TOTAL
TOTAL E&P PNG LIMITED

PAPUA LNG PROJECT

UPSTREAM ENVIRONMENTAL IMPACT STATEMENT

VOLUME 1: MAIN REPORT

Chapter 4: Project Description

TOTAL E&P PNG LIMITED

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4. Project Description

4.1 Introduction

This chapter describes the hydrocarbon resource, how the Project will produce gas and condensate, and how they will be transported to the liquefied natural gas (LNG) facilities. The key Project elements and activities described in this chapter are (see Figure 1.1):

- Development of the Elk-Antelope gas fields, which hosts the hydrocarbon that will be commercialized into gas and condensate products.
- The main Project components to develop the resource, namely:
  - Wellpads and wells where the reservoir fluids will be produced, and the flowlines and trunklines that will transport the reservoir fluids to a gas processing facility.
  - The central processing facility (CPF) where the reservoir fluids will be separated into gas, water and condensate, and processed and the acid gas will be removed.
  - Export pipelines, which will comprise a 40-inch diameter gas pipeline and a 10-inch diameter condensate pipeline. There will be 60 km of onshore and 260 km of offshore pipelines to transport the products from the CPF to the LNG facilities.
  - Infrastructure, which includes the new Logistics Base, incorporating wharfing facilities, the construction and operations accommodation camps, the access road network, the Purari Airstrip extension, landfills, quarries, laydown areas and stockpiles.
- The key activities described relate to the Project phases, as follows:
  - Early works, including the logistics necessary to transport materials, aggregates, equipment and people by sea and river, air and road.
  - Construction.
  - Drilling.
  - Operations, including maintenance.
  - Decommissioning.

Engineering studies are in progress and will continue through the FEED and detailed design Project phases. Throughout these phases, final decisions on design will be made, and some aspects of the Project design described in this chapter (including layout and hence footprint and therefore the disturbance area detailed in Section 4.10.7) may change. An overview of the Project management of change process is provided in Chapter 3 (Impact Assessment Process and Methods).

This chapter also identifies ongoing Project management measures and the major embedded design (also known as in-built design or design controls) features that are intended to mitigate potential environmental and social Project impacts, which are either typical of similar development projects or have been identified during the conceptual and pre-Project design phases. Section 4.13.3 summarizes the embedded design features.

4.2 Gasfield and the Resources

4.2.1 Geology and Reservoirs

The Elk-Antelope gas field covers approximately 14 km by 7 km, within which the two discrete gas reservoirs are separated by a thrust fault. A schematic of the reservoir geological cross-section is provided in Figure 4.1. Section 7.2 provides additional information on the regional geology.

The gas-bearing reservoir comprises limestone and dolostone, including the Upper Limestone, Dolostone, Intra Limestone and Lower Limestone reservoir units, which overlie Mesozoic deposits (Figure 4.1). The limestone geology of the reservoir is capped by shales known as the Orubadi Formation. The following features characterize the lithology, as shown in Figure 4.2:

- The top 100 m consists of geological strata known as Era Beds (sands).
- From 100 m to 1,600 m depth, the strata consist of shales known as the Orubadi Formation.
- The carbonate reservoir is situated in strata comprising 800 vertical meters of limestone and dolostone.

The hydrocarbons in place comprise an estimated 6.2 to 7.5 trillion cubic feet of hydrocarbon gas and with a condensate to gas ratio estimated between 15 and 20 bbl/MMscf. More than 95% of the combined Elk-Antelope hydrocarbons in place are from the Antelope field. The reservoir pressure is 244 to 256 bar and fluids are between 86 and 106°C.

4.2.2 Gas

Table 4.1 summarizes the Antelope and Elk hydrocarbon gas composition. The main difference between the two fields is that Antelope contains higher hydrogen sulfide concentrations than the Elk field. The two fields are separate (see Figure 4.1) and the gases are unlikely to mix.

Table 4.1 – Summary of Antelope and Elk Gas Compositions

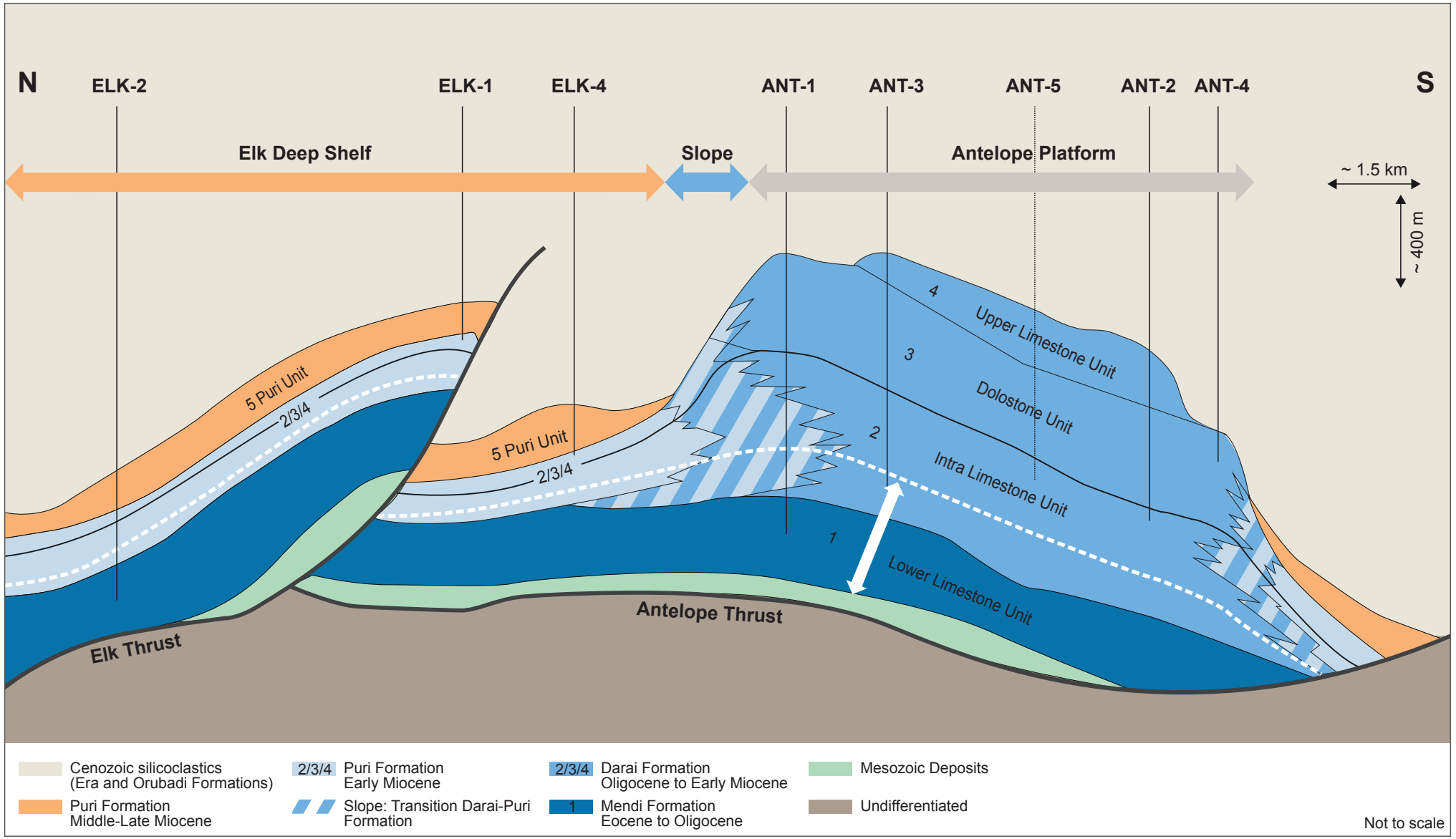
Compound	Concentration	Reservoir	
		Antelope	Elk
Methane	%	86.7	90
Ethane	%	3.6	2.6
Propane	%	1.2	0.6
Other C1-C35 hydrocarbons	%	<1	<1
Carbon dioxide	%	5.7	5.2
Nitrogen	%	0.4	0.4
Hydrogen sulfide	ppm	140 to 200	5
Benzene	ppm	340	340
Toluene	ppm	340	340
Ethylbenzene	ppm	40	40
Xylenes	ppm	880	880
Mercury (in elemental state)	µg/Nm^3	1	1
Arsenic compounds*	µg/Nm^3	To be confirmed	To be confirmed

*Arsenic compound concentrations are being verified with further analysis.

SCHEMATIC OF ELK-ANTELOPE GEOLOGICAL CROSS SECTION

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FIGURE 4.1

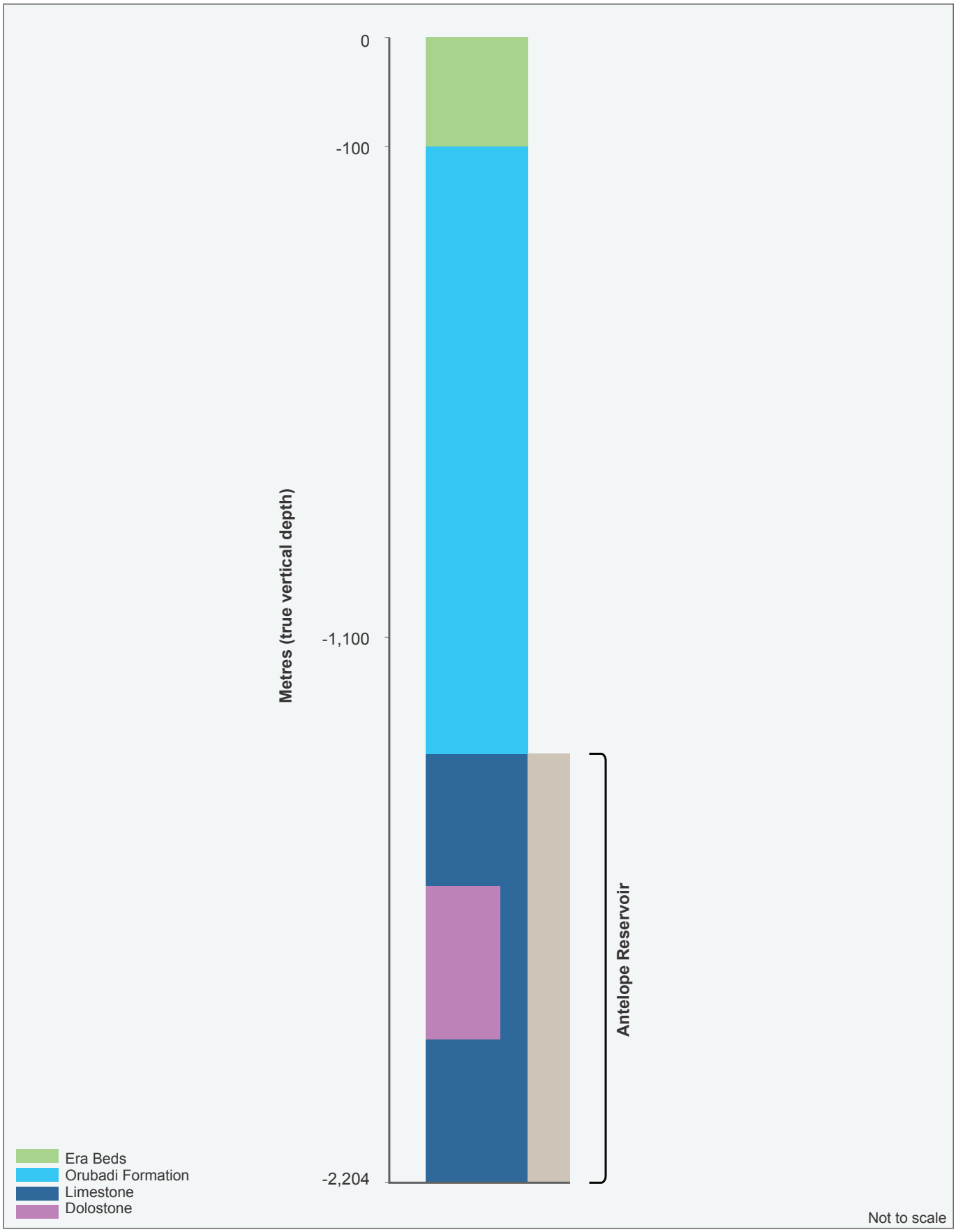


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TYPICAL LITHOLOGY OF THE ELK-ANTELOPE FIELD

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FIGURE 4.2



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4.2.3 Condensate

Condensate from the Elk-Antelope fields has a specific gravity of 0.78 and comprises a mixture of hydrocarbons, including propane, butane, pentane and hexane. The condensate contains some sulfur compounds (0.23% by weight), including hydrogen sulfide and mercaptans,[1] which are considered to be impurities. The condensate also contains aromatic organic compounds. These comprise benzene (1.1%), toluene (4.3%), ethylbenzene (0.5%) and xylenes (7.1%). Naturally occurring radioactive material (NORM) is not expected to occur.

4.2.4 Produced Water

Produced water is extracted from a reservoir as a byproduct during the gas extraction process. It can be produced from the condensation of water previously saturated in the gas or from an aquifer associated with the reservoir. The Elk and Antelope reservoirs are unlikely to produce aquifer water based on their characteristics; therefore, the produced water will be condensation water only.

4.2.5 Production Profiles

The production profiles for the gas, condensate and produced water are provided in Figure 4.3.

The Elk and Antelope wells will be able to deliver close to 900 million standard cubic feet per day (MMscfd) of raw gas to the CPF, which is designed to export about 820 MMscfd of treated gas at peak along with 15,000 barrels per day of condensate. Assuming a 94% availability of the facilities, this result in an average production of 840 MMscfd of raw gas and 770 MMscfd of treated export gas on an annual basis. Part of the raw gas will be used as fuel gas to power gas turbines to produce electrical power for the CPF and wellpads.

4.3 Wells and Wellpads

4.3.1 Number, Location and Footprint

The Elk-Antelope fields will be developed with up to nine wells and three wellpads as summarized in the Table 4.2.

Table 4.2 – Summary of Wells and Wellpads

Field	Elk	Antelope	
Wellpad	ELK-10*	ANT-10	ANT-11#
Area† (ha)	1.6	5.0	1.6
Number of producer wells	1	7	–
Number of acid gas disposal wells	1##	–	–
Number of produced water wells	–	–	1·
Number of acid gas liquid effluent disposal wells††	–	–	1·
Total number of wells	1	7	1**

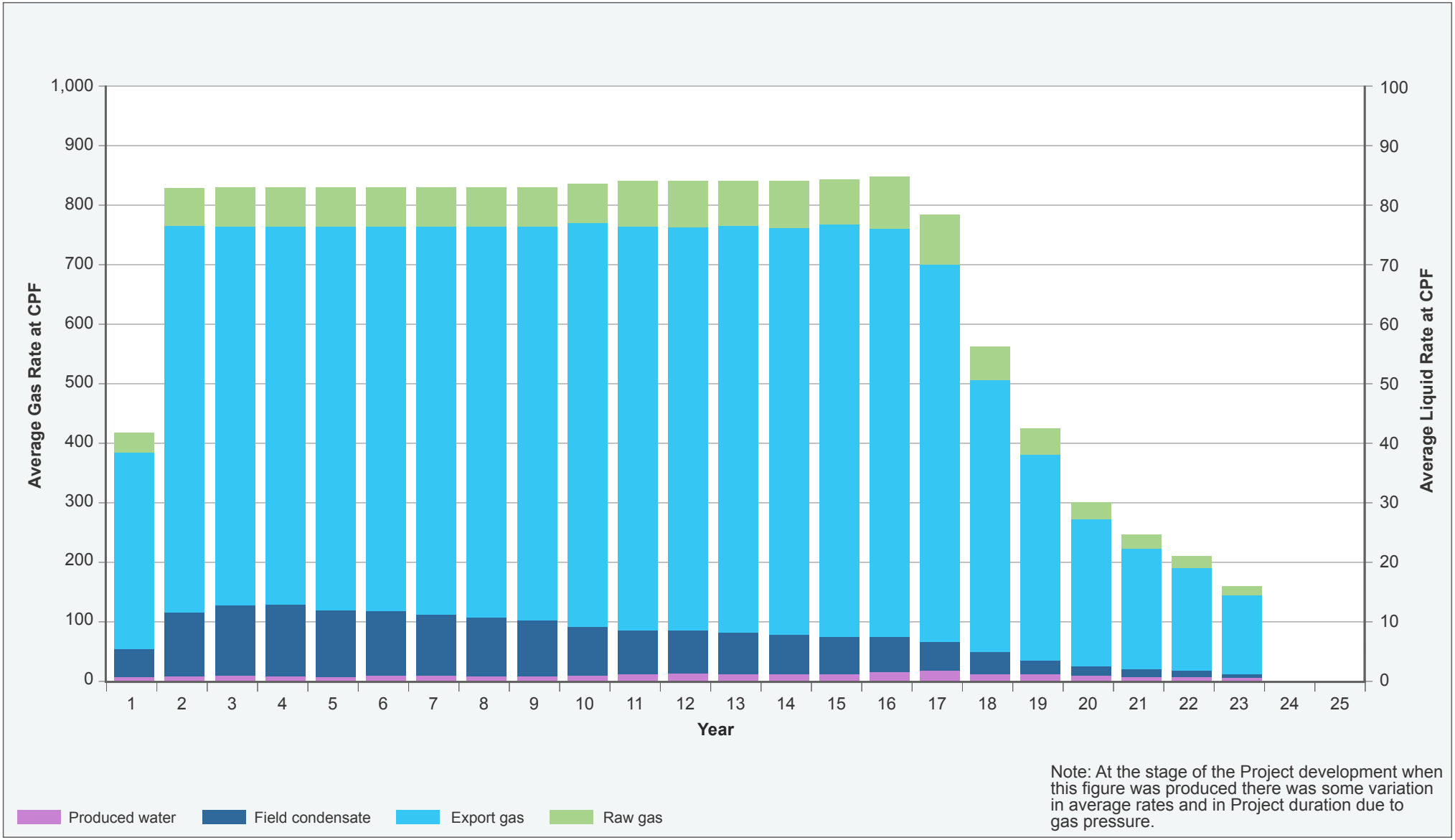
* Existing Elk-1 modified and refurbished. # Existing ANT-1 modified and refurbished. † Footprint including vegetation clearing area. ## Converted producer well. †† Only required until Elk reservoir is depleted. ** A single well used for both purposes.

1 Organosulfur compound.

GAS, CONDENSATE AND WATER PRODUCTION PROFILES

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FIGURE 4.3



Note: At the stage of the Project development when this figure was produced there was some variation in average rates and in Project duration due to gas pressure.

The Elk field will be developed with one production well drilled from the existing Elk-1 wellpad, which will be upgraded and renamed ELK-10. When the Elk reservoir is depleted – after approximately four years of production, – the production well and wellpad will be converted for acid gas disposal. No water injection is planned for the Elk field.

The Antelope field will be developed with a new wellpad, named ANT-10, located near the existing ANT-5 wellpad. Seven producer wells will be drilled from this wellpad. The well on the existing ANT-1 wellpad will be converted to a produced water/acid gas liquid effluent disposal well, and the wellpad will be renamed ANT-11. The location of the wellpads in relation to the field, the gathering system and the CPF is provided in Figure 4.4.

4.3.2 Wellpads and Gathering Systems

Each wellpad will have a wellhead control panel, transformer and technical room. The technical room will house such equipment as batteries, electrical distribution panels, process and electrical control systems, alarms and remotely operated fire extinguishing systems.

The producer wellpads will have systems to inject chemicals into the reservoir fluids. The chemicals will be stored at the CPF and, when needed, will be transported in drums or cubi-containers by road to the wellpad (Section 4.11.1.2).

Buried flowlines on the wellpads will transport the reservoir fluids from each wellhead to the flowline or trunkline.

4.4 Flowlines and Trunklines

4.4.1 Characteristics of the Flowlines and Trunklines

The flowlines and trunklines comprise the gathering system that conveys the reservoir fluids from the wellheads to the CPF, and produced water back to the wellheads. As required by the PNG *Oil and Gas Regulation 2002*, the pipelines are designed in accordance with Australian Standard AS 2885. The key characteristics of the flowlines and trunklines are summarized in Table 4.3. The design life is 25 years.

Table 4.3 – Key Characteristics of Flowlines and Trunklines

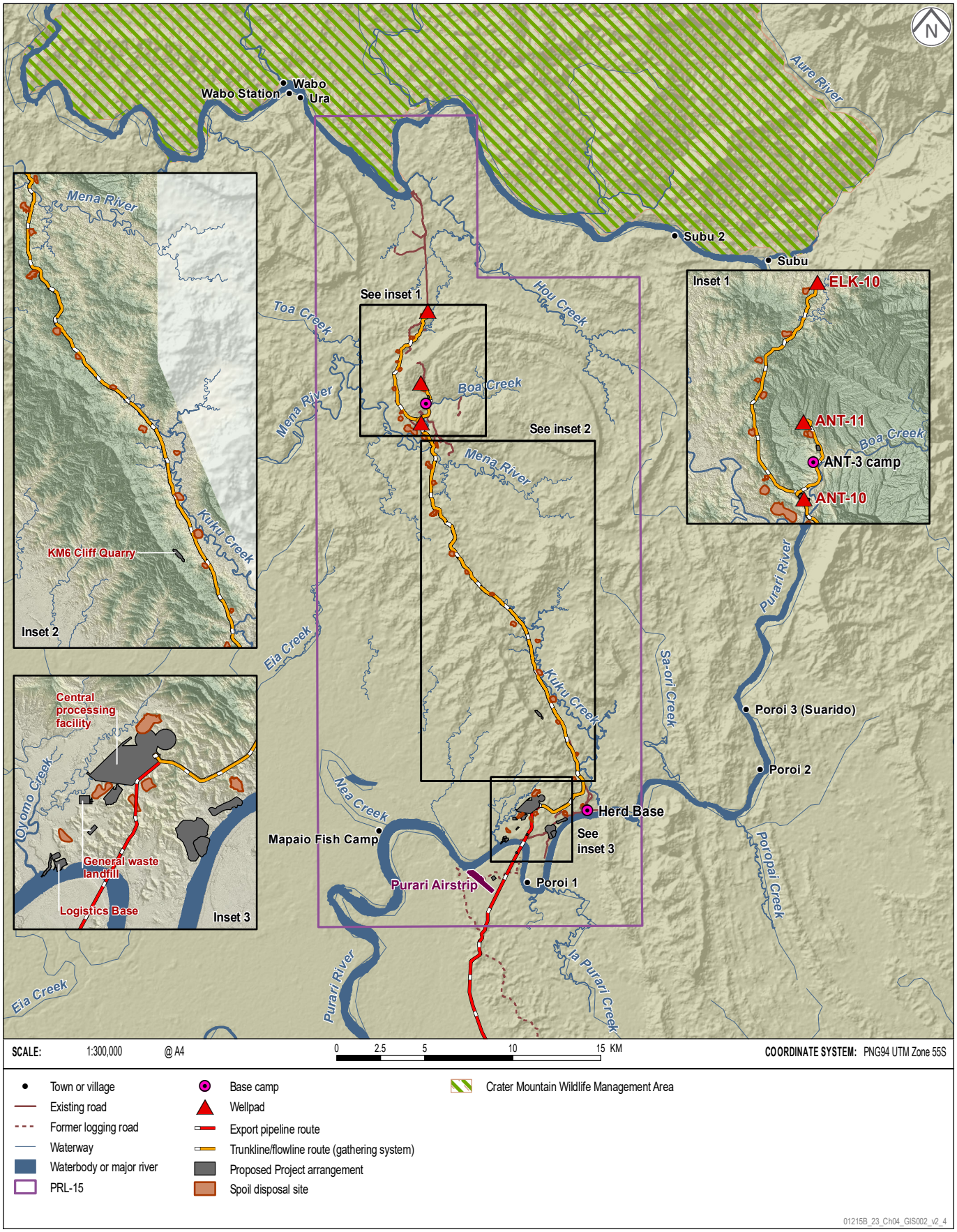
Pipeline	Fluid	Design Capacity	Material	Length (km)†	Diameter (inches)	Design Pressure (bar)	Design Temperature (°C)
Elk flowline*	Reservoir fluids#	200 MMscfd	Carbon steel	36.0	14	219	100
Antelope trunkline #1	Reservoir fluids	450 MMscfd		28.0	22	219	100
Antelope trunkline #2	Reservoir fluids	450 MMscfd		28.0	22	219	100
Water injection flowline	Produced water	3,000 bpd		31.1	4	219	83

* Will be known as acid gas injection flowline when the Elk reservoir is depleted and the flowline is used to transport acid gas. # Acid gas will be transported via this pipeline after the Elk reservoir is depleted and the pipeline will be suitable for both uses. † Length may vary slightly due to minor changes in design.

OVERALL LAYOUT IN PRL-15

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FIGURE 4.4



4.4.2 Routing of the Flowlines and Trunklines

Flowline and trunkline routing has been selected based on the result of multidisciplinary studies, with an iterative process accounting for various constraints, e.g., environmental and societal, geohazards, pipeline constructability and cost (Section 5.4.1).

The key features of the routes are as follows:

- Avoiding communities and sensitive cultural sites.
- Avoiding areas of active landslides.
- Avoiding narrow and eroding ridges.
- Crossing the fewest geohazard zones and following a relatively homogenous slope setting for the flowline.
- Avoiding the sensitive alluvial forest south of the Kuku Ridge and the Pie River catchment for the trunklines.
- Combining Project roads to the wellpads with the pipeline right of way, where practicable, to reduce the disturbance footprint.

The route of each gathering system pipeline is shown in Figure 4.4. The key features of the routes are summarized in Table 4.4.

Table 4.4 – Key Features of the Flowline and Trunkline Routes

Route	Length (km)	Length of Existing Tracks Followed (km)	Number of Waterway Crossings	Number of Major/ Secondary Fault Lines Crossed
Elk flowline*	8.0	2.8	12	0/0
Water injection/acid gas liquid effluent flowline*	3.1	2.1	1	0/5
Antelope trunklines	28.0	21.5	94	0/5

* Not counting the length shared with the Antelope trunklines.

4.5 Gas Processing Facilities

4.5.1 Generalities

The reservoir fluids will be processed before being transported to the PNG LNG Facilities. Processing is to separate the gas from the condensate and to remove carbon dioxide, water and hydrogen sulfide so that the gas and condensate compositions comply with the LNG plant specifications.

4.5.2 Proposed Site

The CPF will be located in PRL-15 near the Purari River, and approximately 30 km south of the ANT-10 wellpad and 40 km from the ELK-10 wellpad (see Figure 4.4). It will be close to a new Logistics Base (Section 4.8.6) and 5 km west of the existing Herd Base (Section 4.8.2).

The site is in a hilly area adjacent to the Purari River alluvial plain with elevations from 50 to 400 m above sea level. The land is covered with dense tropical forest.

The Project will acquire approximately 600 ha of land to site the CPF, the operations camp, the Logistics Base, temporary construction areas (including the construction camp) and restricted zones. A security fence will be installed around individual areas once the boundaries are finalized during FEED. The land to be cleared of vegetation for the CPF facilities and operations camp will be approximately 100 ha.

The northern part of the site is in a hilly area that will require terracing, leveling and grading; however, the site layout and earthworks have been designed to maximize the reuse of cut material and minimize the need for spoil disposal (Section 4.10.2.7). Positioning the processing areas on higher ground reduces the flood risk and the adverse impact of potential earthquakes, and will be advantageous for constructing drainage networks. The temporary construction areas and the operations camp will be sited on the low ground between the hills and the river.

4.5.3 General Description of the CPF

4.5.3.1 General Layout

The layout of the CPF and adjacent operations camp is illustrated in Figure 4.5. The facilities will comprise the following main areas: operations camp, flares, vents and stacks, production facilities (processing, utilities and services), and area for future expansion (e.g., future medium pressure and low pressure compressors). During construction, a temporary construction area will be used for the concrete batching plant, laydown areas, prefabrication and construction facilities (such as contractors' offices, temporary workshops and warehouses). A temporary construction camp will be located adjacent to this area.

4.5.3.2 Services Area

The services area will include the central control room, main office buildings, firefighting equipment, workshop, warehouse and laboratory.

4.5.3.3 Processing Area

The processing facilities will comprise a single gas processing train with the following functions: separation of gas, water and condensate, cooling of fluids, removal of acid gas, dew pointing and metering. A liquid stabilization train will produce stabilized condensate. Other processing units will comprise the acid gas management and gas (i.e., Elk and CO_2) compression units. These processes are described in more detail in Section 4.11.1.

4.5.3.4 Utilities Area

The utilities area will be located upwind from the processing area. Part of the area will be accessible to trucks; and a second area will be dedicated to supply all necessary utilities, which will include compressed air, nitrogen, fresh water, demineralized water, electricity and a heating medium.

4.5.3.5 Condensate Storage Facilities

A storage area for condensate and off-specification condensate will be located next to the utilities area.

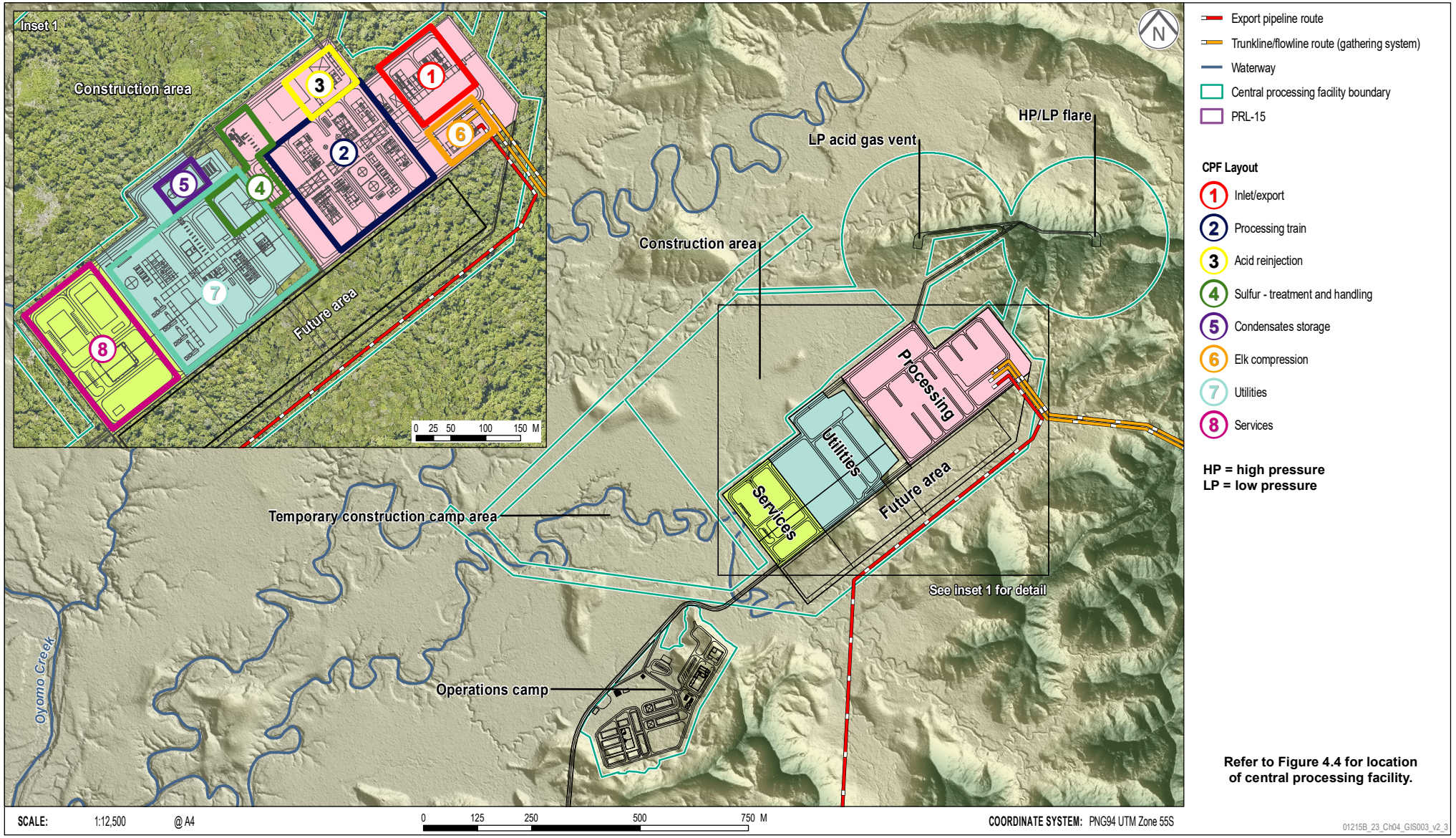
4.5.3.6 Flare and Vents

During normal operations, other than native CO_2, there will no be flaring or venting; however, flares and vents will be necessary occasionally for specific situations such as start-up, maintenance and upset processing situations (Section 4.11.1.2). The buffer zone around the CPF facilities has been sized to include the vents and flares restricted area.

CENTRAL PROCESSING FACILITY SITE LAYOUT

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FIGURE 4.5



4.6 Transporting the Gas

4.6.1 Export Pipelines

This section describes how the Project will transport gas and condensate from the CPF to the downstream facilities in Caution Bay. The Project components described comprise the onshore and offshore sections of the gas and condensate export pipelines and associated infrastructure. The gas and condensate pipelines will be parallel, following the same route, approximately 60 km of which will be onshore and approximately 260 km of which will be offshore. Two pipeline shore crossings are described: the upstream crossing at Orokolo Bay and the downstream crossing at Caution Bay. The pipelines connect to the PNG LNG Facilities at a tie-in point inside the PNG LNG project lease boundary. The description in this section provides the technical characteristics of the components and describes the main activities required for constructing, operating, maintaining and decommissioning the pipelines. LNG facilities inside the PNG LNG project lease boundary are excluded from the scope of this EIS and consequently are not included in the Project description; this also includes any proposed PNG LNG jetty extension.

General Characteristics

The pipelines have been designed in accordance with Australian Standard AS 2885, as required by the PNG *Oil and Gas Regulation 2002*. Indicative key pipeline characteristics are summarized in Table 4.5.

Table 4.5 – Summary of Indicative Key Characteristics of Gas and Condensate Export Pipelines

Parameter	Unit	Gas	Condensate
Material	N/A	Carbon steel	Carbon steel
Design life	years	40	40
Outside diameter	inches	40	10.75
Corrosion allowance	mm	1.5	3.0
Design pressure	bar	129	110
Design temperature	°C	57	77
Operating pressure	bar	85 to119	49
Operating temperature	°C	32	62
Design capacity (gas)	MMscfd	820	N/A
Design capacity (condensate)	bblpd	N/A	15,000
Onshore section length	km	60	60
Offshore section length	km	260	260
Maximum water depth	m	85	85

Notes: The above-ground sections of the pipelines will not be thermally insulated. The gas pipeline will have an internal coating to minimize corrosion during construction and pre-commissioning, and to aid drying after hydrotesting. Offshore sections of the pipeline will have a concrete coating for stability when necessary, and sections of the onshore pipeline in a swampy area will have a concrete coating.

4.6.2 Onshore Pipelines

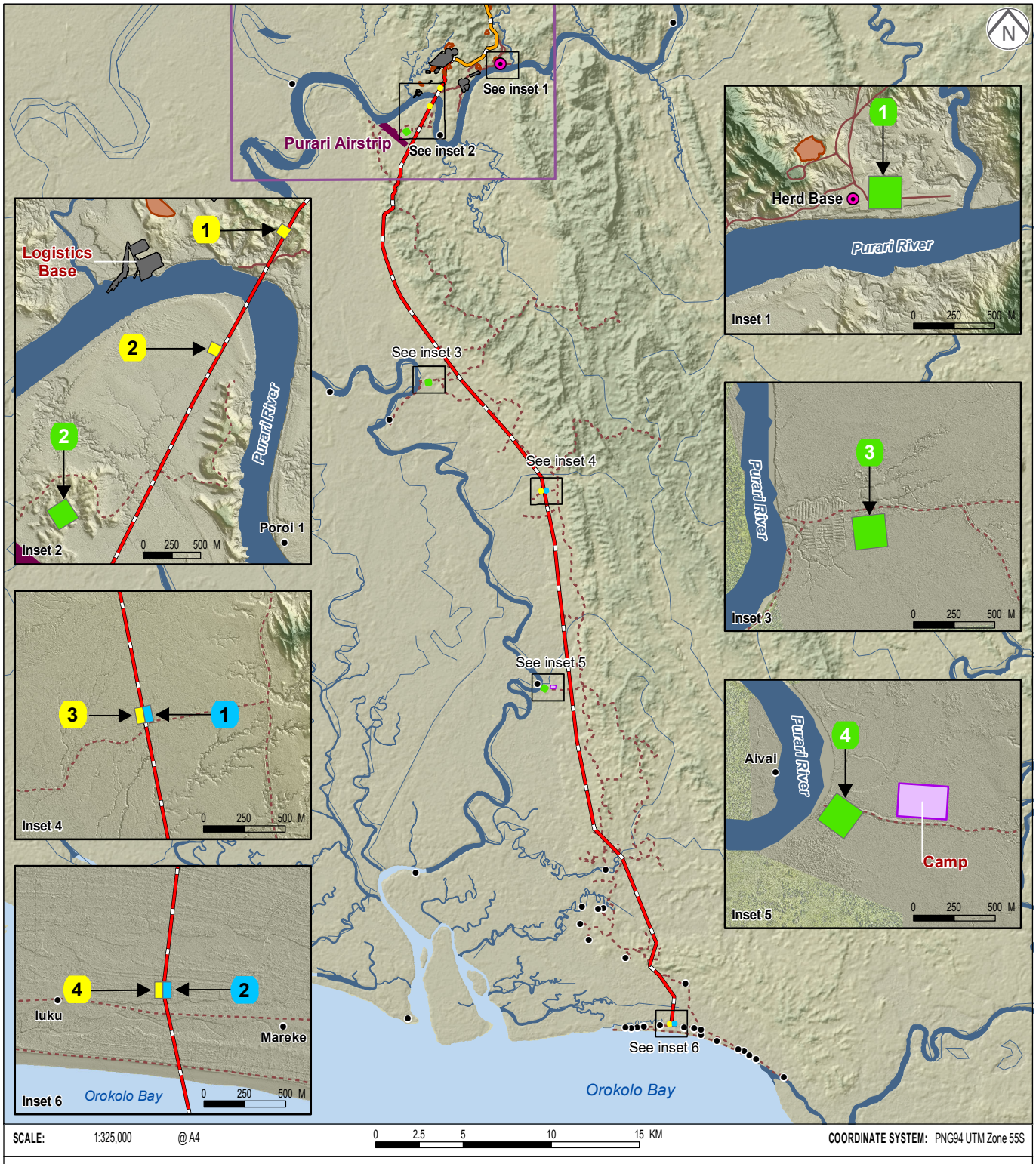
4.6.2.1 Routing

The pipeline route has been selected based on the result of multidisciplinary studies, with an iterative process accounting for various constraints, e.g., environmental and societal, geohazards, pipeline constructability and cost (Section 5.4.2). The proposed onshore export pipeline route is shown in Figure 4.6.

ONSHORE EXPORT PIPELINE ROUTE

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FIGURE 4.6



The key features of the route south from the CPF are as follows:

- Crossing of the Purari River (Section 4.10.5.3) – situated immediately south of the CPF.
- Crossing of a range of hills – over 3 km with slopes of 10 to 15° and areas exposed to shallow landslide risks.
- Crossing an alluvial plain over 38 km – several tectonic faults along the route (Section 4.9.3.3).
- Crossing a hilly area over 10 km – some areas with steep slopes.
- Approaching the shore of Orokolo Bay – crosses a flat waterlogged area with a stretch of sand dunes forming an almost parallel series of ridges oriented northwest–southeast that needs to be crossed in a south-north orientation.
- Combining the pipeline right of way with existing area of disturbance, where practicable, to reduce the disturbance footprint.

The route crosses 79 waterways.

4.6.2.2 Infrastructure

The permanent infrastructure required for the onshore pipeline section comprises 63 km of new access road that will follow the pipeline from south of the Purari River to Orokolo Bay, valve stations for gas and condensate pipelines, and facilities for cathodic protection. Compression stations will not be required. Communication facilities are expected to be located at the valve stations.

The onshore export pipelines will be equipped with six valve stations as follows:

- Condensate valve station on the north side of the Purari River (CVS1).
- Condensate valve station on the south side of the Purari River (CVS2).
- Condensate valve station (CVS3) and gas valve station (GVS1), 30 km south of the Purari River.
- Condensate valve station (CVS4) and gas valve station (GVS2) at the Orokolo Bay shore crossing.

The locations of the valve stations are shown in Figure 4.6. Valve stations will be designed during FEED; however, usually in addition to the facilities for stopping the flow of gas/condensate, a valve station will also include a communications building and tower, and possibly solar power facilities. The total area occupied by each valve station is expected to be approximately 1 ha.

Pipelines are protected against corrosion using cathodic protection. The system is likely to comprise several cathodic protection stations positioned along the pipeline including at the valve stations. The number and location of the cathodic protection stations are yet to be defined. Cathodic protection prevents corrosion by keeping the pipeline at a negative electrical potential (i.e., less than 1 volt). The total area of each cathodic protection station and cleared surrounds could be up to 0.5 ha.

The running track/access road adjacent to the pipeline (Section 4.10.5.1) will be constructed concurrently with the pipeline.

4.6.3 Offshore Pipelines

The selected offshore export pipeline route is shown in Figure 4.7. The route selection has been driven by the need to minimize the overall length, avoid geohazards, maximize the use of the existing PNG LNG pipeline route (with a separation distance of approximately 50 m), and find suitable solutions for the shore crossing at Orokolo Bay and the approach to Caution Bay. The offshore pipelines will be situated at least 5 km from the coast to avoid encroaching on customary land; consequently, the pipelines will need to cross the existing PNG LNG Gas Pipeline to achieve this. From Orokolo Bay, the offshore pipeline route runs in a general southeasterly direction in marine continental waters up to approximately 76 m deep. It crosses the PNG LNG Gas Pipeline approximately 110 km from Orokolo Bay. Two approaches to Caution Bay are being considered and both are assessed in this EIS approximately up to the PNG LNG lease boundary. A decision on the approach will be made during FEED.

4.7 Personnel and Accommodation

4.7.1 Worker Requirements

4.7.1.1 Construction Phase

The approximate number of workers required during construction for the upstream facilities ranges from 50 people during the initial stages of the early works up to approximately 6,000 during the period of peak activities, noting that these numbers are estimates and subject to change.

The different construction activities include preparatory works, early works, drilling, and site preparation and building of the CPF and pipelines; although, not all these activities will take place simultaneously. The construction workers will be demobilized once construction is completed.

4.7.1.2 Operations Phase

The operation of the upstream facilities (e.g., wellpads, trunklines, flowlines, CPF and export pipelines) will require operations, maintenance and security workers. The work is likely to take place 24 hours per day, 7 days per week on a rotation basis with 28 days on/28 days off, with all workers living and remaining onsite in the operations camp during their rotation.

4.7.1.3 National Content

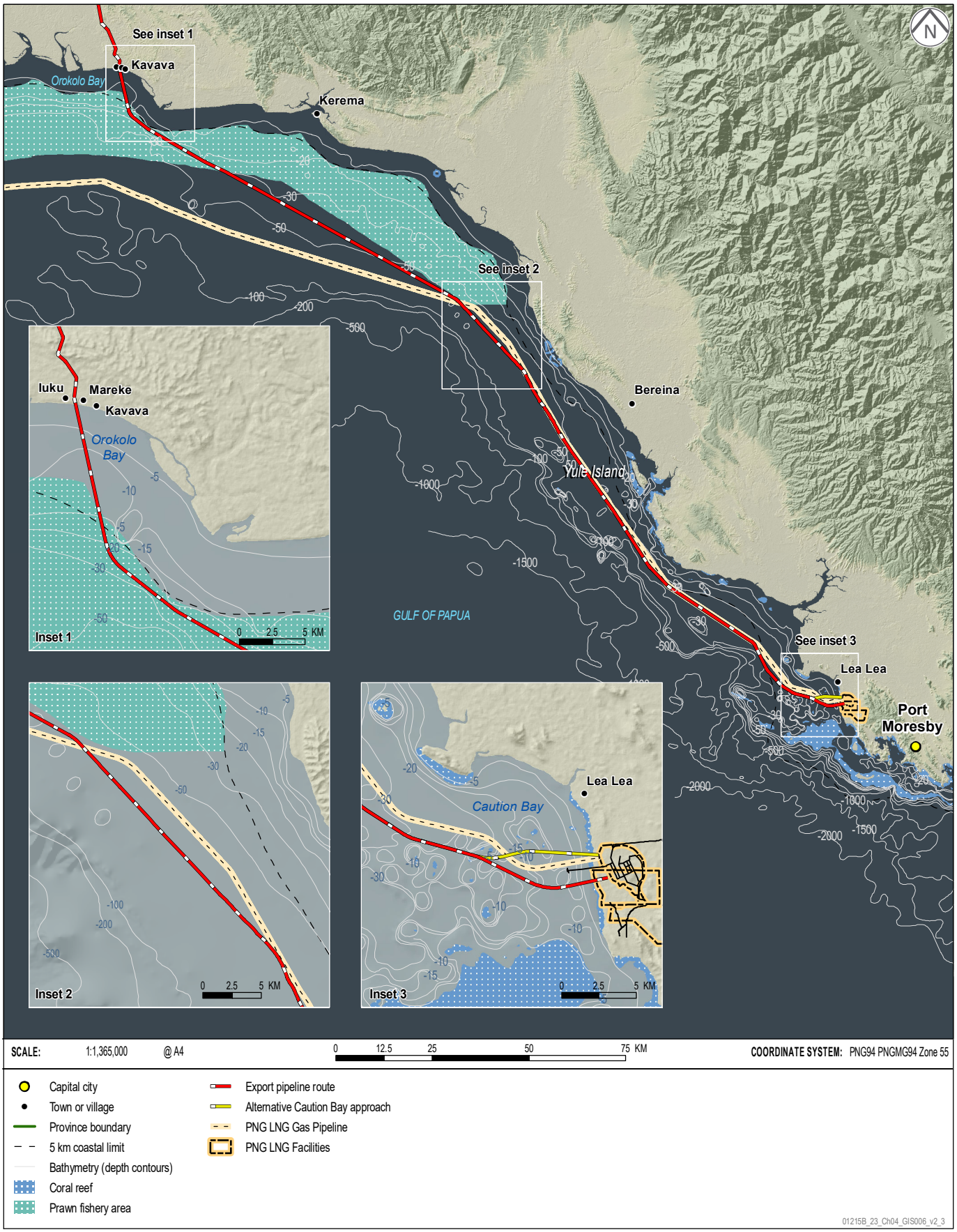
Expatriate specialists will provide an experienced core team during construction and to conduct initial operations, coupled with trained new and experienced-hire PNG nationals. The number of expatriates employed on the Project is expected to decline steadily over time as PNG nationals acquire competency and experience, and in accordance with training and localization plans approved by the PNG Government.

The Project will develop technical and vocational education and training initiatives to facilitate local workforce participation in the Project construction phase.

OFFSHORE EXPORT PIPELINE ROUTE

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FIGURE 4.7



4.7.2 Accommodation Facilities

The accommodation facilities required by the Project during construction and operations, and the key characteristics are summarized in Table 4.6. Camp design and location will be defined during FEED.

The operations camp will obtain power from the CPF power supply, and generator sets will supply power to other temporary accommodation facilities. A sewage treatment plant in the CPF area will treat sewage to the required water discharge specifications, with any water discharges managed in accordance with the PNG environment (water discharge) permit and IFC requirements. Sewage from the temporary construction camps will be treated to the required specifications in containerized sewage treatment plants and disposed of locally under a water and land discharge permit. Sewage treatment and disposal will be further defined during FEED.

Nearby freshwater sources, i.e., rainwater, the Purari River or smaller streams will supply water for accommodation facilities, and on-site treatment plants will treat the water prior to use.

4.8 Infrastructure

Project infrastructure will be a combination of existing facilities, such as port facilities at Port Moresby and Herd Base, and newly constructed infrastructure, such as roads in PRL-15, a new Logistics Base, an extension to the existing Purari Airstrip and waste facilities.

4.8.1 Facilities at Port Moresby

Equipment for Project construction and operations, imported from outside Papua New Guinea, is likely to transit through existing port facilities near Port Moresby. No new port facilities will be required at Port Moresby. The Project is considering using the following facilities:

- Motukea Port (Plate 4.1, photos A and B), where equipment and materials can be directly transferred from ocean-going vessels to barges or landing-craft type vessels that will transport the equipment to the wharf facility at the Logistics Base site on the Purari River.
- Avenell Engineering Systems Ltd (AES) supply base (see Plate 4.1, photos A and C), located 3 km southwest of Motukea Port. This supply base is equipped with a suitable wharf and laydown areas, and the quay was extended in 2017. TEP PNG currently uses this base.

4.8.2 Herd Base

Herd Base, shown in Plate 4.1, photo D, is situated on the north bank of the Purari River, some 10 km upstream from the proposed Logistics Base. The base started operation in 2015 and has supported all past Elk-Antelope fields exploration and surveys. The Project will use Herd Base as a logistics base at during the preparatory works phase and the start of the early works phase while the new Logistics Base and the temporary construction accommodation camp at the CPF site are constructed, and to support the drilling campaign if necessary. This will require enlarging existing storage areas and upgrading unloading equipment. The main facilities at Herd Base are a 700-m^2 warehouse and a 1,500-m^2 pipe yard (pipe yard 1), lifting and handling facilities, a quay and ramp for offloading barges on the Purari River and accommodation for 250 to 300 people.

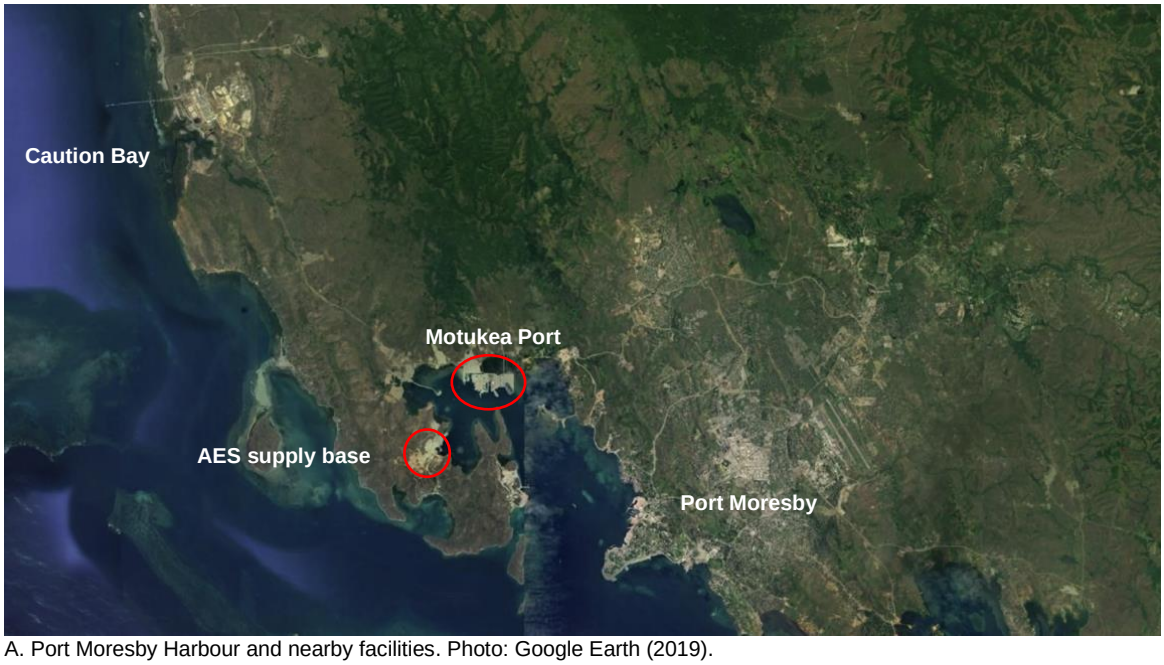
Herd Base will eventually provide backup facilities to the new Logistics Base during operations but would be progressively decommissioned, as appropriate.

Table 4.6 – Accommodation Facilities

Facility	Temporary/ Permanent	Existing/ New	Project Phase	Capacity (Approximate Number of People)	Area (ha)	Comment
ANT-3 camp	Temporary	Existing	Drilling	100	No new Disturbance	This existing camp will be used by the drilling teams as it is close to the drill sites. The Project will refurbish the camp.
Herd Base	Permanent	Existing	Construction and operations	250 to 300	No new disturbance	During the initial stages of the preparatory works, construction workers will be accommodated at the existing Herd Base facilities. Herb Base will also be used as a general support to the Project.
	Temporary	New	Construction	500	No new disturbance	The workers for the airstrip extension will be accommodated within a temporary accommodation camp at Herd Base and will be transported to the airstrip worksite and back every day by bus and ferry.
CPF construction camp	Temporary	New	Construction	4,500	14.3	Comprises laydown and storage areas, offices, and accommodation.
Pipeline construction camp (see Figure 4.6)	Temporary	New	Construction	500	4.0*	Colocated with pipe yard 4 (the furthest south and closest to the mouth of the Purari River is the principle accommodation area for the export pipeline construction). Construction workers associated with pipe yard 1 will be accommodated at the temporary accommodation camp associated with or near Herd Base.
Operations camp (see Figure 4.5)	Permanent	New	Operation	250#	7.1	The camp area will be fenced and have a controlled entry point. The camp will be guarded with CCTV monitoring. The camp will comprise dormitories, dining room, recreation areas, medical center and offices.

* Area represents both the pipe yard and the accommodation camp.

Plate 4.1 – Existing Infrastructure Facilities Used by the Project



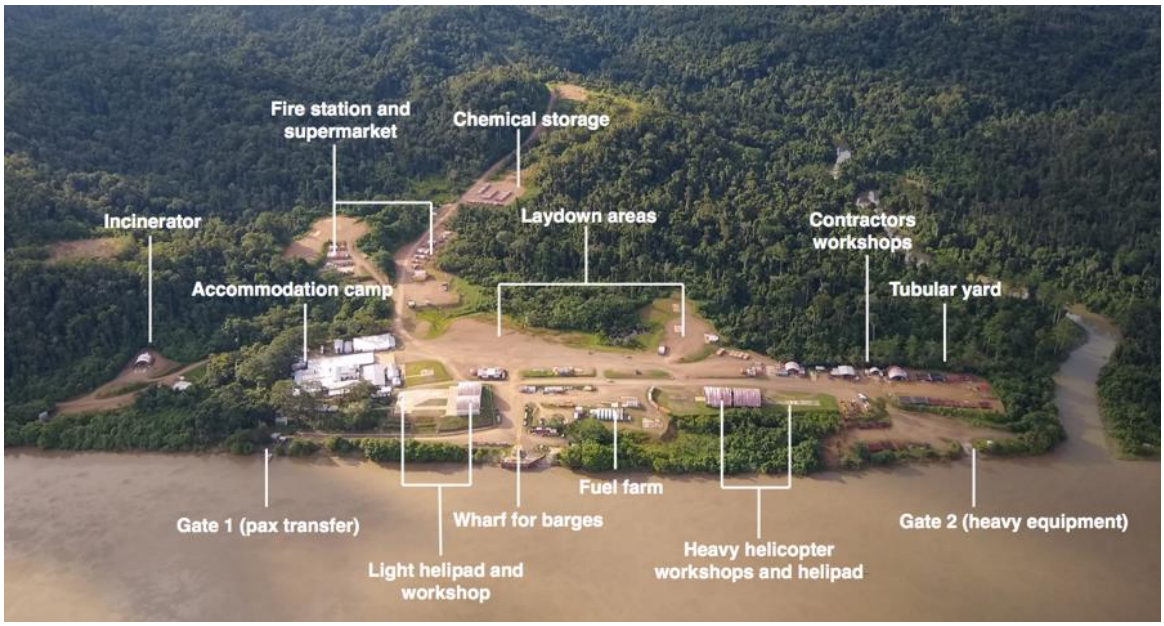
A. Port Moresby Harbour and nearby facilities. Photo: Google Earth (2019).



B. Motukea Port. Photo: ERIAS Group.



C. AES supply base. Photo: Google Earth (2019).



D. Herd Base. Photo: TOTAL.

4.8.3 Roads

The roads that will be constructed by the Project are listed in Table 4.7 and shown in Figure 4.8. The roads will be paved with gravel and have a 25-year design life. Roads, including bridges and culverts, will be designed and built in accordance with the PNG Road Design manual (1985) for the rural roads in a hilly area category.

Table 4.7 – Summary of Project Roads

Road No.	Road Description	Road Type	Length (km)	Width (m)	Maximum Gradient (%)	Design Speed (km/h)
R1	CPF to vents and flares (construction phase only)	Heavy haul	0.9	10	10	30
R2	Logistics Base to CPF	Heavy haul	2.3	25*	5	30
R4	Herd Base to CPF	Standard	4.6	10	12	30
R5#	Herd Base to ANT-10	Standard	25.8	10	12	30
R6	ANT-10 to ANT-11	Standard	2.9	10	12	30
R7	ANT-10 to ELK-10	Standard	7.8	10	12	30

* Initial width 12 m; the width will be revised during the FEED phase to a likely width of 25 m to accommodate transporting the CPF modules. # An existing road that will be upgraded.

The roads will be designed accounting for major landform hazards to reduce risks to safety during construction and during subsequent use.

Flooding is a risk that has been considered; consequently, access roads R2 and R5 will be leveled at 15 m above the floodplain, and bridges and culverts will be placed along the road to avoid water accumulation.

Heavy or prolonged rainfall is the main cause of landslides, and this will be mitigated by constructing effective drainage systems on slopes where landslide has the potential to adversely affect roads.

An access track (Figure 4.8) along the pipeline right of way (ROW) will be retained for surveillance and maintenance purposes only (Section 4.10.5.2).

4.8.4 Quarries

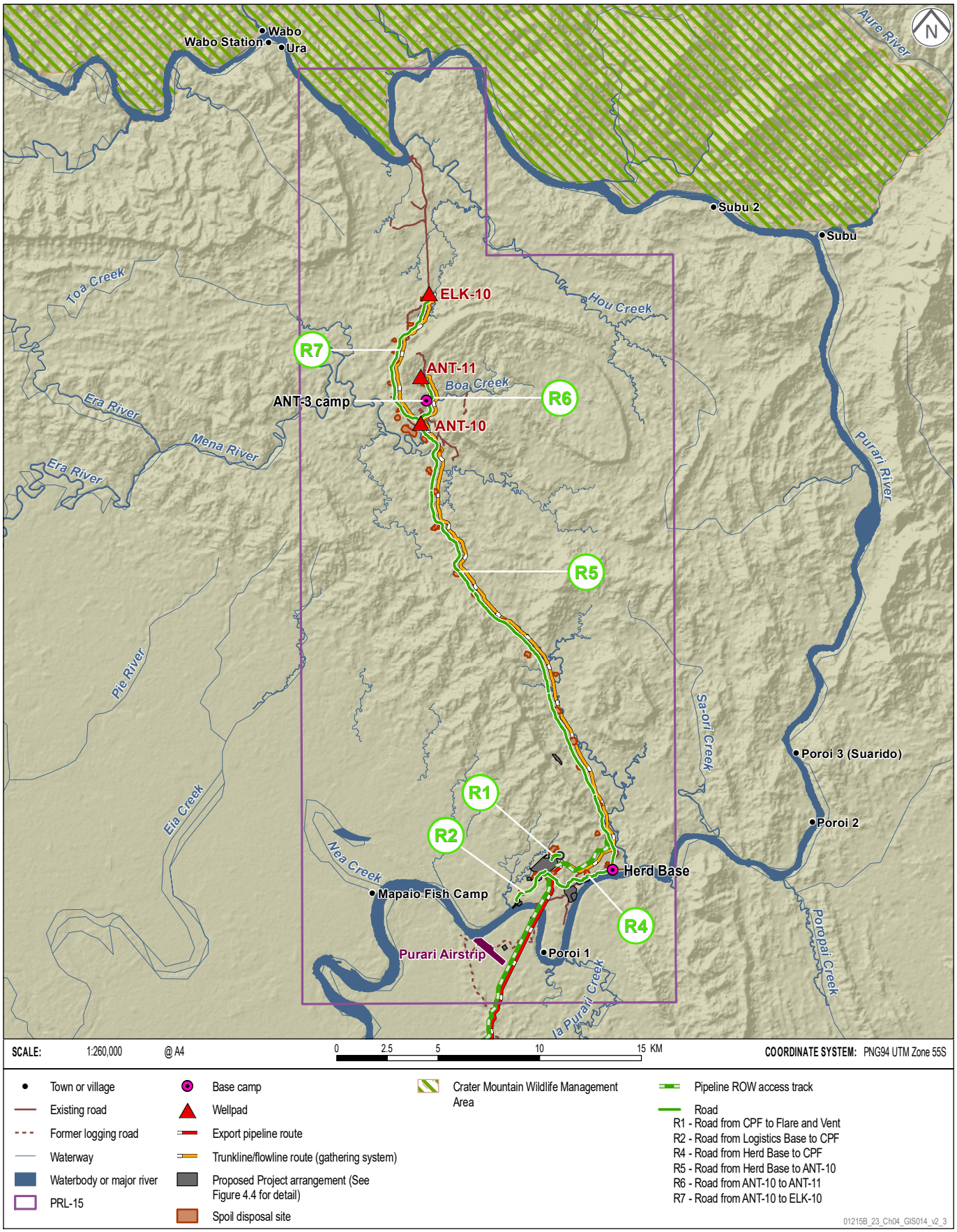
The quarries situated in PRL-15 are Herd Base quarries A, C and D and KM6 Cliff Quarry (Figure 4.9). These quarries may supply construction backfill material for the Project. The need for additional quarries will be investigated.

4.8.4.1 Herd Base Quarries A, C and D

Four quarries are sited near Herd Base. The Project has selected three of these; Herd Base quarries A, C and D for use.

Quarry A is an existing quarry 1.6 km to the southwest of Herd Base by road and 1.8 km from the CPF. The quarry has a 7-ha footprint and materials available comprise conglomerate deposits interbedded in fine-grained material. This quarry will supply the Project with approximately 451,000 m^3 of material comprising general fill material, impervious materials and granular material for pavement layers. Quarries C and D are provisional and, if needed, will be developed. These quarries are located adjacent to each other, approximately 200 m southwest of Quarry A. They have a conservative footprint of approximately 27 ha and 8 ha, respectively.

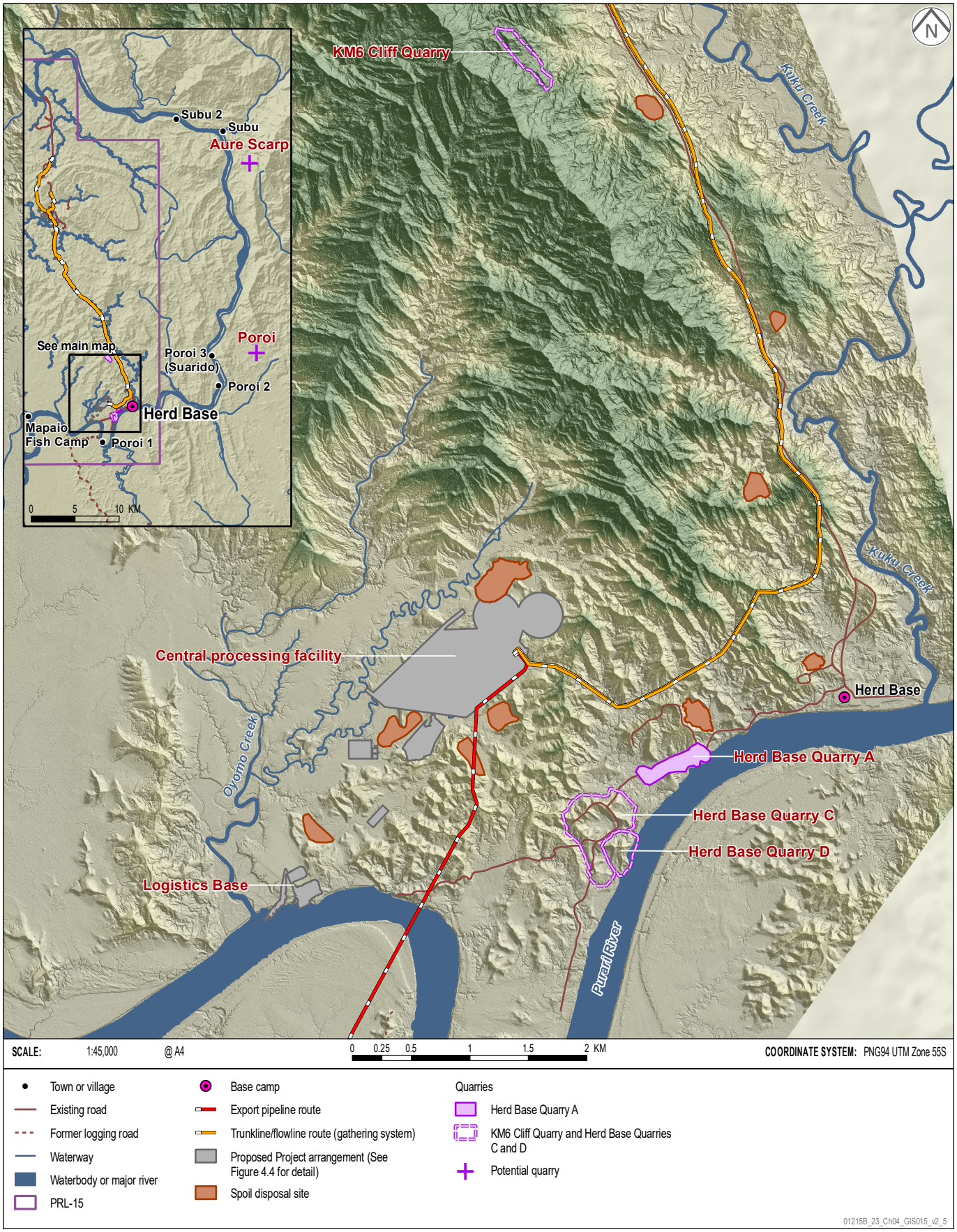
FIGURE 4.8


Wabo
Wabo Station
Ura
Aure River
Subu 2
Subu
Toa Creek
Hou Creek
ELK-10
R7
ANT-11
Boa Creek
ANT-3 camp
R6
ANT-10
Era River
Mena River
Era River
Purari River
R5
Pie River
Sa-ori Creek
Poroi 3 (Suarido)
R1
Poroi 2
Eia Creek
R2
Nea Creek
Herd Base
Mapaio Fish Camp
R4
Purari Airstrip
Poroi 1
Poropai Creek
Ia Purari Creek
N
SCALE: 1:260,000 @ A4
0 2.5 5 10 15 KM
COORDINATE SYSTEM: PNG94 UTM Zone 55S
Town or village
Existing road
Former logging road
Waterway
Waterbody or major river
PRL-15
Base camp
Wellpad
Export pipeline route
Trunkline/flowline route (gathering system)
Proposed Project arrangement (See Figure 4.4 for detail)
Spoil disposal site
Crater Mountain Wildlife Management Area
Pipeline ROW access track
Road
R1 - Road from CPF to Flare and Vent
R2 - Road from Logistics Base to CPF
R4 - Road from Herd Base to CPF
R5 - Road from Herd Base to ANT-10
R6 - Road from ANT-10 to ANT-11
R7 - Road from ANT-10 to ELK-10
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LOCATION OF KM6 QUARRY AND HERD BASE QUARRIES A, C AND D

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FIGURE 4.9



4.8.4.2 KM6 Cliff Quarry

KM6 Cliff Quarry (also called KM6 Quarry) will be a new quarry. The quarry site is located about 7 km northwest of Herd Base by existing roads and about 10 km from the CPF. The quarry has a footprint of 9 ha, and materials available comprise boulders of coarse sandstone, conglomerate, siltstone and very fine-grained sandstone. The quarry is also provisional and might not be developed, as it is unlikely to provide a sufficient volume of the required construction materials to meet Project needs.

4.8.4.3 Other Quarries

The Herd Base quarries do not have enough rocky material to meet the Project's requirements; therefore, rocky material will need to be supplied from other quarries in PRL-15 or possibly off-site quarries. Specific rocky material is required, which comprises granular material for drainage and stability, and general fill material for roads, and the pipeline ROW. Rocky blocks for construction of platform drainage and flood channels are also needed.

Two off-site quarries are currently being investigated east of the Purari River; one along the Aure Scarp and one to the northeast of Poroi 2. Geotechnical surveys are in progress to assess the suitability of the rock present, the volume of rocky material available, and the logistics and access requirements. Only one of these quarries would be developed, if both proved feasible. Approximately 500,000 to 1,500,000 m^3 of rocky material would be extracted from the quarry and the footprint of the quarry would be approximately 25 ha.

Pre-construction environmental and social surveys (Section 4.10.2.1) shall be undertaken of the selected quarry, access route and logistics/wharf facilities once geotechnical surveys are complete and confirm the suitability of materials for Project use.

Off-site existing commercial quarries, such as the Kopi quarry in the Kikori River delta, the Punomo quarry in Kerema, and the Monier and GBCL quarries near Port Moresby, could also be used if no suitable quarry sites in the Project area can be found. In the case that the off-site quarries are used, the material will be barged to the site.

4.8.5 Waste Management

4.8.5.1 General Waste Management

The Project will manage its waste during all Project stages from preparatory works to decommissioning in alignment with TOTAL's general specifications, relevant PNG legislation and guidelines, and relevant international conventions (see Chapter 2). Strategies will be implemented to avoid or minimize waste production. Where this cannot be achieved, options to reduce, reuse and recycle/recover waste will be implemented. Waste disposal is the least preferred option.

The key elements of the waste management strategy, which may involve the export of select wastes, are as follows:

- Reduce – where possible, reduce waste volumes at the source by selecting processes, products and procedures that generate the least waste possible.
- Reuse – where possible, packaging materials will be returned to suppliers for reuse, e.g., empty drums and containers, cardboard and unused products.
- Recycle and recover – where possible, hazardous and non-hazardous wastes, e.g., scrap metal, rubber tires, batteries, empty gas cylinders, will be reprocessed into useful materials or products by third parties.

- Treatment and disposal – if waste materials are still generated after the implementation of feasible waste avoidance, reduction, reuse, recycling and recovery measures, waste materials will be treated and disposed of, and measures taken to minimize potential impacts to human health and the environment.

A preliminary review of existing waste management facilities suggests that limited waste management capacity exists in Papua New Guinea.

A preliminary estimate of some waste types and quantities for the Project is provided in Table 4.8; more comprehensive waste quantities will be determined during FEED. Wastes will be characterized according to composition, source, and type, e.g., hazardous vs. non-hazardous, and managed in appropriately segregated and bunded areas as required. All waste storage areas will be regularly inspected for integrity issues, emissions and leaks; and all waste generated will be tracked by type and volume including transport to its disposal destination.

Waste management requirements (e.g., waste inventory, segregation, storage, disposal, tracking, recording, third-party responsibilities) will be detailed, for various waste types, e.g., liquid, solid, hazardous and non-hazardous wastes, during FEED, and management plans will be prepared for waste-producing or waste-managing facilities and activities in the Project during construction, including preparatory and early works, operation and decommissioning.

Table 4.8 – General Waste Types and Estimated Total Quantities

Waste Stream	Classification	Estimate of Total Waste Generated (m^3)*	
		Early Works/ Construction (5 Years)	Operations (20 Years)
Batteries	Hazardous	225	92
Container, drums, paints, solvents	Hazardous	450	184
Electrical waste	Non-hazardous	300	120
Food and domestic waste	Non-hazardous	7,461	2,920
Glass	Non-hazardous	400	164
HDD# drill cuttings	Non-hazardous	48,500	—
Medical waste	Hazardous	35	14
Oily debris	Hazardous	500	204
Paper and cardboard	Non-hazardous	65,000	26,581
Plastics	Non-hazardous	20,000	8,179
Rubber and tires	Non-hazardous	5,000	2,045
Scrap metal	Non-hazardous	31,500	12,882
Scrap wood	Non-hazardous	50,000	20,447
Waste oil	Hazardous	4,750	1,942
Chemical waste from gas processing	Hazardous	—	80
Oil sludge from gas processing	Hazardous	—	164
Solvents, chemicals, paints	Hazardous	0.9	4
Total estimate per phase		**234,122**	**76,022**
Total with 10% contingency		**257,534**	**83,624**
* Decommissioning wastes are excluded from the table. # Horizontal directional drilling.		**341,158**	

4.8.5.2 Incinerator

Due to limited existing waste management capacity and the Project's remoteness, a suitably sized, purpose-built, high-temperature, industrial incinerator, designed to internationally

recognized standards as IFC Environmental, Health and Safety Guidelines for Waste Management Facilities (IFC, 2007), will be used to reduce the volume of waste for disposal. The high temperature (870 to 1,200°C) will reduce the risk of emissions associated with incomplete burning of hazardous and non-hazardous wastes, and the residual ash disposed of in a landfill. The high-temperature incinerator shall be available during the early works.

The incinerator will be sited at the general waste management area (Section 4.8.5.3), is proposed to incinerate liquid and solid wastes including hydrocarbons and other combustible hazardous materials to reduce waste volumes and will be managed in accordance with IFC requirements. Additionally, smaller incinerator units may be used at the smaller temporary construction camps for non-hazardous combustibles (e.g., food waste and packaging). Any excess waste or incinerator ash from the temporary construction camps will be bought back to the general waste landfill near the CPF for disposal.

4.8.5.3 General Waste Landfills

Landfilling is the least desired option, for disposing of waste that cannot be recycled or incinerated; however, two general waste landfills, which will provide options for segregating hazardous/non-hazardous and/or construction/operations waste, will be located near the CPF approximately 220 m and 450 m west and southwest of the operations camp, respectively (see Figure 4.4). These landfill areas will incorporate designated areas for waste segregation and laydown. The general waste management area and incinerator will be associated with the larger landfill site. The landfills will be designed to comply with TOTAL's general specification for landfills and the IFC guidelines for waste management facilities (IFC, 2007), and will be designed, located, constructed and operated in general accordance with the intent of the PNG Code of Practice for Sanitary Landfill Sites (DEC, 2001). The landfills will be used for ash disposal from the incinerator and other waste that is not incinerated, reused or recycled. The landfills are likely to be divided into different cells to separate wastes with different properties, e.g., hazardous/non-hazardous waste.

4.8.6 Logistics Base

The current logistics base, Herd Base, will support the preparatory works and the beginning of the early works phase, with a small upgrade until the construction of the new Logistics Base is complete. The new Logistics Base will then be used for the remainder of the Project. The base will be constructed on the northern bank of the Purari River, just over 2 km south of the CPF and 5 km downstream from Herd Base.

The Logistics Base will consist of offices, parking area, roads, warehouse, water pumping station, aggregate storage area, container yard, fuel storage and refueling station, a new quay, a small ramp to allow passengers to disembark from river transport vessels and a larger ramp for offloading equipment from barges. The layout of the base and the alignment of the roads to the CPF and Herd Base are provided in Figure 4.10.

The base will occupy approximately 7 ha.

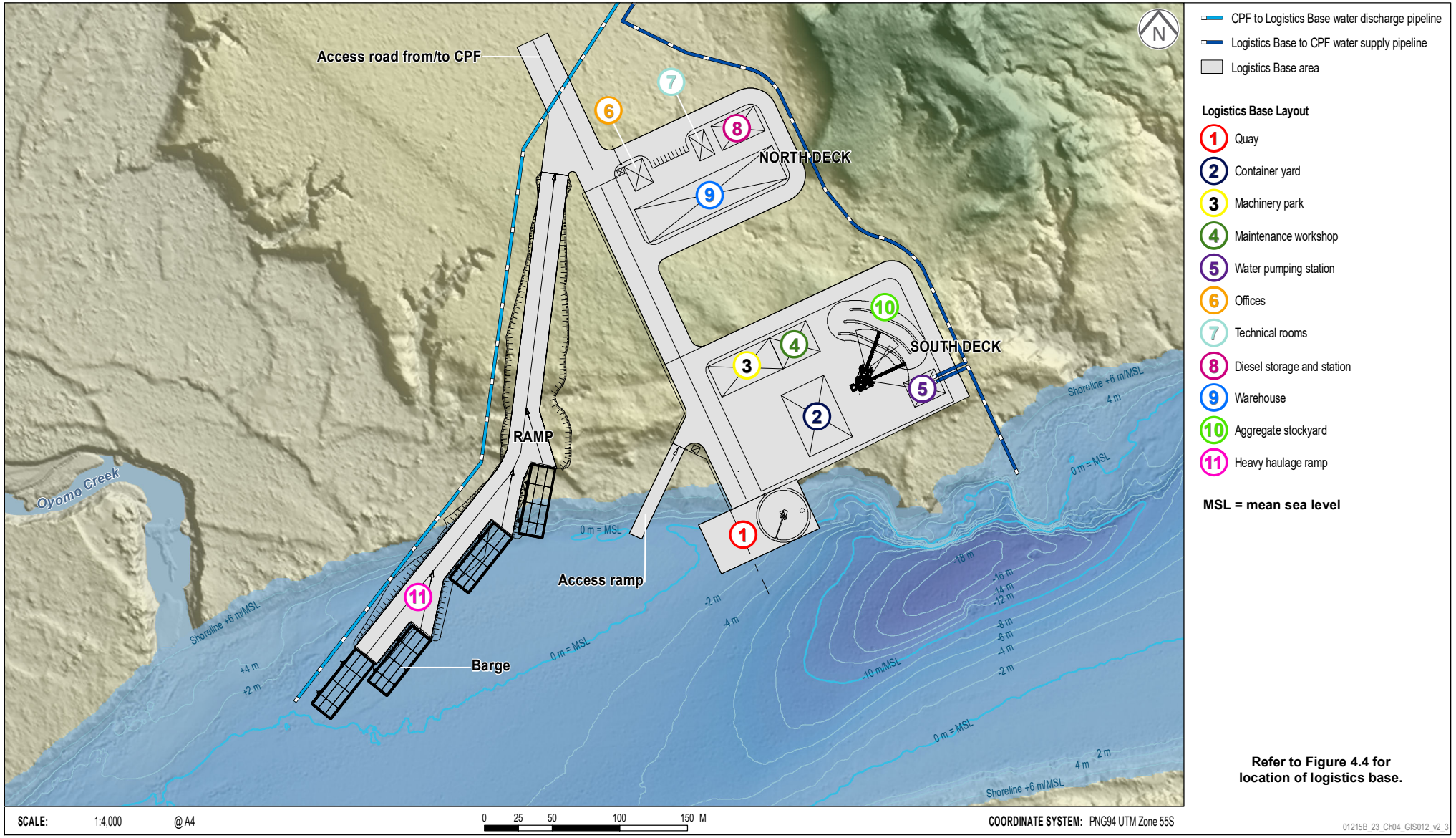
4.8.7 Existing Purari Airstrip and Extension

During the Project, workers will be transported to and from the Project site by fixed wing aircraft to and from Jacksons International Airport, Port Moresby. The numbers of workers transported per month will vary, but the peak will be during construction when there will be a maximum of 6,000 workers on the site (see Section 4.7.1).

INDICATIVE LOGISTICS BASE LAYOUT

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FIGURE 4.10



The existing Purari Airstrip has a terminal building, two helipads, and a dirt track runway 12 m wide and 1,150 m long. The existing operation is carried out using a Twin Otter Dash 6 that can transport a maximum of 19 passengers.

To best meet requirements for transporting Project workers by air the existing airstrip will be upgraded to a Code 2 airstrip, which is a non-precision instrument runway, as per standard runway code categories. A Code 2 airstrip provides horizontal position guidance to aircraft on instrument approach to assist pilots and is the usual standard for small and medium-sized airports. At this stage, TEP PNG does not plan to have night flights to the airstrip and the airstrip will not be designed for night operations.

The runway will be extended to approximately 1,605 m by adding a section of new runway 455 m long and 30 m wide. The final design will be determined during FEED. The runway extension work will occupy approximately 71 ha, and approximately 33 ha of additional land will need to be cleared of vegetation for the visual approach to the runway during landing. The area cleared of vegetation will be 180 m wide at its largest point and will extend in a cone 125 m from both ends of the runway strip. The layout of the extended runway and associated vegetation clearance areas is shown in Figure 4.11.

The airstrip facilities to be constructed by the Project (Figure 4.12) comprise:

- A passenger building with a check-in area, security control area, boarding area and baggage offload area.
- Two aircraft stand areas, an ATR42 stand and a Twin Otter Dash 6 stand. Both stands will be able to be used at the same time.
- A fire station accommodating a firefighting vehicle, fire extinguishing agent and vehicle bay, with a storage area, restroom and watch room.
- A perimeter fence.
- A perimeter road, which will be unpaved and 4 m wide.
- A helipad for emergency use and to periodically support the Project.

4.9 Logistics and Transport

4.9.1 Material, Equipment, Fuel and Chemical Volumes to be Transported

4.9.1.1 Construction Phase

During construction, imported materials, fuel and chemicals, concrete, and equipment comprising CPF modules, pipes, and drilling equipment will be transported to the Project site over a 36-month period. The approximate quantities that are likely to be transported are summarized as follows:

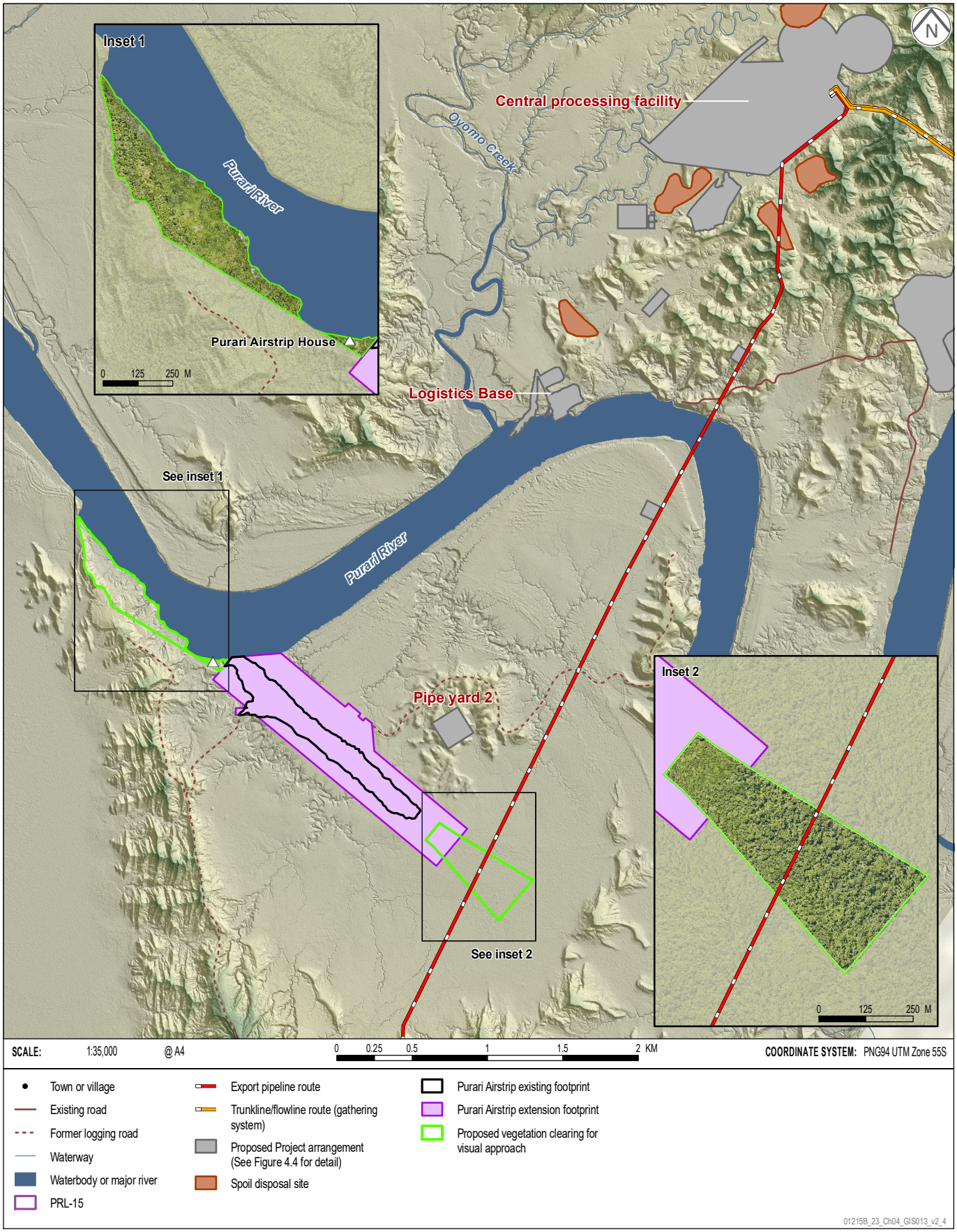
- Early works: 860,000 tonnes.
- CPF construction: 78,000 tonnes.
- Export pipelines: 67,000 tonnes.
- Drilling: 7,000 tonnes.

These figures exclude approximately 600,000 m^3 of aggregates necessary for track construction.

EXISTING PURARI AIRSTRIP AND EXTENSION

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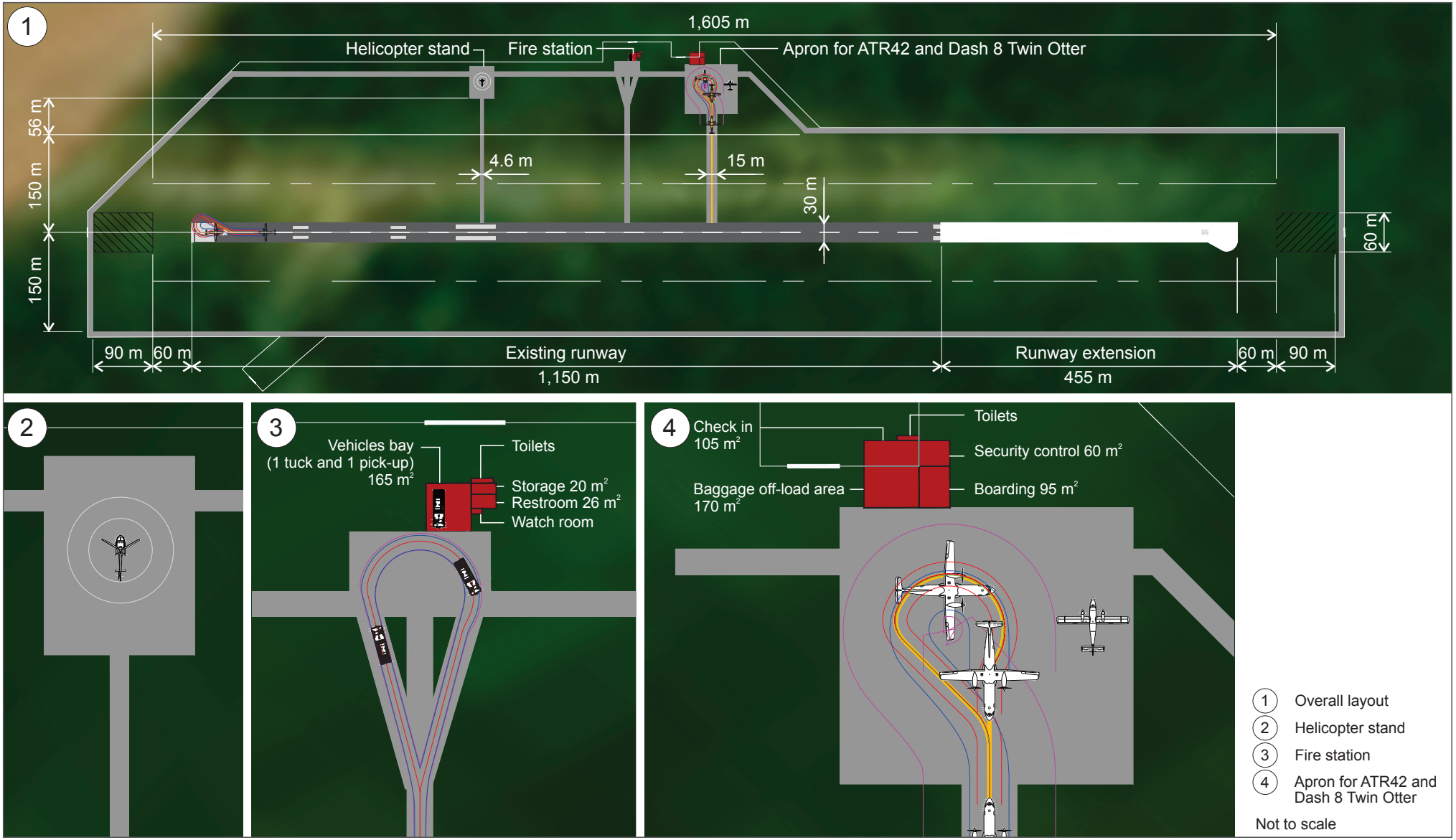
FIGURE 4.11



PURARI AIRSTRIP EXTENSION MASTERPLAN

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FIGURE 4.12



ERIAS Group | 01215B_23_F4.12_v1

Barges will transport fuel in fuel containers to the site along the Purari River. The existing fuel storage and refueling area at Herd Base will be used during the preparatory works and the beginning of the early works. Additional fuel storage and refueling facilities will be installed at the Logistics Base and the CPF construction area. The preliminary estimate of fuel requirements for the early works is 26,000 m^3 per month. The fuel will be stored in 100-m^3 tanks. Between two and four tanks are expected to be required.

Relatively small amounts of chemicals will be required during construction and are expected to comprise principally the non-toxic chemical additives used in preparing water-based drilling mud, and corrosion inhibitor, and biocides used in pipeline and processing equipment hydrotesting. The chemicals will be stored initially at Herd Base during construction then moved to the CPF when an appropriate facility is built (Section 4.11.1.2), and transported to the wellpads in drums or cubi-containers.

4.9.1.2 Operations Phase

Diverse types of materials and equipment will need to be transported to the CPF during the operations phase, mainly for maintenance purposes. The quantities will be significantly less than those needed in the construction phase.

Project facilities will be mostly electrically powered with power provided by gas turbines fueled by reservoir gas. Thus, fuel requirements will be significantly less than during the construction phase. Fuel will be also required for vehicles and diverse, small, diesel-fueled equipment items, such as small generators, compressors and lifting equipment. At this stage, the Project fuel requirements are estimated to be approximately 1,500 m^3 per year, and this will be further defined during FEED. Diesel tanks with a total capacity of 420 m^3 will be situated at the CPF (Section 4.11.1.2).

Key process chemicals used in operations (Section 4.11.1.2) will include the following:

- Monoethylene glycol, which is used as a hydrate inhibitor.
- Corrosion inhibitor.
- Biocides.
- Sodium hydroxide for the flue gas desulfurization process.
- Amines.

The chemicals are expected to be transported in drums or cubi-containers and the quantities required will be defined during FEED.

4.9.2 Transport Methods and Routes

The remoteness of PRL-15 and its lack of established land, water or air access has required TEP PNG to undertake a detailed analysis of logistics and transportation options, and these are summarized in Section 5.7. Sea and river water transport was determined to be the most feasible option for transporting bulk materials and equipment, and air transport was determined to be optimal for workers. These transport routes and methods are described in the following sections.

4.9.2.1 Transport by Water

Transport Routes

Most materials and equipment necessary for Project construction and operations will be transported by sea and river to the Project site from either Motukea Port or the Avenell Engineering Systems Ltd supply base near Port Moresby (see Section 4.8.1). From there it all will

be transported by sea and river to the Logistics Base near the CPF or Herd Base while the Logistics Base is being constructed. From the Logistics Base, the equipment will be transported by road to the different worksites, except the materials and workers for construction of the Purari Airstrip extension, which will be barged across the river to that site.

The river transport routes the Project will use are shown in Figure 4.13, which includes the delta of the Purari River system as it approaches the Gulf of Papua. The transport routes comprise the following:

- Purari River.
- Urika-Ivo River (when the Purari River is impassable).

Some items, such as line pipe, may be shipped directly to the mouth of the Purari or Urika-Ivo rivers and offloaded onto smaller barges or landing craft–type vessels for transport upriver to the pipe yards.

Transshipment at the River Mouths

Wave conditions at the river mouths in the Purari River delta are favorable for transshipment operations during a six-month period of the northwest monsoon from November to April (see Section 7.3.2.2). During this period, large, high-value and motion-sensitive equipment and bulk aggregate transported by sea from Port Moresby will be transferred to smaller barges that are more suitable for river navigation and transported up the river to the Logistics Base.

During the six-month southeast monsoon (i.e., May to October), the prevailing wind and waves approach the river delta from the southeast creating unsettled sea state conditions in the nearshore zone and at the river mouths that are unsuitable for ships to anchor or for transshipment operations.

Types of Transport Vessels

Material and equipment transported by water will be carried on self-propelled barges, landing craft–type vessels or non-propelled barges, which are described briefly in the following sections. Plates 4.2 and 4.3 show typical examples of these types of vessels. The barges selected will be suitable for open sea passage, nearshore zone and shallow river mouth entrance maneuvers, and transits up and down-river.

Self-Propelled Barges

The term self-propelled barge covers a wide variety of vessel types from a conventional barge equipped with thruster units, to small river-sea ships. In general, these barges have a dead weight tonnage (DWT) in the order of 1,600 tonnes.

Landing Craft–type Vessels

Landing craft–type vessels typically have draughts of 2.5 m, and they are currently used on the Purari River to supply Herd Base. In general, these barges have a DWT in the order of 700 tonnes.

Non-Propelled Barges

Dry cargo, such as aggregate, is usually transported in a hold barge, which are equipped with features to keep the cargo dry, such as sideboards or watertight or waterproof hatches. Large items of processing equipment are probably transported on a deck barge, which are sometimes called a flat-top or pontoon barge. Non-propelled barges use a tug to provide propulsion. In general, the non-propelled barges have a DWT in the order of 2,300 tonnes.

ACCESS TO THE PROJECT BY RIVER

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FIGURE 4.13



Plate 4.2 – Examples of Barges




A. Examples of typical coastal aggregate barges with a single open hold. Photos: TOTAL




B. Examples of typical inland aggregate barges. Photos: TOTAL.

Plate 4.3 – Examples of Self-propelled River Transport Vessels




Photos: TOTAL.

Offloading

Barges will be offloaded at the Logistics Base at the barge ramp. The material and equipment will be loaded onto self-propelled modular transporter trailers and transported by road to the worksites.

Navigation Aids and Navigation Equipment

The following aids to navigation (river-based infrastructure) and navigation (vessel-based equipment) will be considered to improve river navigability and safety, and to assist safe passage during the Project:

Navigation Aids

- A control tower may be established at the mouth of the rivers to control entry and exit of barges to the rivers. The location of this tower will be determined during FEED.
- Marks (posts, pellet buoys) will mark problematic shallow water:
  - To be deployed during operations once problem areas have been identified.
  - Buoys (lit) marking access channel through river mouth(s).
  - Reflective strips will be used on marks.
- Chainage markers. These will provide visual confirmation of vessel position on the rivers. They will most likely be painted on trees (for security reasons).
- Search lights will be provided on Project vessels and tugs to help vessel crews to identify aids to navigation and river debris at night.

In addition, TEP PNG will consider providing reflectors for mounting on community canoes and boats so they are visible at night.

Navigation Equipment

- An e-chart of river navigation routes.
- GPS linked to ECDIS (electron chart display and information system) to identify the vessel's position relative to the navigation channel and any nearby navigation hazards and to monitor the vessel's speed and rate of turn around bends.
- AIS (automatic identification system) on all vessels. This system can be used to monitor the vessel's position, course and speed. AIS can be used both by individual vessels to identify their position or course relative to other nearby Project vessels and as part of an overall Project vessel traffic management system.
- Echo sounders with data loggers linked to the GPS. The echo sounder will alert the vessel crew to shallow water and low under-keel clearance.
- VHF used to communicate with other Project vessels and Project river traffic control.

Dredging

The following two areas are likely to require dredging to facilitate navigability:

- Ivo and Upper Purari river junction. Required to reduce vessel downtime during low flow conditions and estimated to be approximately 70,000 m^3.
- Purari River mouth. Required to improve navigability during low tides and estimated to be approximately 500,000 m^3.

Dredging details, e.g., location, schedule, spoil character and disposal, will be finalized during FEED.

Number and Frequency of Barge Trips

Construction Phase

The estimated number of barge deliveries of equipment and material, including food supplies, from Port Moresby and the mouth of the Purari River over the 5-year construction period are shown in Table 4.9. During the peak period (i.e., Year 2), up to four to five barge deliveries are expected to be made per day to the Logistics Base, resulting in nine to ten barges on the river system at any given time. In other periods, the barge numbers will be lower. Small fuel volumes will be carried on the regular barges bringing supplies and equipment to site. A dedicated fuel barge will deliver a larger fuel volume approximately every two weeks, so an extra two return barge trips per month, in addition to those described in Table 4.9, is expected for fuel during peak construction.

Table 4.9 – Transport of Materials and Equipment by Barge

Year	Cargo	Port Moresby to Herd Base	Port Moresby to Logistics Base			Herd Base to Airstrip
		Landing Craft–type Barge (DWT = 700 t)*	Landing Craft–type Barge (DWT = 700 t)	Self-propelled Barge (DWT = 1,600 t)	Flat-top Barge (DWT = 2,300 t)	Landing Craft–type Barge (DWT = 700 t)
1	Material for earthworks	1 to 2 barges/day	-	1 barge/day	-	-
2	Materials for earthworks	1 to 2 barges/day	1 barge/week	1 barge/day	-	1 barge/day[#]
3	Equipment for pipeline, CPF construction and drilling	1 barge/week	1 barge/week	1 barge every 2 days	-	-
4	Equipment for CPF construction	1 barge/week	1 barge/week	1 barge every 2 days	1 barge/ week[†]	-
5	Equipment for CPF construction	1 barge/week	1 barge/week	1 barge every 4 days	-	-

* DWT= dead weight tonnage. [#] For four months. [†] Transports CPF modules.

If required, barge travel will occur at night with the support of navigational aids and in consultation with the community and National Maritime Safety Authority (NMSA) (see 'Navigation Aids and Navigational Equipment' under Section 4.9.2.1).

Operations Phase

During the operations phase, materials and equipment for maintenance plus fuel and chemicals will be transported by self-propelled barges. The frequency of these barges is expected to be approximately three to five barge deliveries per month (including the one per month to deliver the caustic soda (see 'Acid Gas Management' in Section 4.11.1.1).

4.9.2.2 Air Transport

Construction Phase

During construction, workers will be transported between Port Moresby and the Project site. During the peak construction period, 750 workers per week will be transported. The airplane will

land at the Purari Airstrip, and workers will be ferried across the Purari River to the Logistics Base and transported to worksites by bus.

Three aircraft are planned to be used, the Twin Otter Dash 6 (as used currently on the airstrip), and the Dash 8 and ATR42 (Plate 4.4).

Plate 4.4 – Examples of Dash 8 and ATR42 Aircraft



Photo: Gerard van der Schaaf (2015)



Photo: Laurent Errera (2013)

Any of the planes will be used depending on the scheduling and logistics. The assessment is based on flights per day during the 6-month peak construction period being between five and seven flight landings per day at the Purari Airstrip. During the other periods of the construction phase, flights are expected to be less frequent, e.g., there will be approximately one flight per week during the initial period when the number of workers is lowest.

At this stage, it is not planned to have night flights to the airstrip, and the airstrip is not designed for night operations. In case of an accident, the patient will have to be stabilized on site until daylight before being evacuated.

Helicopters may be used during construction and they would be based at Herd Base, if flights are required. Helicopter use would be determined during FEED and in association with the construction contractors.

Operations Phase

Fixed-wing aircraft will transport operational workers between Jackson's International Airport and the Purari Airstrip, and by mini-bus (and ferry) to or from operational areas. One to two flights per week are expected.

At this stage, it is not planned to have night flights to the airstrip, and the airstrip is not designed for night operations. In case of an accident, the patient will have to be stabilized on site until daylight before being evacuated.

Regular helicopter use during operations is not planned at this stage of Project development but will be reviewed during FEED.

4.9.2.3 Road Transport

Road use by trucks is required to transport earthen quarried material and spoil; to transport heavy materials, machinery and equipment for drilling and facilities construction; and to transfer goods and wastes.

Trucks transporting earthen material from the quarries to the worksite are expected to be the main road users with up to 200 deliveries per month, which is approximately six trucks per day during the one-year peak construction period, and 10 to 200 during the rest of the construction period depending on the scale of the activities. Road use by trucks transporting other material will

represent a maximum of 140 trucks per month (i.e., 4 to 5 trucks per day) for a three-month peak period, and 60 trucks per month (i.e., two trucks per day) for the rest of the construction period. These road movements will be in PRL-15 and distant from current settlements.

4.9.2.4 Other Transport

Project area workers will be transported to and from Project sites by dedicated contractors. The Project will provide suitable transport as appropriate to their locations.

4.9.3 Safety and Security

4.9.3.1 Occupational Health and Safety

Occupational health and safety (OHS) will be managed under the Project's health, safety and environment (HSE) management system which consists of a series of management policies, plans and procedures to address OHS risks and emergency situations. This includes provisions for OHS and HSE leadership; HSE induction and ongoing training requirements; specific HSE rules and procedures for undertaking different types of work tasks including risk assessment procedures, use of permits to work for hazardous activities, and the provision of personal protective equipment appropriate for various tasks and activities.

4.9.3.2 Risk Management

To include safety, environment and asset protection in the Project design, safety studies and reviews have been carried out and safety documents have been prepared. The principal techniques used at the pre-Project phase have been hazard identification (HAZID), hazards analysis (HAZAN) and Project reviews (PR). Hazard and operability (HAZOP) and other specific safety studies will be carried out during subsequent Project phases.

4.9.3.3 Site Layout

The key safety principles that have been adopted for the site layout are:

- Processing, utilities, services and flares are segregated into different fire zones.
- Separation distance between fire zones are sufficient to minimize the potential for escalation.
- As far as reasonably practicable, ignition sources are located upwind of or perpendicular to the flammable sources.
- As far as reasonably practicable, escape, evacuation and rescue routes and systems are located upwind of hazardous areas.

4.9.3.4 Seismic Hazards

The Project has undertaken probabilistic and deterministic seismic hazard assessments, and the design criteria include the seismic constraints. The facilities will be in a moderate to high seismic hazard zone (see Section 7.2) The CPF will be situated 6.4 km from a fault line. The CPF will be 38 km from the nearest deep seismic hazard source.

Trunklines

The trunklines will cross the following three, minor, fault lines, which are part of the Mena back-thrust tectonic domain (see Figure 7.3):

- Mena Upper Décollement.
- Kuku Fault.
- Herd Fault.

Seismic hazard assessments undertaken during the pre-Project stage have concluded that, in the event of seismic activity, only very small surface displacements of faults are anticipated; and so no specific design features are required.

Export Pipelines

The export pipelines will cross the Emergent Front fault line, which is part of the Aure Fold and Thrust Belt tectonic domain. Seismic hazard assessments undertaken during the pre-Project stage have predicted the 5,000-year maximum fault movement would be 98 cm and that a 475-year fault movement would be less than 10 cm. This potential movement is considered to be relatively minor, and TEP PNG has anticipated that this can be addressed through a specific trench design or above-ground crossing to be developed. The carbon-steel material used for the pipeline as a whole is also suitable for the fault crossing with potentially some strain-based design. Additional studies will be carried out during the FEED to estimate the strain on pipelines from the adverse impact of landslides triggered by seismic events.

4.9.3.5 Simultaneous Operations

Simultaneous operations (SIMOPS) are likely to be encountered during construction/ commissioning/operations when there are multiple activities occurring on site at the same time, e.g., maintenance overhauls in one unit with another unit in operation or during drilling. Particular attention is required for SIMOPs during the start-up phase when some parts of the plant may well be under construction without mechanical completion and or isolation in place. SIMOPS carry additional risks that must be evaluated and managed. Specific hazards associated with any SIMOPS will be identified and assessed using HAZID and SIMOPS risk assessment studies at a later stage in the Project design.

4.9.3.6 Toxic and Flammable Gas

The native gas is considered toxic, since the hydrogen sulfide concentration is higher than 100 ppm, which is the immediately dangerous to life and health (IDLH) threshold limit. Consequently, toxic gas detection systems will be installed at the CPF. Toxic gas detection systems will not be installed at the wellpads, as they are not permanently manned facilities. Personnel who visit the wellpad will be equipped with a protective mask and an individual portable toxic gas detector.

The presence of flammable gas will be detected by infra-red flammable gas detectors located at the wellpads and the CPF. The presence of flammable gas at a wellpad will trigger an alarm at the CPF control room and cause a manual emergency shutdown. The CPF will be equipped with fixed toxic gas detectors. Whenever the concentration of toxic gases temporarily exceeds the time weighted average, an alarm will be activated at the CPF, workers will put on escape masks and evacuate and there will be an emergency shutdown.

4.9.3.7 Fire-detection and Firewater Systems

The facilities will be equipped with flame, heat and smoke detectors in all locations where there is a fire risk and according to the most adapted detection method. Fire detection at the wellpads will trigger an alarm in the CPF control room and an emergency shutdown will be activated manually. Fire detection in the CPF processing area will automatically trigger an emergency shutdown, and activation of fire suppression systems and procedures.

4.9.3.8 Safety Shutdown Systems and Alarms

The facilities will be equipped with safety shutdown systems. At the CPF, emergency shutdown will be automatic in the event of fire, or toxic or flammable gas detection; however, activating the

emergency depressurization will be performed manually. At the wellpad, fire or gas detection will trigger alarms at the CPF control room, and emergency shutdown will be initiated manually from the CPF control room.

4.9.3.9 Pipeline Protection

The flowlines, trunklines and onshore and offshore export pipelines are designed with cathodic protection and a fiber optic monitoring system that detects ground movement, any intrusion and leaks. The will to connect the upstream and the downstream facilities shall be determined during FEED. The pre-Project design is to install a fiber optic cable in the same trench for the trunkline and for both the onshore and marine export pipelines.

4.9.3.10 Site Security

Site security focuses on protecting the assets and workers. There will be no manned protection on the wellpads and pipeline infrastructure during normal operations, as no workers will be working on these sites.

So that workers are secure at the CPF, all work areas, accommodation areas and other related sites, where workers are required to work, will be in a single perimeter fence containing an area referred to as a global restricted area (GRA). The GRA will minimize the movement of workers and goods outside secure areas and; therefore, will reduce workers' exposure to security risks. If a security situation occurs, a lockdown procedure will be initiated.

The GRA will allow the site to maintain operations in a downgraded security environment. In case of lockdown for a high-risk security situation, the site will be able to continue operating for five days without the need for workers to move out of the GRA. For lower risk-level situations, the facility will be able to operate autonomously for up to one month.

Government security forces and a private security service provider residing in the operations camp will provide security. The private security guards will be responsible for guarding the GRA and controlling access. The government security force will also have a role in controlling access and will provide the security for Project worker movements s outside the GRA, which comprise:

- Logistics movement between the CPF, Logistics Base and Purari Airstrip. These movements will be monitored and, in the event of a security situation, the government security force, who are stationed at the operations camp, will intervene and take appropriate actions, as detailed in the Project's site security plan.
- Movements to the wellpads, and along the flowlines/trunklines and export pipeline operations easements. The government security force will regularly monitor the security situation along roads. Project workers will be provided with a government security escort during a security situation.
- Community affairs engagements with communities, as appropriate and in alignment with the Project's social management plan.

In the GRA, a security coordination room (SCR) will be installed close to the CPF operations control room, which will also be close to an emergency response room. The SCR will monitor the GRA perimeter, access gates, entry barrier , turnstiles and sensitive area doors, and will provide security workers with the capabilities to manage and control vehicle and worker access into the GRA. The SCR will monitor the wellpads and export pipeline protection and all movements outside the GRA.

Private security guards will be deployed to implement permanent access control procedures and to monitor any security situations in the GRA and at the Logistics Base. Herd Base and the

Logistics Base will be equipped with passive protection measures and a permanent access control process using private security guards.

The airstrip operator (e.g., TEP PNG or a third party) will provide security services to protect the Purari Airstrip; however, the Project's private security guards will be mobilized temporarily if necessary whenever there is a flight.

The government security shall protect the GRA and logistics bases, patrol along operation areas (e.g., wellpads and pipeline surface installations) and intervene in case of emergency situations.

4.10 Construction

4.10.1 Timing

Construction activities will take place over approximately 5 years and operations will continue for an estimated 25 years. The post-closure period will commence when operations cease. A notional development schedule is shown in Figure 4.14, noting that these timeframes are subject to obtaining regulatory approvals, achieving the final investment decision (FID), and completing the FEED and detailed engineering phases that may change some aspects of the Project design and schedule.

4.10.1.1 Preparatory Works and Early Works

The preparatory works and early works phases will be undertaken over 32 months. The works will comprise:

Preparatory Works

- Vegetation clearing for the roads R2 and R4, and access to the Purari Airstrip.
- Vegetation clearing for the Logistics Base.
- Vegetation clearing and site preparation, e.g., earthworks and gravel for the hard surfacing, for the Purari Airstrip runway extension.
- Using Herd Base Quarry A and possibly developing Herd Base quarries C and D (if needed).

After FID the following works will be undertaken:

Early Works

- Developing additional quarries if needed.
- Preparing the CPF and construction camp site.
- Constructing the Purari Airstrip runway extension.
- Vegetation clearing and constructing the R5 road from Herd Base to the ANT-10 wellpad.
- Vegetation clearing and construction of the R6 road from ANT-10 to ELK-11 wellpad.
- Vegetation clearing, earthworks and preparation of the ANT-10, ANT-11 and ELK-10 wellpads.

4.10.1.2 CPF Construction

The CPF construction is estimated to take 11 months. Construction activities will mainly take place during daylight hours for safety reasons.

4.10.1.3 Pipeline Construction

Onshore Pipelines

Construction of the flowlines, trunklines and onshore export pipelines will take 32 months. Pipe installation will progress at approximately 380 linear meters/day for the trunklines, 460 linear meters/day for flowlines and about 320 linear meters/day for the onshore export pipelines.

Offshore Pipelines

The offshore pipeline construction is estimated to take 12 months.

4.10.1.4 Drilling

Drilling at ANT-10, ANT-11 and ELK-10 is estimated to take 24 months.

4.10.2 Common Early Works Activities

The following construction activities will occur at all sites at which construction of new or upgraded facilities, infrastructure or drilling of wells will occur:

- Environmental and social preconstruction survey.
- Land survey.
- Archaeological clearance.
- Sediment and erosion control.
- Equipment mobilization.
- Vegetation clearing.
- Grading and excavation.
- Site clean-up and rehabilitation of temporarily disturbed areas.

Equipment required for these tasks will likely include:

- Excavators.
- Dump trucks.
- Graders.
- Dozers.
- Spreaders, pulvimixers and compactors.
- Gravel spreaders and water trucks.

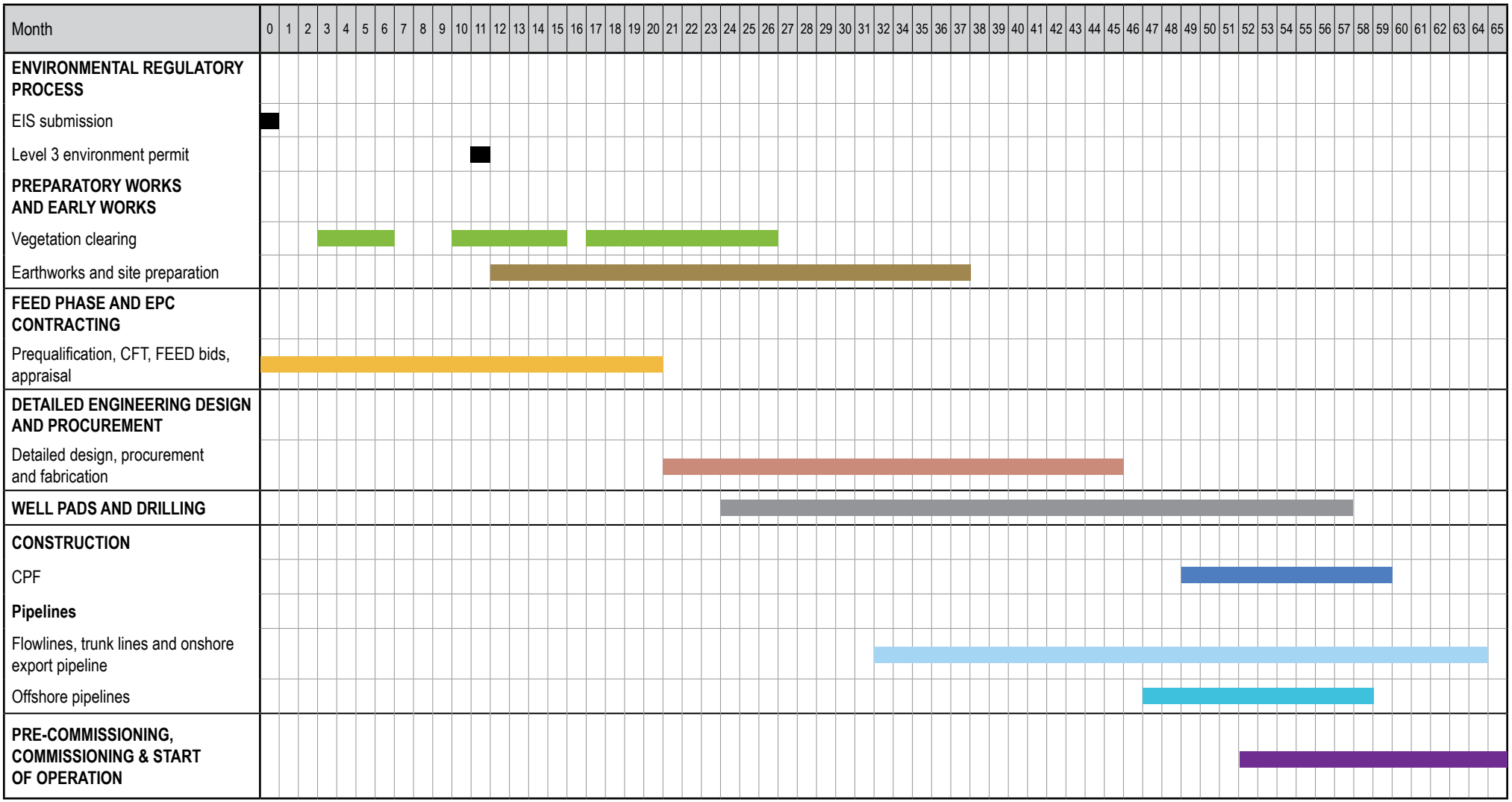
4.10.2.1 Preconstruction Survey

All sites proposed for development as part of the Project will be subject to a preconstruction survey undertaken by environmental or social specialists, in association with Project engineers and surveyors. The purpose of the survey will be to identify any areas that may need to be avoided or protected (e.g., rare or protected plant or species, habitat for rare or protected animals, archaeological sites, burial sites, sites of religious importance, and watercourses) or requiring specific management and mitigation (e.g., weed or invasive species treatment, or active rehabilitation). The surveys will be conducted during FEED when sufficiently detailed information

INDICATIVE PROJECT SCHEDULE

Papua LNG Project | Environmental Impact Statement

FIGURE 4.14



CFT Call for tender
CPF Central processing facility
EPC Engineering, procurement, construction
FEED Front-end engineering design

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on the near final proposed siting and alignment is available. The surveys will be conducted on foot, and the collected information will be recorded in the Project's geographic information system for use in preparing detailed site-scale designs and environmental and social management plans. Areas to be avoided or to be subject to specific mitigation measures will be demarcated in the field, where practicable.

4.10.2.2 Surveying

All sites proposed for infrastructure construction will be surveyed and demarcated to confirm they avoid, to the extent practicable, significant cultural and biodiversity areas and to reconcile other construction constraints encountered. Demarcating areas to be cleared and confining traffic to designated access ways and laydown areas will minimize the extent of site clearing and incidental site disturbance.

4.10.2.3 Archaeological Clearance

All areas disturbed by the Project will undergo a site archaeological clearance survey, and selective subsurface salvage and recording of artefact material where required. The survey and any salvage work will be conducted under a permit obtained from and in consultation with the PNG National Museum and Art Gallery, and will involve engaging with Project-affected communities on appropriate management and mitigation measures.

4.10.2.4 Sediment and Erosion Control

All facilities and non-linear infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. The drainage systems will divert clean surface water runoff away from areas to be disturbed and will collect sediment-laden water from disturbed areas in sediment traps, sediment retention ponds or similar structures prior to discharge.

Sediment retention ponds will be designed to accommodate the high rainfall and will be based on a 100-yr storm event. The size of each sediment settlement pond will be a function of the size of the catchment draining to that pond and will be designed to provide sufficient volume and residence time for sediment settling prior to the overflow discharging from the site. The sediment retention ponds will be inspected after major rain events and will be excavated or cleared regularly to maintain storage volumes at optimal capacity. Material removed from the sediment retention ponds is not expected to be contaminated and can be used on site as required or taken to a Project spoil area. Controlled release of water from sediment retention ponds will be in accordance with the requirements of the relevant environment permit. Erosion control structures will be installed, as required, along access ways and pipeline ROWs that are near streams and rivers.

4.10.2.5 Equipment Mobilization

Construction equipment will be transported to the Logistics Base and from there to the relevant worksite (see Section 4.9). It will then be moved to successive areas as the need arises.

4.10.2.6 Vegetation Clearing

After demarcating the site (see Section 4.10.2.1), the site will be cleared to the designed dimensions. This will involve:

- Clearing vegetation and grubbing stumps. Vegetation that is cut and not grubbed will be cut close to the ground without striking the earth, where practicable.

- Stockpiling timber and woody vegetation not used for construction purposes at the edge of the site or along the side of access ways.
- Clearing, where practicable, merchantable timber for potential sale.
- Pushing cut vegetation to the sides of the cleared areas. Some may be stockpiled for mulching, soil stabilization or rehabilitation works.

4.10.2.7 Grading and Excavation

Earthworks

Sites will be graded and excavated to the designed level and slope to provide a base for the infrastructure. Each wellpad will be a levelled area, covered with gravel and surrounded by a drainage ditch and a fence. Where necessary, concrete slabs will be located around the parts of the pad where drilling equipment will be temporarily located.

Grading activities will use front-end loaders, backhoes, bulldozers, motor graders, hydraulic excavators, rollers and dump trucks. Water trucks, water sprays or dust suppressants will be used as necessary to manage dust. Sites will be trimmed to final grade and compacted. During grading of the non-linear infrastructure sites, and where practicable for linear infrastructure, topsoil (i.e., the top layer of fertile soil, including all plant matter that has not been cleared) will be progressively stripped and either used immediately in rehabilitation works or stockpiled separately for subsequent use in rehabilitation works on the site. Topsoil will be respread over the final surfaces of areas designated for active rehabilitation and landscaping to support natural vegetation regrowth, i.e., regeneration. TEP PNG will avoid sidecasting excavated cut spoil material wherever practical. Excavated material will be used as fill where suitable; and any surplus spoil will be deposited in designated spoil areas in PRL-15. Despite maximizing the reuse of cut material, some imported and quarried material will be required.

The quantities of earthen excavated material, backfill material, spoil and quarried material requirements for the construction of the CPF and wellpads are provided in Table 4.10. Quantities for the flowlines, trunklines and onshore export pipelines are excluded as these will be confirmed during FEED. Preliminary studies for infield flowlines and the trunklines indicate that there will be 3 million m^3 of cut material and 2.3 million m^3 of fill material. Similarly, studies for the onshore export pipelines estimate that there will be 1.3 million m^3 of cut material and 2.5 million m^3 of fill for pipeline padding and fill (geotechnical testing will be undertaken to confirm the quality of the material required). In addition, 0.5 million m^3 of fill material will be required for construction platforms for the Purari River crossing horizontal directional drilling site, valve stations and pipe yards. The selected quarries are described in Section 4.8.4.

Table 4.10 – Quantities of Excavated and Fill Materials

Component	Total Volume of Cut (m^3)	Total Volume of Reuse Material (m^3)*	Total Volume of Spoil (Disposal) (m^3)*	Quarried (Fill) Material (m^3)		
				Herd Base Quarries	Local Quarry	Other Quarries#
ANT-10 wellpad	431,986	48,822	421,480	–	139,027	194
ANT-11 wellpad	14,806	962	15,228	–	31,265	92
ELK-10 wellpad	119,836	1,077	130,634	–	15,049	69
CPF accommodation area	226,883	26,728	220,170	–	–	3,393
CPF and Road R1	2,313,548	1,284,279	1,132,195	–	–	20,135
Road R2	96,951	31,787	71,680	–	–	5,652
Road R4	299,343	188,570	121,850	–	–	21,940
Road R5	984,006	530,067	499,333	91,113		131,915
Road R6	270,436	59,092	232,479	10,251	62,779	–
Road R7	1,212,001	25,548	1,305,098	32,760	28,651	179,362
Logistics Base	106,500	66,000	44,550	8,183	–	4,723
Purari Airstrip extension	100,620	–	110,682†	80,039	–	10,844
Total**	**6,176,916**	**2,262,932**	**4,194,697**	**222,346**	**276,771**	**378,319**

* Value multiplied by a bulk factor of 1.1 to account for expansion.
Material imported from outside the Project area and transported to site by barge. The quarries to be used will be defined during FEED.
† A potential disposal site will be located on the south bank of the Purari River. Its location will be determined during FEED.
** The total volume of cut material equals the sum of the total volume of spoil, multiplied by 0.9 to account for the bulk factor, and the total volume of reuse material. Quarried material is required to cover the needs that are not provided for by the cut material.

Activities Involving Explosives

Explosives may be used during construction activities such as blasting for quarrying and clearing rocky areas for infrastructure development, and seismic surveys. Explosive requirements and potential locations where blasting may be necessary will be determined during FEED and following detailed geotechnical assessments of specific development sites. Explosives management, including authorization, type, procurement, transportation, use, storage, disposal, recording, safety and security, will be undertaken according to PNG laws and regulations, and following TOTAL's general specifications.

Spoil Disposal

The reuse of excavated material will be maximized (see Table 4.10); however, some spoil will be generated that needs to be disposed of. TEP PNG has identified locations, considering seismic hazards, where excess material will be disposed of along roads in shallow areas for stability, while limiting haulage to an average of 3.8 km. These disposal sites are listed in Table 4.11.

The disposal areas will allow excess spoil to be disposed of in a controlled manner. Each disposal site will have sediment controls and drainage to manage water and erosion. Excavated material will be treated with a binding agent to improve its handling ability and to minimize sediment loss during haulage and placement activities.

Table 4.11 – Spoil Disposal Sites

Component	Disposal Site	Area (ha)	Volume to be Disposed of (m^3)	Maximum Capacity of Disposal Site (m^3)
CPF, operations camp and Road R1	CPF-01	10.2	1,017,939	1,073,383*
	CPF-02	3.3	334,426	515,100
Road R2 and Logistics Base	R02-01	1.2	116,230	325,740
Road R4	R04-01	1.7	121,850	404,136*
Road R5	R05-01 to 05-16	7.0 (18.4)	499,333 (1,331,685)	1,000,000 (4,904,037*)
ANT-10	R05-16	4.4	421,480	564,710
ANT-11 and Road R6	R06-01/02	3.5	247,707	257,789
Road R7	R07-01 to R07-08	18.6 (30.2)	1,305,098 (2,113,064)	1,700,000 (2,773,310#)
ELK-10	R07-09	1.7	130,634	171,010
Total		**72.9**	**5,713,165**	**10,585,079**

Notes: Numbers in brackets reflect initial volume calculations used for the impact assessment undertaken in Chapters 11 to 17 and which have been subsequently optimized in pre-Project design. * Volume is from 3D modeling. # Of which 84,610 m^3 of the volume is from 3D modeling.

4.10.2.8 Site Clean-up and Rehabilitation

Following construction, all sites will be cleaned up and rehabilitated where required. Site clean-up activities feature:

- Removing and disposing of all hazardous waste from the site and documenting the process in accordance with local laws and the Project waste management plan.
- Removing surplus material and scrap, unless otherwise identified for retention, for recycling in accordance with the Project waste management plan.
- Removing any temporary buildings from the site.
- Removing all construction equipment, including all equipment owned, leased or rented by contractors.
- Undertaking site restoration, which will involve all or any of the following:
  - Site clean-up. The site will be cleaned of all residual debris. Pits for septic systems will be emptied, neutralized with lime, covered with dirt and compacted.
  - Soil remediation and rehabilitation. Any soil found to be contaminated by hydrocarbons will be managed in accordance with the Project's soil contamination plan.
  - Revegetation. Where soil has been compacted by Project activities, the surface will be ripped to alleviate compaction and assist vegetation regeneration. After ripping, any topsoil and vegetation saved during grading will be spread to reduce the risk of erosion and to promote natural regeneration. Areas will be allowed to naturally regenerate except where active revegetation has been specifically identified during preconstruction surveys and FEED as being required.

4.10.3 Drilling

4.10.3.1 Drilling Program

Drilling will be carried out during one campaign from three wellpads as follows:

- ELK-10 wellpad: one producer well (which will be used later as an acid gas injection well).
- ANT-10 wellpad: seven gas producer wells.
- ANT-11 wellpad: one produced water/acid gas liquid effluent injection well.

Drilling of each well is estimated to take approximately 70 days.

4.10.3.2 Wellpad Preparation

ANT-10 will be a new wellpad, but ELK-10 and ANT-11 wellpads will be established on the existing Elk-1 and ANT-1 wellpads, respectively, which were developed during the exploration and appraisal phases (see Figure 1.3). Accordingly, new ground disturbance for site preparation works will be less than that needed to create three new wellpads. The site preparation for the new ANT-10 wellpad will comprise vegetation clearing, leveling and grading as described in Section 4.10.2. The wellpad will occupy approximately 5 ha. Some site preparation will be required to reuse the Elk-1 and ANT-1 wellpads, and this will comprise some vegetation clearing and earthworks; however, as each wellpad accommodates only one well, as for the original wellpad, the wellpad areas will not need to extend beyond the current boundaries. Once the access roads to the wellpads have been constructed (see Section 4.8.3), the wellpad production equipment will be transported to the site by road and installed. The drill rig will then be transported to the wellpad and drilling will commence.

4.10.3.3 Drilling Method

A general sequence for drilling the gas producer wells and the water injection well is as follows:

- A hole with a 27-inch diameter will be drilled to a depth of 100 m, and a 24-inch diameter casing will be inserted into the hole and cemented in place.
- This process will be repeated using progressively smaller diameter holes and casings as the well deepens. The casings line the hole as it is drilled through the formations. They prevent upper or unstable formations from caving in and either isolate different pressure zones or seal off high pressure zones from the surface, thereby minimizing the potential for a blowout. Casings also prevent fluid loss into or contamination of surrounding freshwater zones.
- When the well is drilled through the hydrocarbon-bearing strata, a pre-perforated production liner will be positioned in the hole to allow reservoir fluids (i.e., gas and condensate) to flow into the well.
- The process of drilling and installing casings and liners will be continued until the well reaches a depth of approximately 2,000 m for both Elk and Antelope wells.
- Tubing will then be lowered vertically into the well. The topmost tubing will be attached to a wellhead installed at the surface.

The drilling will use drilling mud, which will be continuously pumped into the well and back to the surface, as the well is drilled. The drilling mud will act as a lubricant and help keep the drill bit cool and clean. Drilling will generate shards of rock and sand, referred to as cuttings, which will become suspended in the mud and carried to the surface. The drilling will be performed using water-based mud. Oil-based muds and non-aqueous–based muds are favored at this stage, as they have less adverse environmental impact.

The Elk well will be vertical, and the upper 700 m of the Antelope wells will be vertical while the lower parts will have deviated trajectories. The well architecture is illustrated in Figure 4.15, and the diameters and depths of hole, casings and liners are indicated.

When drilling is completed, each well will be cleaned-up and a production test will be carried out. Well clean-up flushes out any debris in the well by allowing the reservoir fluids to flow in a controlled manner from the well. The production test will also allow the reservoir fluids to flow in a controlled manner, and the flow rates and pressure of the reservoir fluids will be monitored. The current plan is that the clean-up/production test will be performed by routing the reservoir fluids to the CPF as soon as they are available. This is considered feasible because earlier well tests carried out during the appraisal phase have found very low quantities of water in the reservoir fluids. Portable well test packages may be considered if the CPF has not been commissioned and is not ready to receive reservoir fluids.

4.10.3.4 Management of Cuttings

Shale shakers will be used to separate the drilling cuttings from the mud at the surface so the clean mud can be reused. The cuttings are then dewatered and mixed with cement to produce a stabilized product that will be disposed at the general waste landfill. Only small volumes of residual waste water are expected and this will be transported to the CPF for treatment, if required, prior to release in accordance with the environment permit. Reusing cuttings for surface grading will be considered if feasible. Cuttings will be managed within the wellpad footprint.

4.10.3.5 Drilling Camp

Key personnel in the drilling crew that must remain on site 24 hr/day are likely to be accommodated at a temporary drilling field camp at the existing ANT-5 wellpad, which was developed during the exploration and appraisal phases, while the balance of the drilling crew will commute form Herd Base.

Drilling field camps typically are designed to accommodate approximately 100 workers and occupy approximately 0.4 ha. They are equipped with portable accommodation units, food storage and preparation areas, a dining hall, recreational facilities, offices, a laundry and self-contained sanitary facilities. A portable diesel generator supplies power. The water source will most likely be that used for supplying water for the drilling operations. Potable water may be bottled or trucked in, eliminating the need for a water treatment plant at the remote location.

4.10.3.6 Water Supply

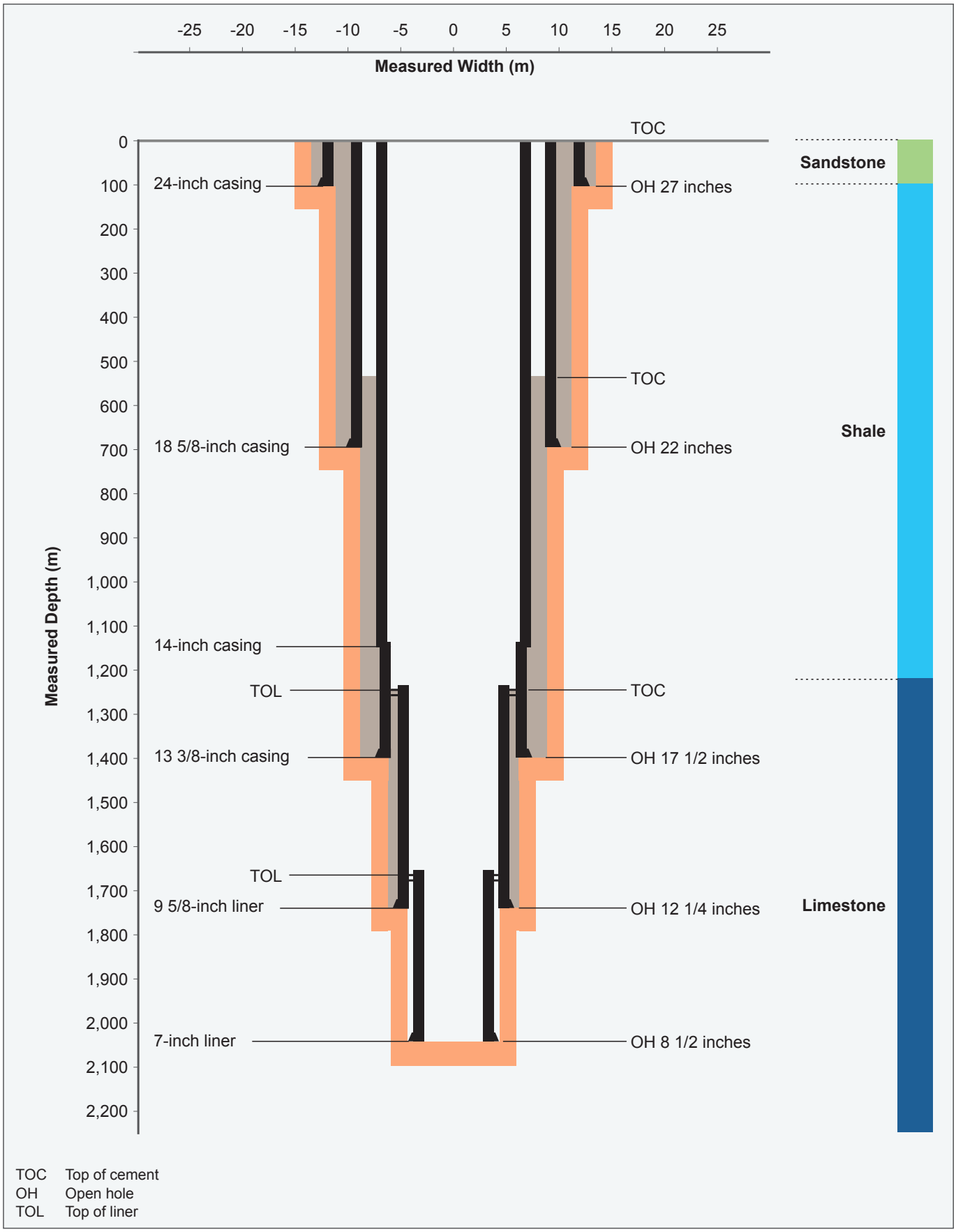
Water will be required to prepare the water-based mud used for drilling. Based on experience, approximately 200 m^3/day of water will be required to drill the appraisal wells, with occasional peaks of up to 1,300 m^3/day. Water is also needed to pressurize the drilling mud for well control purposes, and a flow rate of 100 m^3/day will be required. The total water demand during drilling will consequently be between 300 and 1,400 m^3/day.

Control of well pressure could be accidentally lost during the drilling; this is known as a blowout and could cause an uncontrolled flow of reservoir fluids from the well into the surrounding environment. The likelihood of this type of event occurring is very low; but if it was to occur, additional water would be needed to control any fire ignited by the blowout. For the ANT-10 wellpad, the nearby Boa Creek watercourse is expected to be able to provide enough water most of the time. So that sufficient water would be available during periods of low river flow, a temporary dam structure 5 m high, which will store 2,000 m^3 of water, will be constructed on the creek. In addition, a 1,000-m^3 water pit will be constructed adjacent to the wellpad. Both water storage sources will supply water for drilling and are being considered for controlling a well

GENERAL WELL ARCHITECTURE SCHEMATIC

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FIGURE 4.15



blowout. The future use of the dams and their removal will be finalized during FEED. For the ELK-10 wellpad, the closest watercourse is not expected to be able to provide enough water; therefore a temporary dam structure, similar in size to that on Boa Creek, will be constructed on another watercourse approximately 1,500 m northeast of the pad, on the headwaters of Hou Creek (known locally as Woh Creek). Pipes and pumps will convey the water to the pad.

The final water extraction points and dam structure locations will be defined during FEED.

4.10.3.7 Equipment

The drilling rig site (Plate 4.5) will typically accommodate a main derrick and substructure, power supply system (i.e., generators), flare area, drilling fluids and cuttings management area, which will also cater for equipment discharges, water storage areas, fuel storage, drilling pipe racks, suction pit, circulatory system (i.e., pumps, drilling fluid tanks and shale shakers), tanks for bulk mud products, cement and extra water, storage and truck equipment movement area, well control system (e.g., blowout preventer), and well monitoring system.

Plate 4.5 – Example of a Project Wellpad and Drill Rig



Photo: TOTAL.

4.10.4 Constructing the Central Processing Facility and Associated Infrastructure

4.10.4.1 Constructing the CPF

Early Works

In addition to the common early works activities of vegetation clearing and some earthworks described in Section 4.10.2, the early works activities associated with the CPF will include:

- Establishing the temporary facilities that will be required for the earthworks, which include vehicle washdown facilities, diesel fuel storage and refueling station, waste management area, and water supply headworks.
- Developing other quarries (possibly off site) to provide the rocky material that cannot be provided by reusing cut material or from the Herd Base quarries (see Table 4.10 and Section 4.8.4).

Site Preparation

Site preparation involves constructing platforms to provide a level and solid base on which the infrastructure can be erected, constructing internal site access ways and installing the site perimeter fence. Standard earthmoving machinery will be used to prepare the site for the non-linear infrastructure. The amount of excavated and backfill material is identified in Table 4.10. Relatively small quantities of additional backfill material (e.g., 20,000 m^3), comprising granular fill that is unavailable in the excavated material or at the Herd Base quarries, will be barged to the site from outside the region. The worksite will be equipped with sediment control features, including retention ponds to accommodate the high rainfall at the site and to allow sediment particles to settle. These features will be designed during the detailed design phase (see Section 4.10.2.4).

Construction

The CPF will be constructed using modules that can be assembled off site and by modules that will have to be assembled on site. This approach is dictated by the navigability of the Purari River and by the module dimensions, which are limited to a maximum length of 50 m, width of 20 m and weight of 2,000 tonnes. The pre-assembled modules will be barged to the Logistics Base along the Purari River and then trucked by road to the site for installation. The unassembled modules will be assembled at the site. The CPF construction sequence will be based on the construction contractor's construction execution plan. A possible construction execution plan would include the following elements:

- Civil works (e.g., concrete foundations).
- Steel, pipe and electrical installation.
- Equipment setting.
- Welding and radiography.
- Electrical and instrumentation installation.
- Insulation and application of coating materials.

4.10.4.2 Constructing the Logistics Base

The early works activities associated with the Logistics Base will include:

- Clearing vegetation.

- Installing a temporary ramp to allow the offloading of barges.
- Bulk earthworks requiring material from the Herd Base quarries and material from other quarries, (see Table 4.10 and Section 4.8.4) and spoil disposal.
- Constructing a quay and ramps for offloading modules. Dredging requirements will be determined during FEED; however, it is anticipated that dredging of approximately 6,000 m^3 of sand and sediment from the Purari River adjacent to the Logistics Base will be needed. Periodic maintenance dredging is considered unnecessary but may be undertaken if required. The dredged material disposal area will be defined during FEED and subjected to a pre-construction survey. Constructing the quay will involve sheet piling using 12-m long piles; piling will take approximately two months.

Site preparatory and construction activities are described in Section 4.10.2.

The Logistics Base structures will be constructed using a stick-build approach, i.e., it will be constructed using materials and equipment transported to the site and then installed. Equipment and materials will be barged to Herd Base via the Purari River.

4.10.4.3 Constructing the Purari Airstrip Extension

The pre-early works activities associated with the Purari Airstrip extension and new apron areas include clearing vegetation and earthworks, as described in Section 4.11.2. The total area of clearing will be 71 ha. In addition to vegetation clearing associated with the extension, vegetation clearing to achieve the requirements of the Code 2 visual approach will be undertaken. This will require clearing vegetation in the area of approach to minimize the obstacle limitation surfaces. This equates to approximately 33 ha (see Figure 4.11).

Cut and fill requirements are described in Table 4.10. The hard surfacing (e.g., gravel) for the runway and new apron areas will be laid down and the new passenger and firefighting buildings (see Section 4.8.7) constructed. Any flown-in materials and workers will be transported across the Purari River by barge (see Section 4.9.2.1).

4.10.5 Constructing the Onshore Pipelines

4.10.5.1 Right of Way and Trench Characteristics

Right of Way

A construction easement, commonly referred to as a right of way (ROW), will be required for pipeline construction. Common early works activities for the onshore pipelines are described in Section 4.10.2.

Flowlines and trunklines will be installed in trenches in a corridor cleared of vegetation between ELK-10 (start of flowline) and ANT-10 (trunklines) and the CPF. The onshore sections of the export pipelines will be installed between the CPF and Orokolo Bay, where the pipeline enters the sea. The gas and condensate pipelines will be laid in the same trench. The pipelines' ROW will be cleared of vegetation, and a running track will be constructed that follows the pipelines in the ROW. The running track will be used as an access road for maintenance during operations (Section 4.11.3.2). The running track/access road construction will occur concurrently with the pipeline installation. The pipeline construction contractor will design the running track/access road. Key characteristics of the ROWs are shown in Table 4.12.

Table 4.12 – Key Characteristics of the Pipeline ROWs

ROW	Start to End	Length (km)	ROW Width (m)	Number of Trenches	Pipe Arrangement
Elk flowline	ANT-10 to ELK-10	8.0	32	1	1 flowline (14" diameter)
Trunkline	ANT-10 to CPF	28.0	40	2	One trench with 1 trunkline (22" diameter) 14" diameter (Elk) flowline One trench with 1 trunkline (22" diameter) and a 4" diameter (water) flowline
Water injection flowline	CPF to ANT-11	3.1	32	1	1 flowline (4" diameter)
Onshore export pipelines	CPF to Orokolo Bay	60	35*	1	1 gas pipeline (40" diameter) and 1 condensate pipeline (10" diameter)

Notes: " : inches. * The width may need to be reduced to 16.1 m at some points due to spatial constraints and these locations will be defined during FEED.

Trench Characteristics

Typical trench characteristics are provided in Table 4.13.

Table 4.13 – Key Characteristics of Trenches in the ROW for Trunklines and Flowlines

ROW	Pipes in Trench*	Trench Depth (m)	Trench Width (m)	Distance Between Trenches (m)	Distance Between Pipes in Same Trench (m)	Depth of Pipe Below Surface (m)
Elk flowline	14" diameter	1.4	2.2	N/A	N/A	1.0
Trunkline	22" and 14" diameter	1.7	3.1	5	0.4	1.0
	22" and 4" diameter	1.7	3.0	5	0.4	1.0
Water injection flowline	4" diameter	1.4	2.2	N/A	N/A	1.0
Onshore export pipelines	40" and 10" diameter	2.3	4.1	N/A	0.4	1.0

Notes: * Each pipe is fitted with a fiber optic cable. An electric power cable is installed with one of the trunklines and with each flowline. N/A: Not applicable. " : inches.

Pipe Yards

Four pipe yards are planned to facilitate construction of the onshore export pipelines. These areas will be located along the export pipelines' route and will be used for pipe storage (Plate 4.6), workshops, and, for two of them (i.e., pipe yards 1 and 4), temporary construction camps. The selection of the pipe yard locations has considered topography, existing disturbance, proximity to the river and existing access tracks.

Pipe yard 1 is within Herd Base and will be used for the construction of the flowlines and trunklines between the wellpads and the CPF. The three other pipe yards (2, 3 and 4) are situated along the Purari River at strategic positions along the onshore export pipeline route, close to the river and accessible from both the river and from the export pipeline ROW (via the existing road or track network left behind from previous logging activities in the area). Temporary wharfing facilities will be constructed on the Purari River capable of accepting 1,500- to 2,000-tonne loads. Land requirements and associated vegetation clearing will be kept to a minimum. Sheet piling may be required to stabilize the river banks, but the design will be finalized during FEED. The

wharfs will not be maintained after construction; however, there is potential for the infrastructure to be handed over to the community if there was interest. Pipe yard 4, which is the closest to the Purari River mouth, will include the main accommodation area (i.e., in a temporary construction camp) and the project management office for the construction of the onshore sections of the pipelines. The pipe yard locations and the pipeline construction camp are shown in Figure 4.6. Each pipe yard will occupy approximately 3 ha.

Plate 4.6 – Typical Pipe Yard Laydown Area



Photo: TOTAL.

4.10.5.2 General Onshore Pipeline Construction Activities

Construction Sequence

The onshore pipeline construction activities described in the following subsections are typically performed in the following sequence (Plate 4.7):

- ROW survey, environmental and social clearance surveys.
- Clearing and grading of the ROW and construction of the running track/access road, which is in the pipeline ROW.
- ROW trench excavation.
- Pipe transport, stringing, welding, bending and non-destructive examination.
- Pipeline joint coating and inspection.
- Pipe lowering-in and tie-in, backfilling and hydrostatic testing.
- Reinstating the ROW and installing cathodic protection.

Plate 4.7 – Typical Pipeline Installation Activities



A. Grading. Photo: TOTAL.



B. Pipeline laying spread. Photo: TOTAL.



C. Stringing. Photo: TOTAL.



D. Bending. Photo: TOTAL.



E. Tie in. Photo: ERIAS Group.



F. ROW reinstatement. Photo: TOTAL.

Vegetation clearing will take 11 months followed by 9 months of ROW preparation and pipeline installation. Each ROW will be open for approximately 9 to 11 months, i.e., the time between topsoil clearing and respreading. The two trenches between ANT-10 and the CPF will be installed at the same time involving two pipeline spreads. Due to space constraints and ensuring that the newly-installed pipeline is not worked over, there will be a delay of approximately two to three days between each pipeline spread. The onshore export pipeline installation will involve one pipeline spread.

ROW Survey, Environmental Preconstruction Surveys, Clearing and Grading

Typical ROW and trench profiles are provided in Figures 4.16 and 4.17.

Early works construction activities will be undertaken as described in Section 4.10.2.

Clearing will include removing above-ground vegetation and rock from the pipeline ROW. Any trees and large shrubs requiring removal will be felled and stockpiled adjacent to the ROW. South of the Purari River, the volume of tall trees is not expected to be large as the area has been previously logged. Stockpiled vegetation will be conserved where practicable for reuse after construction to assist with erosion control, serve as mulch and provide a seed source for natural regeneration. Vegetation clearing will be in two stages; firstly a 5-m wide track will be manually cleared, and then the full width of the ROW will be cleared using machinery, with cut trees reused to reinforce the working tracks.

Grading of the ROWs will be carried out where practicable and will comprise the progressive clearing of topsoil from the ROW. The removed topsoil will be either used immediately as fill or stockpiled in spoil areas along the ROWs with appropriate stabilization and erosion control measures. During ROW rehabilitation, topsoil that has been set aside will be respread over areas designated for rehabilitation to support vegetation regrowth.

ROW Stripping and Trench Excavation

The pipeline trench will be excavated using mechanical shovels and other earthmoving equipment. The pre-FEED design is for a trench that is 4.1 m wide and 2.3 m deep; the pipes will be laid in the trench at a depth of 1 m (see Figure 4.17). The detailed trench design will be prepared during FEED, and depth and width may be modified slightly.

Trench depth will be sufficient to give a minimum depth of cover above the pipe in accordance with relevant industry standards. The depth of cover will be increased under roadways and watercourse crossings as appropriate.

In rocky areas, the bottom of the trench may be padded with granular material to provide a uniform bearing surface for the pipe, or a suitable mechanical pipe protection system may be applied.

Preliminary estimates of cut and fill material are provided in Section 4.10.2.7. Detailed estimates will be prepared during FEED, including determination of the quantities of cut material that can be reused as fill, and quantities of material to be supplied from quarries. Any excess spoil will be disposed of at spoil disposal sites which have additional capacity along roads R5, R6 and R7, which follow the ROWs for the flowlines and trunklines.

Pipe Transport, Stringing, Bending, Welding and Radiography

Tractor-trailer trucks will transport the line pipe to work sites from the pipe yards. The pipe will be unloaded and strung end-to-end alongside the trench (see Plate 4.7, photograph C). A hydraulic pipe-bending machine will be used to bend the pipe (see Plate 4.7, photograph D) to conform with the topography or to facilitate lateral changes in direction. Welding crews will clean and align the pipe ends, clamp them into place and weld them into sections of pipeline (called strings) up to 1 km long. Each weld will be inspected visually and by nondestructive testing methods (such as X-ray for a selection) for faults. Unsatisfactory welds will be repaired or cut out and rewelded.

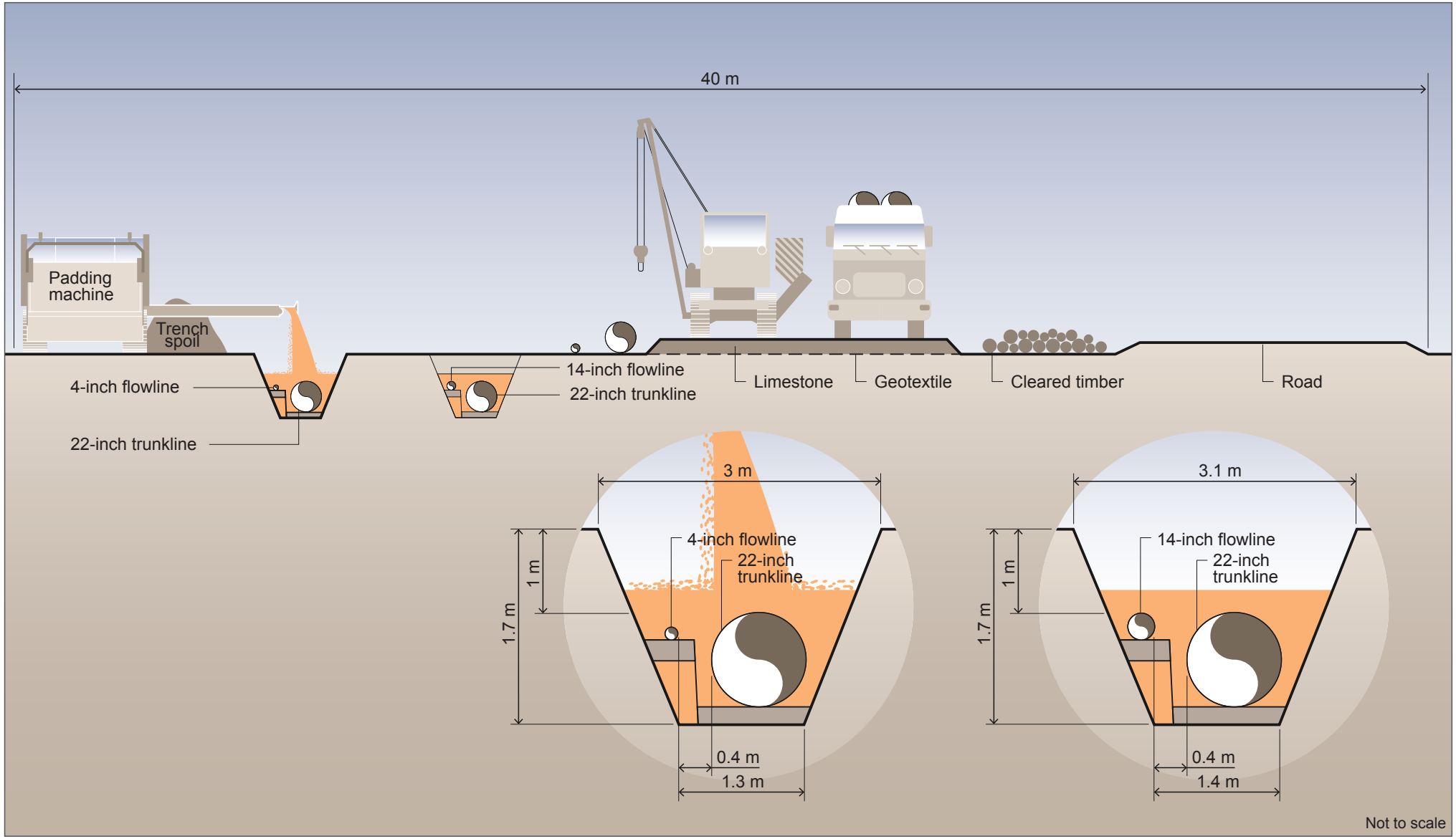
Pipeline Lowering-in, Tie-in and Backfilling

Pipeline strings will be lowered into the trench using side-boom tractors, which will move progressively along the ROW. The pipeline strings will then be welded together, and the pipe

CROSS-SECTION OF TYPICAL TRUNKLINE AND FLOWLINE RIGHT OF WAY

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FIGURE 4.16

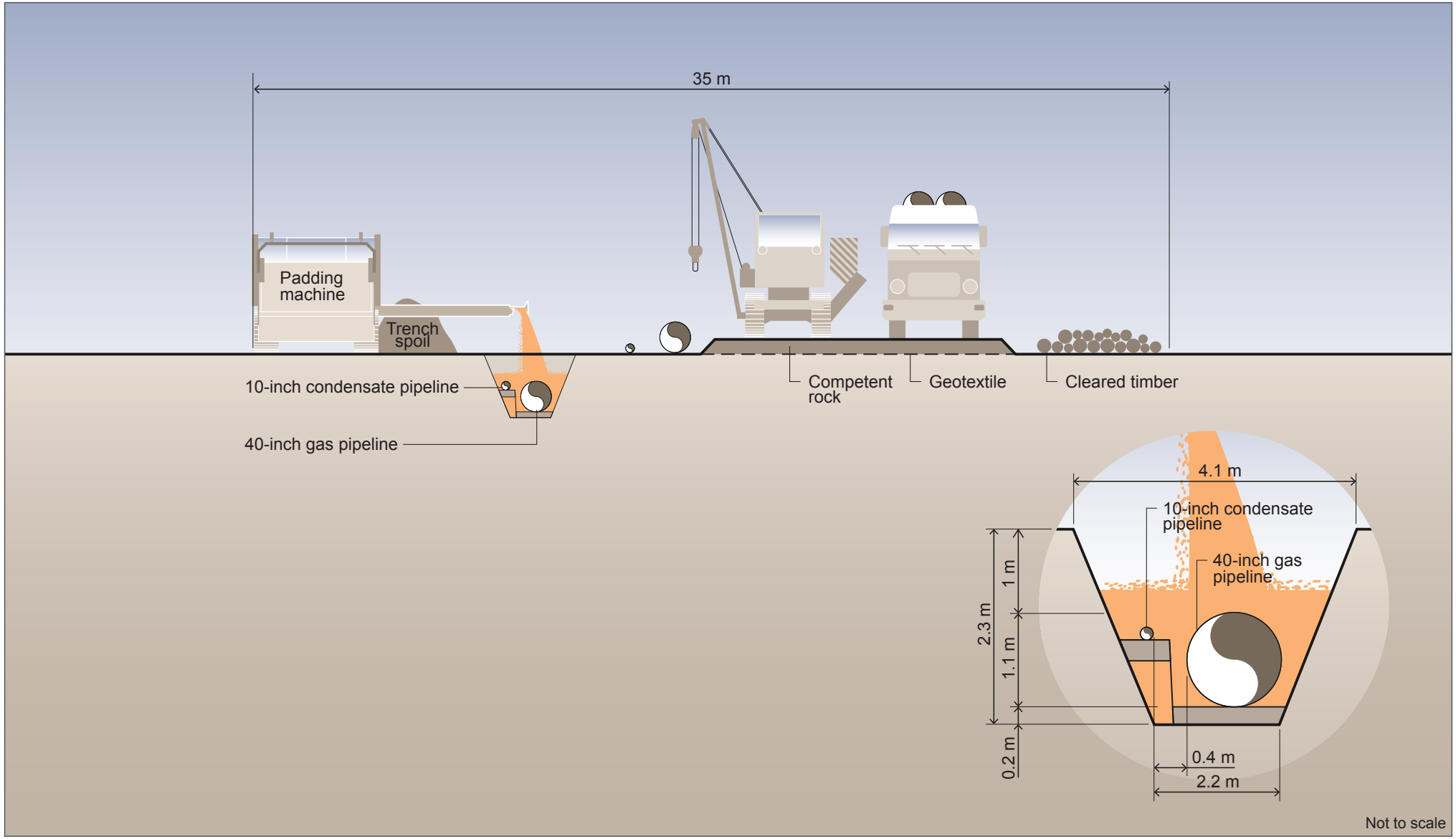


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CROSS-SECTION OF TYPICAL EXPORT PIPELINE RIGHT OF WAY

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FIGURE 4.17



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padded with sand or soil where necessary. It may be necessary to dewater the trench prior to lowering the pipeline string into the trench. Any such water will be pumped out of the trench and discharged to the surroundings in accordance with relevant conditions of the Project's environment permit, including measures to prevent erosion and sediment discharge. Spoil excavated during trenching will be backfilled into the trench.

ROW Reinstatement and Rehabilitation

ROW clean-up and rehabilitation will be undertaken progressively, as soon as practicable after backfilling. Clean-up will involve removing all temporary infrastructure and machinery, while rehabilitation will reinstate a stable land surface, suitable for regeneration of natural vegetation. The ROW will be returned to its natural contour and grade to the extent practicable. Stockpiled topsoil will be respread over areas designated for rehabilitation and salvaged vegetation will be spread over the surface to control erosion and assist in natural vegetation regeneration.

While a 35-m construction ROW is planned for the onshore export pipeline route, a narrower ROW is foreseen for the operations phase (Section 4.11.3). The access road will be maintained but not fenced, and vegetation will be allowed to grow back within the narrower operations ROW. Broader cleared areas will be maintained around the valve stations. Erosion and sediment control measures, such as diversion berms and sediment traps, will be put in place as appropriate.

Pipeline Cleaning, Gauging and Hydrotesting

Once buried, the pipeline will be cleaned, gauged, hydrotested, dewatered and dried.

The Project will determine the method for cleaning the pipeline. Typically, a series of pipeline scrapers each equipped with a brush would be introduced into the pipeline, propelled by a flow of water or compressed air. The cleaning action can be enhanced using water-based biodegradable cleaning gels.

Gauging checks the pipeline for deformation of the cross-section (ovality) and dents. It normally occurs concurrently with cleaning, with the penultimate scraper fitted with one or two aluminum gauging plates.

Hydrotesting involves pressurizing the pipeline to confirm weld integrity. The treated water used for cleaning is reused for the hydrotest process but will require topping up. The pipelines will be tested in sections, generally between valve sites. The preferred course of action is to recycle hydrotest water from one section of the pipe to another. If this is not feasible, hydrotest water will be discharged (see Hydrotest Waste Disposal).

Water will be used for cleaning and hydrotesting, and a small amount of an oxygen scavenger and biocide will be added to the water to prevent the pipeline corroding. Oxygen-scavenger chemicals, such as sodium sulfite, sodium bisulfite and ammonium bisulfite solutions, will be used to reduce the dissolved oxygen in the water to prevent pipe corrosion. A biocide will be used to prevent the development of bacteria that can produce hydrogen sulfide in anaerobic conditions. Water for hydrotesting the onshore pipelines is expected to be drawn from the Purari River at the Logistics Base, and will be filtered/treated as necessary to meet Project requirements for hydrotesting. The quantity of water required for hydrotesting is expected to be approximately equivalent to the total volume of the onshore pipelines as follows:

- Elk flowline: 3,800 m^3.
- Antelope trunkline 1: 7,200 m^3.
- Antelope trunkline 2: 7,200 m^3.
- Water injection flowline: 264 m^3.

- Condensate export pipeline: 3,500 m^3.
- Gas export pipeline: 47,000 m^3.

The total volume of hydrotesting water to be abstracted from the river is therefore approximately 69,000 m^3. Following hydrotesting, the pipeline is dewatered and dried.

Hydrotest Waste Disposal

Pipeline cleaning and testing will require disposal of solid matter removed from the pipeline and used hydrotest water. The former will comprise small volumes of rust and dirt, and will be disposed of as per the Project's waste management strategy (see Section 4.8.5). Hydrotest water will contain traces of corrosion inhibitors and biocides and will typically be safe to discharge to the environment. Once hydrotest water is no longer required, all hydrotest water will be tested to check compliance with the Project's environment permit and IFC Environmental, Health and Safety Guidelines, General and Onshore Oil and Gas Development (IFC, 2012) and then discharged at a controlled rate to a site in accordance with the Project's environment permit. The discharge locations and discharge rates will be defined during the FEED. Hydrotest water will be discharged over protective riprap or a similar energy dissipater to reduce the potential for erosion at the discharge point. The hydrotest water volumes required are indicated in the previous section (i.e., Pipeline Cleaning, Gauging and Hydrotesting).

Gas and Condensate Introduction

Gas and condensate will be introduced into the pipelines after testing has been completed and all equipment is operational. When gas or condensate is introduced at one end of the pipeline, the other end of the pipeline will be vented to the atmosphere and monitored until all the air in the pipeline has been displaced.

4.10.5.3 Special Onshore Construction

Specialist crews will be used to handle complex, difficult or restricted-width areas where construction with standard equipment is not feasible.

Steep Terrain

Pipeline installation in steep areas (i.e., grades of 20 to 50%) typically requires single- or double-joint sections of pipe. These circumstances will require a specific study of slope stability. On steep or unstable slopes, heavy machinery will be secured by a cable and winch system to prevent rollovers and runaways.

Watercourse Crossings

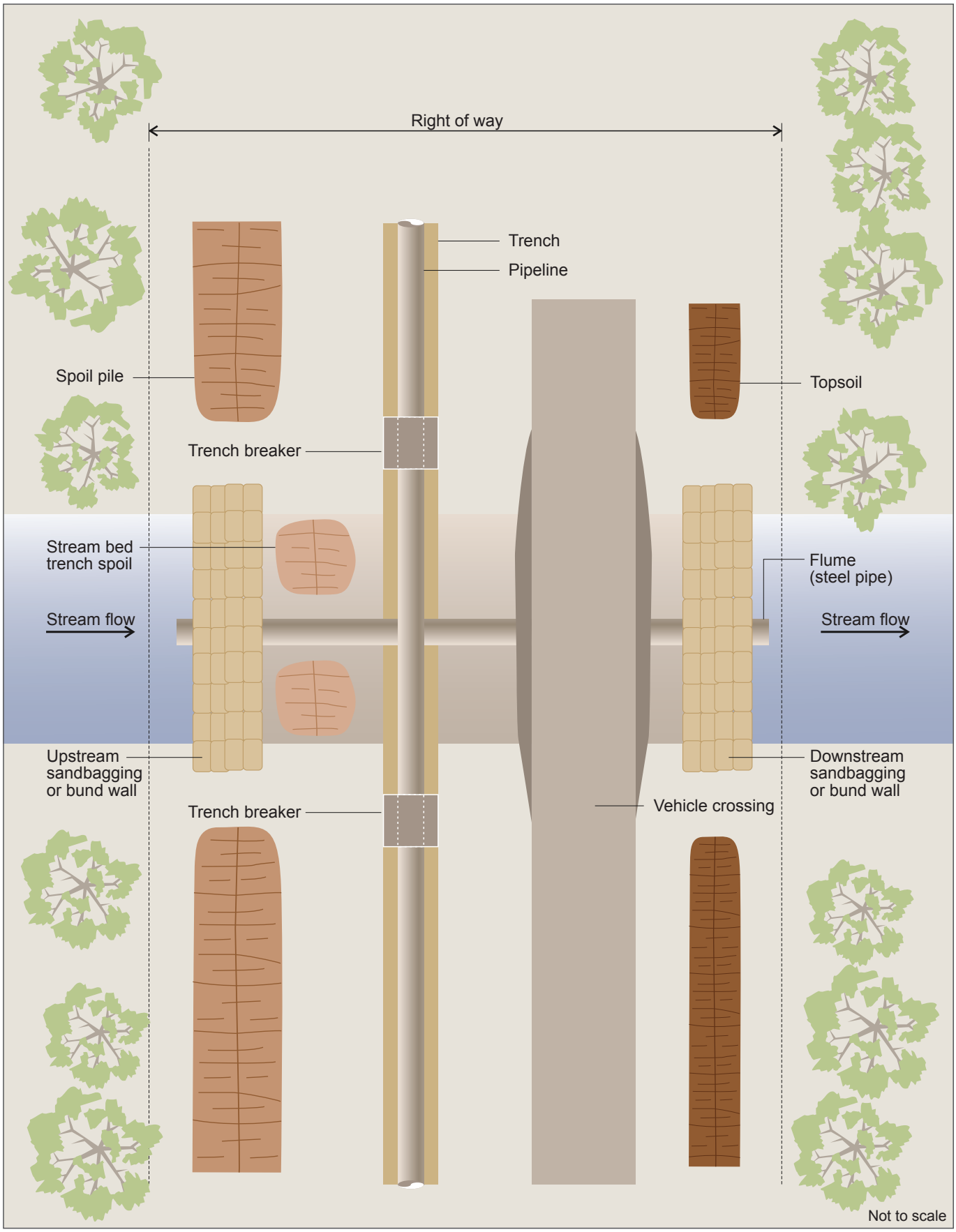
Watercourses will be crossed by the pipeline using trenching (open-cut method), except for the Purari River, which will be crossed by horizontal directional drilling (HDD) described below. The open trench method for watercourse crossings will involve temporarily damming the watercourse and diverting water past the work area (Figure 4.18). At crossings the ROW width may be widened as necessary when approaching the crossing; however, this will be defined during the FEED. The additional ROW width, if necessary, will allow for storing the additional depth of material required to be excavated from the river bed and banks. Clearing at watercourse crossings will be determined by the watercourse size, but will typically be 1 ha for minor watercourses. Environmental management aspects during construction and rehabilitation include:

- Construction, to the extent practicable, when water levels are low.

TYPICAL PIPELINE WATERCOURSE CROSSING (OPEN TRENCH, FLUME PIPE METHOD)

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FIGURE 4.18



Source: CNS (2009)

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- Maintaining a vegetation buffer or reducing the width of the crossing disturbance.
- Pipe to be strung, welded, coated and tested ready for installation prior to watercourse trenching, to minimize the disturbance timeframe.
- A temporary vehicle crossing will be constructed across the river for construction traffic, with a flume pipe to allow continued watercourse flow.
- Erosion and sediment control measures will be installed as required (Figure 4.19).
- The trench through the watercourse will retain hard plugs at each bank until just prior to pipe installation.
- The pipe will be lowered in and backfilled immediately, perhaps with additional rock armoring if required.
- The original riverbed material replaced on the river bed to a depth equivalent to the original conditions.
- Immediately after backfill and prior to dismantling any flow diversion measures, watercourse banks will be reinstated and rehabilitated.

Horizontal Directional Drilling

Horizontal directional drilling (HDD) will be used for the pipeline crossing of the Purari River, as this river is too wide and the flow too fast for conventional trenching to be used. This is the only watercourse that is proposed to be crossed using this technique.

Areas, approximately 150 m by 75 m and 100 m by 50 m, will be cleared and graded on the rig and pipe side of the river, respectively (Figure 4.20; however, the temporary construction areas adjacent to the ROW will be rehabilitated after construction. The crossing will be established by first drilling a pilot hole approximately 24 to 25 m deep, which will be then progressively expanded to obtain the final diameter using different sized rotary cutting tools that are passed successively through the hole. The pipestring will then be pulled through the hole. If ground conditions are poor, a pre-welded casing may be first pulled into the hole prior to the pipestring. Figure 4.21 shows the typical stages of a HDD river crossing with tunneling.

At the HDD rig side, drilling muds and cuttings will be contained in a closed system that recirculates the drilling fluid through a holding tank (slurry mixing tank), while a series of shakers will be used to separate the drill cuttings before recirculating drilling fluid down the hole. Slurry containment pits will contain the drilling mud, and the HDD drill cuttings will be managed as for the cuttings generated during producer well drilling (see Section 4.10.3).

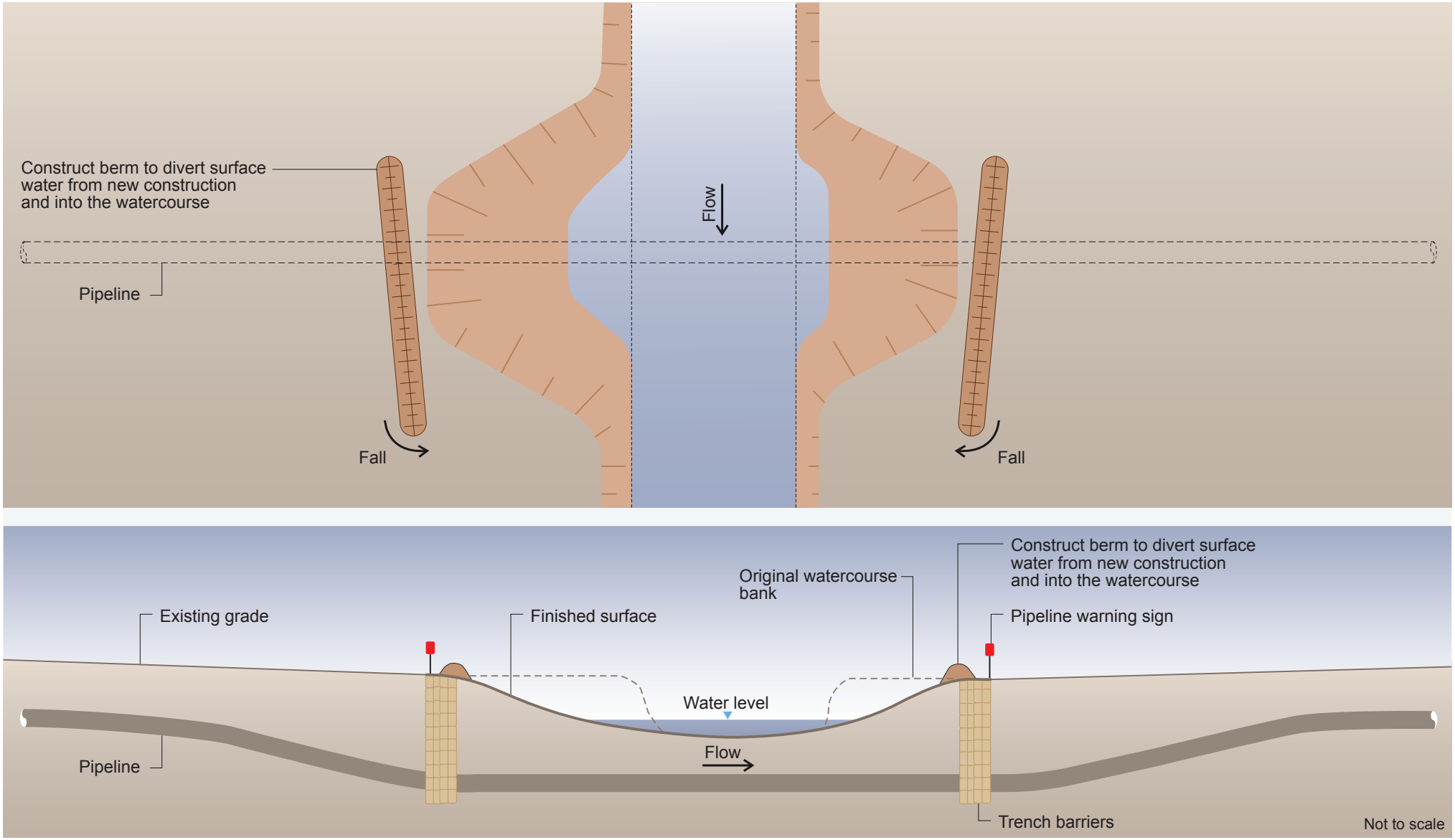
4.10.5.4 Constructing the Onshore Pipeline Infrastructure

Site preparation and rehabilitation associated with constructing the onshore pipeline infrastructure described in the previous sections, such as cathodic protection stations, valve stations, pipe yards and temporary accommodation camps for the construction workers, will be as described in Section 4.10.2. The use of pipeline markers will be defined during FEED.

PIPELINE WATERCOURSE CROSSING EROSION AND SEDIMENT CONTROL

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FIGURE 4.19

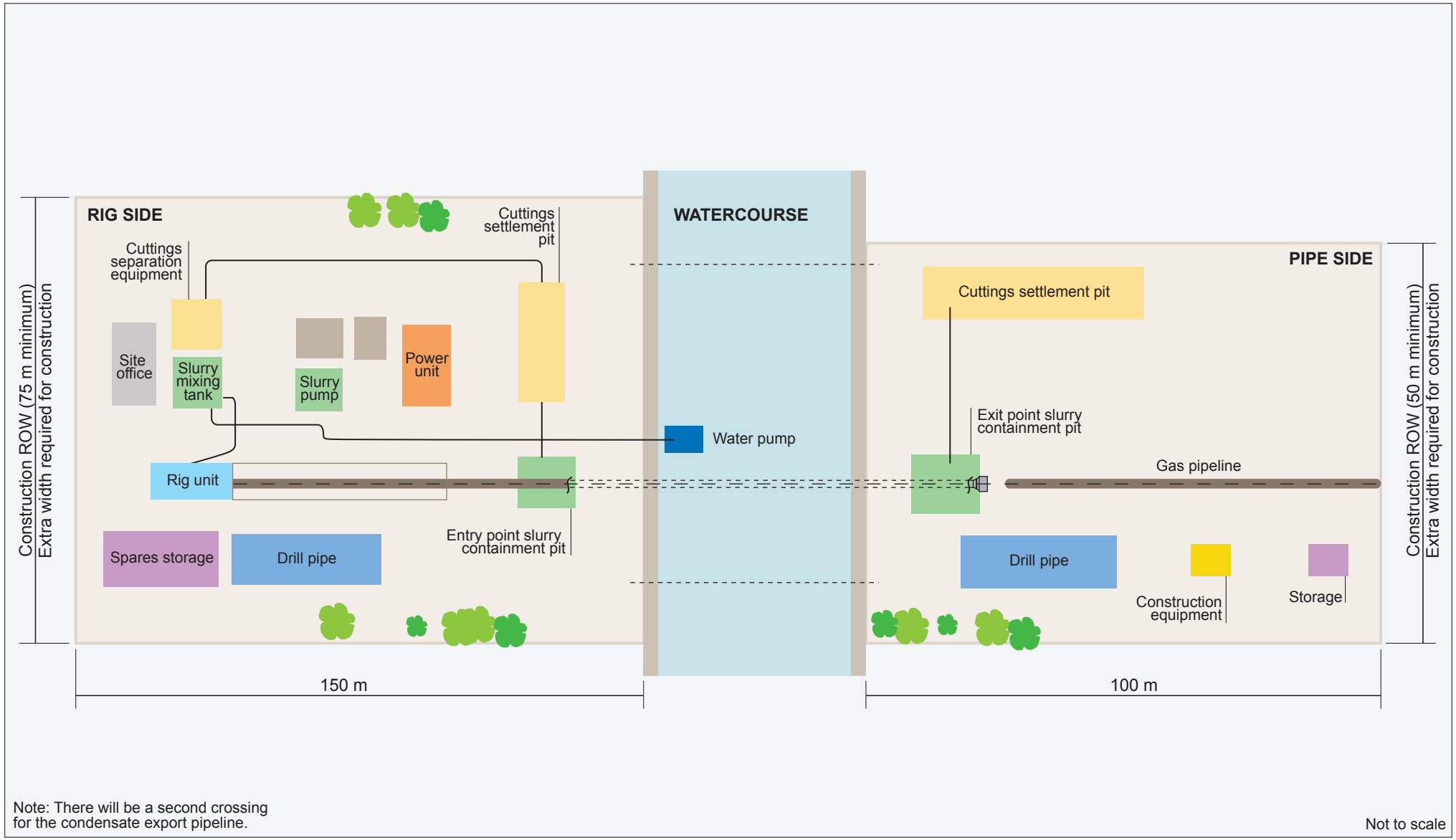


Source: CNS (2009)

TYPICAL HORIZONTAL DIRECTIONAL DRILLING CONSTRUCTION SITE

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FIGURE 4.20



Note: There will be a second crossing for the condensate export pipeline.

Not to scale

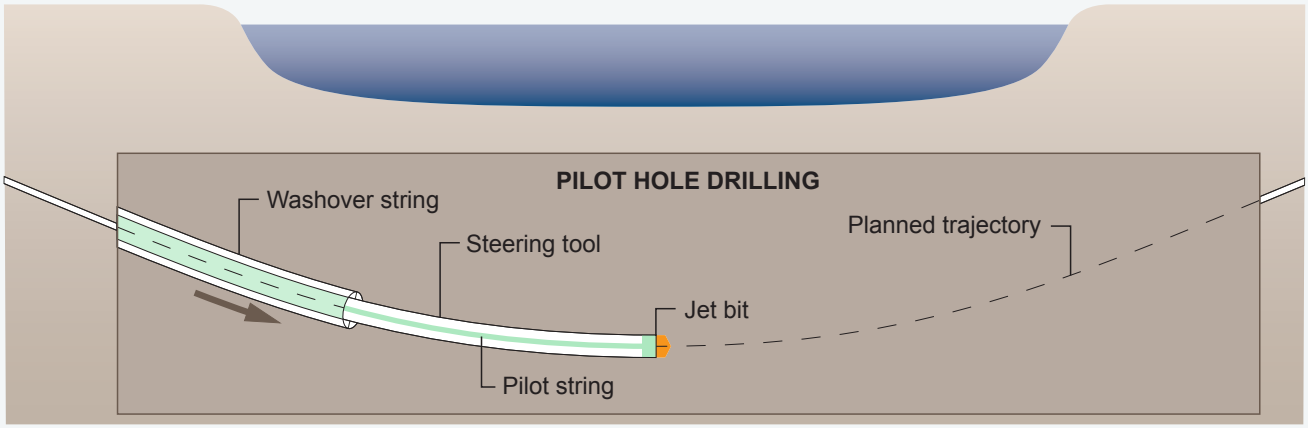
Source: CNS (2009)

TYPICAL STAGES OF HORIZONTAL DIRECTIONAL DRILLING CONSTRUCTION

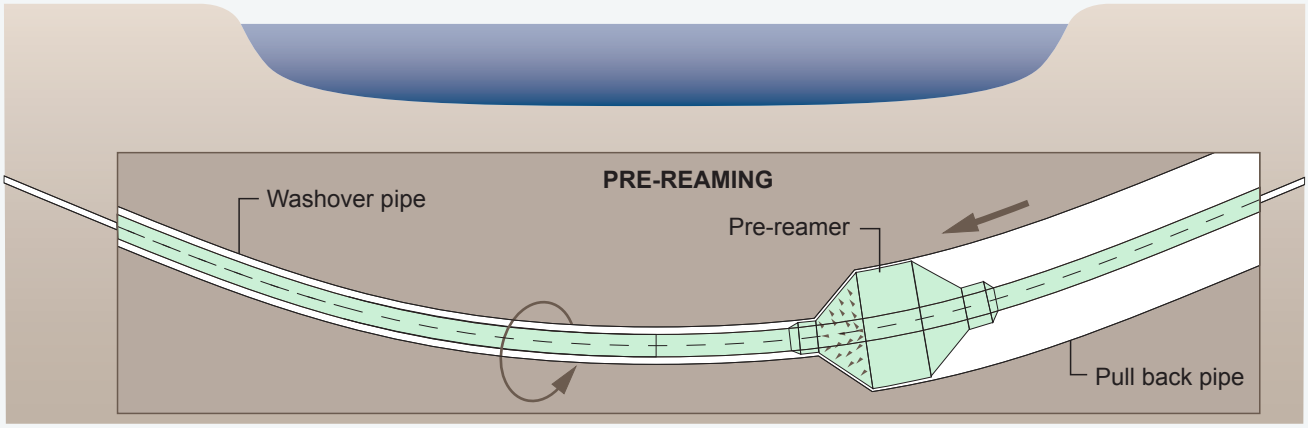
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FIGURE 4.21

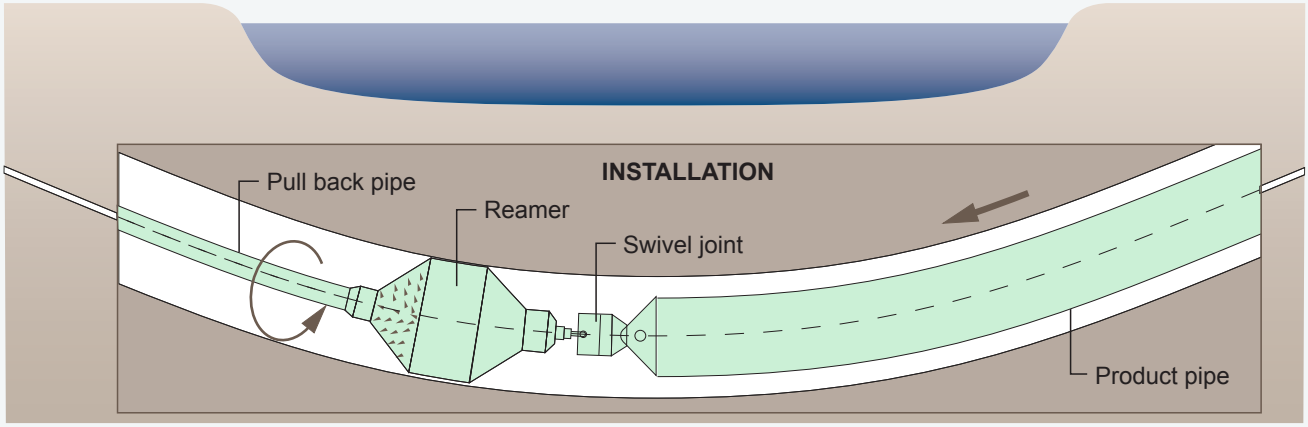
Drilling the profile



Enlarging the hole



Installing the pipe



Not to scale

Source: CNS (2009)

4.10.6 Constructing the Offshore Pipelines

4.10.6.1 Shore Crossing Construction

Pipeline shore crossings at Orokolo Bay and Caution Bay will be constructed using an open trench method. The installation method and the definition of facilities and equipment necessary are yet to be defined; however, the pipelines will probably be installed using a shore-pull technique, whereby a winch situated onshore is used to pull the pipestring towards the shore from a laybarge anchored offshore. The laybarge will be anchored in water approximately 10 to 15 m deep and will be situated approximately 5 km offshore in Orokolo Bay and between 4 and 5 km offshore in Caution Bay, depending on the approach route adopted (Figure 4.22). This method will require that the trench be excavated prior to pipeline installation. It is likely that sheet piling would be used to keep the trench open during construction (Plate 4.8, photo A), with the piles cut to approximately 1 m below the seabed and backfilling to cover the trench following pipeline installation. Temporary construction areas adjacent to the ROW at the coast are likely to be required to accommodate the winch area, offices, space for truck circulation (Plate 4.8, photo B). The section of land-based pipeline will be welded to the offshore pipeline on the surface. The pipelay vessel will winch the end of the offshore pipeline and the land-based pipelines to the surface, weld them together and lower them back to the seabed.

Plate 4.8 – Examples of Shore Crossing



A. Typical shore crossing using sheet piling.
Photo: Jan De Nul Group.



B. Example of a wider right of way at a shore crossing.
Photo: Gorgon.

The pipe pull phase will be a 24-hr operation that will only last several days, during which time there will be additional lighting requirements.

The shore approach routes at Orokolo Bay and Caution Bay are shown in Figure 4.7. The approach at Caution Bay has been designed to avoid congested use areas, fishing zones and sensitive marine ecosystems (e.g., coral reefs, seagrass and mangroves), as much as possible while also addressing the potential for unexploded ordinance and the presence of the PNG LNG Gas Pipeline.

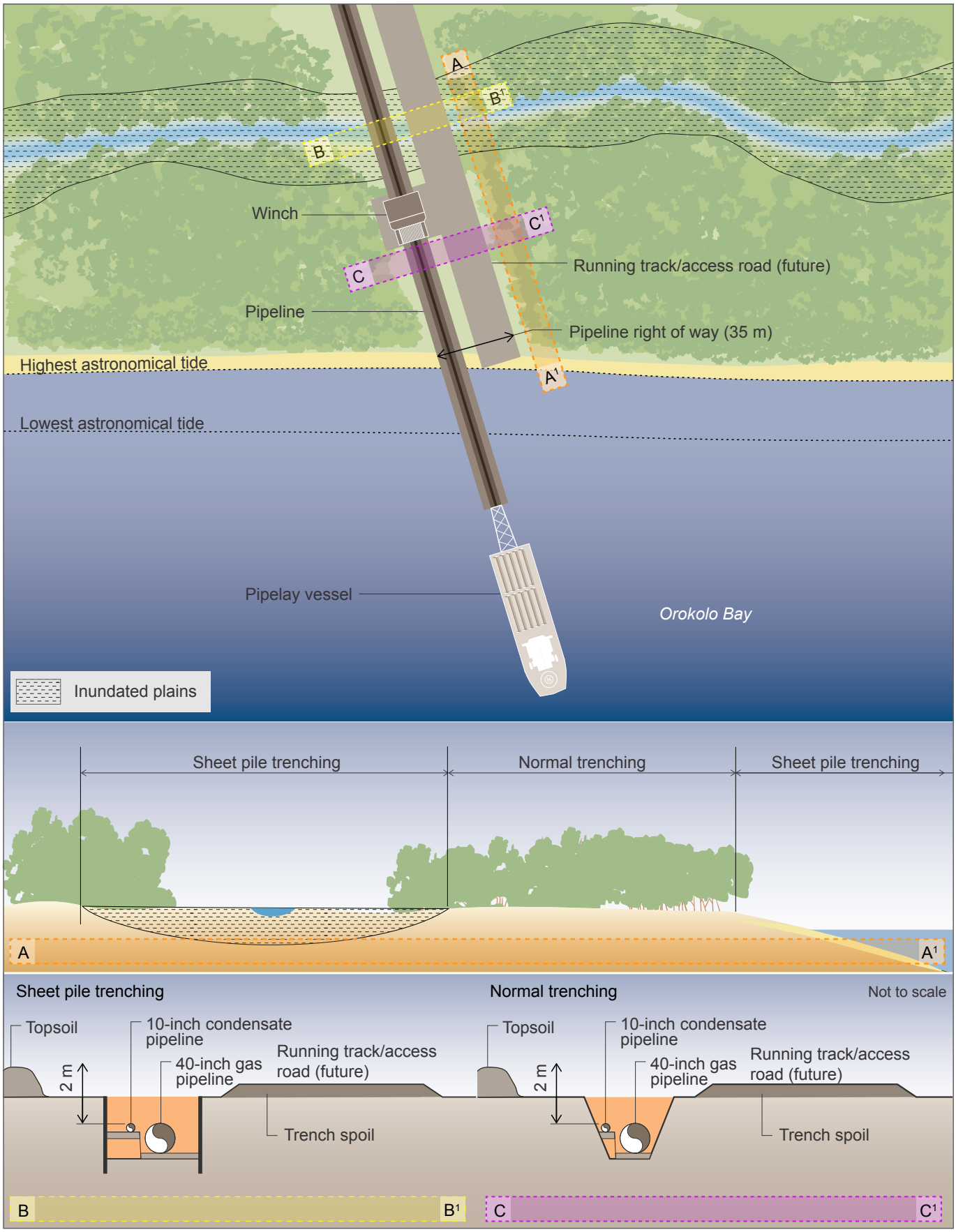
4.10.6.2 Offshore Pipeline Installation

The offshore condensate and gas pipelines will each be 260 km long and follow the same route. The distance between the gas and condensate pipelines may vary between 10 and 50 m, and an exclusion zone of typically 500 m shall be maintained around the pipelay vessel.

PROPOSED OROKOLO BAY PIPELINE SHORE CROSSING CONSTRUCTION

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FIGURE 4.22



Pipelaying

The pipeline will be installed on the seabed using a dedicated pipelaying vessel. Typically, the pipelaying process is as follows:

- Sections of pipe with anticorrosion material and concrete coating, for sections where this is necessary, are stacked on the pipelaying vessel.
- Pipe ends are prepared for welding.
- Successive joints of pipe are aligned and welded together.
- Welds are subject to non-destructive testing and repaired as necessary.
- Anti-corrosion material and a field joint infill are applied to the welded joints.
- The pipeline is lowered to the seafloor.

A constant tension will be applied to the pipeline as it is progressively lowered from the vessel to the seabed, to prevent the pipeline from bending excessively. Offshore pipelaying will be a continuous process. Barges, either towed by tugs or self-propelled, will bring the pipe and other supplies to the pipelaying vessel. An offshore pipelay spread typically comprises:

- A pipelaying vessel.
- A general supply vessel.
- Pipe supply vessels that continuously supply the pipelaying vessel.
- Bulk carriers that transport pipe to a location from which it can be loaded onto the pipe supply vessels.
- A dedicated survey vessel.
- An accommodation vessel.
- Crew boats to transfer workers to and from shore bases.

These vessel types and their roles in pipeline installation are described in the following sections.

Pipelaying Vessel

The pipeline will be installed using a heavy lift dynamic positioning vessel, which is also referred to as a laybarge. The pipeline contractor and laybarge will be defined during FEED. The laybarge will move forward along the pipelaying route using a dynamic positioning system, which will also avoid the need to use anchors. Plate 4.9 shows an example of a pipeline installation vessel.

Plate 4.9 – Typical Offshore Pipeline Installation Vessel



Photo: Saipem.

Support Vessels

General Supply Vessel

A general supply vessel will move continuously between the pipelaying vessel and the onshore support base to:

- Deliver general stores (e.g., food, water, fuel) and supplies (e.g., field joint-coating material, welding materials).
- Return waste that cannot be disposed of offshore or treated onboard will be managed, in compliance with national and international regulations.

A supply base, comprising facilities such as a wharf, crane, laydown area, ablutions and office facilities, may be required for the offshore pipeline construction activities. If so, existing facilities or facilities built for other Project purposes will be used and this will be defined during FEED.

Pipe Supply Vessel

Pipe will arrive with anti-corrosion coating on it and will be shipped to offshore holding locations as close as possible to the pipelaying vessel. Pipe supply vessels will then bring the pipe to the pipelaying vessel.

Survey Vessel

A dedicated survey vessel will accompany the pipelaying spread to conduct the pre-lay survey ahead of pipelaying, and subsequently survey the as-installed position of the pipeline.

Pipeline Stabilization and Protection

Stabilization

The pipeline will have a concrete coat for sections where this is needed for stability. The concrete coat stabilizes the pipeline on the seabed under all design environmental conditions. Additionally, the weight coating will provide protection against adverse natural or third-party impact. Due to the prevalence of soft deltaic sediments in the Gulf of Papua, the pipeline is expected to partially settle in these sediments. Where the seabed is hard or the sediments thin, the pipeline may remain largely on the seabed surface. Localized sections of the pipeline may become unsupported (i.e., freespan) if lateral currents are sufficiently strong to scour the seabed underneath the pipeline. TEP PNG has undertaken a freespan analysis considering seabed depressions. The proposed pipeline route has been modified to avoid areas where there is a freespan risk.

Protection from Vessels and Anchors

The offshore pipeline will be buried with a 1-m cover depth to the top of the pipe when located in water shallower than 20 m for protection against impacts from vessels and anchors.

For the shipping channel crossing offshore from the PNG LNG Facilities in Caution Bay, the pipeline will be trenched and buried with a 2.5 m cover depth from top of pipe. Rocks will also be placed over the seabed in the shipping lane in this area for 700 m. The cover depth to the top of the pipeline in other trenched sections in Orokolo Bay and Caution Bay will be defined during FEED.

Methods of Protection

Pipeline protection methods depend on seabed conditions and will be selected during FEED. Trenching in harder substrates using techniques such as dredging and cutting is typically

undertaken before the pipe is laid, with the pipe laid directly into the trench. Trenching in softer substrates using techniques such as ploughing and jetting is typically undertaken almost simultaneously with pipelaying, with the soft sediment pushed back over the laid pipe and trench.

Dredging

Dredging may be required in shallow water and at the shore crossings. If dredging is necessary, one or both of the following dredging techniques may be used depending on seabed conditions:

- Suction dredging, which suits very fine muds and silts. The suction head operates close to the seabed and disturbed sediments tend to remain close to the suction head, with minimal amounts becoming suspended in the water. There are two methods of suction dredging:
  - Cutter suction: this method can effectively dredge most seabed types, including rocky material in water up to 30 m deep.
  - Trailing suction: this method is most effective for softer seabeds and water up to 80 m deep.
- Dipper or backhoe dredging, which uses an excavator attached to a barge. This method suits hard seabeds but is slow and best suited to short trenches in shallow water up to 15 m deep.

Cutting

Mechanical cutters use a series of chains or rotating disks to cut a trench and remove the excavated material. Cutters are usually self-propelled and produce trenches with steep sidewalls into which the pipestring can be laid. This method only suits hard seabeds, such as very stiff clays or rock. It may be used in Caution Bay.

Ploughing

This technique buries pipelines that have already been laid and is like conventional agricultural ploughing. A surface vessel pulls a plough to create a vee-shaped trench under the pipeline, into which the laid pipestring drops progressively. This method works in most seabeds, including sand, clay and low-strength rock. Ploughed trenches will typically backfill naturally.

Jetting

Jetting is suitable for sand and soft-to-medium clays but will not work in hard clay or rocky seabeds. High-pressure water jets dislodge sediment around the pipeline and deposit the sediment adjacent to the pipeline while the pipestring falls under its own weight through the liquefied sediments. Trenches excavated by jetting will normally backfill naturally.

Grout-bag Support

Grout bags are used to support a span that is greater than the design criteria allow. The bags are placed in position by divers and filled with a cement-grout slurry, which then sets.

Spoil

Trenching spoil disposal will be addressed during FEED and in association with the construction contractors when the construction method is determined.

Protection from Prawn Trawls

Partial self-burial of the pipeline in the soft sediments will reduce the risk of contact with trawl gear in the prawn trawling grounds of the Gulf of Papua. Moreover, the pipeline's concrete coating, for the sections where it is used, will protect the pipeline from the adverse impact of the equipment typically used by prawn trawlers operating in the Gulf of Papua. There are no protrusions on the

pipeline that could cause trawl gear to become snagged. Pipeline freespans (see Pipeline Stabilization and Protection above) can represent a snagging risk; however, the Project has undertaken a freespan analysis and modified the pipeline route to minimize this risk.

Pre-commissioning Activities

Post-installation Survey

A post-installation survey will confirm that the pipeline's installation conforms with design specifications. This may be achieved using video or bathymetric surveys, as permitted by environmental conditions. Pipeline freespans in excess of specification criteria will be rectified.

Navigation charts will be updated in consultation with the NMSA once the pipeline installation is finalized.

Cleaning, Gauging and Hydrotesting

Once installed, the pipeline will be cleaned, gauged, hydrotested, dewatered and dried before gas or condensate are introduced. Pipeline cleaning will follow the approach described for onshore pipelines (see Section 4.10.5.2) and will use either a freshwater- or seawater-based gel that is non-hazardous and biodegradable.

Water will be required for both the cleaning and hydrotest procedures. The water supply will be defined during FEED but will probably be drawn from the Purari River or from the sea at either the Orokolo Bay or Caution Bay shore crossing. The total volume of the offshore pipelines is 220,000 m^3. The volume discharged after cleaning may be two to three times this volume and the hydrotest water volume will be similar to the pipeline volume.

The hydrotest water discharge rate will depend on the capacity of the dewatering train, but would typically be 15 to 23 m^3/minute. Consequently, discharge could take six to ten days from one or more discharge lines. Discharge will be in accordance with the Project's environment permit and options may include the Purari River, Orokolo Bay or Caution Bay. Following removal of hydrotest water, the pipeline will be dried with compressed air until a specified dewpoint is reached at the outlet.

Clean-up and Regeneration of Shore Crossing Sites

The shore crossing sites will be cleared of construction equipment and unused construction materials. Materials that are unable to be recycled will be disposed of in accordance with the Project's waste management strategy.

Offshore Construction Crew and Accommodation

The offshore pipeline construction crews will be mainly accommodated offshore (i.e., on specific accommodation vessels). The specialized construction crew for the Orokolo Bay shore crossing may be partially accommodated at pipe yard 4 camp and this will be defined during FEED.

4.10.6.3 Special Offshore Construction

The Project pipelines will cross the PNG LNG Gas Pipeline approximately midway between Orokolo and Caution bays (see Figure 4.7). The crossing point has been identified:

- After conducting specific route selection studies driven by the need for the pipeline to be more than 5 km from the coastline.
- For the angle of crossing to be between 60 and 90°.
- For the overall Project pipeline length to be minimized and for potential seabed abnormalities and geohazards to be avoided.

At the crossing point, the Project pipelines will be raised 150 cm above the seabed and supported by several prefabricated mattresses or concrete engineered blocks that will be positioned on the seabed prior to pipeline installation. This will enable the Project pipelines to pass over the PNG LNG Gas Pipeline with a gap of 30 cm between the pipelines, avoiding direct contact, and without excessive bending.

Mattresses/blocks will be installed, leading up to and over, each side of the PNG LNG Gas Pipeline and will be installed at 15-m and 10-m intervals for the gas and condensate pipelines, respectively (Figure 4.23). The crossing of the Project gas pipeline will have a total span of 180 m and the crossing of the condensate pipeline will have a span of 64 m and no support will be within 2 m of the existing PNG LNG Gas Pipeline. This pipeline support system will also carry the fiber optic cable that will be installed in parallel with the gas and condensate pipelines. The PNG LNG Project fiber optic cable is buried parallel to the PNG LNG Gas Pipeline and consequently this system of crossing the latter should also prevent direct contact between the Project pipelines and the fiber optic cable.

4.11 Operations

4.11.1 Operating and Maintaining the Processing Facilities

4.11.1.1 Gas Processing Systems

A simplified description of the gas processing systems is provided in the following paragraphs and illustrated in Figure 4.24.

Gas-condensate Separation and Export

Receiving Facilities

Flowlines and trunklines will transport reservoir fluids comprising a gas-condensate mixture from the Elk and Antelope wellheads to the CPF. At the CPF, the reservoir fluids will flow into receiving facilities where the fluids from the two reservoirs will be commingled after Elk gas goes through a dedicated compression. The receiving facilities will comprise an inlet separator (i.e., a vapor-liquid separator), which separates the gas from the non-stabilized condensate. The gas will be routed through the gas processing units and the liquid routed to the condensate stabilization unit, where the produced water is separated from the condensate.

Gas Processing

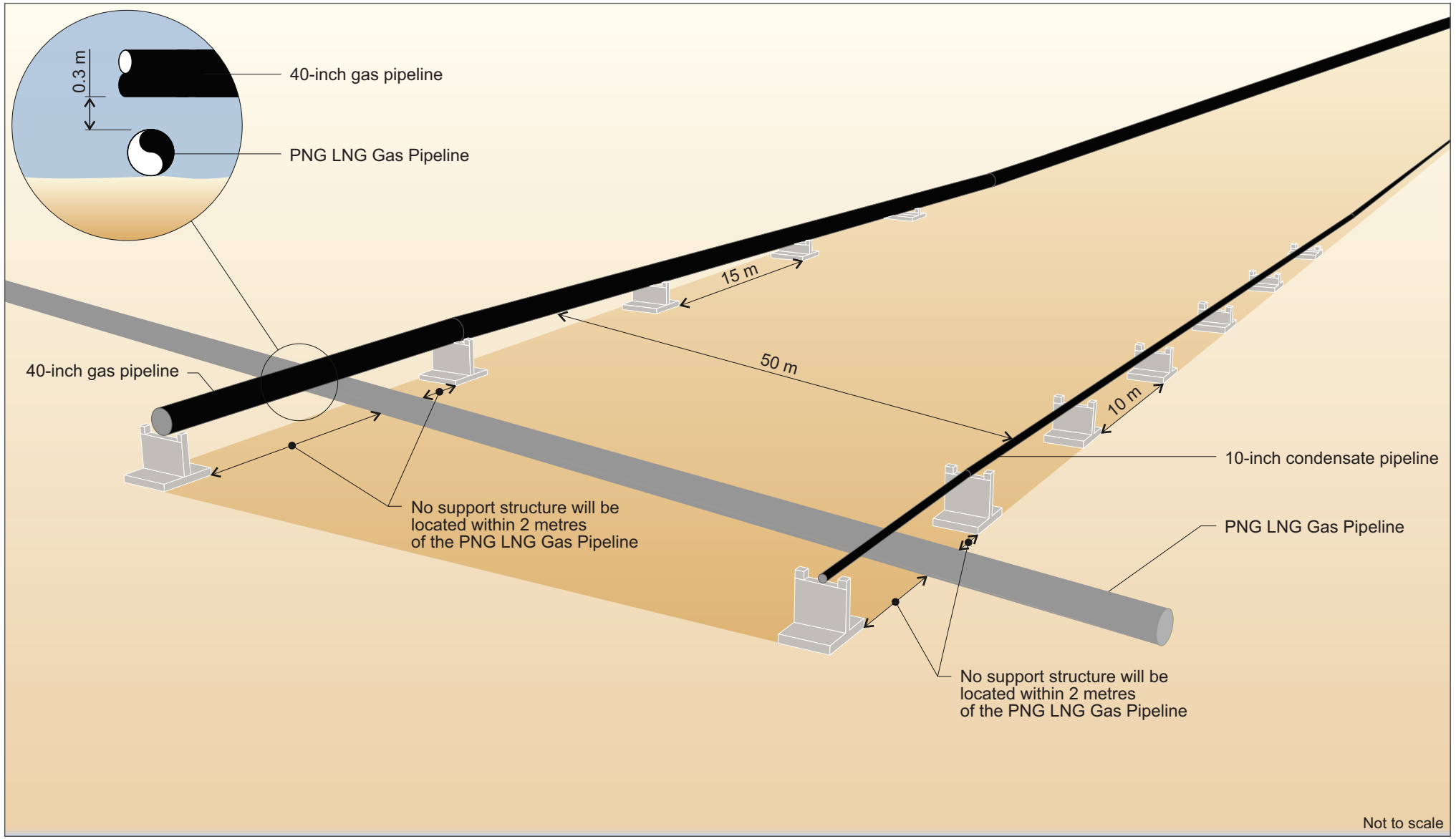
The raw gas from the Elk and Antelope fields is expected to have slightly different compositions (see Section 4.2.2) but will be commingled at the receiving facilities and processed together after the Elk fluid goes through a dedicated compression. The raw gas contains carbon dioxide (CO_2) and hydrogen sulfide (H_2S), which are referred to as ‘acid gas’; however, the Elk gas contains lower concentrations of H_2S than the Antelope gas. The export gas specification requires an H_2S concentration of less than 3 ppm and a CO_2 concentration of less than 45 ppm. To achieve this, gas processing will remove the acid gas. The gas leaving the inlet separator will; therefore, be routed to an acid gas removal unit (AGRU; see Acid Gas Management). The processed gas leaving the AGRU will pass through a dewpoint unit[2] and will then be ready for export.

2 The dewpoint unit condenses part of the natural gas to a liquid state by cooling the gas below the dewpoint in a propane refrigeration loop.

SCHEMATIC OF THE PNG LNG PIPELINE CROSSING

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FIGURE 4.23

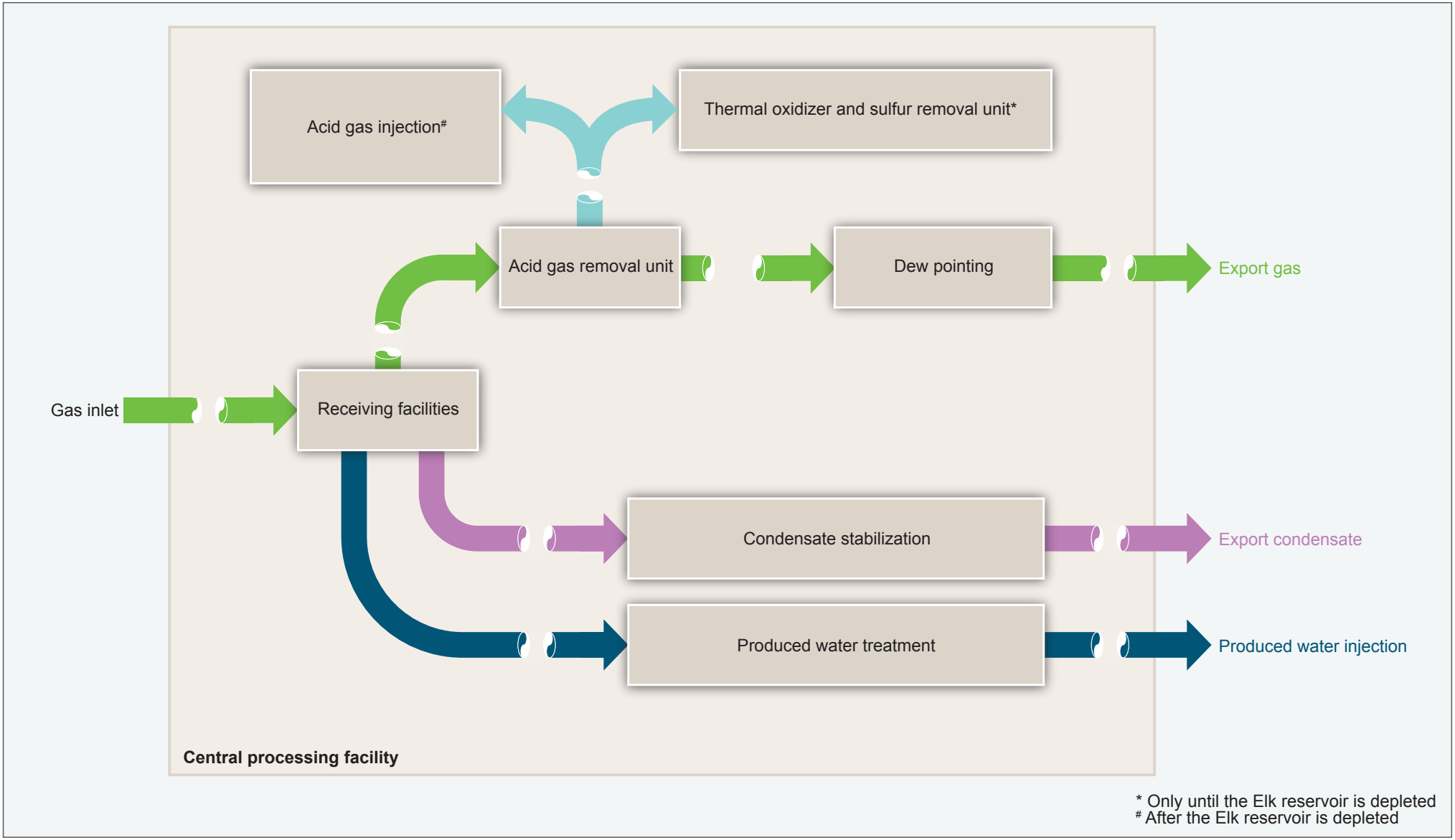


Note: Design of support structures will be finalised during front-end engineering design and will likely be concrete engineered supports (as pictured) or prefabricated mattresses. The support type will depend on the substrate present at the site.

GAS PROCESSING SCHEMATIC

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FIGURE 4.24



ERIAS Group | 01215B_23_4.24_v2

Gas Export

The processed gas leaving the dewpoint unit will be warmed using heat exchangers, it will pass through a gas export metering unit and will be conveyed to the export pipeline which will transport the gas to the LNG plant in Caution Bay.

Compression

For the first 10-year production period, the natural reservoir pressure will convey the gas from the Antelope reservoir to the CPF and from commingled gas to the LNG plant at Caution Bay, without the need for gas compression. Dedicated compression is required for the Elk flowline until the Elk reservoir is depleted so the pressure matches that of the Antelope reservoir. In subsequent years the Antelope reservoir pressure will decrease because of depleting reservoir fluids, thus requiring additional gas compression to boost the pressure of the gas that flows into the CPF. Consequently, the CPF facilities have been designed with areas for installing the additional compression units.

Condensate Stabilization and Export

Non-stabilized condensate that is separated from the gas in the inlet separator will be conveyed to the condensate stabilization unit. The unit will include a degassing drum and a stabilization column. Water separated from the condensate in the degassing drum will be routed to the produced water treatment unit. The stabilized condensate will be routed to the export pumps that will pump the condensate to the LNG plant at Caution Bay via the condensate export pipeline.

Acid Gas Management

Several acid gas management concepts were, and still are, being assessed that variously consider acid gas removal; these are described in more detail in Section 5.5.1. The concept presented in this section is representative of various concepts under investigation and is used to address air quality and GHG requirements (Chapter 15).

Acid Gas Removal

Gas processing would include removing H_2S and CO_2 from the raw gas using an AGRU (see Gas-condensate Separation and Export). The AGRU will consist principally of an amine absorption unit and an amine regeneration unit. The raw gas that leaves the receiving facilities will be contacted with an amine solution, which will absorb the H_2S and CO_2 gases. The gas from which the acid gases have been removed will be routed to the export facilities. The amine solution, now rich in H_2S and CO_2, will be routed to a regeneration unit where the solution will be heated using boiler-generated steam. This process will require 72 m^3/day of demineralized water that would be sourced from the Purari River. The acid gas will be released from the amine solution in the form of vapor, which would be routed to an acid gas injection unit. The regenerated amine would be reused in the amine absorption unit and wastewater generated by the condensation of the steam would be routed to a wastewater treatment plant.

Acid Gas Injection

Once the Elk reservoir has been depleted, it may be possible for acid gas removed from the raw gas using the AGRU to be disposed of by injecting it into the reservoir. The injection equipment will comprise two electric gas compressors, a low pressure unit and a high pressure unit (Section 4.11.1.2, Fuel Gas System). The compressed gas will be transported to the ELK-10 wellpad via the Elk trunkline where it will be injected into the reservoir using the ELK-10 well, which will be converted to a gas injection well. Mixing of the gas injected into the depleted Elk reservoir with the Antelope reservoir gas is unlikely to occur (see Section 4.2.2), as the two reservoirs are geologically segregated.

Thermal Oxidizer and Flue Gas Desulfurization

During at least the first four years of production when it may not be possible to dispose of acid gas by injection, acid gas from the AGRU will be treated using a thermal oxidizer and flue gas desulfurization process. This treatment will allow CO_2, separated from the export gas, to be discharged without releasing sulfur as H_2S. The flue gas desulfurization process uses a caustic soda wash to remove sulfide from the acid gas. The efficiency of this sulfur recovery process will be approximately 80 to 95%. The treatment process was selected following assessment of various sulfur recovery technologies and disposal options, which are still being optimized (see Chapter 5).

The treatment process involves incineration of acid gas in the thermal oxidizer to convert sulfur compounds, including H_2S, into sulfur dioxide (SO_2). Incineration will take place in a closed chamber.

A flue gas desulfurization process then remove the SO_2 from the flue gas using liquid caustic soda (NaOH) that is injected directly into the flue gas stream, which converts SO_2 to sulfite salts. This desulfurization process will be based on a pH control system, maintained between pH 6 and 7, which selectively removes SO_2 from the flue gas but leaves CO_2. The treated flue gas will be released to the atmosphere via a conventional stack. The liquid effluent containing the dissolved sulfite salts will be injected into the ANT-11 well, along with produced water from the condensate stabilization unit.

Approximately 16 m^3/day of NaOH will be required for the flue gas desulfurization. NaOH will be imported in liquid form from Australia to the AES base at Port Moresby. The liquid will be transported in offshore cargo carrying tanks (approximate capacity of 20 m^3) approved for the transport of hazardous liquids, i.e., compliant with International Organization for Standardization (ISO), International Maritime Organization (IMO) and International Maritime Dangerous Goods (IMDG) standards. The process will also require approximately 100 m^3/hr (2,400 m^3/day) of water for the AGRU and diluting the NaOH, which will be sourced from the Purari River. Most of this water is vaporized in the desulfurization process and reports in the treated flue gas. The volume of liquid effluent from the desulfurization process that will be injected into the ANT-11 well is expected be approximately 45 to 65 m^3/hr. This represents approximately 60 to 70% of the liquid volume injected into the reservoir, with the remaining 30 to 40% being treated produced water.

The liquid effluent from the desulfurization process will have near neutral pH (pH 6 to 7) and be at a temperature of about 80ºC prior to mixing with the produced water. It will mostly comprise water (90%), with the remaining volume comprising dissolved sodium bisulfite ($NaHSO_3$) (6.4%) and sodium sulfite (Na_2SO_3) (3.6%).

The treated flue gas from the desulfurization process will mainly comprise water, oxygen, nitrogen, CO_2, with traces of oxides of nitrogen, volatile organic compounds and SO_2.

Once the Elk reservoir has been depleted and acid gas injection commences, the thermal oxidizer and flue gas desulfurization processes would remain on standby, ready to operate at short notice so that acid gas can be treated if acid gas injection is not possible.

Produced Water Management

No reservoir water is expected. Relatively small quantities (e.g., 3,000 barrels of water per day) of condensation water, produced during condensate stabilization, are expected. The selected management approach for the produced water is to inject it into the Antelope reservoir. Consequently, produced water separated from the condensate in the condensate stabilization process will be routed to a produced water treatment unit and the treated produced water piped to the ANT-11 wellpad. The produced water unit comprises a degassing drum and a flotation unit.

The oil concentration in the injected produced water will be less than 50 mg/L and total suspended solids will be less than 100 mg/L.

4.11.1.2 Utilities

Fuel Gas System

Part of the processed gas (e.g., 26.2 MMscfd) will be used as fuel to provide power at the CPF. High pressure (HP) fuel gas will be taken from the gas processing train downstream from the AGRU, while low pressure (LP) fuel gas will be taken from the condensate stabilization degassing drum. HP fuel gas will have hydrogen sulfide concentrations of less than 3 ppm. The main consumers of the HP fuel gas will be the power generation gas turbines and the amine regeneration boilers. The main consumer of LP fuel gas is likely to be the amine regeneration boilers and the thermal oxidizer.

Power Generation

The power demand for the CPF, wellheads and Logistics Base will be 38 MW. Gas turbines burning fuel gas will generate the required power at the CPF. Four turbines will be installed with one being in reserve and placed on standby. The main power consumers will comprise the various electrically-driven pumps and compressors at the CPF. A power cable laid in the trunkline/flowline ROW between the CPF and the wellpads will supply power to the wellpads from the CPF. The wellpad power demand is negligible compared to that of the CPF.

Permanent lighting is planned for facilities that will be constantly manned in the CPF and the Logistics Base.

Nitrogen Systems

Nitrogen will be required at the CPF for instruments and will be used as inert gas for purging equipment and maintaining an inert atmosphere in vessels and pipes for safety reasons. The nitrogen will be generated on site using a typical nitrogen generation unit.

Firewater System

The CPF will be equipped with fixed firewater systems to protect processing and storage facilities. The main system components will comprise ‘deluge’ systems, fire monitors and hydrants, firewater distribution network including pumps, and firewater storage tanks. The system will be designed to provide 845 m^3/hour of firewater for three hours and foam at a rate of 21 m^3/hour for one hour. The firewater storage capacity will be 3,000 m^3 and foam storage capacity will be 21 m^3.

Water Systems

Freshwater will be supplied to the CPF, accommodation buildings and utilities from the pumping station at the Logistics Base. The water will be pumped from the Purari River to the CPF through a PVC pipeline that will be laid in association with R2. The maximum water abstraction rate may be at least 2,500 m^3/day (additional requirements for pipeline hydrotesting are described in Section 4.10.5.2), which includes potable water (approximately 100 m^3/day) and process water (approximately 2,400 m^3/day). The water to be used as potable water will be filtered and treated. The remainder will be used as utility water, part of which will be demineralized water for the AGRU, dilution of the caustic soda and for condensate stabilization. The demineralized water system will comprise two 700-m^3 storage tanks and distribution pumps.

Utility and Instrument Air System

Typical industry utility and industrial air systems will be used, including air compressors, air drier and distribution networks. Valve operation will consume the majority of the instrument air. The main utility air consumer will be the purge gas rate on the power gas turbines, compressors and pumps.

Diesel Systems

The principle use of diesel will be during start-up of the processing facilities when no fuel gas is available to provide power. Some small temporary and mobile items of equipment will also be fueled with diesel during normal operation.

Heating Systems

Three boilers and waste heat recovery units installed in the power gas turbines will generate hot water from 145 to 170°C. This will be used as a heating medium for the amine regeneration reboilers (part of the AGRU) and the condensate stabilization unit.

Chemical Systems

Chemicals will be selected according to TOTAL's General Specification: Environmental Requirements for Project Design and E&P Activities (GS EP ENV 001) considering the following criteria:

- Lowest toxicity.
- Lowest bioaccumulation potential.
- Highest biodegradation.
- Chemicals subject to bans or phase-outs.

The chemicals necessary in the CPF include hydrate inhibitor, corrosion inhibitor, biocide, caustic soda and oxygen scavenger. Storage areas will have an impervious slab with a slope towards a gutter and drainage system. Appropriate secondary containment will also be installed and rainwater infiltration will be prevented from entering hazardous materials storage areas. Table 4.14 summarizes the key chemicals and other hazardous materials to be stored at the CPF, and their uses.

No hydrocarbon will be stored within 50 m of any well, unless it is stored in an appropriate operational storage tank with facilities in place to prevent any leakage or spillage from contacting the ground. Any spills or leaks will be directed away from the well.

Table 4.14 – Key Chemicals and Hazardous Materials Use

Chemical	Use	Type of Storage	Total Capacity (m^3)
Corrosion inhibitor	Prevents corrosion. Injected into the production manifold at the production wellpads. Transported in drums or cubi-containers by road to the wellheads where a remote injection system is installed.	Tank	34
Monoethylene glycol (MEG)	Hydrate inhibitor. Injected into the processing flow stream where there is a risk of hydrates being formed, which can cause blockages. The MEG is stored at the CPF and transported by road in drums or cubi-containers to the wellheads where a remote injection system is installed. The MEG injected into the dew pointing unit is recovered from the stabilized condensate and reused.	Tank	300
Tri-ethylene glycol (TEG)		Tank	300

Table 4.14 – Key Chemicals and Hazardous Materials Use (cont'd)

Chemical	Use	Type of Storage	Total Capacity (m^3)
Biocides	Prevents bacteria developing in water from the open drain network that is recycled back to the process and in the produced water that is disposed of by injection into the Antelope reservoir. Biocide is injected in small quantities into these process streams.	Drums/ cubi-containers	TBD
Oxygen scavenger	Blanketing of equipment is required to limit oxygen entrance. Some oxygen can come from open drain effluent recycled in production. As soon as oxygen is measured above 30 ppb, oxygen scavenger must be injected (then potentially continuously).	Drums/ cubi-containers	TBD
Antiscale	Prevents scaling of pipework and vessels.	Drums/ cubi-containers	TBD
Amine	Used in the acid gas process to absorb hydrogen sulfide. The amine is regenerated.	Tank	1,400
Sodium hydroxide	Used in the acid gas process to absorb sulfur dioxide during the desulfurization process.	Tank	TBD
Propane	Used as a refrigerant in the condensate processing. Two bullets normally empty to be able to drain the full propane loop and the third one large enough to refill the loop.	Bullets	150
Diesel	Fuel for diverse small equipment items that are not electrically driven.	Tank	420
	Emergency fuel supply at the operations camp.	Tank	10

TBD: To be defined during FEED. The number and volume of tanks will also be defined during FEED.

Flares

In 2014, TOTAL officially endorsed the World Bank Zero Routine Flaring by 2030 initiative, which is reported in the company's 2014 Sustainable Growth Report, and is committed to develop the Project without routine flaring; however, the CPF will be equipped with high pressure (HP) and low pressure (LP) flares for safety reasons. The HP and LP flares will be situated on the same stack, as there are no operational or safety related constraints that require separate stacks. The HP flare has been designed for an emergency relief rate of 1,850 MMscfd of gas and has a height of 104 m. The LP flare is designed for 58 MMscfd and has a height of 30 m.

The flares will be used only for safety flaring in alignment with the no routine flaring policy, as follows:

- During start-up after a shutdown, flaring will be tolerated for six hours, which is the time necessary for the processing systems to stabilize.
- In the event of upset conditions, such as the unavailability of acid gas treatment or unavailability of gas export, the CPF production will immediately be reduced and flaring of gas at the minimum turndown capacity of the plant will be tolerated for six hours. After six hours, if the problem is not resolved, wellheads will be remotely shutdown.
- Flaring of gas from depressurizing the processing equipment for safety reasons prior to planned preventive maintenance.
- Emergency depressurization of the facilities in the event of a safety situation. Emergency depressurization will occur infrequently, and the flaring duration will be less than 20 minutes.

Open Drain Systems

The CPF will be equipped with three open drain networks to manage and control surface water in the facility. Two drains will discharge to the Purari River and one to the surrounding environment by percolation and evaporation:

- Open drain network 1 (OD1) will collect rainwater runoff from areas where there is a permanent risk of hydrocarbon contamination. The drained water will be routed to a 18-m^3 hydrocarbon-water separator. The treated water will be then directed to a 2,340-m^3 observation basin. If the water quality complies with the Project's environmental permit discharge values, the water will then be discharged to the Purari River.
- Open drain network 2 (OD2) will collect rainwater runoff from areas where there is a risk of accidental contamination from hydrocarbons in the area. The drained water will be routed directly to the observation basin (without passing through the separator) and if the water quality complies with discharge values it will be discharged to the Purari River.
- Open drain network 3 (OD3) will collect rainwater runoff from areas where there is no processing equipment, and it will be disposed of to the surrounding environment by natural percolation and evaporation.

The hydrocarbon-water separator has been designed with a retention time of 30 minutes based on the flow for a washdown of the processing areas. The observation basin is sized to contain site runoff from 20 minutes of rain and three hours of firewater.

4.11.1.3 Water Storage

The water storage facilities comprise the following:

- Produced water holding tank with a capacity for five days of produced water in case of a temporary upset of the produced water system.
- Various water tanks to store utilities potable water, accommodation potable water, utility water, demineralized water and fire water.

4.11.1.4 Process Control

The CPF, Project pipelines, gathering systems and wells will be monitored and controlled 24 hours per day from the CPF control center under the Project's supervisory control and data acquisition system. The integrated control and safety system will be designed to monitor, control and protect Project facilities. Pressure, temperature, level, flow rate and position instrumentation and control systems will be monitored. Process and safety control systems will provide surveillance to safely shutdown the process if a safety situation occurs (see Section 4.9.3.7). Upstream operations will collaborate with the downstream operations to facilitate process control and maintenance schedules.

4.11.1.5 Maintenance

Planned maintenance shutdowns are to be scheduled and coordinated to achieve an operations availability of 93% over the design life of 25 years. Piping, valving and equipment will be designed so that sections of the plant can be isolated for maintenance work. Vents and drains will allow for safe and effective depressurizing, draining and purging of equipment. Where possible, common equipment will be considered across the facilities (e.g., gas turbines, valves, instrumentation) to minimize spares holdings and workers' competency requirements.

Plant data and equipment performance monitoring systems collects and plots data, monitors critical rotating equipment and processes data so it can be accessed locally and remotely for troubleshooting and predictive maintenance.

The Project is not expecting naturally occurring radioactive material (NORM) to be generated; however, contingency plans will be prepared for the unlikely event NORM occurs.

4.11.2 Operating and Maintaining the Wells and Gathering Systems

The Antelope wellpad layout during production is shown in Figure 4.25. The Elk wellpad will have a similar layout, but for only one wellhead. The wellpads will be unmanned and therefore, no permanent lighting is planned. Each wellpad will be equipped with pressure relief and venting systems and a power cable will supply electricity from the CPF. The gathering system and wells will be routinely inspected and maintained. Later in their life, some wells are expected to require the following interventions:

- Well stimulation to restore the permeability and yield of the wellbore.
- Mechanical repair of surface or down-hole equipment.
- Potential water shutoffs to restrict inflow into the wellbore and eliminate produced water in the wellstream.

The open drain system described in Section 4.11.1.2 will apply at the wellpads. OD1 water will be drained to a dedicated sump for collection and transport to the CPF where it will be treated with other OD1 wastewater. Process control will be automated as much as practicable. All the wells will be capable of being remotely started and shutdown from the CPF control center.

4.11.3 Operating the Pipelines

During operations, the Project will require a narrower ROW than during construction to be used for surface and aerial inspection, maintenance and possibly emergency response. The width of the pipeline operations ROW will be minimized, but may fluctuate depending on the topography and operational requirements. No permanent structures will be allowed in the ROW. Vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow. All of the remaining construction ROW will be allowed to regenerate or to return to its former use after construction activities cease.

A small team will operate the pipelines using standard systems and procedures so that pipeline integrity is maintained.

4.11.3.1 Monitoring and Control

The CPF will have a control room that can monitor and control the overall pipeline system, so that there will be an operable, reliable backup system in an emergency situation. Pipeline, processing and well flowrate adjustments will be made so that daily nominations are met. An online analyzer with read-out in the CPF control room will be used to monitor and control gas quality, and pipeline shutdown will occur automatically should the gas quality specifications be exceeded.

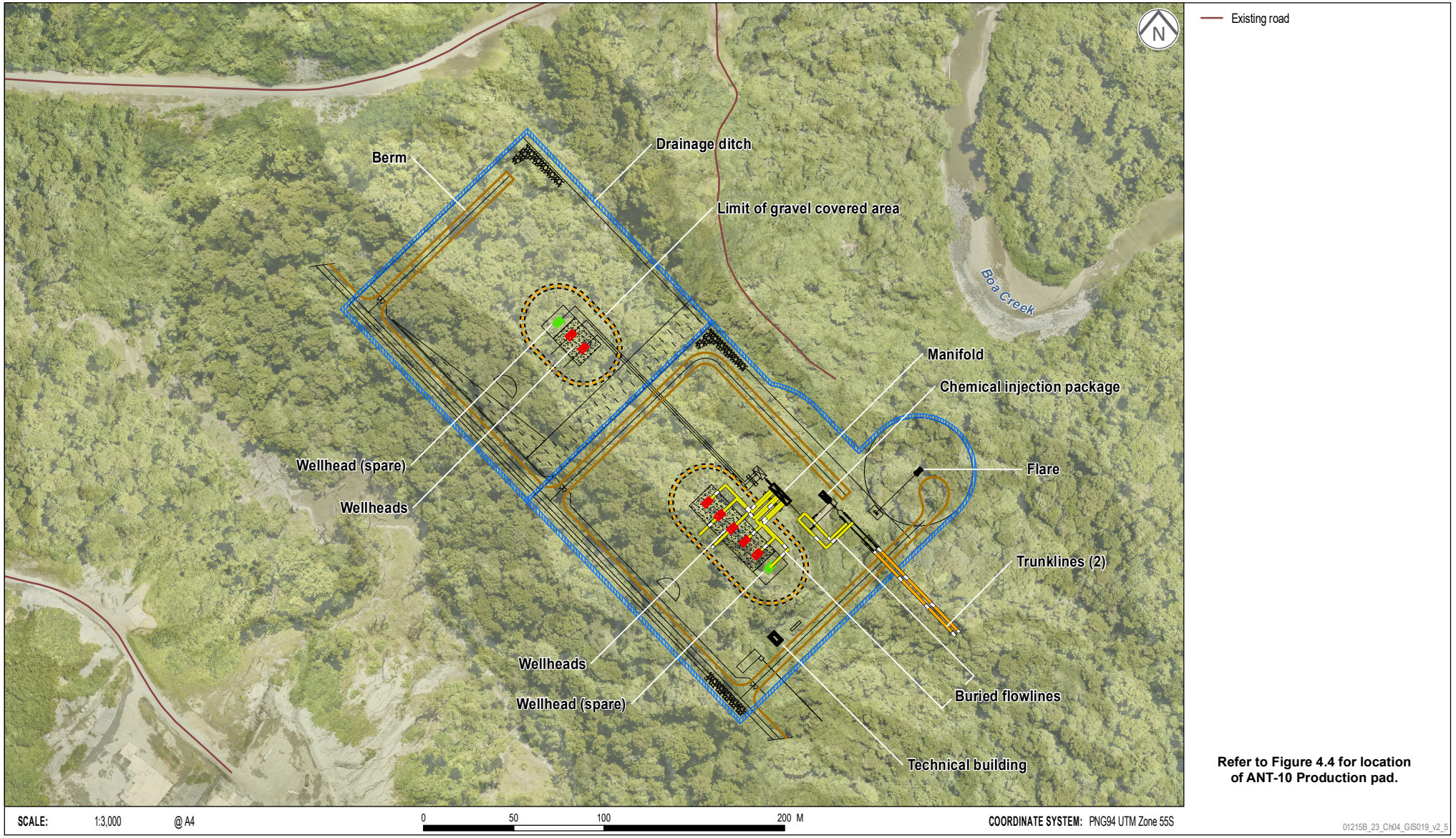
4.11.3.2 Inspection and Maintenance

Pipeline inspection and maintenance will be performed in alignment with an inspection and maintenance program that will be developed during FEED. Routine ground or aerial patrols will be undertaken to monitor and manage tree regrowth and soil erosion. Routine visual inspection from helicopters or fixed-wing aircraft will be used to monitor for threats to pipeline integrity, which could include slope instability or vandalism. Pipeline valve stations will be visited for routine inspections.

ANTELOPE PRODUCTION WELLPAD LAYOUT

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FIGURE 4.25



Ground and aerial markers with distance indicators will be installed along the pipeline route to aid in maintenance and possible emergency response. Pigs will be passed through the pipelines at programed intervals to internally test the pipeline wall integrity. All pipelines will be equipped with pig launchers and receivers to enable such tests. A pig is a pipeline inspection and gauging device that is introduced into a pipeline periodically to inspect the pipeline wall condition. The pig is introduced into the pipeline using a pig launcher, an oversized section of pipe that can be shut off from the rest of the pipe. The pig is introduced into the launcher, the launcher is closed, and the pig propelled along the pipeline by the fluid or gas transported by the pipeline. The pig receiver is a similar device to the pig launcher and is used to extract the pig. Pigs can be used to clean pipelines by scraping the inside of the pipeline. The pigs used for the Project are essentially only for inspection and are not expected to be required for cleaning. Pipeline scrapping is not expected to be required and if it is, it will be infrequent.

Full-time workers or contractors based at the CPF will be trained in, and will have responsibility for, pipeline inspection and maintenance, including vegetation maintenance and erosion control.

The offshore pipeline will be subject to routine external surveys to confirm a stable position on the seabed. The initial and pre-lay surveys will identify any seabed processes that could pose a risk to the pipeline, which in turn, will determine the appropriate long-term inspection frequency.

4.11.4 Operating and Maintaining the Camps

Camps will be maintained and operated to meet safety, hygiene, public amenity, hazardous materials, environmental and pollution control requirements. Solid and liquid waste will be managed as part of the waste management plan (see Section 4.8.5).

4.11.5 Cleaner Production and Energy Balance

The greatest Project energy demand is estimated to be from the various electrically-driven pumps and compressors at the CPF that will provide power to the CPF, the wellpads and the Logistics Base. Raw gas will fuel the gas turbines to generate power rather than importing another fuel, or engaging an independent or third-party provider.

Several measures have been considered in the design to maximize energy efficiency:

- Hot water has been selected as the most appropriate heating medium.
- Waste-heat recovery units will be installed on the power gas turbines to supply part of the amine reboiler heating requirements.
- A free-flow gas export scheme has been selected for the initial production phase to reduce energy use (versus compression).
- Heat from hot processes or exhaust streams will be recovered to reduce system loads.
- Buildings will be insulated, where practicable.
- Energy-efficient glass and shade windows from the sun will be installed, where practicable.

TOTAL's General Specification, Sustainable Development: Environmental Requirements for Project Design and E&P Activities (GS EP ENV 001) requires 'Minimization of GHG emissions and optimization of energy efficiency shall be considered in the selection of the development scheme and main equipment.'. Energy efficiency opportunities will be under continual review during Project design, construction and operations, e.g., opportunities to pre-cool using heat recovery to a process stream requiring heating.

4.12 Decommissioning

Decommissioning requirements (see Chapter 19) will be further developed during FEED and shall address:

- Decommissioning and disposal options for all equipment and materials, including products used and wastes generated on site.
- Removing condensate from pipelines, and removing surface equipment and facilities.
- Decommissioning wells, flowlines, trunklines, and land-based and marine export pipelines.
- Reinstating land.

Decommissioning details will be developed as operations progress and finalized before the completion of field life. They will be based on standards and technology that exist at that time and will include details on decommissioning activities and arrangements for post-decommissioning monitoring.

Project decommissioning activities will comply with regulatory requirements that are in force at the time of decommissioning, and good industry practice.

4.12.1 Decommissioning the Wellpads and CPF

Individual equipment items may be decommissioned when they have no further foreseeable use. Each production facility will be decommissioned when its operation is no longer economically viable. Reuse and recycling alternatives will be considered where feasible, for example:

- Removal for use by another operator or for sale to a third party.
- Rerouting hydrocarbons to a future development.
- Access to the plant and equipment by new production fields.

If none of the above options is feasible, the facilities or parts thereof and associated infrastructure will be decommissioned. Larger equipment may require a life-cycle analysis of the energy, safety, resource and environmental implications of recovery and recycling alternatives.

The overall aim is to leave Project land, and any equipment and infrastructure that remains, in a condition that allows it to be transferred with minimal residual liabilities or risk to public safety and the environment.

The nominal life of the proposed facilities is approximately 25 years (and so it is reasonable to expect that the decommissioning procedures and regulatory requirements of the day will reflect advances in technology, new information, different monetary and other values for land and materials, and the PNG Government's decision on whether and if so how to exercise its rights to take over or transfer facilities and licenses. Commitments to specific procedures now cannot anticipate future circumstances. For present purposes, therefore, the Project will follow the regulatory requirements and good industry practice at the time of decommissioning.

Project decommissioning, when it ultimately occurs, is expected to entail the following:

- Plugging of development wells.
- Dismantling above-ground facilities, including production equipment and wellheads.
- Removing dismantled equipment.
- Site clearance, cleanup and rehabilitation.

The hydrocarbon product to be processed will be predominantly gaseous, therefore soil contamination is not expected to be an issue; however, in addition to regular liquid hydrocarbon management (e.g., clean-up following diesel fuel spills), a soil contamination survey will be conducted to determine if there has been any inadvertent and unobserved contamination. If any contamination is discovered, a soil remediation program will be instigated, consistent with good industry practice environmental management, as it stands at the time of decommissioning.

Decommissioning plans will be prepared for facilities before decommissioning work starts and will be documented in the Project's environmental and social management plan (see Chapter 19, Environmental Management, Monitoring and Reporting).

4.12.2 Decommissioning the Pipelines

Decommissioning the pipelines includes decommissioning flowlines, trunklines and the export pipelines. The nominal life of the proposed pipelines is approximately 25 years for the trunklines, water injection line and Elk flowline, and 40 years for the export pipelines.

4.12.2.1 Decommissioning the Flowlines, Trunklines and Onshore Export Pipelines

Pipeline decommissioning requires the flowlines, trunklines and onshore export pipelines to be made safe by:

- Purging and flaring gas or condensate from within the flowlines, trunklines and onshore export pipelines, which will then be filled with water and capped.
- Removing all above-ground components of mainline valves.

The flowlines, trunklines and onshore export pipelines will remain buried, because recovering the pipe would be extensive and create unnecessary environmental disturbance. If the pipelines were still in an operable condition, their cathodic protection facilities would be retained to prevent corrosion and to leave open the option of recommissioning at some future date should additional gas reserves in the region become economic in the future.

4.12.2.2 Decommissioning the Offshore Export Pipelines

Current standard international industry practice for decommissioning offshore pipelines is to:

- Flush the pipeline of hydrocarbon liquids and vapor.
- Flood the pipeline with seawater.
- Seal the pipeline openings with mechanical plugs.
- Abandon all offshore sections of pipeline in place to minimize the disturbance of removal.
- Update navigation charts for offshore areas to show what remains, in consultation with the NMSA.

It is possible that these current practices will have changed by the time the pipeline comes to the end of its service life and, if so, decommissioning will follow industry practice of the day.

4.12.3 Decommissioning the Infrastructure

All logistical infrastructure not required for operational purposes may be dismantled and removed for sale, recycling or disposal, or may be retained by the State or provincial governments as public assets. Infrastructure retained for operation will be decommissioned, and sites stabilized and rehabilitated as for the production facilities described in Section 4.12.1. This is expected to include the Logistics Base, Purari Airstrip, roads, and pumping stations (for water abstraction).

Quarries and spoil disposal areas will be rendered safe, stabilized and rehabilitated to a self-sustaining state.

4.13 Project Summary

4.13.1 Project Activities

A summary of the Project phases and the activities or drivers of change that are likely to cause impacts are provided in Table 4.15. These are the phases and activities upon which the impact assessment presented in Chapters 11 to 18 are based.

Table 4.15 – Summary of Project Activities

Project Activity	Project Phase			
	EW*	C#	O†	D**
Land acquisition.	✓	✓		
Logistics and transport including equipment, plant, construction materials, supplies and workforce (barging, Purari Airstrip and Project roads).	✓	✓	✓	✓
Vegetation clearing.	✓	✓		
Earthworks (including sidecasting, if required).	✓	✓		
Quarries.	✓	✓	✓	
Construction and operation of temporary construction camps (CPF, Herd Base, Ant-3 and pipe yard 4).	✓	✓		
Construction and operation of accommodation camps (CPF, Herd Base).		✓	✓	✓
Construction works (construction camps, wellpads, CPF, roads, Logistics Base).		✓		
Jetty construction (Logistics Base, access to pipe yards).		✓		
Drilling.		✓		
Dredging at the Logistics Base.		✓	✓	
Water extraction from the Purari River for water supply (including for hydrotesting).	✓	✓	✓	✓
Construction of water supply dams on Hou and Boa creeks.		✓		
Operation of fixed and mobile plant and equipment.	✓	✓	✓	✓
Fuel and energy consumption (including power generation).	✓	✓	✓	✓
Onshore pipeline construction (including associated infrastructure).		✓		
Offshore pipeline construction.		✓		
Disposal of pipeline hydrotest water.		✓		
Construction of pipeline watercourse crossings.		✓		
Construction, including trenching, of the Orokolo Bay export pipeline shore crossing.		✓		
Waste generation, storage and disposal.	✓	✓	✓	✓

Table 4.15 – Summary of Project Activities (cont'd)

Project Activity	Project Phase			
	EW*	C#	O†	D**
Construction and operation of landfills.		✓	✓	✓
Spoil disposal.		✓		
Waste incineration.		✓	✓	✓
Operation of wellpads.			✓	
CPF operations (gas processing).			✓	
Gas flaring.			✓	✓
Produced water and flue gas desulfurization liquid effluent disposal.			✓	
Acid gas injection.			✓	
Project facilities and camps lighting emissions.	✓	✓	✓	✓
Use of hazardous materials.	✓	✓	✓	✓
Discharge of surface runoff (roads, wellpads, CPF, pipeline ROWs).	✓	✓	✓	
Pipeline operations.			✓	
Pipeline maintenance (including maintenance of access roads).			✓	
Rehabilitation works.	✓	✓	✓	✓
Project employment and procurement.	✓	✓	✓	✓

Notes: * Preparatory works and early works. # Construction. † Operations. ** Decommissioning and closure. Activities will be dependent upon the decommissioning plan that will be developed; however, it is expected that there will some similarity with the activities identified for the other Project phases.

4.13.2 Disturbance Footprint

Table 4.16 and Figures 4.26 to 4.30 summarizes the estimated direct disturbance areas associated with Project facilities from north to south. The disturbance footprint area, due predominantly to vegetation clearance, is much smaller than the land requirements presented in Chapter 13, Table 13.6, as land requirements need to accommodate additional land uses such as safety/security exclusion zones and buffer areas around Project infrastructure, and contingencies for Project infrastructure location changes. The land required in addition to the disturbance footprint shall not have the forest cleared or be otherwise disturbed.

The Project design will be refined during FEED and detailed design, and the footprint may change, e.g., since the assessment was completed for the EIS, the ROW for the trunklines has been reduced from 49 to 40 m and spoil disposal areas for roads R5 and R7 have been reduced from 18.4 ha and 30.2 ha to 7 ha and 18.6 ha, respectively. The estimated direct disturbance areas and associated impact assessment are based on the larger values.

Table 4.16 – Project Facilities and Associated Direct Disturbance Areas

Project Facility	Estimated Total Area of Direct Disturbance (ha)	Does Project Facility Coincide with Existing Disturbance?
Wellpads		
ELK-10	2	Yes
ANT-10	5	No
ANT-11	2	Yes

Table 4.16 – Project Facilities and Associated Direct Disturbance Areas (cont'd)

Project Facility	Estimated Total Area of Direct Disturbance (ha)	Does Project Facility Coincide with Existing Disturbance?
Flowlines and Trunklines Construction ROW		
Elk flowline to ANT-10	24	Yes (for approximately 1.6 km)
Water injection/acid gas liquid effluent line ANT-10 to ANT-11	10	No
Flowlines and trunklines ROW from ANT-10 to CPF	136	No
Dam for water supply ELK-10, ANT-10	2	No
CPF		
CPF, including construction and operations accommodation camp	100	No
Export Pipeline Construction ROW		
Export onshore pipeline including HDD sites and valve stations	217	Yes
Infrastructure		
Herd Base quarries A, C and D, KM6 quarry and associated access	52	Quarry A - yes KM6, quarries C and D - no
Roads (R1, R2, R4, R5, R6, R7)	132	R1, R2 – no R4 (Herd Base to Quarry A), R5, R6, R7 (for approximately 1.6 km) – yes
Pipe yards (3)*, pipeline construction camps	19	Pipe yards 1, 4 – yes Pipe yards 2, 3 – no Pipeline construction camp - no
Logistics Base	7	No
Purari Airstrip extension and vegetation clearing for visual approach	103	Yes
Spoil disposal areas (25) and associated access	120	No
General landfills	5	No
TOTAL	**936**	

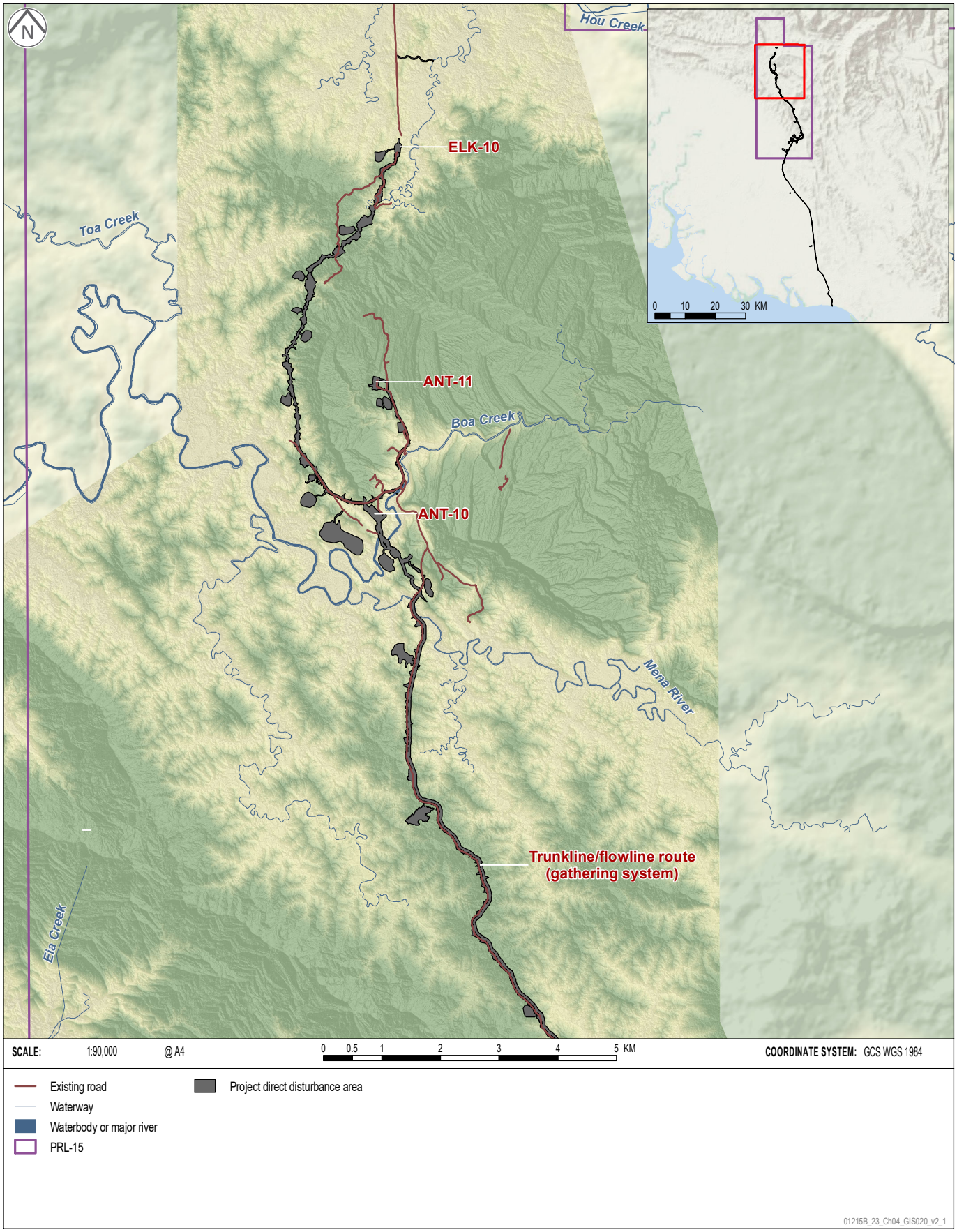
Note: * Pipe yard 1 and its associated accommodation camp are located within Herd Base.

Of the estimated direct disturbance area, approximately 190 ha (20%) uses existing disturbed areas and the onshore export pipeline route traverses 217 ha of degraded vegetation.

PROJECT DIRECT DISTURBANCE AREAS - 1

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FIGURE 4.26



PROJECT DIRECT DISTURBANCE AREAS - 2

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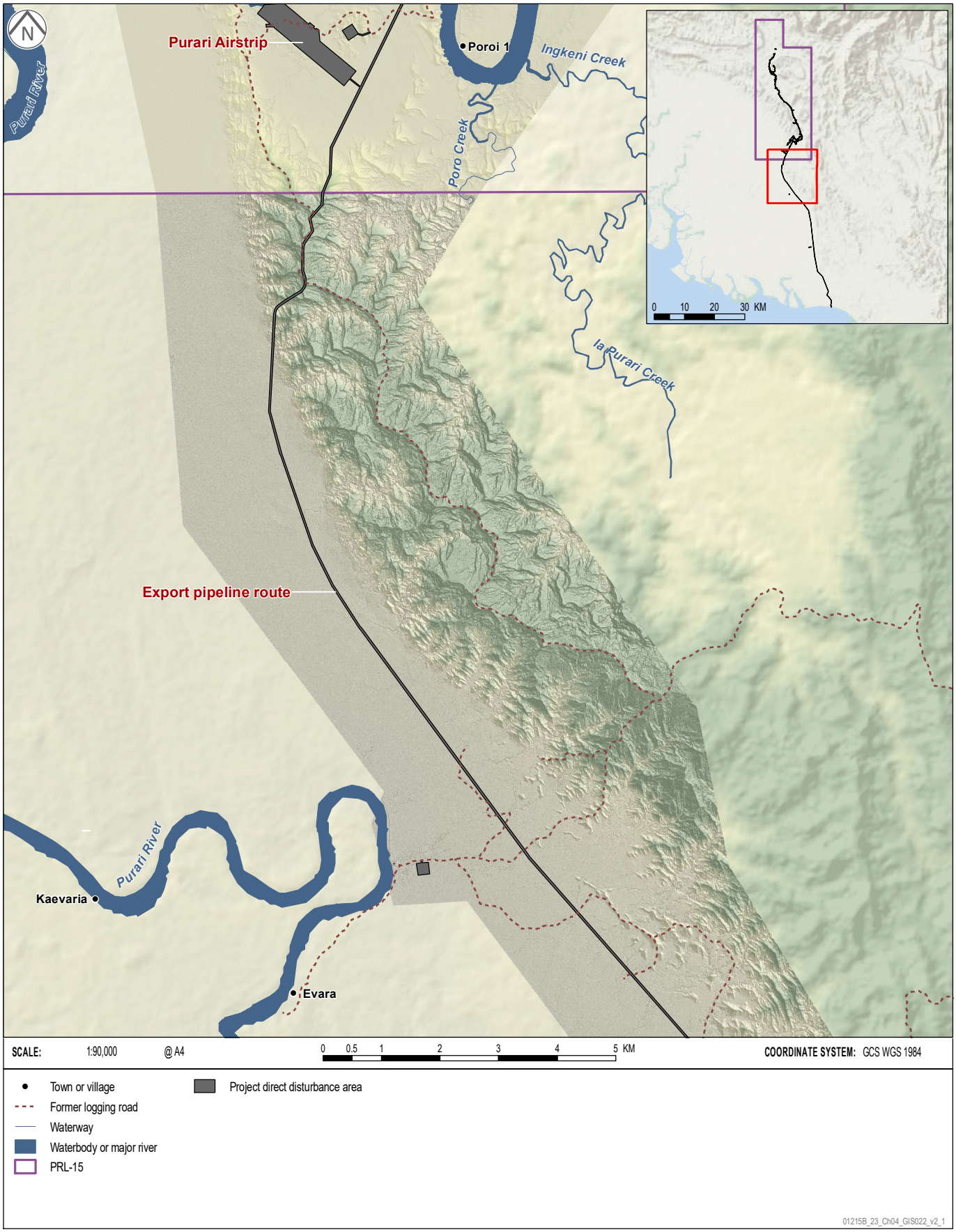
FIGURE 4.27



PROJECT DIRECT DISTURBANCE AREAS - 3

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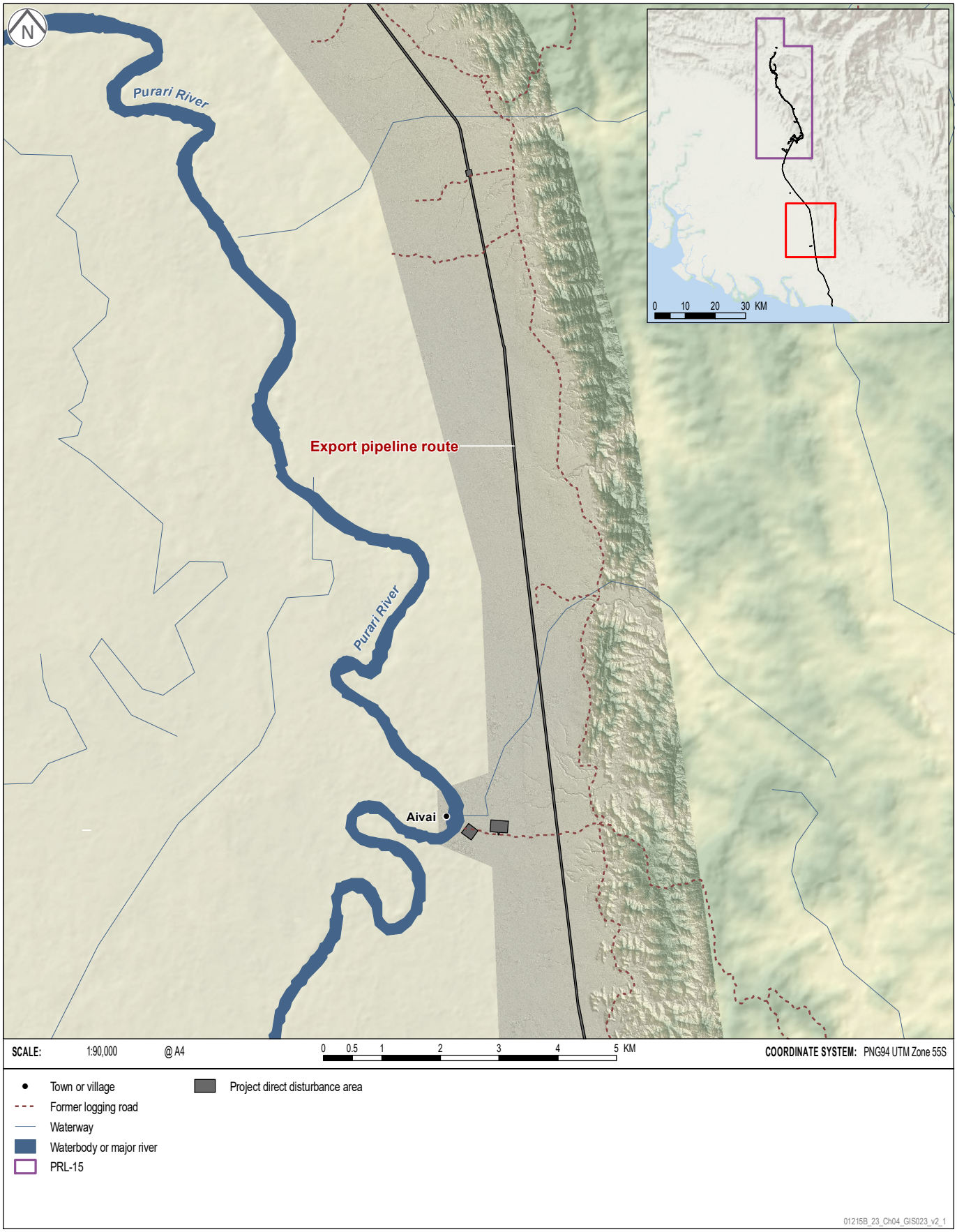
FIGURE 4.28



PROJECT DIRECT DISTURBANCE AREAS - 4

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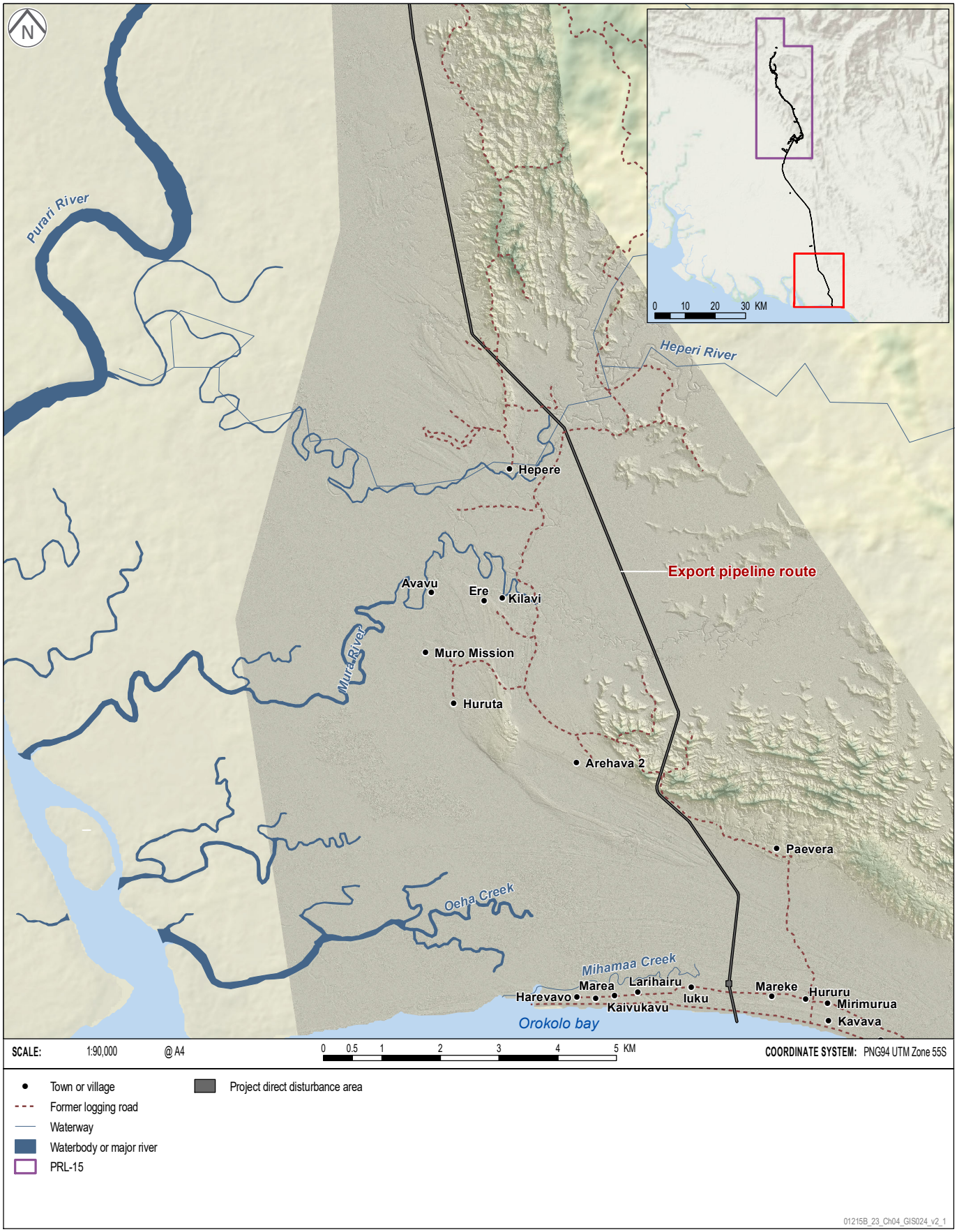
FIGURE 4.29



PROJECT DIRECT DISTURBANCE AREAS - 5

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FIGURE 4.30



4.13.3 Embedded Design Controls

Pre-Project design has followed the first two steps of the mitigation hierarchy (see Section 3.1.4.3) to anticipate and avoid, or where avoidance is impossible, to minimize adverse impacts through prudent infrastructure location and design.

Positioning Project infrastructure has included 'micro-siting' of wellpads and other facilities, and prudent routing of access roads and pipelines to avoid sensitive features, and physical and economic displacement where possible. In addition to the actual siting of facilities, the construction and design details have considered possible receptors, e.g., the footprint of individual facilities has been reduced as far as practicable and drainage systems have been designed to minimize the effects of runoff.

Table 4.17 summarizes the major embedded design controls already incorporated in the current pre-Project base case design, which are based on good international industry practice. Embedded design optimization will continue during FEED.

Additional mitigation for impacts remaining after embedded design and management measures have been applied but is insufficient to reduce an impact to an acceptable level has been identified and is presented in impact assessment Chapters 11 to 16.

Table 4.17 – Embedded Design Controls

No.	Discipline	Embedded Design Controls
ED001	Air quality	Vessels will comply with applicable International Maritime Organization requirements related to fuel to minimize related atmospheric emissions.
ED002	Air quality	The Project will design its plant to meet the applicable emission standards and relevant ambient air quality criteria beyond the proposed facility boundary.
ED003	Landform and soils; groundwater; surface water quality; freshwater and estuarine biodiversity; marine water quality; marine biodiversity; ecosystem services	Adopt standard industry practices to prevent and protect against soil/water contamination, due to Project activities, such as: ♦ Preparing hydrocarbon and chemical management procedures, as part of the Hazardous Materials Management Plan. ♦ Building infrastructure on impervious surfaces where required. ♦ Providing permanent fuel and chemical stores, and maintenance and refueling areas with secondary containment of an appropriate volume to prevent loss to the environment or mixing with incompatible materials. ♦ Installing interceptor pits or similar to collect contaminated surface water runoff and to treat it when required. ♦ Installing tanks above ground with impermeable liners and bunds around tanks. ♦ Regularly inspecting and maintaining containers, and storage and transfer infrastructure to prevent/control spills or leaks. ♦ Installing readily accessible spill kits and training personnel in their use. ♦ Appropriately treating and disposing of any accidentally contaminated soils.
ED004	Landform and soils; groundwater; surface water quality; ecosystem services	The drilling will be performed using water-based mud.
ED005	Landform and soils; groundwater; climate change; ecosystem services	Landfills will be designed to comply with TOTAL's general specification for landfills, and will be designed, located, constructed and operated in general accordance with the intent of the Code of Practice for Sanitary Landfill Sites (DEC, 2001) and other applicable standard industry practices.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED006	Landform and soils; freshwater and estuarine biodiversity; surface water; marine water quality; marine biodiversity; ecosystem services	Minimize chemical use and select chemicals considering the following criteria: ♦ Lowest toxicity, lowest bioaccumulation potential and highest biodegradation; ♦ Chemicals subject to bans or phase-outs.
ED007	Landform and soils; groundwater; surface water quality; freshwater and estuarine biodiversity; ecosystem services	Use low-pressure detection alarms to detect pipeline leaks.
ED008	Landform and soils; groundwater; surface water quality; freshwater and estuarine biodiversity; ecosystem services	Use fiber optic cable laid in the same trench to monitor pipelines. This cable will detect intrusions and ground movements.
ED009	Landform and soils; groundwater; freshwater and estuarine biodiversity; ecosystem services	Locate valve stations along the onshore pipeline route to isolate pipeline sections if a leak occurs.
ED010	Groundwater; ecosystem services	Wells are to be cased and cemented to insulate and protect any aquifers.
ED011	Groundwater; ecosystem services	The gathering and reinjection system, and wells and export pipeline system will be routinely inspected, monitored and maintained, as part of operational control (including pipeline instrumented pigging, well wellbore and reservoir pressure monitoring).
ED012	Groundwater; ecosystem services	Hydrotesting will be undertaken to confirm weld integrity.
ED013	All disciplines	Project design is based on a risk-management approach, considering geotechnical constraints (e.g., flooding, landslides risks, geohazards) and anticipating and avoiding, or where avoidance is not possible, minimizing environmental and social impacts (e.g., avoiding sensitive features, and physical and economic displacement, priority ecosystem services, and minimizing the Project footprint, land clearing and disturbance, emissions and discharges).
ED014	Hydrology, fluvial geomorphology and sediment processes; ecosystem services	All facilities and infrastructure will be constructed with surface-water drainage systems to reduce the potential for soil loss and degradation both on and off construction areas, and to limit soil erosion and discharge of sediment-laden water to local drainage lines and watercourses. Bridges and culverts will be designed to allow for high flow events following heavy rainfall and to replicate natural flow characteristics as far as practicable. The design is: ♦ To account for local rainfall conditions and catchment size of works areas. ♦ To allow avoiding unseasonal waterlogging ♦ To allow for rainfall events with an ARI of at least two years for temporary roads and up to 20 to 50 years for long-term major haulage routes as far as practicable.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED015	Surface water quality; ecosystem services	The CPF will have an open drain system to manage rainwater; the system will have three separate networks: OD1 = permanently hydrocarbon-contaminated drains. OD2 = accidentally hydrocarbon-contaminated drains. OD3 = hydrocarbon-free drains. Water from each system will be treated separately and discharged to the environment according to applicable limits.
ED016	Surface water quality; freshwater and estuarine biodiversity	All OD1 waters will undergo water treatment by a hydrocarbon/water separation system prior to discharge to the Purari River according to applicable standards. All OD2 waters and water from primary treatment will be sent to an observation basin and treated by the hydrocarbon/water separation system prior to release if required. Clean OD2 water will be discharged to the Purari River. Non-contaminated stormwater (OD3) will be disposed of by natural percolation and evaporation.
ED017	Surface Water Quality	All OD1 water from wellpads will be collected in a dedicated closed tank and transported to the CPF for treatment prior to being discharged.
ED018	Surface water quality	The produced water generated at the CPF will be injected back into the reservoir. Produced water will be retained in a tank with a capacity to contain five days of water production, as a backup if injection is unavailable.
ED019	Surface water quality; air quality; noise	All vehicles (including vessels and aircraft) and machinery, plant and equipment will be regularly maintained to the manufacturer's specifications; defective items will be removed from service until they are repaired.
ED020	Surface water quality; ecosystem services	Rainwater infiltration into hazardous materials storage areas will be prevented.
ED021	Surface water quality; freshwater and estuarine biodiversity	Requirements for hazardous material transfer, overfill protection, and alarms will be implemented, e.g.: ♦ Using dedicated fittings, pipes, and hoses specific to materials in tanks. ♦ Providing secondary containment, drip trays, etc. at connection points or other possible overflow points. ♦ Using dripless hose connections for vehicle tank and fixed connections with storage tanks. ♦ Providing automatic fill shutoff valves on storage tanks to prevent overfilling. ♦ Using piping connections with automatic overfill protection (float valve). ♦ Fitting tanks with high-level alarms with both audible and visible annunciation.
ED022	Marine water quality; marine biodiversity; ecosystem services	Ballast waters, liquid effluents and waste from vessels will be managed in accordance with the MARPOL 73/78 requirements.
ED023	Air quality, GHG	The flares will be used only for safety flaring in alignment with the TOTAL no routine flaring policy
ED024	Air quality	During the first years of production when it is not possible to dispose of acid gas by injection, a sulfur recovery unit will be installed and operated at the CPF to remove sulfur-containing compounds from the acid gas after it has passed through a thermal oxidizer.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED025	Air quality, GHG	Once the Elk reservoir has been depleted, acid gas removed from the raw gas using the AGRU will be disposed of by injecting it into the reservoir.
ED026	Air quality	The sulfur recovery unit will remain on standby, ready to operate at short notice so that acid gas can be treated if acid gas injection is not possible.
ED027	GHG	The Project will generate its own electricity during the operations phase, which will minimize the use of diesel and related emissions.
ED028	GHG	Waste-heat recovery units will be installed on the power gas turbines.
ED029	GHG	Buildings will be insulated, where practicable.
ED030	Noise; air quality; terrestrial biodiversity	Fixed or mobile equipment will be used and/or located considering people and other sensitive receptors.
ED031	Noise	Minimize noise from machinery, plant and equipment, as far as practicable.
ED032	Noise	The Project will design its plant and undertake activities to comply with the applicable noise criteria.
ED033	All disciplines	The Project will maintain a grievance mechanism that is legitimate, accessible, predictable, equitable, right-compatible, and transparent.
ED034	Community health and safety	Continue pre-employment and ongoing health and fitness to work screening and annual medical checks for all workers working for the Project in the Project area.
ED035	Community health and safety	Design Project infrastructure (including workforce accommodation) to minimize vector harborage (e.g., minimize pooling water, proper waste disposal) and human exposure (e.g., screening of doors and windows) to minimize spread of disease
ED036	Governance and leadership	Transparency and ethics: ♦ The Project operator will pay taxes and royalties in an accurate and timely manner during construction and operations phases. ♦ The Project operator reports within the PNG Extractive Industry Transparency Initiative (EITI) framework, the amounts of taxes and royalties paid within its operated perimeter.
ED037	Governance and leadership	Continue the employment and, when possible, the recruitment of women in community relations positions (community liaison officer, village liaison officer) to conduct specific engagements with women and ensure that women's views and interests are identified.
ED038	Conflict, law and order	The Project has been and will continue to work with security forces in alignment with Voluntary Principles on Security and Human Rights.
ED039	Landscape and visual amenity	Waste will be managed to reduce, reuse and recycle/ recover the waste where practicable. Waste management requirements (e.g., waste inventory, segregation, storage, disposal, tracking, recording) will be detailed during FEED.
ED040	Landform and soils; hydrology, fluvial geomorphology and sediment processes; surface water quality; freshwater and estuarine biodiversity	Hydrotest water discharges will be managed according to applicable requirements.

Table 4.17 – Embedded Design Controls (cont'd)

No.	Discipline	Embedded Design Controls
ED041	Marine biodiversity	The offshore pipelines will be buried with 1-m cover depth to the top when located in water shallower than 20 m.
ED042	Commercial traffic and transport	Liaise with NMSA to establish a safety exclusion zone around offshore export pipeline construction activities.
ED043	Commercial traffic and transport	Continue to work with relevant commercial operators to: ♦ Coordinate barge movements along the Purari River. ♦ Notify them, as required, of in river Project activities and the associated hazards.
ED044	Commercial traffic and transport	Inform NFA and commercial fishing fleets who operate in the vicinity of the offshore export pipeline route of construction activities, including timing of construction activities and the safety exclusion zone.

4.14 References

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