adventist and Pentecostal	Yes	Yes	Weekly	Few people
Imbrinis	Catholic	Yes	Yes	Weekly	Few people

Source: Coffey village surveys 2017.

Archaeology and Cultural Heritage

A study conducted by Andrew Long and Associates in 2018 (Appendix 13), included a review of registered National Museum and Art Gallery (NMAG) cultural heritage sites within social catchments 1B and 1C. The study identified one registered site within the Hotmin road (public) corridor (applying a 50-m buffer) near Green River Patrol Station. This site is a cave/rockshelter (site code RAK). Another six registered sites were identified within 1.5 km from the Hotmin road (public) corridor. In Social Catchment 1C one registered site was identified within 1.5 km of the Vanimo to Green River Road (Table 7.48).

Table 7.48 NMAG registered cultural heritage sites within 1.5 km of the Hotmin to Green River road and the Green River to Vanimo road (catchments 1B and 1C)

National Site File code	Site name	Site type	Social catchment
RAK	Panganggan Cave	Cave/Rockshelter	Social Catchment 1B
CQX	Kwemi Village	Archaeological	Social Catchment 1B
RED	Bipan Village	Archaeological	Social Catchment 1B
RCC	Mukwasi Village	Archaeological	Social Catchment 1B
RAH	Dieru Settlement	Archaeological	Social Catchment 1B
RAJ	Green River Gravel Rise	Archaeological	Social Catchment 1B
RCD	Unknown	Archaeological	Social Catchment 1B
RCR	Biaka Village	Archaeological	Social Catchment 1C

Source: ALA, 2018 (Appendix 13).

Status of Social Values 3 and 4 within Social Catchments 1B and 1C

There is a strong connection to the land and the traditional ways of life within Social Catchment 1B and south of the Bewani Mountains within Social Catchment 1C. As the corridor moves further north towards Vanimo, traditional ways of living are more susceptible to change due to the presence of industrialised practices such as logging and cash cropping.

SV3 – An enduring ability to sustain cultural identity and traditions including connection to ancestors

Due to their isolation, low population density and the absence of demand for access to their land for industrial agriculture, communities south of the Bewani Mountains through to Hotmin have been able to maintain their cultural identity and traditions. Elements of tradition continue to be passed down through generations and practised, while being overlaid with Christian religious activities. Areas close to Vanimo are more susceptible to experiencing cultural change due to the influence of non-traditional practices in and around the urban setting.

SV4 – An enduring ability to maintain customary rights to land access and resource use

South of the Bewani Mountains, pressures on land access and resources is relatively low compared to north of the Bewani Mountains where logging practices are putting pressure on the local populations' access to land and natural resources.

There is a strong connection to the land and the traditional ways of life within these social catchments. Opportunities to improve living standards through increased wealth and basic services from the proposed infrastructure and road development are acknowledged throughout the catchment.

Personal and Community Wellbeing (Social Values 5 and 6)

Infrastructure

Housing infrastructure within Social Catchments 1B and 1C is basic and minimal, with no piped water or sewage systems. Almost all houses (over 75%) across the two catchments are semi-improved, i.e., built from a mix of bush materials and iron roofing (Plate 7.74). A small portion of houses are made entirely of bush materials and a small portion are built entirely of modern building materials.

There is little to no government services or public infrastructure. Community halls and recreational facilities are rare and generally not maintained when present. Health and education infrastructure is often degraded to non-existent, and remoteness is often an obstacle when accessing services.

Water supply infrastructure is nearly non-existent south of the Bewani Mountains, where almost all water is sourced from rivers, lakes, natural springs or bore water, and is untreated prior to consumption.

Sanitation infrastructure is varied across the two catchments. Some villages have good access to latrines, including Amini and Sumumini in Social Catchment 1C and Hotmin, Uramesin 2, Temsapmin and Bisiabru in Social Catchment 1B. Other villages within the two catchments primarily use the bush for sanitation purposes.

Waste disposal methods primarily include pits or open dumping. A small percentage of households burn their rubbish.

Plate 7.73
Church in Idam 2

Plate 7.74
Typical house in Uramesin 2

Education

New Infrastructure and Road Corridor, Hotmin to Green River

Overall, education levels within the Social Catchment 1B are low. Most people surveyed in 2017 had received education up to elementary level, however few had received education beyond that. Hotmin had the highest percentage of people having attended / attending secondary level education (25% of people surveyed). Wokomo has the lowest percentage of formally educated people, with 74% of people surveyed having no formal education (Table 7.49).

To provide a broader context, the level of education within the Ambunti/Drekikier and Vanimo/Green River districts were analysed from the 2011 census data. Education within Ambunti/Drekikier District is lower across all levels compared to Vanimo/Green River District. When compared to the rural population of PNG, the population of Ambunti/Drekikier has slightly lower levels of education attainment, apart from grades 1 to 6.

Literacy levels within the catchment are low with respondents to household surveys revealing that 86% were illiterate.

Table 7.49 Highest education levels attained within Social Catchment 1B

Village	None	School grades 1 - 5	School grades 6 - 12	Bible studies	Tertiary/trade certificate	Unknown
Uramesin 2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Bisiabru	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Hotmin	26%	30%	24%	5%	0	15%
Temsapmin	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Idam 1	43%	38%	16%	2%	2%	0%
Idam 2	25%	55%	13%	0%	0%	7%
Wokomo 1	74%	21%	0%	0%	5%	0%

n.a.: not available.

Source: Coffey household and village survey 2017.

Of the 13 villages that were surveyed in 2017 in social catchments 1B and 1C, 11 of them had a school. The condition of these schools varied from poor to satisfactory to good. In Hotmin, the elementary school comprised four classrooms which were reported to be in a good to satisfactory condition. Idam 2 has the largest school in Social Catchment 1B, with 11 classrooms and approximately 280 students (Plates 7.75 and 7.76). The school teaches prep through to grade eight.

Schools in villages surveyed in Social Catchment 1C had an average of 10 classrooms and five teachers. Schools in the north of the catchment (Sumumini and Imbrinis) were well attended, while attendance at schools south of the Bewani Mountains was more irregular.

There are no high schools, tertiary institutions or vocational training centres in social catchments 1B or 1C.

Coffey

Plate 7.75
School building in Idam 2

Coffey

Plate 7.76
School classroom in Idam 2

Table 7.50 details the school infrastructure in villages surveyed by Coffey (2017) within social catchments 1B and 1C.

Table 7.50 Schools in surveyed villages in social catchments 1B and 1C

Village	Condition of classrooms	Enrolment	Grades taught	Attendance	Teachers
Social Catchment 1B					
Temsapmin	Good (2), Poor (2)	No data	No data	Most on a regular basis	No data
Hotmin	Good (2), Satisfactory (2)	75 students (35 boys, 30 girls)	Elementary	Very few on a regular basis	No data
Idam 1	Good (4), Poor (4)	86 students (49 boys, 37 girls)	E1, E2A, E2B	Most on a regular basis	No data
Idam 2	Good (5), Satisfactory (2), Poor (4)	280 students (50 boys, 40 girls, 190 unknown)	Prep, 1, 3 - 8	Not many on a regular basis	No data
Bisiabru	Poor (2)	27 students (14 boys, 13 girls)	Prep	Most on a regular basis	No data
Social Catchment 1C					
Amini	4 (good), 2 (satisfactory)	No data		Not many on a regular basis	6
Sumumini	3 (good), 3 (satisfactory),	No data		Most on a regular basis	6
Kwomtari	2 (good), 2 (poor)	No data		Very few on a regular basis	1
Kilifas	6 (good), 6 (satisfactory), 6 (poor)	No data		Very few on a regular basis	4
Itomi	4 (good), 4 (poor)	No data		Not many on a regular basis	3
Imbrinis	8 (good), 8 (poor)	No data		Most on a regular basis	7

Source: Coffey village and household surveys (2017).

Existing Infrastructure and Road Corridor, Green River to Vanimo

Village education statistics were not collected during the 2017 surveys for Social Catchment 1C, however LLG area data from the 2011 NSO census provides a picture of the level of formal education qualifications within the catchment's population (Table 7.51).

Approximately 50% of the population across the four LLGs within the catchment have never attended school. The Walsa Rural LLG population has the lowest rate of formal education (approximately 40% formally educated), while the Bewani/Wutung Onei Rural LLG population has the highest rate (approximately 72% formally educated). Bewani/Wutung Onei Rural LLG also has the highest rate of people with secondary education qualifications (55% of the population). The percentage of the population who have completed school education to grade 5 is fairly consistent across the four LLGs (on average 16%).

Table 7.51 Highest education levels attained within Social Catchment 1B

LLG	None	School grades 1 - 5	School grades 6 - 12	Bible studies	Tertiary/ trade certificate	Unknown
Amanab Rural	52%	17%	25%	n.a.	5%	n.a.
Bewani/Wutung Onei Rural	28%	16%	52%	n.a.	4%	n.a.
Walsa Rural	59%	17%	21%	n.a.	2.4%	n.a.
Green River Rural	56%	14%	25%	n.a.	2.1%	n.a.

n.a.: not available.

Note: the sum of all corresponding percentages does not equal 100% due to decimal rounding.

Source: NSO, 2014.

The literacy rate within the Vanimo/Green River District is 65% which is similar to the literacy rate across the province (62%), and the national rate of 67% (NSO, 2014). The average literacy rate across the four LLGs within the catchment is 56%. The highest literacy rate is found within Bewani/Wutung Onei Rural (75%), which includes the villages Imbrinis and Sumumini, the two villages surveyed in 2017 closest to Vanimo.

Health

Current health services within social catchments 1B and 1C are minimal, with inadequate equipment and resources to service the needs of the population.

Health statistics for Social Catchment 1B indicate that the level of reported childhood immunisations varies. Of the 20 children aged between 0 and 5 years included in the survey, 40% had reportedly received the full triple antigen vaccination (for diphtheria, tetanus and pertussis), while 35% had received partial vaccination and 25% had not received any stages of the vaccination.

Just under 75% of children in the four villages surveyed at the household level had received a measles vaccination. Hotmin and Idam 1 had one child each that was not vaccinated for measles, while Idam 2 and Wokomo 1 had two children each that were not vaccinated. During the village surveys with community leaders, four of the seven villages surveyed indicated that young children were receiving regular immunisations.

Health care services (including an ante-natal clinic and tetanus vaccination) were available to mothers during pregnancy in Hotmin, Idam 1 and Idam 2. Mothers in Wokomo 1 did not attend an ante-natal clinic or receive tetanus vaccinations during their pregnancy.

The characteristics of illness experienced within Social Catchment 1B are reflective of those experienced across Sandaun and East Sepik provinces. The common illnesses experienced within the seven surveyed villages included malaria, diarrhoea, upper respiratory tract infections, fever and skin and eye infections.

While health statistics specific to Social Catchment 1C could not be obtained, some of the key health issues within Sandaun Province are relevant to this catchment:

- Malaria and pneumonia are the two most common illnesses people are admitted to health care facilities for.
- Other common illnesses include other respiratory illnesses, diarrhoea and anaemia.

- The rates admissions to health care facilities for malaria, malnutrition and other respiratory illnesses are high compared to many other parts of PNG.
- The rates of admission to health care facilities for anaemia and pneumonia are high compared to average admissions in PNG.

Only two of the eight villages surveyed in Social Catchment 1B have an aid post (Green River and Idam 2), meaning some villages, such as Wokomo 1, are 24 hours away from their nearest aid post and further from a hospital. Access to health services is also made difficult by high transport costs and the lack of transport infrastructure. The condition of these aid posts is poor and they often lack basic needs such as sanitation, separate water supplies and electricity, and basic medical supplies are in short supply.

Social Catchment 1C enjoys slightly better access to health services, particularly north of the Bewani Mountains, where villages such as Imbrinis can access services in Vanimo including Vanimo General Hospital (1-hour travel time). Remote villages in the south of the catchment, however, have very limited access to health services. For example, neither Amini nor Itomi have an operational aid post, and the closest health services are 4 to 5 hours away. In Kwomtari, the aid post is constructed out of bush materials and at the time of the 2017 Coffey survey there were no supplies of in date medication and sterilising equipment.

Data collected during the 2017 village surveys by Coffey show that health care services provided to villages in Social Catchment 1C include:

- Child immunisations.
- Assistance during birth by qualified medical officer.
- Assistance from trained village birth attendant.
- Assistance from traditional village birth attendant.
- Medical patrols.

However, not all of these services are available to all of the villages. Only two of the villages, Imbrinis and Sumumini, reported receiving birthing assistance from a trained medical officer, while four villages, Imbrinis, Sumumini, Kilifas and Itomi, reported receiving birthing support from a traditional village birthing assistant.

Basic medical facilities within the existing aid posts in Social Catchment 1C is also slightly better than in Social Catchment 1B. The provision of basic medical supplies and other hygiene related services such as separate water supplies and plumbing is present in some of the aid posts.

Law and Order

There are very limited formal law and order services in social catchments 1B and 1C. Villages often manage disagreements by themselves, turning to local leaders and ward development committees for assistance. For example, in Kwomtari survey respondents identified they had their own way of settling internal disputes which often involve sharing food to quell any misunderstandings.

Concerns relating to law and order were only identified in two of the surveyed villages (Amini and Sumumini), where the need for increased security and police patrols were reported.

Within Social Catchment 1C, alcohol consumption was observed in several villages surveyed (Coffey, 2017) and there were reports of law and order problems such as lawless youth.

Status of Social Values 5 and 6

Summary statements of the status of social values (SV) 5 and 6 are provided below.

SV5 - An environment amenable to personal and family health, safety and security

The current physical and social environment of social catchments 1B and 1C is moderately supportive of health, safety and security. The villages generally live a traditional subsistence lifestyle which is dependent on favourable environmental conditions. However, the subsistence based lifestyle is becoming supplemented more and more by opportunities to enter the cash economy, particularly in the villages closer to Vanimo and near the logging camps. Increased exposure to the cash economy in some circumstances has seen a rise in substance abuse and law and order issues. Villages in the more remote locations generally experience a safe environment however face difficulty when access to services is needed. These factors combine to indicate a moderate level of vulnerability.

SV6 - The availability of services supportive of personal health, safety and security

Social catchments 1B and 1C have limited public infrastructure and, in general, do not have access to services supportive of personal health, safety and security. Where infrastructure such as aid posts exist, they often lack staff and medical supplies.

7.3.6 Social Catchment 1D: Vanimo Ocean Port

Social Catchment 1D comprises the capital of Sandaun Province, Vanimo and the settlements of Wesdeco and Cis Point (see Figure 7.31).

Location

Vanimo is a township located on the north coast of Sandaun Province, approximately 30 km east of the Indonesian border. Wesdeco is a settlement located less than 0.5 km due east of the existing Port of Vanimo. Cis Point is a peri-urban settlement located approximately 1 km from Vanimo town centre.

Vanimo, Wesdeco and Cis Point fall within the government administrative boundaries of Vanimo Urban LLG. Wesdeco and the existing Port of Vanimo are located in ward three (Wesdeco) and Cis Point is situated in ward two (Dali/Makepa).

The proposed Vanimo Ocean Port will be located next to Wesdeco settlement in ward three.

Population and Demographics

Population data for Social Catchment 1D is based on the 2011 national census (NSO, 2014) and the 2000 national census (NSO, 2000). Population characteristics of the social catchment are shown in Table 7.52.

Table 7.52 Population and household characteristics of Social Catchment 1D

Settlement	Population	Households	Male	Female
Vanimo Town*	13,970	2,370	7,404	6,566
Cis Point†	144	11	108	36
Wesdeco†	507	82	274	233

* NSO, 2014.

† NSO, 2000.

The age distribution within the Vanimo Urban LLG is shown in Table 7.53. The age profile is skewed to the younger age groups for both male and females. Approximately 1.4% of the Vanimo

Urban LLG are in the 65 plus age group which aligns with the national trend where approximately 2.6% of the population are aged 65 and over (NSO, 2015a).

Table 7.53 Total population by Vanimo Urban Local Level Government, age and sex

Age (years)	Number and percentage of population	Males	Females	Gender ratio*
0-4	1,801 - 13%	915	886	103
5-9	1,779 - 13%	930	849	110
10-14	1,610 - 12%	829	781	106
15-24	1,666 - 12%	916	750	122
20-24	1,419 - 10%	792	627	126
25-29	1,256 - 9%	623	633	98
30-34	944 - 7%	469	475	99
35-39	894 - 6%	472	422	112
40-44	711 - 5%	356	355	100
45-49	652 - 5%	349	303	115
50-54	478 - 3%	295	183	161
55-59	304 - 2%	199	105	190
60-64	193 - 1%	111	82	135
65-69	117 - 1%	62	55	113
70-74	45 - <1%	23	22	105
75-79	23 - <1%	15	8	188
80-84	11 - <1%	4	7	57
85-89	3 - <1%	1	2	50

NSO, 2014.
* Number of males per 100 females.

Livelihoods (Social Values 1 and 2)

Due to their location, fishing is the key subsistence activity practiced by the settlements of Wesdeco and Cis Point. The settlements of Wesdeco and Cis Point are located in close proximity to the Port of Vanimo which is primarily used for commercial activities such as timber and palm oil operations. Vanimo is the economic hub of Sandaun Province offering a wide range of shops, markets and logging operations.

Natural Capital / Subsistence Activity

Communities situated on the coastal plains of Vanimo cultivate low intensity mixed staple gardens such as sago and coconut crops (Hanson et al., 2001). Fishing is conducted for subsistence (for direct consumption), local (for market) and commercial purposes.

Subsistence (or artisanal) fishing is conducted using spears, line and net fishing. Line and net fishing also occurs along the beaches when boats are not available. Deeper reef areas offshore from the entrance of Dakriro Bay are fished via line and net fishing methods. Men, women and children practise subsistence fishing with men typically catching finfish and women harvesting invertebrates such as octopus. The main fishing locations identified by locals are around Vanimo Bay as shown in Figure 7.37. The type of fish and seafood reportedly caught and consumed in Wesdeco and Cis Point include bundle fresh fish, finfish, beche de mar, tuna, reef fish and octopus.

MXD Reference: 11575B_11_GIS013_v0_3

Source:
Fishing points from Coffey 2017 marine resource use survey.
Infrastructure and roads from FRL.
Villages from FRL and Coffey.
Imagery from Google Earth (DigitalGlobe captured 14 December 2014).

coffey
A TETRA TECH COMPANY

Date: 29.08.2018
Project: 754-ENAUABTF11575A
File Name: 11575_11_F7.37_GIS

Frieda River Limited

Sepik Development Project

FRIEDA RIVER

Fishing locations in Catchment 1D in proximity to Vanimo

Figure No: 7.37

Marine resources are harvested by coastal settlements. People reported that harvesting invertebrates was a typical daily ritual, which may indicate a scarcity of this form of seafood, possibly due to unsustainable harvesting due to increased population pressure. According to locals interviewed in Cis Point, the types and numbers of fish caught have remained the same over the last five years; conversely, locals from Wesdeco reported a reduction in fish caught over the last five years despite the settlement being adjacent to Cis Point settlement.

The Vanimo fish market is a small informal facility with no services (e.g., power, refrigeration or running water) located on the beach near the banana boat landing close to the area of retail shops. Most fishing vendors are women from outside of Vanimo. As the informal market can operate whenever a vendor has fish to sell, it operates up to seven days a week. The purchase price of fish is in the order of PGK6 to PGK8 per kilo for single fish, or PGK10 per kilo for a bundle of smaller fish.

The type of fish observed as being available at Vanimo fish market included (Plate 7.77 to 7.79) long-toms and garfish, cod, sea perch, mixed reef fish and crayfish.

Provincial fisheries staff indicated that commercial fishing was not a significant industry in the Vanimo area for a range of reasons. This includes a lack of islands and reef areas within a reasonable distance, concerns around safety when fishing in open waters, and a general lack of interest by local residents. Observed overseas fishing vessels operate offshore approximately 30 km north of Vanimo. Fish are caught primarily via seiners (a method of fishing that employs a fishing net called a seine).

Excess fish from artisanal fishing are sold at the local fish market. Fish sold are not sourced from Dakriro Bay.

The Vanimo Urban LLG has a range of stores and markets for buying food including supermarkets. The strong presence of food in stores and markets within the town indicates that they are a key source of food for residents. Key sources of water for residents of Vanimo Urban LLG are rainwater tanks and local creeks and rivers (Vanimo Urban LLG, 2014).

Domestic water supplies in Cis Point and Wesdeco are obtained from dug wells or tanks which vary in condition.

Cash Economy Activity

Coastal communities within this social catchment have greater access to the cash economy compared to the other social catchments, due to their location.

Income

While communities in the Vanimo Ocean Port social catchment have good access to a cash economy and opportunities to earn an income, levels of income are low compared to other parts of PNG (Hanson et al., 2001).

Opportunities to earn an income in this catchment include selling fresh food such as surplus garden produce, fish, seafood and betel nut at market places in Vanimo town centre, Wesdeco and Cis Point. Income is also derived from wages and royalties from forestry operations near Vanimo and Aitape. The logging company, Vanimo Forest Products, a Malaysian owned company, is the major employer. Income is also earned from small-scale tourism operations or driving Public Motor Vehicles (PMVs).

Coffey

Plate 7.77
Fish sold at Vanimo fish market

Coffey

Plate 7.78
Vanimo Fish Market

BMT WBM

Plate 7.79
Scarlet sea perch (*Lutjanus malabaricus*) and estuary cod (*Epinephelus coioides*) at Vanimo fish market

While large scale agricultural production is limited in Vanimo Urban LLG, commercial agricultural operations are situated in Bewani/Wutung Onei Rural LLG (adjacent to Vanimo Urban LLG) including oil palm plantations, rubber farming and cocoa farming (Sandaun Provincial Government, 2013).

Status of Social Values 1 and 2 within Social Catchment 1D

Summary statements of the status of social values (SV) 1 and 2 within Social Catchment 1D are provided below.

SV1 - The capacity to support subsistence livelihoods

Fishing plays an important role in supporting a subsistence livelihood within Wesdeco and Cis Point settlements. Other subsistence practices, such as mixed staple gardens are limited due to Vanimo's urban and industrial setting.

SV2 - Opportunities for participation in the cash economy

Opportunities for participation in the cash economy are greater within Social Catchment 1D compared to social catchments 1B and 1C, due to the proximity of the provincial centre, Vanimo. Such opportunities include selling fish and other fresh produce. While these activities generate small incomes for some families, income levels are low in Social Catchment 1D compared to other parts of PNG.

Culture (Social Values 3 and 4)

The population of Vanimo is made up of residents born in the town with ancestral links to the area as well as migrants from other rural areas of PNG and international residents (Vanimo Urban LLG, 2014).

The Vanimo language group, also referred to as Dumo, Duso, Manimo and Wanimo is made up of two dialects, Vanimo and Waromo (Clifton, 2014) and is spoken by residents of Vanimo and surrounding settlements.

Governance

The Vanimo-Green River District is made up of five LLGs. Vanimo, Cis Point and Wesdeco fall in the Vanimo Urban LLG which is divided into seven different wards.

Most wards lack adequate government facilities and systems such as ward centres, village court systems and ward development committees (Vanimo Urban LLG, 2014). Local government centres are understaffed and ill-equipped to support staff in effectively governing their people.

Vanimo township supports public infrastructure, such as provincial government buildings, a court house, police station and army barracks. A corrections facility is located within close proximity to Cis Point. The 'Cis' in Cis Point stands for 'Correctional Institution Services'. However, absence of a court system and an under-resourced police service has led to increasing law and order problems in the town and surrounding areas (Vanimo LLG, 2014).

Religious and Traditional Practice Adherence

There are churches of a number of denominations throughout the Vanimo Urban LLG such as Catholic, Lutheran, United, Revival and Baptist. The main religion followed in Wesdeco settlement is Catholic. Residents of Cis Point are understood to adhere to a range of faiths (including Catholic and Revival) and to attend church services in Vanimo.

Customary practices associated with fishing continue to be part of daily life for families from Wesdeco and Cis Point (Coffey, 2017; Si and Lahe-Deklin, 2015). Men use trapping techniques including gill nets, circle nets, handlines, trolling gear and spear guns to catch finfish. Catching seafood is another customary practice that continues in communities within the catchment, particularly by women. Traditionally, women of the Vanimo (or Dumo) language group with assistance from their children would participate in an activity known as ‘coral gleaning’ where they would harvest small reef fish and invertebrates (Si and Lahe-Deklin, 2015). Residents of Cis Point are also understood to engage in customary practices associated with food production in kitchen gardens.

Archaeology and Cultural Heritage

A review of registered cultural heritage site files at the NMAG in 2018 has identified no registered cultural heritage sites within Social Catchment 1D (Appendix 13.2).

Status of Social Values 3 and 4 within Social Catchment 1D

Summary statements of the status of social values (SV) 3 and 4 within Social Catchment 1D are provided below.

SV3 - An enduring ability to sustain cultural identity and traditions including connection to ancestors

The cultural identity and traditions in communities are challenged by pressures such as population increases and commercial activities. As the economic hub of Sandaun Province, Vanimo is exposed to culturally diverse practices and people. This decreases the catchment’s ability to maintain its cultural traditions.

SV4 - An enduring ability to maintain customary rights to land access and resource use

Communities in the Vanimo Ocean Port social catchment have retained customary rights to use land and access its resources through activities such as fishing, catching seafood and maintaining gardens. These rights and access to land are under pressure in Vanimo and surrounding areas due to the increasing development of the town, migration to settlements surrounding Vanimo from rural areas and commercial agricultural operations in proximity to Vanimo.

Personal and Community Well-being (Social Values 5 and 6)

In comparison to the other social catchments, the Vanimo LLG supports a range of public services and infrastructure.

Infrastructure

Infrastructure and public services in Vanimo include an airport, port, a general hospital, educational institutions, several churches, banks, postal services, Provincial government buildings, embassies, trade stores, supermarkets and recreational areas.

Timber for export constitutes the bulk of goods handled at the existing Port of Vanimo with bulk fuel and break bulk cargo also imported and exported from the port (PNG Ports Corporation, 2018). Most road infrastructure in the social catchment is in poor condition and road connections to other main towns (such as, Vanimo to Aitape) are limited.

Community and recreational sporting facilities are rather limited in the catchment. Cis Point has a volleyball court and one other playing field available to locals. Wesdeco has one playing field and Vanimo has one recreational area.

Typical housing differs between the settlements of Wesdeco and Cis Point. In Cis Point houses are generally built out of sawn timber framing with corrugated iron roofs while in Wesdeco houses are generally made from bush materials with iron roofing.

Mobile phone systems were installed in Vanimo in 2006 yet respondents to social surveys (Coffey, 2017) had mixed views on the level of mobile phone coverage within the catchment.

Education

The township of Vanimo offers a range of educational institutions including elementary, primary, high schools and a technical college.

In Vanimo Urban LLG school attendance levels are the highest in elementary and primary school compared with high school. The highest level of education achieved was reported as Grade 10. Residents of Wesdeco and Cis Point reported that the highest grade level achieved was elementary level. Within the Vanimo Urban LLG, all seven wards have elementary and primary schools. The only secondary school in Vanimo Urban LLG is situated in ward seven. Overall, there are 10 elementary schools, three primary schools, two secondary schools and four private schools. There are no tertiary institutions or vocational training centres in Social Catchment 1D.

Schools in Cis Point and Wesdeco are challenged by similar barriers to effective education that many other schools in PNG face, they lack proper classroom facilities, teachers housing and do not have a water supply. Table 7.54 provides details on the elementary schools in Wesdeco and Cis Point.

Table 7.54 Schools at settlements surveyed in catchment 1D

Settlement	Number of classrooms	Condition of classrooms	Enrolment	Grades taught	Attendance	Responsible authority	Operational
Wesdeco	3	Poor	154 (76 boys and 78 girls)	Grade 1	Most children in settlement	Catholic Church	Yes
Cis Point	2	Satisfactory	47 (28 boys and 19 girls)	Grades Prep, 1, 2	Most children in settlement	Other	Yes

Source: Coffey village survey (2017).

Health and Nutrition

The main illness that appears to be hyperendemic to all communities within the catchment is malaria. Other illnesses such as fever and skin infections are also prevalent in Wesdeco.

Data compiled by the Vanimo General Hospital for 1991 to 1997 indicates that the average number of malnourished children in the Vanimo Green River District categorised as having energy malnutrition was 3,691. A further 272 children were categorised as having severe protein malnutrition (Hanson et al., 2001).

According to the Sandaun Provincial Education Plan (Vanimo LLG, 2014), provision of sufficient health services and medical supplies are developmental priorities for settlements residing within the Vanimo Urban LLG.

The key health issues and concerns within the catchment reported by community leaders and governmental officials included:

- Human immunodeficiency virus, acquired immunodeficiency syndrome (HIV/AIDS) and sexually transmitted infections (STI) transmissions.

- Increase in teenage pregnancies.
- Access to a clean water supply.
- Consumption of addictive substances: alcohol and betel nut.
- Inhalation of addictive substances: tobacco and marijuana.

Medical services in the catchment often lack facilities and labour to ensure the population receives adequate treatment for prevalent illnesses (AusAid, 2004). Vanimo General Hospital and the Dapu Urban Clinic in Vanimo provide medical services to residents of this social catchment. Both have insufficient staff and shortages in medical equipment (Vanimo Urban LLG, 2014). There are no village aid posts in Cis Point or Wesdeco.

Law and Order

Vanimo supports infrastructure to maintain law and order such as a police station, a court house and corrections service near Cis Point. However, institutions that support law and order are under-funded and under-resourced to manage law and order issues in this social catchment. Increasing law and order issues reportedly being experienced within Vanimo relate to unsettled youth, rising drug and alcohol abuse, gambling and stealing.

Participation of Women

Responses to key informant interviews indicate that women are ill represented in decision making in Cis Point. Decisions are mainly made by men and there is no active network or organisation for women to actively participate. Anecdotal information collected through Coffey’s 2017 surveys reported domestic violence to be prevalent in households.

Similar to other social catchments, women’s primary role is to help provide for their families through activities such as harvesting seafood such as molluscs.

Status of Social Values 5 and 6 within Social Catchment 1D

Summary statements of the status of social values (SV) 5 and 6 within Social Catchment 1D are provided below.

SV5 - An environment amenable to personal and family health, safety and security

The current physical and social environment of the Social Catchment 1D is moderately supportive of health, safety and security. Local communities and officials have expressed concerns relating to health, education and law and order issues in the social catchment. These factors combine to indicate a high level of vulnerability.

SV6 - The availability of services supportive of personal health, safety and security

A wide range of public infrastructure and services are available in Vanimo and to a lesser extent, surrounding settlements. Much of this infrastructure is in a need of an upgrade and / or characterised by a lack of staff and equipment which limits the extent it can adequately service the community. There are many community members who hold strong views on the need to improve infrastructure and law and order services.

7.3.7 Social Catchment 2: Sepik River Corridor

The Sepik River corridor social catchment extends from the proposed Sepik River bridge crossing to the mouth of the Sepik River, and including the proposed May River Port and Auom 3 at the southern end of Lake Warangai and comprising communities from several language groups along the upper, middle and lower sections of the river. The Sepik River will be used as a barging corridor to support the construction of the Project and will provide an alternative means of access during operations if required. Focus group surveys of these communities in 2010 provides a general baseline of the socio-economic conditions along the Sepik River corridor.

The communities – Bin, Angoram, Moim, Kamanimbit, Sapanaut, Pagwi, Ambunti, Yessan, Swagup, Kubkain, Tauri, Auom 3 and Iniok – were selected for survey based on both geographical spacing and coverage of customary groups. They are representative of the general population along the relevant sections of the Sepik River that will be used for barging during construction. Auom 3 was selected as it is reliant on Lake Warangai as a source of drinking water and fish and this lake is hydraulically connected to the Frieda and Sepik rivers via several channels. Yessan and Sapanuat were only surveyed as part of the baseline health survey due to flooding, which meant that other villages (Kubkain, Pagwi, Moim and Kamanimbit) were inaccessible. Therefore, information presented in this baseline characterisation includes a full suite of socio-economic and health information for at least five locations.

Location

The Sepik River corridor is located within the Sandaun East Sepik provinces extending from the proposed Sepik River bridge crossing to the mouth of the river at Cape Girgir (see Figure 7.32).

In most of the communities visited along the Sepik River, residents' houses were located along the river bank with no obvious community centre. Swagup was an exception where houses lined the edge of the swamp and were clearly established around the *haus tambaran* (ancestral worship house). It was common for villages to be split across both sides of the river, requiring canoes to shuttle residents from one side to the other.

Population and Demographics

Communities surveyed along the Sepik River corridor ranged in estimated population from 229 at Pagwi to 1,884 in the largest community at Angoram. Data from the 2011 census indicate a reasonably balanced gender ratio in most communities, except for Yessan and Kubkain where 42% and 43% of the population was male, respectively (NSO, 2014). Table 7.55 provides the population and gender ratio at each location.

Table 7.55 Population of selected communities along Sepik River corridor

Community	Population estimate	Gender ratio (Number of males per 100 females)
Iniok	499	90
Auom 3	118	79
Tauri	664	92
Kubkain	324	76
Swagup	552	104
Yessan	721	73
Ambunti	547	94
Pagwi	229	99
Sapanaut	438	96
Moim	1,012	110
Kamanimbit	560	98
Angoram	1,884	102
Bin	1,008	93

Livelihoods (Social Values 1 and 2)

Information on agricultural subsistence livelihood activity has been drawn from surveys including a health baseline survey conducted by CEH in 2010 (Appendix 13) and household, village and women's surveys conducted by Coffey in 2010. This has been supported with information from secondary sources and Sepik River Awareness campaigns in 2011, 2015 and 2016.

Natural Capital / Subsistence Activity

Villagers in the Sepik River corridor are highly dependent on the river for subsistence. Gardner et al. (1996) described that, on the Sepik River plains, fewer gardens were made and inhabitants relied more on fishing and sago supplemented by hunting in the wet season. Staple crops were sago (by far the most important food crop), taro, yam and banana (Hanson et al., 2001; ANU, 1999). Generally, small gardens were made on levee banks parallel to rivers, with gardening activity restricted to the dry season (ANU, 1999). Flooded gardens were also observed during 2010 household and village surveys. The regular deposition of silt is considered important for maintaining soil fertility (ANU, 1999). All the communities surveyed along the Sepik River corridor relied heavily on fish and other freshwater fauna species from the river as their main food source and for income. All communities fished daily for household consumption. Hunting occurred less frequently with target species including turtles, crocodiles, snakes, pigs, cassowaries, birds and possums. The crocodile industry is dependent upon wild production for the harvests and the habitats that support breeding. Breeding activity and local community harvesting of crocodile eggs, juveniles and adults occurs in off-river waterbodies rather than main river channels. Villagers of Auom 3 are also highly dependent on fishing for household consumption and for their livelihood (Coffey Environments, 2015); with all households surveyed reporting the consumption of fish on the previous day.

The Sepik River is linked to the spiritual, emotional and physical wellbeing of people living along its banks. Sepik people believe that the Sepik River gave life to all other rivers around the world and was the river where human life on earth evolved. For all the communities included in the surveys, the river was used as a:

- Primary source of drinking water and for washing, cleaning and cooking.
- Primary source of staple food items fish and sago, in addition to other river food species and a variety of aquatic plants.
- Transport corridor to access gardens, other villages and health and other services elsewhere.
- Primary source of income (e.g., sale of fish, crocodiles, shellfish, hard-shell turtles).
- Place of worship and traditional customary activities.

Although the Sepik River is pivotal to the villages' existence, the river is also used for human waste and rubbish disposal. It was recognised among communities that not all people residing along the Sepik River had the knowledge or desire to properly care for it.

Sewerage reticulation or treatment did not exist at any community included in the survey; households used pit latrines. Similar to the mine area communities, often one toilet was shared among several households. Sanitary waste was often discharged directly to the river and/or surrounding environment.

Cash Economy Activity

Communities along the Sepik River corridor subsisted on fishing, garden products, particularly sago, and some hunting. Most residents were not formally employed, although the CEH health baseline survey found that 55% of households surveyed in Ambunti (20 households) and 50% in Angoram (20 households) did earn a salary. Those who participated in formal employment worked mainly in:

- Education.
- Trades.
- Law enforcement.
- Health.
- Government administration.
- Transportation.

Other income was derived from the sale of crocodile meat, skins and eggs, fresh and smoked fish, arts and crafts, garden produce, cocoa and timber. Provision of accommodation lodging, tourism, transport and employment on rubber farms were additional sources of income in the Sepik River corridor.

In Auom 3, the dominant form of income was from work with FRL, with smaller amounts derived from alluvial mining upstream in the Telefol and Miyan social sub-catchments. While income from alluvial mining was relatively small (9%), it was an important source of income for residents of this village (Coffey Environments, 2015).

Of the representative communities, only Ambunti reported having local access to banking services, which was via the Sepik Savings and Loans Society. None of the communities reported having any savings to deposit in a bank. Household expenses (classified from most to least expensive for households) were reported as:

- School fees.
- Food.
- Motorised canoe transport and canoe repairs.
- Fuel.
- Medical costs.
- Clothes.

Status of Social Values 1 and 2 within Social Catchment 2

Summary statements of the status of social values (SV) 1 and 2 within Social Catchment 2 are provided below.

SV1 – The capacity to support subsistence livelihoods

The subsistence base of villages in this social catchment is robust given favourable seasonal conditions, but vulnerable to climatic extremes such as flooding and drought conditions as were being experienced in late 2015. Environmental change occurring currently, such as sedimentation due to alteration to catchment vegetation cover and the reduction of aquatic vegetation and crocodile habitat in off-river waterbodies due to the introduction of exotic fish species, was increasingly being noticed.

SV2 – Opportunities for participation in the cash economy

Market access and the availability of aquatic resources for which there is a demand afford Sepik villages a modest level of opportunity to participate in the cash economy. Opportunities for migration and labour market participation within East Sepik and other areas of PNG have historically been important for income generation.

Culture (Social Values 3 and 4)

Local language groups varied along the river, with an estimated 10 different languages spoken in the Sepik River corridor villages. Language groups identified at each of the surveyed villages were:

- Sepik River Iwam (Iniok).
- Wogamusin, Guvlu and Gubrukomnau (Kubkain).
- Galadup (Swagup).
- Yessan-Mayo (Yessan).
- Kara, Manung, May River and Mamara (Ambunti).
- Iatmu (Pagwi, Moim, Angoram).
- Kanda (Kamanimbit, Angoram and Bin).
- Ama (Angoram).
- May River Iwam (Auom 3).

No language group was recorded at Sapanaut.

All surveyed communities described a deep spiritual connection with the Sepik River and indicated that cultural and customary practices continued to be an important part of daily life.

Community leaders at Moim and Angoram explained that Sepik River people believe that both good and bad spirits reside in the river; the good spirits provided assistance to Sepik people and protected their land and gardens and the bad spirits brought sickness and death. They explained that Sepik River people are able to call upon the water spirits (which often took the form of crocodiles) when they require assistance with tasks such as fishing or even fighting.

At Angoram, approximately 260 km downstream of the mine area, the crocodile was central to many of these beliefs. Angoram residents described how they could call upon the river animals, such as the crocodile, to protect them from danger or bring danger to rivals. They described how they could summon danger to be brought upon the Project if they thought that their river or way of life might be threatened by the Project.

Governance

In the Sepik River corridor, village magistrates, land mediators, community leaders and, in some cases, church leaders generally provide authority and administer law and order.

A district court servicing all villages along both the lower and middle Sepik River was located at Ambunti. All matters concerning district law and justice generally occurred at the police station in Ambunti. Another small police station and rural lock-up capable of holding alleged offenders for short durations was located at Angoram.

Along the Sepik River corridor, police trained and paid by the government were only stationed at Ambunti and Pagwi. Auxiliary police (volunteers who did not possess uniforms or weapons) assisted with law enforcement in all communities in the study area. However, in more than one community, concerns were raised about the conduct of some auxiliary police and, in some cases, their alleged involvement in criminal activities.

Religious and Traditional Practice Adherence

At Pagwi, community leaders felt that very few traditional practices took place in the village due to the multi-racial nature of the population, although Christian religious beliefs and activities were a prominent part of the local culture.

Several Christian denominations were active in the Sepik River corridor and many activities and celebrations relate to the Christian calendar. Catholic, Seventh Day Adventist and Revival churches were the most prominent (Table 7.56). At Swagup, only one member of the community was reportedly a member of a religious faith (the Catholic Church). Most the Swagup population had more traditional spiritual beliefs reportedly associated with their ‘insect cult’.

Table 7.56 Dominant religion by village

Community	Religions
Iniok	Assemblies of God, New Guinea Revival
Swagup	Traditional beliefs, Catholic
Ambunti	Catholic, Assemblies of God, South Sea Evangelical Church, Seventh Day Adventist
Pagwi	Catholic
Moim	Catholic, Church of Latter Day Saints
Kamanimbit	Catholic, Seven Day Adventist, Revival International
Angoram	Predominantly Catholic but many religions present
Bin	Catholic, Christian Revival Church
Auom 3	Sepik Christian Mission, New Guinea Revival

Source: Coffey household and village survey 2010.

Most of the surveyed communities (exceptions being at Moim, Pagwi and Iniok) indicated that cultural and customary practices continued to be an important part of daily life. They noted that many traditions had been passed through generations. These ranged from simple everyday activities such as making sago, sing-sings with neighbouring villages, wood carving (Plates 7.80 and 7.81), entertaining tourists with traditional dances and songs, and fishing using traditional trapping techniques, to some more ritualistic and spiritual customs such as:

- Limiting access to the spirit house and close surroundings of the spirit house to men and boys only.
- Initiating young boys by residing in the spirit house for an extended period or, in some cases, by whipping their backs to cause scars that resemble those on the back of a crocodile. At Kamanimbit, residents believed that to heal these wounds, Sepik River water should be poured on the cuts.
- Dressing traditionally to celebrate special events.
- Observing menstruation ceremony, where for the duration of a woman’s menstruation, they must be segregated from the rest of the community. It was believed that the blood from the woman was impure and reduced the effectiveness of men to hunt and the quality of fishing grounds. The women reported this custom to be practised only irregularly.
- Teaching boys how to construct canoes.
- Conducting traditional funerals.
- Worshiping animals in the river. In Kamanimbit, residents believed that crocodiles could be called upon by throwing a type of ginger into the river. Making offerings of ginger to the river was also thought to bring rain and return lost people to the village.
- Offering bride price and conducting traditional wedding ceremonies.

Archaeology and Cultural Heritage

Due to the nature of the Project's potential impact on the Sepik River corridor (i.e., as a barging corridor to support the construction of the Project and an alternative means of access during operations if required), a separate survey of cultural sites was not conducted in the study area. A preliminary survey of cultural sites was undertaken within the mine area (Denham and Hitchcock, 2015) and a targeted cultural heritage survey by ALA in 2016 (Appendix 13). This included consultations and observations of sites belonging to the Sepik River Iwam who live largely along the Sepik River between the Wario-Sepik junction and Iniok (Iniok-Nenuwe), upstream of the junction of the Frieda and Sepik rivers.

A total of 35 sites were recorded in the Sepik River corridor area as belonging to the Sepik River Iwam and May River Iwam people. The most significant sites were places associated with original/semi-mythical ancestors and associated *masali* and former locations of *haus tambaran* (spirit house).

All surveyed communities described a deep spiritual connection with the Sepik River and explained that it contained many sacred sites, both within the river and along the river's edge. Most communities were reluctant to describe the nature of the sites; however, community members at Angoram noted that the sites related to initiation and spiritual beings.

Status of Social Values 3 and 4 within Social Catchment 2

Summary statements of the status of social values (SV) 3 and 4 within Social Catchment 2 are provided below.

SV3 – An enduring ability to sustain cultural identity and traditions including connection to ancestors

Christian religious beliefs and activities have become a significant part of village culture along the Sepik River corridor where communities also maintain a strong cultural connection with the river. Cultural and customary practices continue to be an important part of daily life; however, traditions are not as readily passed down to younger generations. Most cultural sites have not been subject to disturbance from development activity.

SV4 – An enduring ability to maintain customary rights to land access and resource use

While customary rights to land and water resources are currently intact, in some areas of land may be under pressure to be alienated for commercial agricultural activity, such as oil palm.

Personal and Community Well-being (Social Values 5 and 6)

According to the PNG Rural Development Handbook (Hansen et al., 2001), inhabitants of the Sepik Valley are amongst the most disadvantaged in PNG with poor access to services. This was supported by the findings of Coffey's household and village surveys (2010) which identified a continued lack of functioning services within many of the villages.

Infrastructure

Houses in the Sepik River corridor are predominately constructed from bush materials (Plate 7.82) and those closer to the riverbank or on swamp land are on stilts, with house floors approximately two metres above ground level. Some housing and infrastructure at the larger communities of Ambunti, Angoram and Pagwi were constructed from manufactured materials such as concrete, sawn timber and iron.


Coffey

Plate 7.80
Traditional wood carving from Bin


Coffey

Plate 7.81
Wood carving


Coffey

Plate 7.82
House made of bush materials in Iniok

There is no road transportation and communications infrastructure in many of the villages in the Sepik River corridor and where it does exist, it is in a poor state of repair. Road infrastructure links Pagwi and Timbunge to the provincial capital, Wewak. The 170 km journey can take up to five hours to drive. In a traffic survey completed for the Project by Coffey in 2015 it was noted that the road from Pagwi to Wewak was generally in good condition, however it reportedly deteriorates rapidly during rainy periods and requires substantial maintenance. Most road users were pedestrians, followed by private buses. Road use was busiest between 6 a.m. and 12 p.m. The main reasons for travel on the road in the fortnight prior to the survey were to go to market, school, visit relatives or for medical reasons.

Airstrips exist at Ambunti and Angoram. The Angoram airstrip is in disrepair and had not been used for approximately 20 years. The airstrip at Ambunti is a grass strip running perpendicular to the Sepik River.

The Sepik River provided the most accessible and effective transport corridor for residents living along its banks. All communities had access to paddle and motor canoes, and canoe traffic was observed as being of high volume. Most communities found it difficult to quantify, even approximately, the river traffic that passed their village each day and simply described it as 'many', while the community leaders at Angoram estimated that anywhere between 100 and 300 vessels may pass on any one day. This river traffic consists predominantly of canoes, but also occasional logging barges which anecdotal evidence suggests pass about once per week. A barge loading facility is located at Iniok and is used by FRL.

In the Sepik River corridor, no communities had access to mains electricity although some communities could run public (communal) generators when availability of fuel permitted.

Except for Ambunti, residents in the study area did not have access to banking or postal services. The next nearest banking and postal services were located at Maprik or Wewak.

Several residents in the communities surveyed owned mobile phones despite mobile service being intermittent, at best, or non-existent in most places. Ambunti was the only village where mobile phone service was reasonably reliable. None of the communities visited had landlines or public telephones.

Recreational infrastructure available to communities included mainly volleyball courts, soccer fields and, occasionally, a basketball ring or a kickboxing ring.

Details on access to transportation and communications infrastructure in the Sepik River corridor communities are provided in Table 7.57.

Table 7.57 Transportation and communication infrastructure

Community	Road infrastructure	Airstrip	Nearest airstrip	Riverside infrastructure	Tele-communications
Iniok	None	None	Ambunti; 90 km; 12 hours (hrs) by motor canoe	Barge loading facility used for the unloading and storage of fuel and other cargo.	1 x UHF radio
Kubkain	None	None	Hauna; 14 km; 1/2 hour by motor canoe	None	1 x UHF radio

Table 7.57 Transportation and communication infrastructure (cont'd)

Community	Road infrastructure	Airstrip	Nearest airstrip	Riverside infrastructure	Tele-communications
Swagup	None	None	Ambunti; 34 km; 2 hrs by motor canoe	None	Intermittent mobile phone service (B-Mobile)
Ambunti	Road connection to Pagwi, 29 km away	Tuesdays and Thursdays, operated by MAF	-	Disused jetty	Mobile phone service (PNG Telecom); 3 x UHF radios (at the hospital, police station, church)
Pagwi	Sealed road connection to Wewak, 170 km away	None	Ambunti; 29 km	Concrete landing served as boat ramp	Intermittent mobile phone service; 2 x UHF radios (at the police station and church)
Moim	None	None	Wewak; 70 km	Number of small timber jetties	None
Kamanimbit	None	None	Timbunge; 20 km; 30 minutes by motor canoe	None	None
Angoram	Partially sealed road connection to Timbunge 64 km, and Wewak, 100 km away	Disused	Timbunge; 64 km	None	Intermittent mobile phone service (B-Mobile); 2 x UHF radios (at the church and health centre)
Bin	None	None	Timbunge; 93 km	None	None
Auom 3	None	None	Ambunti	None	None

Source: Coffey household and village survey 2010.

Angoram's public infrastructure was previously substantial with the presence of a main road, airstrip and power generation and distribution. At the time of Coffey's survey in 2010, infrastructure was in poor condition with reportedly no mains power generation at Angoram for at least 15 years. The condition of the infrastructure is unlikely to have improved since this time.

Community access to public services and facilities is outlined in Table 7.58.

Table 7.58 Public and community services and facilities

Community	Recreation	Religious	Post	Banking	Electricity
Iniok	None	Revival church	None	None	None
Swagup	Soccer field; basketball court; volleyball court	None	None	None	None
Ambunti	4 x soccer fields; volleyball court	Southern Seas Evangelical Church; Catholic Church, Seventh Day Adventist Church and Assemblies of God	Have post office infrastructure but not operational	Sepik Savings and Loans Society	Generator
Pagwi	None	Catholic church	None	None	Generator
Moim	Volleyball court; soccer field; basketball court	Catholic church; Church of Latter Day Saints	None	None	Generator
Kamanimbit	Volleyball court; soccer field	Catholic church; Church of Latter Day Saints; Revival International church	None	None	None
Angoram	2 x soccer fields; kickboxing ring	Catholic Church; Sepik River Church; Pentecostal Church; Nazareth Church; Four Square Church; Seventh Day Adventist Church; Protestant Church; Baptist Revival Church; PNG Revival Church	None	None	Infrastructure for mains electricity in disrepair Generator
Bin	Soccer field; volleyball court; basketball court	Catholic Church; Revival Church; Four Square Church	None	None	Generator
Auom 3	None	Revival Church; Sepik Christian Ministry Church	None	None	None

Source: Coffey household and village survey 2010.

Education

Education levels in communities along the Sepik River corridor were not formally recorded as part of the socio-economic survey; however, all communities, except Sapanaut, had elementary prep classes and some had primary classes. High or secondary school classes were only available at Angoram, Ambunti and Wewak.

Table 7.59 outlines community access to education services and facilities.

Table 7.59 Education services and facilities

Village	Service within village	No. students	Staff	Nearest service	Distance to nearest service
Iniok	Elementary school (P to E2)	-	None	Community school at Auom 2	17 km. Have infrastructure and materials but, at the time of the survey, no teacher. The school had not been operating since late 2009
Kubkain	Elementary school (P to E2)	24	One teacher	High school (Gr 9, 10) at Ambunti; senior high school (Gr 11, 12) at Wewak	56 km and 166 km, respectively
	Community school (Gr 4, 6, 7)	100	Two teachers		
Swagup	Elementary school (P to E2)	23	One teacher	High school (Gr 9, 10) at Ambunti; senior high school (Gr 11, 12) at Wewak	34 km and 144 km, respectively
	Community school (Gr 3 to 8)	60	One teacher		
	Women's training programs run by the Seventh Day Adventist Church (domestic science and health education)	Unknown	Unknown		
Yessan	Elementary school (P to E2)	Unknown	One teacher	High school (Gr 9, 10) at Ambunti; senior high school (Gr 11, 12) at Wewak	2 hrs by motor canoe
Ambunti	2 x elementary schools (P to E2)	200	Six teachers	-	-
	2 x community school (Gr 3 to 8)	500	Seven teachers		
	High school (Gr 9 to 10)	400	Nine teachers		
	Vocational college	43	Unknown		
Pagwi	Catholic mission school (Gr 1 to 8)	150	Five teachers	-	-
Sapanaut	None	-	-	Pagwi	5 km

Table 7.59 Education services and facilities (cont'd)

Village	Service within village	No. students	Staff	Nearest service	Distance to nearest service
Moim	Elementary school	Not operating in 2010	Not operating in 2010	High school at Angoram; senior high school (Gr 11, 12) at Wewak	20 km and 71 km, respectively
	Community school (Gr 3 to 5, 7)	>100	Five teachers		
Kamanimbit	Elementary school (Gr 2)	50	One teacher	High school (Gr 9, 10) at Angoram; senior high school (Gr 11, 12) at Wewak	85 km and 84 km, respectively
	Community school (Gr 3 to 8)	250	One teacher, two teacher's aides		
Angoram	3 x elementary schools (P to E2)	270	Nine teachers	-	-
	Community school (Gr 3 to 8)	620	16 teachers		
	High school (Gr 9 to 10)	360	Eight teachers		
	Vocational training centre	None	Five teachers		
Bin	Elementary school (P to E2)	140	Two teachers	High school (Gr 9, 10) at Angoram; senior high school (Gr 11, 12) at Wewak	31 km and 91 km, respectively
	Community school (Gr 3, 4, 6, 7)	150	Four teachers		
Auom 3	Elementary school (P to E2)	34	Two teachers	Primary School in Mowi or Iniok	13 km, 6 hours by paddle canoe

P = Prep; E2 = Elementary Grade 2; Gr = Grade.

Source: Coffey household and village survey 2010.

A common concern of most communities was the insufficient or inadequate staff and/or materials and infrastructure to operate regular and effective classes and provide students with a reasonable level of education. Attracting and retaining teachers to the more remote villages in the area was described as challenging, particularly where communities found it difficult to provide adequate housing and/or where teachers were unable through remoteness and lack of facilities to receive their salaries from the government.

Schools constructed in flood-prone areas along the Sepik River had to be temporarily closed at times due to flooding. At Ambunti, community leaders described damage of school property and threats made to teachers causing them to leave as key barriers to education. The expense of school fees was considered prohibitive for some families.

Health and Nutrition

The baseline health survey (CEH, 2018) found that, overall, environmental health differed markedly between the urban areas of Ambunti and Angoram and the more remote villages of Bin, Sapanaut, Swagup and Yessan. Immunisation coverage was variable and generally below that reported nationally in PNG.

The prevalence of cataracts was three times that observed in the mine area communities (Social Catchment 1A), but was not considered to be exceptional for rural and remote villages of PNG. The prevalence of pterygium[7] was unusually high and significantly greater than that observed in the mine area communities.

Significantly lower prevalence of skin infections was observed on a whole-of-study population basis than observed in the mine area communities for all classes of fungal infections. Sores and tropical ulcers were identified at only about half of the levels reported in the mine area communities. Tropical ulcers were evenly distributed between all age groups. Ringworm was observed mainly in infants and children.

Overcrowding and ventilation were not of health concern for any of the households surveyed in the Sepik River corridor (Appendix 13). The medical conditions reported in the 12 months before the baseline health survey included:

- Hypertension – 3.3%.
- Asthma – 5.1%.
- Dengue-like fever – 17.1%.
- Pneumonia – 22.5%.
- Intestinal parasites – 59.5%.
- Malaria – 65.2%.

Both the socio-economic survey and baseline health survey questioned participants on the use of alcohol and other stimulants. Overall consumption of tobacco was similar among males and females. Overall, the smoking rate (48%) was the same as that observed in the mine area communities (49%), but higher than the national average (37%). Along the Sepik River corridor, alcohol was predominantly consumed by males. Except for Bin, more than 40% of males in Sepik River corridor communities consumed alcohol. More than 25% of females in Ambunti, Angoram and Sapanaut consumed alcohol. Alcohol consumption amongst males (8%) and females (0%) at Bin was inexplicably low. Female consumption at Swagup and Yessan was also low (< 5%).

Malaria was hyperendemic in all the surveyed communities. Most households had access to at least one mosquito net, but insufficient nets were available for all family members. This was particularly notable at Bin and Sapanaut where 35% and 10%, respectively, of family members had nets. General practice at these communities appeared to be to reserve the mosquito nets for babies and infants.

In all communities surveyed, women reported having some sort of access to maternal health services. Where clinics were not held in the village they were visited by other villages nearby:

- Kubkain quarterly clinics were held out of Maposi.
- Swagup clinics were visited by Ambunti staff.
- Pagwi clinics were conducted by Burui health clinic.
- Moim clinics were visited by staff from Angoram.
- Bin was visited by staff from Marienberg.
- Kamanimbit clinic was visited by staff from Timbunge.

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[7] A non-cancerous growth of the clear, thin tissue that lays over the white part of the eye (conjunctiva).

Women from all the communities surveyed were aware of, and said they had access to, contraception methods for family planning. However, few used contraception often stating that their husbands would not agree to it. Traditional methods were said to be used in some places (sometimes involving ovulation calculations, sometimes herbal mixtures), but traditional means were thought to be used less and less. Swagup was an exception, where women explained that traditional family planning methods were still very much practiced but could not be described because it was reportedly the role of husbands to prepare the preventative remedies. Practices and periods of abstinence after the birth of children varied and were often at the discretion of husbands.

The health infrastructure at communities within the Sepik River corridor was, at best, degraded and, at worst, non-existent. Health service delivery was intermittent, with health patrols and extension programs conducted infrequently in most places and reportedly conditional on the availability of qualified and motivated staff from the district health centres.

The Angoram District Hospital is located some kilometres from the Angoram centre and is therefore problematic for access for most residents, and is only operational for outpatients. At the time of the survey the hospital generated electricity through solar and gas and sourced water from rain water tanks. It stocked medicines and basic supplies such as bandages, but was unable to sterilise equipment and many facilities needed maintenance (Appendix 13). The household and village survey found that the hospital often had to operate without electricity, making it impossible to store immunisation and other medicines requiring refrigeration.

There were two health centres at Ambunti, one operated by the government and one by the Seventh Day Adventist Mission. The government health centre was being upgraded at the time of the survey and provided a limited range of facilities.

At Kamanimbit and Angoram, a health extension program conducted by the Department of Health in early 2010 focussed on awareness of HIV/AIDS and other sexually transmitted diseases. A cholera awareness program had also been delivered at some communities in 2009.

Community access to health services and facilities is summarised in Table 7.60.

Table 7.60 Health services and facilities

Village	Service within village	Nearest service	Distance to nearest service	Staff
Iniok	None	Hauna aid post Mowi aid post	21 km 9 km; 3 hrs by motor canoe	Two health volunteers; one trained as birth attendant
Kubkain	Aid post (dysfunctional)	Ambunti hospital	56 km; 7 hrs by canoe and foot	Four health volunteers also trained as birth attendants
Swagup	None	Ambunti hospital	34 km; 2 to 4 hrs by motor canoe	One health volunteer; one trained birth attendant
Yessan	None	Ambunti hospital	20 km; 2 hrs by motor canoe	Unknown

Table 7.60 Health services and facilities (cont'd)

Village	Service within village	Nearest service	Distance to nearest service	Staff
Ambunti	Government district health centre; Seventh Day Adventist health centre	-	-	Two nurses at government centre; one at mission centre; one health extension officer, several health volunteers and trained birth attendants
Pagwi	None	Burui health centre	5 km; 1.5 hrs by foot; 15 minutes by car	One nurse
Sapanaut	None	Burui health centre	2 hrs by road	Unknown
Moim	Aid post	Angoram district hospital	20 km	Three health volunteers
Kamanimbit	None	Timbunge health centre	20 km; 30 minutes by motor canoe	One health volunteer
Angoram	District hospital	-	-	One doctor; two nurses
Bin	None	Marienberg	15 km; two hours by motor canoe	One health volunteer also trained birth attendant
Auom 3	None	Mowi aid post	2 hours by motor canoe	Unknown

Source: Coffey household and village survey 2010.

Nutritional surveys identified that the principal diet consisted of sago and fresh or smoked fish, supplemented by bananas, green vegetables and coconuts. The exception was recorded at Angoram where some store foods were included in the diet. Generally, gardens in the Sepik River corridor were reported to only be productive in the relatively short dry season (June to September).

Table 7.61 presents the mean adult values for weight and height in villages surveyed along the Sepik River corridor during the baseline health survey. Calculated BMIs show that in most villages surveyed people tended to be close to the BMI for overweight individuals, i.e., BMI greater than 25.

Table 7.61 Nutritional status of adults in Sepik River corridor

Village	Weight (mean +/- sd) kg		Height (mean +/- sd) cm		Calculated BMI	
	Males	Females	Males	Females	Males	Females
Swagup	66.8 +/- 6.1	55.4 +/- 8.1	162.3 +/- 3.8	148.8 +/- 6.0	25.4	25
Yessan	62.8 +/- 4.8	52.5 +/- 8.0	159.1 +/- 4.5	150.2 +/- 5.2	24.8	23.3
Ambunti	67.5 +/- 6.7	63.4 +/- 10.8	165.8 +/- 5.8	157.5 +/- 4.4	24.6	25.6
Sapanaut	66.8 +/- 6.9	58.5 +/- 9.0	162.2 +/- 7.3	152.2 +/- 5.9	25.4	25.3

Table 7.61 Nutritional status of adults in Sepik River corridor (cont'd)

Village	Weight (mean +/- sd) kg		Height (mean +/- sd) cm		Calculated BMI	
	Males	Females	Males	Females	Males	Females
Angoram	67.2 +/- 6.7	53.7 +/- 9.4	160.9 +/-8.6	150.9 +/- 6.9	26	23.6
Bin	65.0 +/- 10.9	58.0 +/- 5.9	156.3 +/- 5.5	147.0 +/- 5.8	26.7	26.8
Auom 3	60.2 +/- 3.6	50.2 +/- 7.2	163 +/- 0.05	151 +/- 0.05	23	22

Source: CEH, 2018.

Law and Order

Domestic violence was common across all communities surveyed, acknowledged by both male and female survey participants. The perceived severity of domestic violence varied from men to women. Domestic violence was described as often sparked by a wife's refusal to partake in sex (often also resulting in marital rape), disagreements over additional wives and sometimes over money. Some women believed they deserved domestic violence to 'learn a lesson'. In Angoram, women reported some incidents of domestic violence as fatal. In most communities surveyed, women had avenues to report incidences of domestic violence, and in some cases, to be compensated, but in other cases there was reluctance to use those avenues for fear of exacerbating the situation.

Alcohol was considered a significant contributor to the incidence of crime across all communities, despite village laws existing in most places banning the consumption of some or all types of alcohol. Homebrew was most often consumed across the Sepik River corridor and often perceived as causing most social problems from domestic violence and physical abuse through to public nuisance. In Angoram, the consumption of homebrew and the actions of those under the influence of alcohol had created a general feeling of fear among the community with many members concerned about their personal safety. In some cases, the feeling of fear had led to the carrying of weapons including bush knives, slingshots and sometimes homemade guns in order for people to protect themselves.

Drugs and gambling were reported to occur in all communities except Swagup, although the women there reported marijuana use as an emerging issue. In Ambunti and Pagwi, men, women and children participated in gambling, which in some cases resulted in school absenteeism and theft to support gambling habits. In Kamanimbit, residents believed gambling, or specifically unpaid debts from gambling, was the cause of some inter-village disharmony, sometimes resulting in physical assault. In Kubkain, community leaders and women's representatives felt that marijuana use was becoming a problem among the men in the village, and was purchased from river traders who themselves smoked the drug.

Participation of Women

All the communities included in the socio-economic survey described the role of women as being to:

- Care for husband and children.
- Tend to gardens.
- Raise livestock (chicken, pigs and crocodiles).
- Make sago.
- Fish (for food and sale at markets).
- Make arts and crafts for sale (in some communities).

In Moim, Angoram, Swagup, Ambunti and Kamanimbit, the women explained that they played an active role in the decision-making involving their families. They all claimed to have access to their own (small amount of) money, usually as the result of their contributions to income generation by fishing and/or gardening, that they could choose to spend (or save) how they wished.

The women in Ambunti explained that they played a larger role in the economic stability of the family through their ability to earn income and that they therefore had a right to contribute to decision-making in the family. In the satellite villages of Ambunti, the women were thought to contribute less to the decision-making commensurate with their economic contribution.

In Bin, the participation of women in family decision-making was said to be dependent on the level of respect a husband had for his wife. They claimed not to have access to their own money, nor any savings.

In Pagwi, the women described how their opinions were not considered in the home and they were unable to contribute to decision making, even regarding their children, due to the male-dominated culture. However, because they were nearly entirely responsible for income generation for their families through the sale of fish at the markets, they could have a small amount of money to spend or save as they wished.

In most communities, women and youths had access to social and sporting organisations, often run by church groups. At Ambunti, numerous women were involved in the Ambunti District Council of Women, which was affiliated with the East Sepik Council of Women.

Status of Social Values 5 and 6 within Social Catchment 2

Summary statements of the status of social values (SV) 5 and 6 within Social Catchment 2 are provided below.

SV5 - An environment amenable to personal and family health, safety and security

The physical and social environment of Sepik River communities appears to be under considerable stress, with hyperendemic malaria and water-borne disease being pervasive and the availability of food being highly dependent on seasonal conditions.

SV6 - The availability of services supportive of personal health, safety and security

Services (policing, education and health) are limited at best, and non-existent in the more remote areas. Villages are reliant on their own initiatives and strategies to support the fundamental needs of families.

7.3.8 Social Catchment 3: Sandaun and East Sepik Provinces

Information presented in the baseline characterisation for Sandaun and East Sepik provinces was obtained primarily from secondary sources. Information was also gathered from a joint provincial development workshop held in October 2009 and from interviews with representatives of the provincial government administrations in March 2010. The semi-structured interviews sought information about:

- Current level of services and/or infrastructure pertaining to each area of interest.
- State of development or growth plans for each service and/or infrastructure.
- Capacity to accommodate increased demand.
- Capacity to plan for increased demand.

Consultation was also conducted and feedback obtained at quarterly Joint Provincial Consultative Committee meetings held with key staff of both provincial governments.

Location

Sandaun Province

Sandaun Province is in the north-west of mainland PNG, along the northern section of the Indonesia and PNG border, and shares provincial borders with Manus, East Sepik, Southern Highlands and Western provinces. The province encompasses an area of 36,000 km^2 and is the third largest province in PNG in terms of land size. The northern region of the province is comprised of a coastal environment, the Sepik River basin comprises the centre of the province and mountainous regions are in the south. It also shares a common international border with the Indonesian province of Irian Jaya and a road links the provincial capital Vanimo to Jayapura (Hanson et al., 2001).

East Sepik Province

The East Sepik Province occupies 43,700 km^2 in the north-west of PNG. Wewak is the provincial capital, located on the coast of the province. A scattering of islands occurs off shore. Ranges, including the Torericelli and Prince Alexander ranges, dominate the coastal landscape. The remainder of the province's geography is dominated by the Sepik River.

The province is bordered to the north by the Bismark Sea and Manus Province, to the east by Madang Province, to the west by Sandaun Province and to the south by Enga and Southern Highlands provinces.

Population and Demography

Sandaun Province

As per NSO (2014), the total population of the Sandaun Province in 2011 was 248,411, of which 127,771 (51.4%) were men and 120,640 (48.6%) women. This equates to a gender ratio of 107 males per 100 females who were divided between 44,934 households. A population density of 7 persons per square kilometre (NSO, 2014) is due to approximately half of the province being unoccupied (Hanson et al., 2001). Aitape-Lumi District is the most populated in the province.

Between 2000 and 2011, Sandaun Province experienced an annual population growth rate of 1.8% (compared with 2.0% between 1980 and 1990 and 2.8% between 1990 and 2000).

The median age in 2011 was 19.1 (compared with 21.4 across PNG). In 2011, 41.1% of the population was under the age of 15 and 2.3% were 65 and over, resulting in a high dependency ratio of 76.8 (NSO, 2015a).

East Sepik Province

In 2011, the population of East Sepik Province was 450,530, with a near even gender ratio of 101 males to 100 females and an average household size of 5.2 people (NSO, 2014). The province contains the most heavily populated areas of the Sepik region. The population of the provincial capital, Wewak, was 24,471 in 2011 (NSO, 2014).

In the years 2000 to 2011, East Sepik Province experienced annual population growth of 2.1%, compared with annual population growth for PNG of 3.1% (NSO, 2015a).

Some out-migration occurs from this province, largely from the Sepik Valley around Ambunti. Large migrant communities from the East Sepik region are found in Rabaul, Madang, Lae and the West New Britain oil palm settlements (Hanson et al., 2001).

The median age in 2011 was 19.2 (compared with 21.4 for PNG). In 2011, 40.8% of the population was under the age of 15 and 3.1% were 65 and over resulting in a high dependency ratio of 78.1 (NSO, 2015b).

Livelihoods (Social Values 1 and 2)

Sandaun Province

Natural Capital / Subsistence Activity

Sandaun Province is one of the most remote provinces of PNG. Due to the rugged terrain and lack of access routes (i.e., roads and rivers), there are few opportunities to generate an income in rural areas and young people generally stay in their community (AusAid, 2004). East Sepik Province covers a vast area with many isolated areas due to challenging terrain and flooding along lower reaches of river plains. Only 8% of the population of Sandaun Province lived in urban areas in 2000. The remaining 92% of the population lived in rural settings and were reliant on subsistence farming.

People in Sandaun Province have a strong connection to the land. As income opportunities or participation in the cash economy is limited, access to land is an essential requirement for their subsistence livelihoods.

Subsistence agriculture consists primarily of sago with low intensity mixed staple gardens in Vanimo-Green River, Aitape-Lumi and Nuku districts. In Telefomin district, subsistence agriculture comprises mainly low intensity taro with some low intensity sweet potato. Coconut and banana are important on the coastal plains. The Sepik River acts as a lifeline for much of the Sandaun Province, providing water, fish and a mode of transport (Hanson et al., 2001).

Unlike its neighbour, East Sepik Province, Sandaun has significant areas of high or very high land potential, particularly across the northern half of the province. Land potential in Telefomin District in Sandaun Province is less, rated at moderate and low, because of the steep slopes of the southern mountains, high rainfall and frequent cloud cover. The Sepik Valley in Sandaun Province has low land capability potential because of the poor soils caused by high rainfall and inundation (Hanson et al., 2001).

Sandaun Province experiences no agriculture pressure on land and some potential for agricultural development, especially in the Torricelli foothills, where the land potential is high and where markets exist and are reasonably accessible in Wewak.

Cash Economy Activity

Rural people in the Sandaun Province are amongst the poorest in PNG. Across the province, income is estimated at less than PGK20 per person per year. The estimated annual income for most people surveyed in Sandaun Province in 2011 was less than PGK5,000 (ASPBAE, 2011).

People around Vanimo earn low incomes from the sale of fresh food and betel nut. In the Torricelli foothills income is from minor sales of cocoa and robusta coffee. Smallholder cocoa production is increasing around Lumi, but market access is limited by poor road conditions and occasional periods of criminal activity along the Sepik Highway. Forestry operations have provided some employment opportunities and royalties for Sandaun people (Hanson et al., 2001).

The provincial capital, Vanimo (population 13,970), has an economy based around the timber industry. Vanimo Forest Products, a Malaysian-owned logging company, is the major employer.

Telefomin is near the Ok Tedi Mine from which some landowners receive royalties, while in other areas mineral exploration provides a source of employment. Artisanal gold mining is also undertaken in several areas.

In 2011, 13.5% of the male population over 10 years received a wage from employment, an increase from 8% in 2000. This was true of only 4% of females (increase from 2% in 2000). Subsistence employment was undertaken by 49% of males and 65% of females (NSO, 2011).

Employment in urban areas of the province was primarily in a wage job for both males and females. In 2000, people in rural areas primarily classified their employment as gardening and fishing for personal use (NSO, 2000) whereas in 2011 more males reported being in wage jobs than gardening and fishing for money (NSO, 2011).

Selling betel nut was the highest-ranking income generating activity in 2011 with 54% of households claiming to sell betel nut followed by 52% of households selling food crops or cooked food (NSO, 2011).

East Sepik Province

Natural Capital / Subsistence Activity

People in the East Sepik Province have a strong connection to the land. Traditionally, customary owners never considered their land as property, but as a domain for survival of land group members, past, present and future. Land is considered a source of social, spiritual, ecological and subsistence values.

People use the land to grow crops such as taro, yam, sago, and banana. As in Sandaun, the Sepik River acts as a lifeline for a large part of East Sepik providing water, fish and a mode of transport (Hanson et al., 2001).

In East Sepik Province, low intensity subsistence agriculture dominates the land use, primarily for yam, taro and banana. Sago is important across much of the province. The land potential for agriculture across the province is generally low, except in the north around Dreikikir and Maprik, where it is very high. The Sepik Valley has low potential because of the frequent flooding of the Sepik River and resultant nutrient poor soils (Hanson et al., 2001).

Most of the rural population of East Sepik Province is located near the Sepik River and relies heavily on the river and its tributaries as their water supply for drinking, cooking and washing. No sewerage systems are present in rural areas and, therefore, the river is often used for disposal of human waste and rubbish, which contaminates the water source. Water in urban areas is safe for washing and cooking. However, drinking water quality is not completely reliable, especially if the water is from backup tanks or rainwater storage (Hanson et al., 2001).

Cash Economy Activity

A large portion of the population lives in rural settings (approximately 90%) with most people living a subsistence lifestyle with limited sales of surplus agricultural production or cash crops. The lack of income generating opportunities in rural areas has led to out-migration from rural to urban areas across East Sepik Province (East Sepik, 2010).

People around Dreikikir, Maprik and Yangoru earn moderate incomes from the sale of cocoa, coffee and fresh food. Those in the Sepik Valley earn low incomes from minor sales of fresh food, cocoa, fish and betel nut (Hanson et al., 2001). People in the northern fall of the Central Range and in remote areas of the Sepik Valley have very low incomes. Growth of cocoa by small scale farmers to earn cash is increasing in the province, particularly west of Maprik where most villages have at least one cocoa fermentary. However, the marketing of cocoa is constrained by poor road maintenance. Growing and selling vanilla bean provides substantial income depending on market conditions. There are large fresh food and fish markets at Pagwi, Angoram, Maprik and Wewak. Two tuna canneries in Wewak (owned by South Seas Tuna Corporation and Frabelle) are the biggest employers in the area (Mercy Works, 2014). In 2010, the number of people employed by industry in East Sepik was 4,000 (compared with 82,500 nationwide) (East Sepik, 2010). The Sepik River is also recognised for ecotourism. The tourism sector has been identified as an area for economic development in the East Sepik Provincial Integrated Development Plan (2011-2015) (East Sepik, 2010).

Status of Social Values 1 and 2 within Social Catchment 3

Summary statements of the status of social values (SV) 1 and 2 within Social Catchment 3 are provided below.

SV1 – The capacity to support subsistence livelihoods

The subsistence base of the social catchment is robust given favourable seasonal conditions. The agricultural potential of land in some areas of Sandaun Province is greater than East Sepik Province, but both are vulnerable to climatic extremes such as flooding and drought conditions, as were experienced in late 2015.

SV2 – Opportunities for participation in the cash economy

Limited market access and the low availability of cash crops, for which there is a demand, mean there is limited opportunity for communities in Sandaun and East Sepik provinces to participate in the cash economy. Opportunities for migration and participation in the labour market in other areas of PNG have historically been important for income generation in these provinces.

Culture (Social Values 3 and 4)

Sandaun Province

Along with its cultural heritage sites, Sandaun Province has various World War II heritage sites. No large-scale archaeology expeditions or investigations have occurred in this region.

Sandaun Province does not have a homogenous culture with a large range of languages and village groups (AusAid, 2004). As with other areas of PNG, people of Sandaun have an important connection with the land and the natural resources upon which they heavily rely. Although some level of traditional beliefs is still widely held, 98% of the Sandaun population in 2000 considered themselves Christian.

East Sepik Province

The Sepik River is an important cultural link to the past for people living near the river as discussed in Section 7.3.6.

The culture of the people of East Sepik Province varies greatly due to the variety of language groups and clans. No large-scale archaeology expeditions or investigations have occurred in this region.

Cape Wom, located near Wewak in the East Sepik Province, marks the site of the formal Japanese WWII surrender in PNG (McKinnon et al., 2008).

Governance

Sandaun Province

Sandaun Province has four districts, 17 LLGs, 418 wards and 852 villages. The four districts are Aitape-Lumi, Nuku, Telefomin and Vanimo-Green River (CIA, 2011).

The provinces are responsible for planning and implementing governance processes and systems and public services such as law and order, health and education.

Development planning for the provinces is undertaken using a bottom-up approach. Ward planning (including consultation, needs assessments, screening and prioritisation of ward proposals for development) informs district planning, in which LLG plans are summarised and a development framework established in line with the National Government's Medium Term Development Plans and the National Medium Term Development Goals. While development planning may take place, almost without exception there are insufficient funds to implement the plans in part or in full.

East Sepik Province

East Sepik Province has six districts and 26 LLGs. The districts are Ambunti-Dreikikir, Angoram, Maprik, Wewak, Wosera-Gawi and Yangoru-Saussia (NSO, 2014). The Project is located within Ambunti-Drekikir District, which has four LLGs each containing several wards – Ambunti Rural (30 wards), Drekikir Rural (32 wards), Gawanga Rural (20 wards) and Tunap/Hunstein (38 wards). Within each ward are one or more census units.

Development planning occurs in the East Sepik Province in the same manner as described for Sandaun Province, with the same lack of funding resulting in the same lack of implementation of the plans.

Religious and Traditional Practice Adherence

Religious and traditional practices have not been described at a provincial level, as this is more appropriately addressed at a village level, i.e., for Social Catchments 1A, 1B, 1C and 2.

Cultural Heritage and Archaeology

Cultural heritage and archaeology have not been described at a provincial level, as this is more appropriately addressed at a village level, i.e., for Social Catchments 1A, 1B, 1C and 2.

Status of Social Values 3 and 4 within Social Catchment 3

The status of social values 3 and 4 has not been assessed at a provincial level, as this is more appropriately addressed at a village level, i.e., for Social Catchments 1A, 1B, 1C and 2.

Personal and Community Well-being (Social Values 5 and 6)

Sandaun Province contains some of the country's most challenging terrain and as such is one of the most remote and underdeveloped in PNG. Across both Sandaun and East Sepik provinces there is a lack of functional health services and/or medicine and access to education services is limited.

Infrastructure

Sandaun Province

The lack of economic activity in the Sandaun Province has, over many years, resulted in widespread rural poverty, poor infrastructure and poor social services in most of the province.

Only the coastal areas and inland hills of Sandaun Province have a relatively good network of roads. Poor roads are a major constraint to development in other areas of the province. There are often limited funds for maintenance and some roads become impassable after extended periods of wet weather. Some roads in the province are constructed and maintained by logging companies and deteriorate once logging activities finish. Most of the inland districts can only be accessed by light aircraft or vessels reaching the upper Sepik River. Most residents of Sandaun Province are very remote and require more than one day's travel to reach basic services.

Reliable communications infrastructure in Sandaun is limited. In 2006, mobile phone systems were installed in Aitape and Vanimo, but limited range and high costs restrict usage. Many districts are restricted to an unreliable two-way radio system operated by the health centres and churches (Sandaun Provincial Government, undated).

Water supply and sanitation infrastructure is limited and only available in urban areas. Most people do not have access to piped water and must rely on surface and groundwater supplies for their water for all uses. Access to potable water is limited (Hanson et al., 2001).

East Sepik Province

Access to infrastructure and services in East Sepik Province ranges from good in the northwest, moderate in the centre and east, to very poor in the south and southwest. Except for people living close to Wewak and between Dreikikir and Yangoru, most of the population of East Sepik Province are required to travel four to eight hours to access services (Hanson et al., 2001).

Road infrastructure is limited. The Sepik Highway runs from Wewak to Maprik, but is in poor condition due to low levels of ongoing maintenance. Sealed roads in urban areas are largely poorly maintained and few sealed roads exist beyond urban areas and the Sepik Highway. Travel by boat along the Sepik river system is a popular means of travel. The river system plays a vital part in transporting agricultural goods and fish to market (Hanson et al., 2001).

Communications infrastructure in East Sepik Province is limited. Most districts have access to very high frequency (VHF) radio, but in most cases, this is run down or only in fair condition. Mobile phone, land lines and internet services remain limited to most of the population outside of major towns (East Sepik, 2010).

Electricity supply in urban areas is unreliable. Voltage variations and surges are commonplace and power cuts are frequent, particularly during periods of heavy rain. There is no mains power available to the rural population. Generators are used as an alternative source of power, but are not affordable for most of the population, who go without electricity or may have a shared generator for the village.

Education

Sandaun Province

Education infrastructure has been outlined for three of the four districts of Sandaun Province, for which information was available. In the districts of Telefomin and Nuku, there were approximately:

- Twenty-seven community schools run by the government.
- Thirty-two elementary schools run by the government.
- Five primary schools, of which four were run by the government.
- One secondary school run by the government.
- Two vocational centres run by the government.

In the district of Vanimo-Green River, there were approximately:

- Ninety-five elementary schools, of which 49 were run by the government.
- Fifty-six primary schools, of which 21 were run by the government.
- Three secondary schools, of which one was run by the government.
- Three vocational centres, of which one was run by the government.

An education experience survey and literacy assessment conducted in 2011 found the literacy rate for Sandaun Province in 2000 was 52.9%, compared with 62% recorded in the 2011 census (ASPBAE, 2011; NSO, 2011). The literacy rate of males was 68% compared with 55% for females (NSO, 2011).

In 2011, 43% of males over the age of five in the province had never been to school (down from 53% in 2000), compared with 48% females (up from 41% in 2000). Only 1% of males (down from 1.5% in 2000) and 0.5% females had completed Grade 12 (NSO, 2000; NSO, 2011).

Almost 9% of males and 5% of females claimed to have a qualification with this defined as a degree, diploma, certificate or professional title acquired after successful completion of a course lasting three months or longer (NSO, 2011).

East Sepik Province

Access to education is limited within East Sepik Province. Many students from rural areas are required to travel large distances or live away from home to attend school. AusAid (2005) states that, within East Sepik Province there were approximately:

- Twenty-eight community schools.
- Two hundred and eleven elementary schools, of which 65 were run by the government.
- Two hundred primary schools, of which 74 were run by the government.
- Twelve secondary schools, of which seven were run by the government.
- Nine vocational centres, of which three were run by the government.

Relative to world standards, school retention rates in the East Sepik Province were low. In 1999, the education system offered a post-primary education for only about one in six children and less than 2% of students enrolling in Grade 1 reached Grade 12 (WEF, 2000).

The literacy rate in East Sepik Province in 2011 was 64.7%, up from 52.7% in 2000 (compared with the PNG average rate in 2000 of 67%). About 41% of the province's population had completed Grade 1 to 2, 26% had completed Grades 4 to 6 and just 20% had completed from Grade 7 up.

Health and Nutrition

Sandaun Province

Sandaun Province is one of the most under-resourced provinces in PNG for health infrastructure, with only 2.4 doctors, 59 nurses and 323 hospital beds per 100,000 people (Dugue and Izard, 2004). Most communities in the Sandaun Province have an aid post, although some have been closed for years or lack medicine. In 2000, Sandaun Province had 10 health centres and 19 health subcentres. There was also one urban clinic and one provincial hospital, both in Vanimo (NDOH, 2000). Malaria is endemic along the coastal section of the province and poses a significant threat to children under the age of five years. Access to health services is limited and communicable diseases are a problem. In general, health education is limited (Hanson et al., 2001).

The infant mortality rate was 105 per 1,000 live births in 2000 in Sandaun Province compared with 57 for PNG (NSO, 2000). Child malnutrition rates within the province were among the highest in the country (Hanson et al., 2001).

East Sepik Province

Access to health facilities in East Sepik Province is limited and, like Sandaun Province, East Sepik is one of the most under-resourced provinces in PNG. For each 100,000 people, there were only 1.8 doctors, 64 nurses and 261 hospital beds. There are two hospitals in the East Sepik area, located at Wewak and Angoram, with the hospital at Angoram only open to outpatients. Most people must travel for four to eight hours to reach health services (Dugue and Izard, 2004). In 2006, only 51% of aid posts were considered open in the East Sepik Province (PNGHD, 2008).

The people of the East Sepik Province lack water supply infrastructure and rely heavily on the Sepik River for washing, drinking and cooking, and for the disposal of human waste and garbage. This makes the province particularly susceptible to the spread of water-borne diseases due to poor sanitation practices (Hanson et al., 2001).

In 2004 the total number of confirmed cases of HIV/AIDS within East Sepik Province was 66, of these 34 were women, 27 were men and 5 did not record gender. This is a relatively low level compared with other provinces, however, the disease still poses a significant risk to the community. The province’s link with Jayapura (Indonesia) through the vanilla trade, and urban and village environments that provide trading and entertainment, are all considered to be high risk areas for the transfer of HIV/AIDS. Communities within the province have a basic knowledge of the severity of HIV/AIDS and how it is transmitted however further awareness and initiatives are required to create a greater understanding of the disease amongst the community (AusAid, 2005).

In 2008, Save the Children’s East Sepik Women and Children’s Health Project was implemented to treat common diseases in the area. Malaria was the main illness treated by this Project, almost half of those treated for malaria were children under five years old. Malaria is rife throughout the province and especially prevalent along the Sepik River, its tributaries and associated swamps (Save the Children, 2009).

Malnutrition problems are evident in the region, associated with inadequate intake of energy and protein. Children are particularly vulnerable, and child malnutrition in the region is of concern (Hanson et al., 2001).

The infant mortality rate in 2000 in East Sepik was 79 per 1,000 live births (compared with 57 for PNG), and the child mortality rate was 36 per 1,000 live births compared with 75 for PNG (NSO, 2000).

Law and Order

Sandaun Province

Alcohol and marijuana are predominantly consumed by young men and in some areas young men have established networks to distribute marijuana (AusAid, 2004). Other common problems experienced by Sandaun communities include domestic violence, violence in relation to land disputes and alcohol consumption, adultery, men having several wives, people having multiple sex partners and prostitution. Communities commonly rely on village leaders to resolve law and order issues (AusAid, 2004).

East Sepik Province

Alcohol is consumed by both men and women of different ages across communities in the province and the East Sepik police commander has identified alcohol consumption as a major issue for the province (Sirias, 2016). In rural areas, tension between ethnic, communal or clan groups occasionally leads to outbreaks of fighting. This may involve the use of firearms, rioting and looting. Private security firms play a major role in providing safety and security in the region. Domestic violence is likely to be common in the province, although no statistics are available (DFAT, 2009).

Status of Social Values 5 and 6 within Social Catchment 3

Summary statements of the status of social values (SV) 5 and 6 within Social Catchment 3 are provided below.

SV5 – An environment amenable to personal and family health, safety and security

The physical and social environment of Sepik River communities appears to be under considerable stress, particularly in recent years of drought. Combined with social dysfunction due to alcohol and drug use (and consequent domestic violence) family health, safety and security would have a high level of vulnerability.

SV6 – The availability of services supportive of personal health, safety and security

Services (policing, education and health) are limited at best, and non-existent in the more remote areas. Villages are reliant on their own initiatives and strategies to support fundamental needs of families.