3. TRANSPORTING THE GAS

3.1 Overview

In PNG LNG Project terminology, ‘flowlines’ and ‘spinelines’ gather field production for initial processing. These flowlines connect wells to buried spinelines and are described in Chapter 2, Producing the Gas.

Pipelines are generally buried in their own right of way (ROW) and serviced by a roadway to provide access during construction. Spinelines may also have parallel access ways.

Pipelines are specifically designed, constructed and operated to perform reliably and safely, with low intervention, for a design life of 30 years.

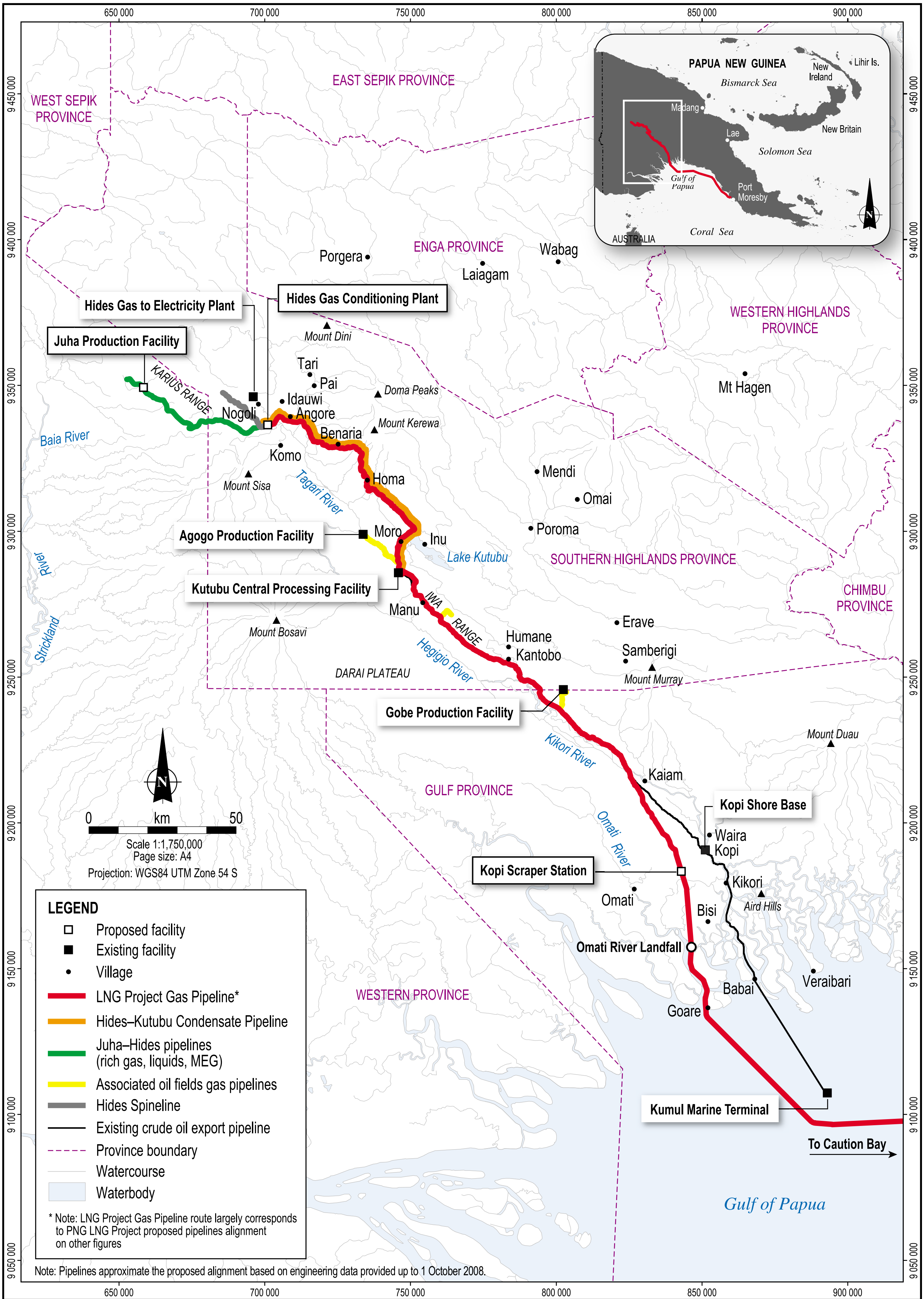
For the project, the principal pipelines will transport rich gas and liquids from the Juha Production Facility to the Hides Gas Conditioning Plant, condensate from the Hides Gas Conditioning Plant to the Kutubu Central Processing Facility and gas from the Hides Gas Conditioning Plant (and associated gas from the existing Kutubu, Gobe and Agogo oil field production facilities) to the LNG Facilities near Caution Bay. The specific individual pipelines (Figure 3.1) are:

- Onshore and offshore LNG Project Gas Pipeline (from the Hides Gas Conditioning Plant to the LNG Facilities at Caution Bay).
- Hides–Kutubu Condensate Pipeline.
- Juha–Hides Rich Gas Pipeline.
- Juha–Hides Liquids Pipeline.
- Hides–Juha MEG Pipeline.
- Gobe Gas Pipeline (Gobe Production Facility to the LNG Project Gas Pipeline).
- Agogo Gas Pipeline (Agogo Production Facility to the LNG Project Gas Pipeline).
- Kutubu Gas Pipeline (Kutubu Central Processing Facility to the LNG Project Gas Pipeline).

Figure 1.1 provides an overview of the proposed pipeline alignments while Figure 1.3, in the same chapter, shows the phases of the project in which the pipelines will be constructed.

This chapter describes the following information relating to the pipelines:

- Design criteria (Section 3.2, Pipeline Design Criteria).
- The pipeline routes and their respective design and construction issues and pipeline permanent design infrastructure (Section 3.3, Pipeline Descriptions and Routes).
- Construction (Sections 3.4, Constructing the Onshore Pipelines, 3.5, Constructing the Common Onshore Pipeline Infrastructure, and 3.6, Constructing the Offshore Pipeline).
- Functions and how the pipeline system will be operated (Section 3.7, Operating the Pipelines).
- Decommissioning (Section 3.8, Decommissioning the Pipelines).



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PNG LNG Project

PNG LNG Project pipelines

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3.2 Pipeline Design Criteria

ExxonMobil Engineering Practices System (EMEPS) will serve as the basis for project design specifications (as described in Section 2.1, Introduction).

Pipelines will have a nominal design life of approximately 30 years; however, they should be capable of remaining in service for some time thereafter.

All the onshore pipeline is principally designed to AS 2885.1 and will have an external corrosion coating of three-layer polyethylene, joint coating of urethane or urethane epoxy and a mechanical protection coating. They will be buried for most their length although there are exceptions which include valve stations, fault crossings, entries into the processing facilities and at the scraper station southwest of Kopi.

AS 2885.4/DNV OS-F101, Code for Submarine Pipeline Systems, is the principal design reference for the offshore pipeline. The offshore section of the gas pipeline will have an internal solvent-based epoxy coating, external protection by fusion-bonded epoxy inside a concrete weight coat and cathodic protection against galvanic corrosion.

The onshore and offshore pipeline designs will undergo further refinement during the detailed design stage of the project. A number of details will need to be optimised within the requirements of the standards.

Onshore, these refinements are expected to focus on:

- Seismic and geohazards such as geological faults, areas of slope instability, soil liquefaction or lateral spreading, karst topography and stream crossings.
- Corrosion hazards (i.e., soil resistivity implications for cathodic protection design).
- Flow assurance. This will be essentially an optimisation of the hydraulic design of the pipeline system to reliably transport fluids through each pipeline under a range of operating conditions.

Offshore, these refinements are expected to focus on:

- Wall thickness and concrete weight coating.
- Installation optimisations.

Pipeline preliminary design parameters are summarised in Table 3.1.

The pipelines, their routes and their associated facilities are described in the following section (Section 3.3, Pipeline Descriptions and Routes).

Table 3.1 Summary of pipeline preliminary design parameters

Parameter	LNG Project Gas Pipeline		Hides–Kutubu Condensate Pipeline	Juha–Hides Rich Gas Pipeline	Juha–Hides Liquids Pipeline	Hides–Juha MEG Pipeline	Gobe Gas Pipeline	Agogo Gas Pipeline	Kutubu Gas Pipeline
	Onshore	Offshore							
Length (Approximate)	284 km (Hides to Omati River Landfall)	407 km	104 km	55 km	55 km	55 km	10 km	19 km	2 km
Nominal diameter	DN 800 (32”), Hides to Kopi scraper station DN 850 (34”), Kopi scraper station to Omati River Landfall	DN 850 (34”)	DN 200 (8”)	DN 350 (14")	DN 200 (8")	DN 50 (2")	DN 250 (10”)	DN 250 (10”)	DN 200 (8”)
Maximum flowrate (capacity)	1,133 kSm^3/h (960 Mscfd)	1,133 kSm^3/h (960 Mscfd)	233 m^3/h (35,000 bbl/d)	295 kSm3/h (250 Mscfd)	110 m^3/h (17,000 bbl/d)	78 m^3/day (490 bbl/d)	76 kSm^3/h (65 Mscfd)	141 kSm^3/h (120 Mscfd)	218 kSm^3h (185 Mscfd)

3.3 Pipeline Descriptions and Routes

3.3.1 Pipeline Routing Standards

3.3.1.1 Onshore Pipeline Routing

Pipeline routing is an iterative analysis of alternatives featuring inputs from pipeline engineering, environmental, socio-economic, and safety and security in association with consideration of construction, schedule and costs factors. ExxonMobil standards provide direction for reducing impacts on land use from pipeline developments, in accordance with these standards, the broad criteria used to guide the selection of onshore pipeline routes in the project area have been as follows:

- Avoid the resettlement of individuals, households and communities to the maximum extent practicable.
- Locate pipeline routes as close to existing or previously used roads (public, logging and mining access ways, etc.) as practical in order to reduce land disturbance associated with project access road building and maintenance, to the extent practicable.
- Choose pipeline routes to preferentially traverse the following land use types to the extent practicable:
  - Land that is close or adjacent to existing infrastructure.
  - Land that has been disturbed by previous non-agricultural activities (e.g., petroleum development, timber harvesting, infrastructure construction [roads/power lines], mining).
  - Land that is currently being used for agricultural activities with a preference for plantation-type land rather than small scale gardens of individual landowners.
  - Land featuring pioneer and/or regrowth forest rather than primary tropical forest.

Additional site selection and routing criteria based on the varied physical ground conditions and environmental and social sensitivities and constraints encountered in the upstream project area are described in Section 6.1, Routing Process.

As will be described in Section 6.1.2, Evolution of the Route, the onshore pipeline has been routed on the basis of numerous and successive multi-disciplinary engineering, environmental, socio-economic and cultural heritages studies. To the extent practicable, the project onshore pipeline route reduces disturbance to new land between Kutubu and Kopi as a portion of the ROW will be somewhat parallel to the existing crude oil export pipeline route.

Elsewhere, in particular in the vicinity of Hides and Homa, existing public roads and four new access tracks will be used and upgraded to service the project. To the west of Kopi, where practicable, existing logging roads will be used and upgraded for access in this area in preference to clearing new areas of forest.

As the project advances through FEED and detailed design, a preconstruction pipeline route survey will be conducted on foot for detailed route design and selection at the local scale. As well as pipeline engineers and surveyors, the survey will include inputs from environmental and social teams, most notably biodiversity and cultural heritage, as well as specialists in revegetation for areas that may be difficult to regenerate following construction disturbance. (see also Section 2.4, Common Construction Activities).

3.3.1.2 Offshore Pipeline Routing

The offshore pipeline has been routed on the basis of a preliminary marine survey, which included geophysical characterisation, seabed sampling and underwater photography. The results of this survey have enabled a feasible route to be chosen (see Section 6.2.4, Section D: Omati River Landfall to LNG Facilities Site Landfall). In addition, information on existing resource use activities, such as prawn trawl fishing and subsistence fishing activities, gathered as part of the environmental assessment, has contributed to routing.

An additional data collected during a detailed marine survey, which was completed in December 2008, will be used to support detailed design.

3.3.2 LNG Project Gas Pipeline

3.3.2.1 Onshore Section

Overview

The onshore section of the LNG Project Gas Pipeline will be installed from the Hides Gas Conditioning Plant to the Omati River Landfall south of Kopi, where it will connect to the offshore section of the pipeline (see Figure 3.1). The onshore pipeline will be approximately 284 km long, and will be buried to a minimum depth of cover of 750 mm, increasing to 1,200 mm in or adjacent to roads. (See Chapter 6, Facilities and Pipelines Location Context, for a description of the pipeline routes and their broader environmental context.)

The onshore pipeline will have mainline valves at Kutubu, Gobe airfield and at the scraper station approximately 10 km southwest of Kopi (see Figure 3.1). The valves will be capable of being remotely operated from the control centre at the Hides Gas Conditioning Plant. Associated oil field gas will connect into the LNG Project Gas Pipeline from the Kutubu Central Processing Facility at the Kutubu mainline valve, and from the Gobe Production Facility at the Gobe mainline valve. From the Agogo Production Facility, there will be a buried tie-in with a manual isolation valve to the LNG Project Gas Pipeline. The gas tie-ins on the LNG Project Gas Pipeline will be installed during Phase 1 (see Section 1.2.1, Project Description) and designed to allow the connections to be made without interruption to the operation of the main pipeline. Further description of the pipeline mainline and check valves is given in Section 3.3.6.2, Mainline Valves and Check Valves.

A pig launcher will be installed at the Hides Gas Conditioning Plant, a pig receiver and launcher at the Kopi scraper station, and a pig receiver at the LNG Plant. Pigging of the DN-800 section will be from the Hides Gas Conditioning Plant to the Kopi scraper station, and pigging of the DN-850 section will be from the Kopi scraper station to the LNG Plant.

Pipeline Route and Crossings

This section describes the features of the onshore pipeline routes with specific design and installation requirements. Unless explicitly stated otherwise, all major (greater than 10 m wide with a water depth greater than 1 m deep) and minor (less than 10 m wide with a water depth less than 1 m deep) watercourses will be crossed using the open trench method.

Hides to Kutubu. The Hides-to-Kutubu pipelines will run cross-country from the Hides Gas Conditioning Plant, past the Angore gas field then to Kutubu Central Processing Facility. The pipeline will take a direct route through the sections where existing roads require switchbacks to maintain grade. Steep slopes, unstable volcanic soils and a landslide-prone terrain between the upper reaches of the Maruba River catchment and Homa present construction safety challenges and long-term stability hazards. The decision to by-pass Homa (see Section 6.2.2.2, Options Within the Eastern Route) reduces these risks considerably.

The LNG Project Gas Pipeline between Hides and Kutubu will share the same right of way (ROW) as the Hides–Kutubu Condensate Pipeline.

South of Ridge Camp, the Hides–Kutubu Condensate Pipeline will follow its own ROW southwest to the Kutubu Central Processing Facility (see Section 3.3.3, Hides–Kutubu Condensate Pipeline), while the LNG Project Gas Pipeline will bypass Kutubu to the southeast.

One major watercourse crossing, the Tagari River, will most likely be completed by horizontal directional drilling. There are 12 other major watercourse crossings and 56 minor watercourse crossings along this section of the route.

Existing above-ground flowlines will need to be crossed in two locations by trenching to standard depth. No special measures are required.

Kutubu to Omati River Landfall. The route of the onshore section of the LNG Project Gas Pipeline from the Kutubu Central Processing Facility to the Omati River Landfall will generally parallel the existing DN-500 (20-inch) crude oil export pipeline until it reaches the Kikori River crossing. Up to this point, the ROW will generally be formed by creating a separate, adjacent ROW formation. Numerous deviations from the existing ROW will be needed to accommodate the greater turning radius of the larger-diameter pipe and where terrain prevents the use of the existing ROW for the new pipeline or road upgrade deviations.

Where the existing crude oil export pipeline crosses the LNG Project Gas Pipeline the vertical separation between the two pipelines will not be less than 300 mm or as per AS 2885.1.

From the Kikori River crossing, north of Kaiam, the route will diverge from the existing crude oil export pipeline ROW and travel south-southeast and then directly south to the Omati River Landfall. This alignment shortens the route, avoids any further crossings of the crude oil export pipeline and crosses fewer watercourses.

There are approximately 13 major watercourse crossings and 82 minor watercourse crossings. Of the major watercourse crossings, three (the Mubi, Wah and Kikori rivers) are likely to be completed by horizontal directional drilling.

3.3.2.2 Offshore Section

Overview

The offshore section of the LNG Project Gas Pipeline will run from the Omati River Landfall downriver to the open sea, to the west and south of Kumul Marine Terminal and eastwards across the Gulf of Papua to Caution Bay approximately 20 km northwest of Port Moresby. Section 6.2.4, Section D: Omati River Landfall to LNG Facilities Site Landfall sets out the rationale for the route:

the most direct route from landfall to landfall in water deep enough to avoid undue effect from surface waves and which steers clear of the crude oil export infrastructure.

The offshore section will have a constant wall thickness but a variable concrete coating thickness (Table 3.2) sufficient to ensure pipeline stability throughout all phases of the design life. The pipeline will self bury in the seafloor for some of the route and will be installed in a trench in shallow water at both ends.

Table 3.2 Concrete coating thickness

Water Depth	Indicative Concrete Coating Thickness (mm)
Shallow-water segment in the Omati River and in the open seas in water depth less than 10 m	65 to 150
Between 10 m and 60 m water depth	120 to 150
Between 60 m water depth and the Caution Bay Landfall	65 to 120

Pipeline Route and Crossings

Section 6.2.4, Section D: Omati River Landfall to the LNG Facilities Site, describes the physical features of the route of the offshore section of the LNG Project Gas Pipeline. This section describes some of the route features that will affect pipeline design and construction.

Kumul Marine Terminal (Crude Oil Export Infrastructure). The pipeline route around the Kumul Marine Terminal (see Figure 3.1) avoids the following hazards:

- The DN-500 (20-inch) crude oil export pipeline to the Kumul Marine Terminal.
- The crude oil export tanker anchoring zone around the Kumul Marine Terminal single-point mooring.

Omati River Landfall. The northwestern end of the offshore pipeline needs to be protected from shipping traffic in the Omati River and in the shallow waters of the open sea immediately offshore. Initial information indicates that ships operating in this area have drafts up to 3 m and the pipeline will therefore be trenched until a water depth of between 5 and 10 m is reached.

Caution Bay Landfall. Figure 1.1 shows the offshore pipeline route into landfall at Caution Bay, which will generally lie on the seabed in water depths greater than the potential draft of LNG carriers but will be buried as the pipeline crosses the shipping channel and approaching shore in a back-filled, open-cut trench between landfall and a water depth of 15 m. Rock will be used to armour the surface of the backfilled trench where it intersects the shipping channel.

Further optimisation of the pipeline routing and the landfall location will be done during FEED and in detailed design.

Maximum Water Depth. Water depths less than approximately 100 m are within the capability of most pipelay barges laying large diameter lines and so the route avoids water much deeper than this.

Interface Between the Offshore Pipeline and the LNG Plant

The offshore pipeline will tie into a short section of onshore pipeline to the LNG Plant on the beach approximately 100 m landward of mean sea level (MSL) at the northern end of the LNG Facilities site. From there, the short (approximately 2 km long) onshore pipeline routes in a southeast direction to the pig receiver at the LNG Plant. Further optimisation during FEED and detailed design will precisely align the onshore pipeline from the tie-in point to the pig receiver at the LNG Plant.

3.3.3 Hides–Kutubu Condensate Pipeline

The proposed DN-200 (8-inch) Hides–Kutubu Condensate Pipeline will transport condensate from the Hides Gas Conditioning Plant to the Kutubu Central Processing Facility in the same ROW as the LNG Project Gas Pipeline. At a point south of Ridge Camp, the condensate pipeline runs in its own ROW 1 km southwest and then routes northwest to parallel the crude oil export pipeline for the final 1 km to the existing crude oil storage tanks at the Kutubu Central Processing Facility. This arrangement will be evaluated further during FEED and detailed design. There will be four mainline and two check valves on the condensate pipeline as described in Section 3.3.6.2, Mainline Valves and Check Valves.

3.3.4 Juha–Hides Rich Gas Pipeline, Juha–Hides Liquids Pipeline and Hides–Juha MEG Pipeline

3.3.4.1 Overview

The Juha–Hides Rich Gas Pipeline and Juha–Hides Liquids Pipeline are planned to be constructed in Phase 4 (see Section 1.2.1, Project Description) to transport rich gas and liquids, respectively, from the Juha Processing Facility to the Hides Gas Conditioning Plant. The Hides–Juha MEG Pipeline will be constructed at the same time to transport regenerated MEG with corrosion inhibitor from the Hides Gas Conditioning Plant to the Juha Production Facility for storage prior to injection into the Juha–Hides pipelines or transportation to the wellheads via the Juha MEG Pipeline.

3.3.4.2 Pipeline Route and Crossings

The route features that will affect pipeline design and construction are discussed below. (Section 6.2.1, Section A: Juha Production Facility to Hides Gas Conditioning Plant describes the features of the route of the Juha–Hides pipelines.)

The route from the Juha Production Facility to the Hides Gas Conditioning Plant will generally follow a southeasterly direction for some 20 km to the Baia River valley. Once out of the valley, there is a steady elevation rise to the Hides Gas Conditioning Plant. The route stays south of the Hides Ridge and joins the Hides gathering system ROW some 2 km from the Hides Gas Conditioning Plant.

This pipeline ROW has been provisionally routed along the construction logistics access route required to build the Juha Production Facility. Optimisation of the pipeline ROW for steeper grades will be performed when FEED and detailed design are conducted for Phase 4.

It is anticipated that there will be two open-cut major watercourse crossings and several open-cut minor watercourse crossings (less than 10 m wide).

3.3.5 Associated Oil Field Gas Pipelines

3.3.5.1 Overview

Gas from the associated oil fields of Kutubu, Gobe and Moran will be treated to the required quality specification and metered before being fed into the LNG Project Gas Pipeline. Pig launchers and receivers are planned to be installed on the Agogo (Moran oilfield), Kutubu and Gobe gas pipelines.

3.3.5.2 Pipeline Routes and Crossings

The Agogo Gas Pipeline will follow the road from the Agogo Production Facility for approximately 19 km to the intersection with the road from Moro to Kutubu, where it will tie-in to the LNG Project Gas Pipeline.

The Gobe Gas Pipeline will approximately parallel the road from the Gobe Production Facility for approximately 10 km to the intersection with the Kantobo to Kopi road, where it will tie-in at the LNG Project Gas Pipeline mainline valve.

The route for the Kutubu Gas Pipeline will be approximately 2 km long. The Kutubu tie-in will most likely be connected from the existing plant to the Kutubu mainline valve on the LNG Project Gas Pipeline.

There are no planned watercourse crossings. The pipelines from Agogo and Gobe will approximately parallel the existing roads that contain pipelines for oil production.

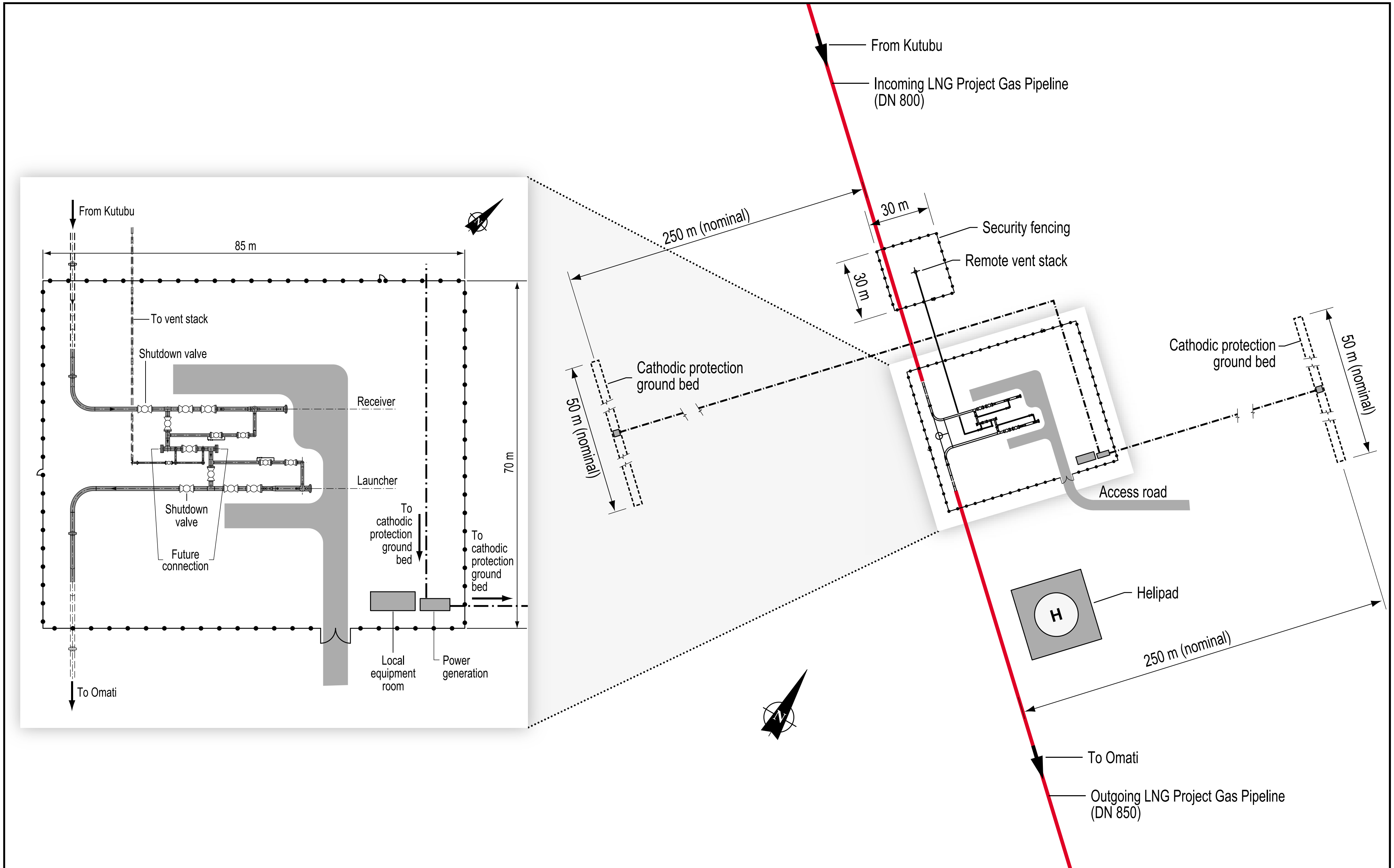
3.3.6 Common Onshore Pipeline Permanent Infrastructure

The onshore pipelines will require the following permanent infrastructure, which will be located either within, or adjacent to, the ROWs or at the processing and production facilities and final site selection for this infrastructure will be informed by preconstruction environmental and social surveys, notably biodiversity and archaeology (see Section 2.4, Common Construction Activities). This permanent infrastructure includes:

- Scraper station or pig launcher/receivers.
- Mainline valves and check valves.
- Blowdown vents.
- Cathodic protection impressed current facilities and test points.
- Communications facilities.
- Pipeline route marker signs.
- Compressor station.

3.3.6.1 Scraper Station

Typically, a scraper station has a pig launcher and receiver, valve assemblies and piping. Standard pigs clean the internal pipe wall while intelligent pigs provide a record of pipe wall thickness, detect dents, gouges or corrosion pitting and generally monitor the overall physical integrity of the pipeline. Pig launchers and receivers enable pigs to be inserted and retrieved respectively. Figure 3.2 shows a typical scraper station layout.



Job No: 1284	Esso Highlands Limited	Indicative Kopi scraper station layout	Figure No: 3.2
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The scraper station on the LNG Project Gas Pipeline (see Figure 3.2) will be located approximately 10 km southwest of Kopi (see Figure 3.1) at which point the pipeline diameter will increase from DN 800 (32") to DN 850 (34"). The scraper station requires a cleared area of approximately 0.6 ha.

Pig launchers and receivers will be located at the beginnings and ends of project pipelines.

3.3.6.2 Mainline Valves and Check Valves

Mainline valves enable sections of a pipeline to be isolated for maintenance or, in the event of a serious leak or rupture, to limit the amount of gas or liquid released. The mainline valves will be buried, with only the actuator and its associated equipment visible above ground. Mainline valves can be remotely controlled. Valve sites will have a security fence.

Check valves are simple mechanical devices that automatically prevent the contents of a pipeline from flowing backwards.

LNG Project Gas Pipeline (Onshore Section). This pipeline will require three mainline valves spaced at intervals of approximately 80 km along the LNG Project Gas Pipeline and provisionally located at Kutubu, Gobe airfield and at the Kopi scraper station. The final spacing will be a subject of risk assessment to be conducted during FEED and detailed design, which will consider the inventory of gas and the consequence of loss of integrity. These mainline valves will each comprise an actuated shutdown valve with a bypass containing isolation valves and a pipeline blowdown vent.

Hides–Kutubu Condensate Pipeline. Four mainline valves at approximately 20- to 25-km intervals will separate the pipeline into five segments and limit the volume of a potential spill from each segment to approximately 800 m^3. A check valve approximately 12 km downstream of the last mainline valve will provide additional protection within the Lake Kutubu catchment. This valve will be buried; however, a security fence to restrict access will be installed as necessary. The volume between the last mainline valve and the check valve will be approximately 360 m^3.

Juha–Hides Rich Gas and Liquids Pipelines and Hides–Juha MEG Pipeline. Two mainline valves located approximately 19 km and 44 km from Juha will segment the liquids line into three, so as to limit the maximum spill volume to 800 m^3. The valves will be controlled from the Hides Gas Conditioning Plant. The rich gas and MEG lines can be isolated at each end and will not require intermediate valves.

Hides Spineline and MEG Line, Angore Spinelines and Angore MEG Line, Juha Spinelines, Associated Oil Field Gas Pipelines, and LNG Project Gas Pipeline Offshore Section. The Hides Spineline (17 km long), Hides wellpad G to Hides wellpad E (7 km long), and MEG pipelines (24 km long), the Angore Spineline and Angore MEG Pipeline (9 km long), Juha Spinelines (7 km long) and the associated oil field gas pipelines will be able to be isolated at both ends but do not require intermediate mainline valves.

There are no mainline valves planned for the offshore section of the LNG Project Gas Pipeline.

3.3.6.3 Blowdown Vents

Blowdown vents evacuate the pipeline contents and allow piping to be depressurised prior to maintenance or in an emergency.

A manual blowdown vent system will be installed at the Hides Gas Conditioning Plant for the Hides Spineline. The Hides–Kutubu Condensate Pipeline will only have a blowdown vent installed at the Kutubu end, as the Hides Gas Conditioning Plant will not have sufficient liquids-handling capacity to allow venting there. Blowdown vents will be installed at the start and end of all other pipelines and at the Kopi scraper station on the LNG Project Gas Pipeline. Rich gas pipelines and gathering systems will be vented to facility flares. The blowdown vents on the LNG Project Gas Pipeline will vent to atmosphere.

3.3.6.4 Cathodic Protection Impressed Current Facilities

Cathodic protection impressed current facilities prevent corrosion of the pipe by keeping the pipeline at a negative electrical potential (less than 1 volt). Cathodic protection test points allow the effectiveness of the corrosion protection system to be monitored.

Cathodic protection facilities will be installed in 11 intermediate cathodic protection stations located along the pipelines. The test points will be installed at pipeline-to-pipeline crossings and at approximately 3-km intervals on all pipelines.

Sacrificial magnesium anodes will provide temporary cathodic protection of the pipelines during construction.

3.3.6.5 Communication Facilities

Control and communications facilities to activate valves will be located with the mainline valves. The existing communications towers of the crude oil export pipeline will be used by the project for this purpose.

3.3.6.6 Pipeline Marker Signs

Pipeline marker signs will be installed so that the public will be aware of pipeline location, to help avoid interference and to aid in maintenance and possible emergency response. The signs will be inter-visible, with separations of between several hundred metres and several tens of metres between markers. Pipeline marker signs will not be able to be used in swamp conditions. (Plate 3.1 shows a typical pipeline marker sign.)

3.3.6.7 Compressor Station

Pressure is required to move gas through a pipeline against the resistance of friction and gravity, and long pipelines may require one or more compressor stations, in order to keep the gas moving at the desired rate.

The project will rely initially on compression at Hides, Agogo, Gobe and Kutubu to maintain gas flow to the LNG Plant. Booster compression is identified as a possibility during Phase 3 of the project (see Section 1.2.1, Project Description). Site selection for the compressor station at Hides will be subject to the site selection criteria described in Section 6.1, Routing Constraints and

Plate 3.1
Typical pipeline marker sign

Plate 3.2
Example of a pipeline watercourse crossing with a shoo-fly road

Plate 3.3
Example of a pipeline laying spread

Criteria, and preconstruction environmental and social surveys as required (see Section 2.4, Common Construction Activities).

3.4 Constructing the Onshore Pipelines

This section describes the pipeline ROW design criteria, the construction program and how the project's onshore pipelines are planned to be constructed.

3.4.1 Right of Way Design Criteria and Standards

3.4.1.1 Right of Way Construction Preliminary Design Criteria

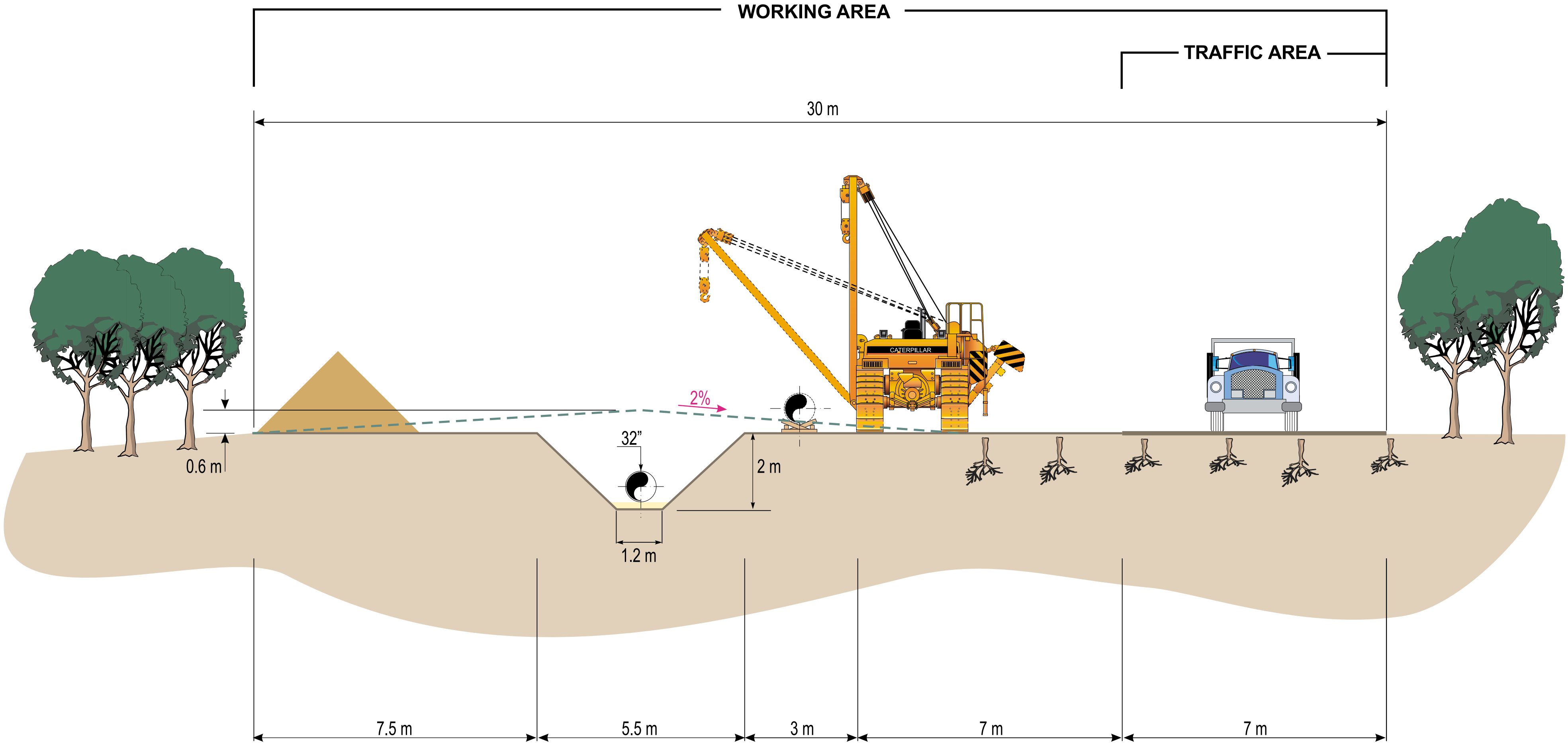
A construction easement, commonly referred to as a right of way (ROW), will be required for the pipelines. The pipeline construction ROW is the prepared surface from which the pipeline construction crew carry out the pipeline installation work. The standard pipeline ROW width for the PNG LNG Project will be 30 m, except on Hides Ridge where it will be narrowed to 18 m (see also Chapter 7, Project Substantiation (Alternatives Analysis). It should be noted that this width does not necessarily include all construction disturbance areas. This is explained further in Section 3.4.1.2, Right of Way Construction Disturbance Area.

The ROW will accommodate construction equipment, storage of trench spoil and (except in areas where a separate roadway will be used) vehicle traffic. The width of the ROW involves balancing a number of considerations, including safety, timing, and environmental and cost criteria, to ensure that construction activities can be performed safely with minimum risk of accident or injury to personnel or adverse impacts on the environment.

Figure 3.3 shows a typical cross-section of the ROW, and Table 3.3 shows the preliminary design criteria that will be applied to ROW construction.

Table 3.3 Preliminary design criteria for the pipeline ROW

Parameter	Preliminary Design Criteria
Curve radius, horizontal or vertical minimum	52 m, based on 46-m minimum cold bend radius (for DN 800 pipe).
Vertical Grades	
• Design intent	0 to 22%.
• Maximum	50% (for maximum length of 300 m per occurrence without relief).
• Minimum grades in box cut	0.5% (for drainage).
Parameter	Preliminary Design Criteria
ROW formation width:	
• Standard	30 m.
• Swamp • Hides Ridge	8 m* (raised ROW construction working platform width). 18 m.
Cross-fall on ROW formation	4% maximum.



Note: Not to scale.	PNG LNG	Job No: 1284	Esso Highlands Limited	Typical ROW cross-section
		File Name: 1284_09_F03.03_HB	PNG LNG Project	Figure No: 3.3

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Table 3.3 Preliminary design criteria for the pipeline ROW (cont'd)

Parameter	Preliminary Design Criteria
Batter Slopes	
Cut slopes:	
• Limestone	0.25H:1V to 0.5H:1V.
	Bench height 10 m maximum.
	Bench width 2 m minimum.
• Volcanic soils	1H:1V to 4H:1V (subject to seismic verification and geotechnical confirmation).
	Bench height 6 m maximum.
	Bench width 3 m minimum.
• Fill slopes	1.5H:1V.
Pavement (working platform and/or running surface)	Rock subgrade: 300 mm.
	Clay or volcanics subgrade: 500 mm.

* Pipeline trench excavated along one side beyond 8-m formation.

3.4.1.2 Right of Way Construction Disturbance Area

A wider construction ROW is required in certain locations and special conditions, such as the following:

- Watercourse crossings.
- Steep and/or mountainous terrain.
- Extremely undulating terrain (e.g., karst).
- Areas of excess rock.
- Horizontal directional drilling locations.
- Road crossings.
- Vehicle turnarounds.

The ROW construction disturbance area is the total area of land disturbed by pipeline construction, including the pipeline construction ROW, cut and fill slopes, areas affected by sidecast material in steep and mountainous terrain, and areas for horizontal directional drilling set up and execution. The pipeline construction disturbance area (which incorporates the ROW) may be up to 60 m wide in some steep areas due to bench cuts and up to 75 m wide at horizontal directional drilling sites (see Section 3.4.4, Special Construction).

'Shoo-fly roads' will be constructed in some locations. These are deviations from the ROW intended to allow construction vehicles to bypass the ROW in very steep areas, since pipelines can proceed on slopes greater than acceptable for vehicular traffic, and at some watercourse crossings. Shoo-fly roads will be approximately 8 m wide, may have a grade steeper than 16% and may incorporate a temporary bridge at watercourse crossings. An example of a shoo-fly road is shown in Plate 3.2.

3.4.1.3 Pipeline Operations Easement

Sections 76 and 111 of the Oil and Gas Act provide terms for operations of pipelines:

> 76(b) to carry on all operations, to execute all works and to do all other things that are necessary for or incidental to the construction and operation of the pipeline.
>
> 111(b) that is at a distance not exceeding 10m on either side of the pipeline.

During operations, the project will require a 15 m wide pipeline operations easement for aerial inspection, maintenance and possibly emergence response. Within this area, vegetation will be cut to low levels and trees with extensive root systems will not be allowed to grow. Also no permanent structures will be allowed. All of the remaining construction ROW will be allowed to regenerate or to return to its former use after construction activities cease.

3.4.2 Construction Environmental Safeguards

Standard industry practice will be implemented to reduce environmental effects during construction. The main measures are listed below. A summary of the mitigation and management measures adopted by the project, including those relevant to LNG Facilities construction, is given in Chapter 29, Summary of Mitigation and Management Commitments, and Chapter 30, Environmental Management, Monitoring and Reporting.

The main construction environmental safeguards include:

- **Sediment control and management.** The proposed management measures for sediment control including measures such as use of fabric silt fences downstream of flow paths and channels to intercept sediment generated during construction, are describes in relevant sections of Chapter 18, Environmental Impacts and Mitigation Measures: Upstream Facilities and Onshore Pipelines.
- **Management of other construction wastes:** The proposed management strategy for all project waste is described in Chapter 25, Waste Management.
- **Management of soil contamination:** The proposed management and mitigation measures strategy for soil contamination are described in Chapter 18. Environmental Impacts and Mitigation Measures: Upstream Facilities and Onshore Pipelines.
- **Management of hazard and risk:** Discussions of the projects proposed approach to managing safety, security and emergency response is described in Chapter 27, Environmental Hazard Assessment.
- **Management of emissions:** The proposed management and mitigation measures for air, noise and lighting emissions including dust control are described in Chapter 18, Environmental Impacts and Mitigation Measures: Upstream Facilities and Onshore Pipelines.
- **Management of traffic:** The proposed management of traffic both onsite and offsite is described in Chapter 23, Project-wide Socio-Cultural Impacts and Measures, and Chapter 27, Environmental Hazard Assessment.

- **Management of chemical and fuel storage:** The proposed approach to managing chemical and fuel storage is described in the relevant sections of Chapter 18, Environmental Impacts and Mitigation Measures: Upstream Facilities and Onshore Pipelines, and in particular Sections 18.3 to 18.6 referring to protection of ground and surface water resources.
- **Environmental monitoring:** The proposed environmental management and monitoring is described in Chapter 30, Environmental Management, Monitoring and Reporting, while a summary of management commitments framework is given in Chapter 29, Summary of Mitigation and Management Commitments.

3.4.3 Onshore Pipeline Construction Activities

3.4.3.1 Mobilisation

The construction of the onshore pipelines between Hides and the Omati River Landfall is expected to begin 12 months after contract award and is expected to take 18 to 24 months. The construction schedule requires road access and new ROW formations to be established ahead of pipelaying.

The Kutubu and Gobe gas pipelines will then be constructed. (The pipelines from Hides to the Juha Production Facility, Agogo Gas Pipeline and pipelines from South East Hedinia to the Kutubu Central Processing Facility will be constructed later during Phases 4 and 5, respectively (see Section 1.2.1, Project Description).)

The onshore pipeline contractor is expected to divide the installation into four spreads for the Phase 1 pipeline construction:

- Spineline and gathering lines at Hides.
- Mainline pipelines (normal construction).
- Mainline pipelines (special construction), i.e., steep or narrow areas, roadway crossings, and watercourse crossings.
- Mainline pipelines (swamp construction), i.e., the final 15 km to the Omati River Landfall.

Each of these spreads will require different equipment and different labour mixes and will yield different pipelaying rates. Plate 3.3 shows an example of a pipeline laying spread.

The average production rate for pipelaying during Phase 1 is estimated at around 500 m per calendar day. Mainline sections are expected to range between 300 to 750 m per day. Pipelaying rates in areas of difficult soils and topography are estimated to average 50 m per day and are likely to occur on Hides Ridge and the sections between Kutubu to Moro, Homa to Idauwi and the Moro to Ai’io River where two pipeline route deviations were considered (see Section 6.2.3.1, Moro to the Ai’io River). These rates have been reduced for scheduling purposes to account for the effects of inclement weather, challenging terrain and construction adjacent to the existing operating crude oil export pipeline.

Efficient progress relies on the ability to receive regular deliveries of line pipe and to lay the pipe in a sustained and consistent routine. The pipeline construction crews workforce will therefore only be able to be mobilised after the following prerequisites have been met:

- Roadways, bridges and culverts are sufficiently complete to safely support work.
- Sufficient line pipe has been stockpiled along the route.
- Facilities for accommodation and fuel supply have been established.

The line pipe (34”, 32”, 22” and 8” in 12-m or 18-m sections) is expected to be transported by ship to an anchorage offshore from Kopi, from which point lighters will take the pipe to Kopi for customs clearance. (The option also exists to offload pipe at Lae for onward transport by truck via the Highlands Highway to Hides or Moro (see Chapter 5, Project Logistics, for details of project logistics)).

The line pipe will be unloaded at the Kopi wharf directly onto trucks for transport to one of 11 pipe laydown areas (one at Kopi, and the other 10 adjacent to the construction camps or at other sites near the ROW). An example of a laydown area is shown in Plate 3.4.

Line pipe will require weight coating for swamp sections, at stream crossings and where the water table might flood the trench. Pipe will be weight-coated either before shipment to Papua New Guinea or possibly at a concrete coating plant at Kopi. A mobile concrete plant may also be used.

Pipeline construction operations will most likely start near Kopi and Gobe and head north towards Kutubu, preferably at the beginning of the drier season.

3.4.3.2 Pipeline Construction Sequence

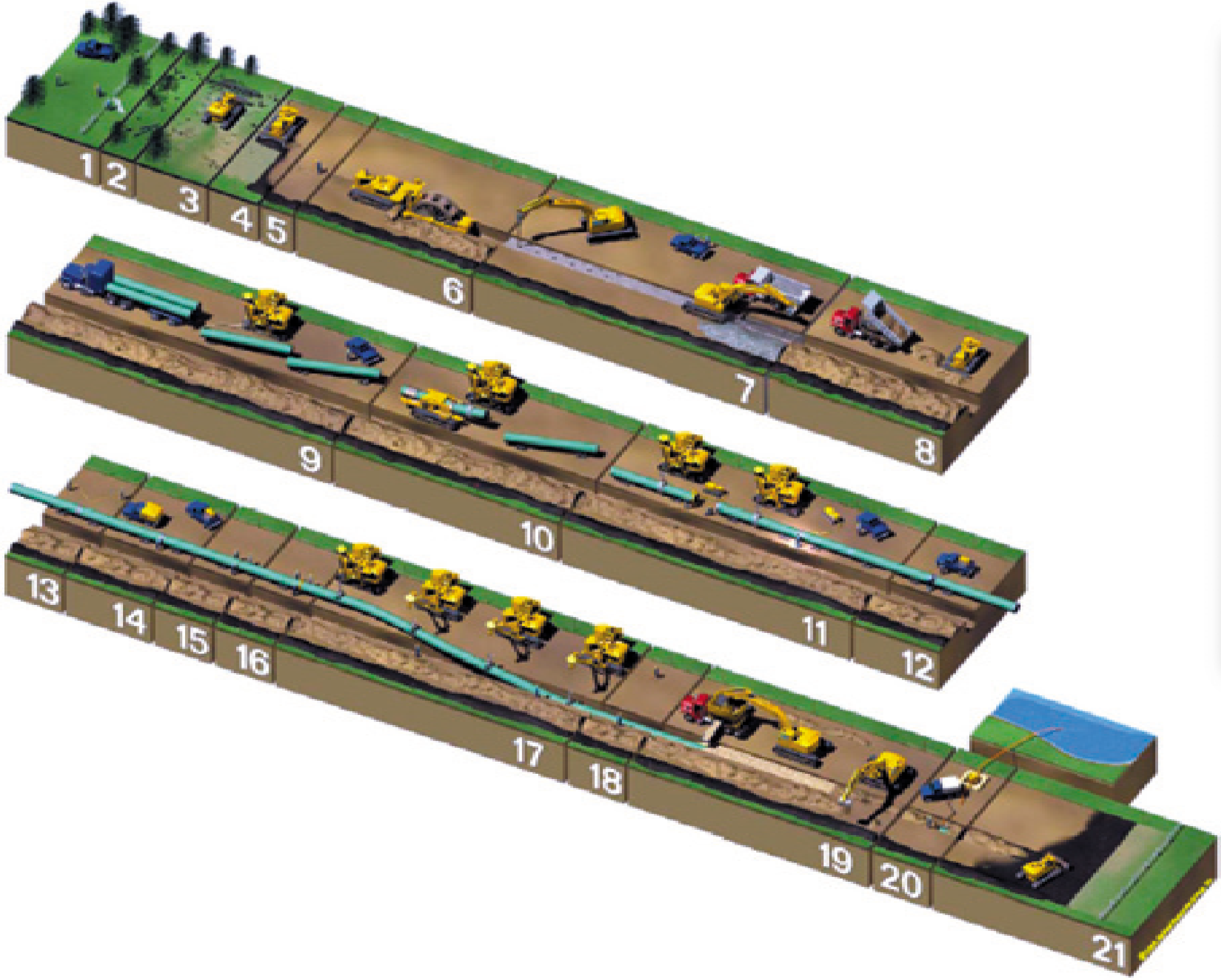
Figure 3.4 illustrates a typical pipeline construction sequence on land. The construction activities are numbered to correspond to the description below.

Construction of the pipelines and spinelines will typically involve:

- ROW survey, environmental and social clearance surveys (see Section 2.4, Common Construction Activities), clearing and grading (activities 1 to 3).
- ROW stripping and trench excavation (activities 4 to 8).
- Pipe transport, stringing, welding, bending and non-destructive examination (NDE) (activities 9 to 14).
- Pipeline joint coating and inspection (activities 15 and 16).
- Pipe lowering-in, tie-in and backfilling, and hydrostatic testing (activities 17 to 20).
- ROW reinstatement and installation of cathodic protection (activities 20 and 21).

Pipeline construction in special circumstances is discussed in Section 3.4.4, Special Construction. Testing and commissioning of the pipelines are discussed in Section 3.4.6, Pipeline Cleaning, Gauging and Testing**.**

Contractors will be required to develop a project-specific safety plan and to perform risk assessments for various activities, including excavations. Site-specific security measures will be considered and appropriately applied at excavation sites. These measures will include security



1	Survey and pegging
2	Clearing
3	Grading
4	Soil stripping
5	Pegging centreline of trench
6	Trenching (wheel ditcher)
7	Trenching (rock)
8	Padding trench bottom
9	Transport and stringing pipe
10	Bending pipe
11	Line-up initial weld
12	Final weld
13	As-built footage
14	X-ray inspection weld repair
15	Pipeline coating
16	Pipeline inspection
17	Lowering pipe into trench
18	As-built survey
19	Padding, backfill, grading
20	Hydrostatic testing
21	Rehabilitation and clean-up

PNG LNG	Job No: 1284	Esso Highlands Limited	Typical onshore pipeline construction sequence	Figure No: 3.4
	File Name: 1284_09_F03.04_HB	PNG LNG Project		

Plate 3.4
Example of a laydown area

Plate 3.5
Roadway or ROW grading,
showing soil stockpiles at the right

Plate 3.6
Example of pipe bending

(watchmen), active dewatering, provision of a physical barrier, community awareness programs and signage as appropriate.

ROW Survey, Environmental Preconstruction Surveys, Clearing and Grading

In addition to the common survey activities described in Section 2.4.2, Surveying, survey pegs will mark the pipeline centreline, changes in wall thickness, ROW boundaries and intersection points with other infrastructure, such as the crude oil export pipeline. The existing crude oil export pipeline will be identified and marked where nearby to ensure that construction activity maintains a safe separation distance.

For the ROW, preconstruction environmental and social surveys will have identified sensitive biodiversity and cultural sites and/or constraints that may require further mitigative actions i.e., local scale and sensitive features close to the ROW requiring avoidance at the time of pipeline construction. During pipeline construction, an environmental and social clearance survey will locate and mark constraints on the ground to ensure that construction activity and workforce crews avoid these areas.

Clearing will include removal of above ground vegetation and rocks to the side of the ROW. Any trees and large shrub debris requiring removal will be felled and stockpiled alongside the ROW. Where practicable, timber cleared will be used during construction including as material for bridge construction and supporting access in swampy areas. After pipeline construction, landowners will be permitted to use the timber for construction material and firewood as they desire.

Smaller vegetation moved to the side of the ROW will be conserved where practicable for reuse after construction to spread over the ROW to assist with erosion control, serve as mulch, and provide a ready source of seed for natural revegetation.

Grading of the ROWs will involve progressive clearing of topsoil, where practicable, which will be either used immediately as fill, stockpiled in spoil areas along the roadways (Plate 3.5) or sidecast in steep areas. Where it is stockpiled for later use, topsoil stockpiles will be stabilised, and erosion control measures implemented in accordance with the project’s erosion and sediment control management plan (see Chapter 30, Environmental Management, Monitoring and Reporting). Topsoil will be respread over the final surfaces of any areas along the roadways or ROWs that are designated for rehabilitation to support regrowth (see Section 3.4.5, ROW Reinstatement and Rehabilitation) or will be left in place to revegetate naturally.

Following grading, crushed limestone may be placed in areas used by construction equipment.

ROW Stripping and Trench Excavation

The pipeline trench will be centred on a line usually about 10 m from one side of the 30-m-wide ROW. This provides an approximate 10 m width for storing topsoil and trench spoil and a working area of 20 m for construction equipment and pipe.

The pipeline trenches will be excavated using a range of specialised equipment, including wheel ditchers or excavators in softer ground and rock saws in limestone or other hard material where proximity to the existing crude oil export pipeline precludes drilling and blasting.

The trench will be excavated to a sufficient depth to give a minimum depth of cover above the pipe in accordance wit the requirements of AS2885.1. The project minimum depths of cover to suit varying conditions are:

- 750 mm for gas pipelines in standard conditions.
- 900 mm for high vapour pressure or dense phase fluid pipelines.
- 1,200 mm for pipelines under roadways.

The depth of cover over the pipe will be increased at 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 by use of rock jacket or similar type of protection.

The length of the open trench will typically not exceed 10 km along the ROW. Access across the open trench will be provided to allow for people and animals to cross safely, and there will be ramps in open trenches to assist egress.

Pipe Transport, Stringing, Bending, Welding and Radiography

When the trench has been excavated, the line pipe will be delivered to the working spread by tractor-trailer trucks. The pipe will be unloaded and strung end to end alongside the trench using sidebooms and other equipment.

A hydraulic pipe-bending machine will bend the pipe to conform with the topography or to facilitate lateral changes in direction. Pipe may be ‘cold bent’ or roped (using the natural flexibility of the pipe) in the field, or factory induction bends may be used. Plate 3.6 shows an example of pipe bending. Pipe diameter, length and wall thickness are variables that may limit the radius of curvature of a cold field bend (reducing the angle that may be pulled from a pipe length). Factory induction bends can achieve much tighter radii and will be used where cold bends are not appropriate. The welding crews will clean and align the pipe ends and clamp them into place, then weld them into sections of pipeline (called strings) up to 1 km long. The welding crews clean and align the pipe ends and complete a number of welding passes. An example of pipeline stringing and welding is shown in Plate 3.7.

Each weld will be wire-brushed to remove weld spatter and inspected visually and by non-destructive testing methods (such as X-ray) for faults. Unsatisfactory welds will be repaired or cut out and rewelded by a repair crew and tested again until acceptable.

Valves and pipe fittings will be installed as welding proceeds.

Pipe Coating and Inspection

A coating will be applied to the external surface of all pipe to protect the steel from corrosion when it is buried or submerged. In addition, concrete weight-coating will be applied to pipe intended for swamp and underwater installation, and ‘rockjacketing’ (a flexible, concrete coating) will be applied to pipe intended for installation in rocky terrain.

During the corrosion-coating process at the pipe-coating plant, pipe lengths will be passed through a mild acid solution to clean the steel and then dried, heated and abraded to produce a surface profile for the coating. The corrosion coating will be sprayed, rolled or extruded onto the pipe, and the pipe will be cooled and checked for coating defects prior to stockpiling.

Plate 3.7
Example of pipeline spread stringing and welding pipe

Plate 3.8
Example of a pipeline watercourse crossing

Plate 3.9
Typical horizontal directional drilling rig

A pipe-coating plant typically requires an area of flat land up to 10 ha to accommodate line pipe stockpiles, the coating plant and administrative facilities. If required, the plant will be located on Motukea Island and operated to conform to government regulations and legislation concerning occupational health and safety and environmental requirements, including appropriate safeguards to contain spills and avoid ground contamination.

At the pipeline construction site, the joints of each accepted weld will be cleaned, grit-blasted, then heated and coated against corrosion by liquid urethane or urethane epoxy. The coating is cured, then wrapped in a protective pipe wrap and inspected visually and with a high-voltage holiday detector for coating defects, which if present, will then be repaired.

Pipeline Lowering-in, Tie-in and Backfilling

Lowering-in refers to the placement of the pipestrings into the trench by side-boom tractors as they gradually move along the ROW. The side-booms require enough distance from the trench line to place the pipeline into the trench without touching the trench wall.

The pipeline will be lowered into the trench by side-boom tractors with slings made to reduce coating damage. Specialised tie-in crews will then join the pipeline strings together. Tie-ins will mainly be carried out in the trench by lifting each end of the strings. Once in the trench, pipe may be padded with sand or soil where necessary to protect its coating during backfill operations.

Cathodic protection test point leads and a fibre-optic cable for project communications will be installed at this point. Where pipelines are located within a road easement, marker tape bearing the words ‘Buried High Pressure Gas Pipeline’ will be placed on top of the pipeline.

Prior to lowering-in the pipe, it may be necessary to dewater the trench (e.g., in areas of high watertable or after rain). Any such water will be pumped out of the trench and discharged to land through a filter medium and energy dissipaters in order to prevent erosion and sediment discharge, and in accordance with project environmental (waste discharge) permit requirements.

In areas of naturally high water table, the pipestring will be weight-coated. Trench breakers will be used along the trench where required to prevent shallow groundwater flow and erosion in the steeper sections.

An as-built survey will be undertaken before backfilling of the trench to provide GPS coordinates for the buried pipeline.

Spoil excavated during trenching will be backfilled into the trench and, except in swampy areas, will be compacted to leave at least a 300-mm crown above the trench to accommodate later settlement. The ROW will then be graded with excess backfill material spread over graded areas as necessary. Topsoil will be replaced over the final surfaces of any areas where it is needed to promote natural revegetation.

3.4.4 Special Construction

Specialist crews will be used to handle difficult or restricted-width areas where construction with the mainline equipment is not feasible. They will normally work ahead of the mainline crew.

3.4.4.1 Steep Terrain

Pipeline installation in steep areas (i.e., grades of 20% to 50%) will require equipment and methods specific to the situation, typically involving single- or double joint sections of pipe being winched into place then welded together from bell holes. For grades above 50%, installation is expected to require special equipment, such as a cable-based ‘skycrane’ system. These circumstances require a pipeline design based on a specific study of slope stability. On steep or unstable slopes, heavy machinery will be secured by a cable and winch system to prevent roll-overs and runaways.

Temporary shoo-fly roads will be constructed to allow construction equipment and pipeline transportation to bypass the steep areas.

As described in Section 7.10.1.3, ROW Formation Earthworks on Hides Ridge, optimisation of ROW and access road routing design on Hides Ridge has routed the ROW along the ridge and the access track parallel to the ROW on the side of the ridge to reduce the amount of sidecasting required. Similar optimisations will be investigated during FEED and detailed design to mitigate impacts from sidecasting in other steep terrain areas by:

- Examining the separation of the pipeline ROWs and roadways or access tracks to reduce sidecasting where practicable.
- Using fine particle size organic matting or a lattice framework or similar in karst areas to trap organic matter across sidecast where safe and practicable.
- Implementing sediment control measures downstream of sidecast material where safe and practicable.

Construction in steep terrain is particularly challenging in high-rainfall and seismically active areas such as PNG. Management and mitigation measures to minimise the potential adverse impacts to landforms and soils, water resources and hydrology and, water quality are described further in Sections 18.2.2, Mitigation and Management Measures, 18.4.3, Mitigation and Management Measures, and 18.5.3, Mitigation and Management Measures, respectively.

3.4.4.2 Relationship to the Crude Oil Export Pipeline

Due to the engineering constraints associated with differences in the curve radii of the two pipelines, at no point will the LNG Project Gas Pipeline share the same ROW as the crude oil export pipeline. Typically, there will be a separation between the two pipelines of at least 50 m although this will vary. Nevertheless, between Kutubu and Kopi, the southern logistics corridor for the project will use the crude oil export pipeline easement as its roadway. This is discussed further in Chapter 5, Project Logistics.

3.4.4.3 Installations In or Crossing of Roadway and Traffic Management

Sections of new pipeline in, or crossing, roadway will require specific plans to allow traffic to pass safely with minimum delay. Where the pipeline is to be installed in or across, roadway, road traffic will be managed by:

- Formation and implementation of traffic management procedures.
- Liaison and coordination with local traffic management service providers.

- Unhindered and safe vehicle access at nominated periods.
- Use of barricades, road plates, lights, traffic controllers etc. to facilitate the unhindered and safe passage of vehicles.

3.4.4.4 Watercourse Crossings

Watercourses will be crossed either by trenching (open-cut method) or by horizontal directional drilling as described below.

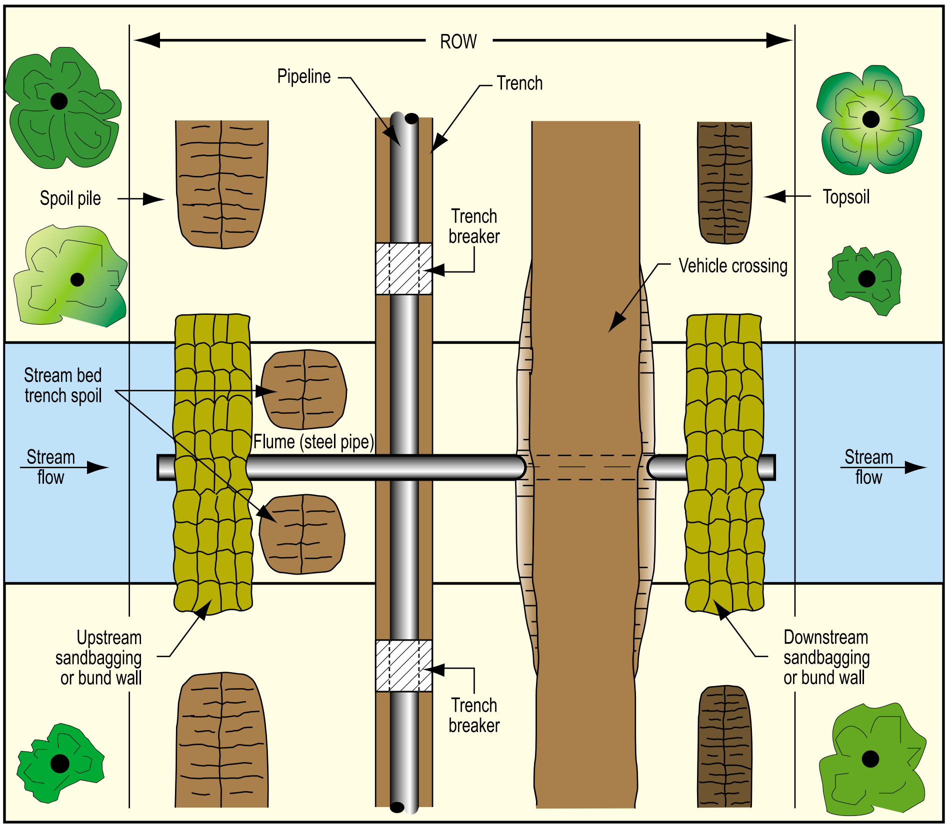
Trenched Watercourse Construction. Where circumstances permit, conventional trenching with culverts will be used as a first preference for watercourse crossings. The two main options differ in whether the pipeline crossing is dammed and pumped around the work area or, allowed to free-flow through a flume. These are shown in Figure 3.5. Plates 3.8 and 3.2 show further variations on the same theme. Watercourse crossings require additional workspace to accommodate the necessary handling and storage of excavated materials coming from the river bed and banks. At crossings the ROW width will widen from 30 m to 40 m for the last 50 m approaching both sides of the crossing. This additional width allows for the storage of the additional depth of material required to be excavated from the river bed and banks, and also additional width for crossing fabrication. Clearing at watercourse crossings will be determined by the watercourse size; typically it will be 2 ha over both sides of major watercourses and 1 ha for minor watercourses.

Environmental management aspects during construction and rehabilitation include:

- Construction, to the extent practicable, when water levels are low.
- Maintaining a vegetation buffer at watercourse crossings or reducing the width of the crossing disturbance.
- Pipe will be strung, welded, coated and tested ready for installation prior to watercourse trenching.
- A temporary vehicle crossing will be constructed for construction traffic across the river, with a flume pipe to allow continued watercourse flow. In some circumstances, such as a watercourse crossing at the foot of a steep slope, a shoo-fly road (see Plate 3.2) will also be constructed to connect with the temporary vehicle crossing.
- Erosion and sediment control measures will be installed as required. Figure 3.6 shows cross berms to prevent erosion into the watercourse.
- The trench through the watercourse will retain hard plugs at each bank until just prior to pipe installation.
- Pipe will be lowered in and backfilled immediately, and the original riverbed material will be 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 banks will generally be rehabilitated. Bank rehabilitation will comprise grading and recompaction of the excavated material, with matting or similar appropriate materials to retain steeper slopes while natural vegetation regrowth takes place. Where necessary, additional methods of bank stabilisation may be required (e.g., rock riprap). As shown in Figure 3.6, the watercourse crossing rehabilitation process comprises:

A

Typical open trench isolation crossing
(using flume pipe method)



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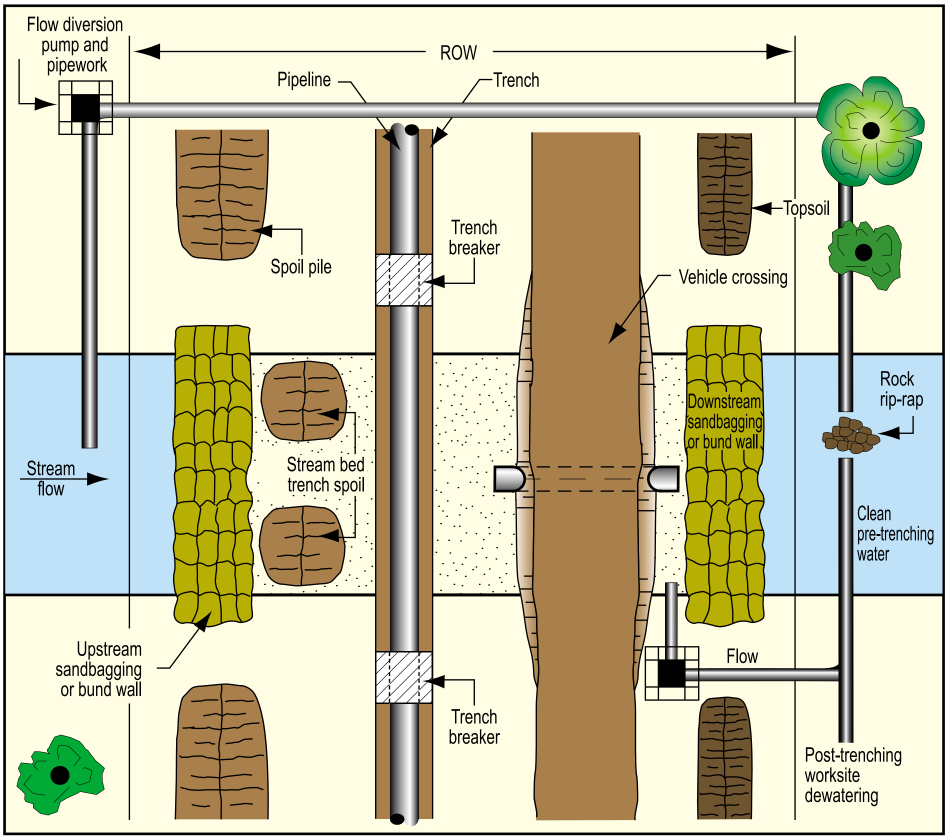
B

Typical open trench isolation crossing
(using dam and pump method)



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PNG LNG	Job No: 1284	Esso Highlands Limited	Pipeline watercourse crossing	Figure No: 3.5
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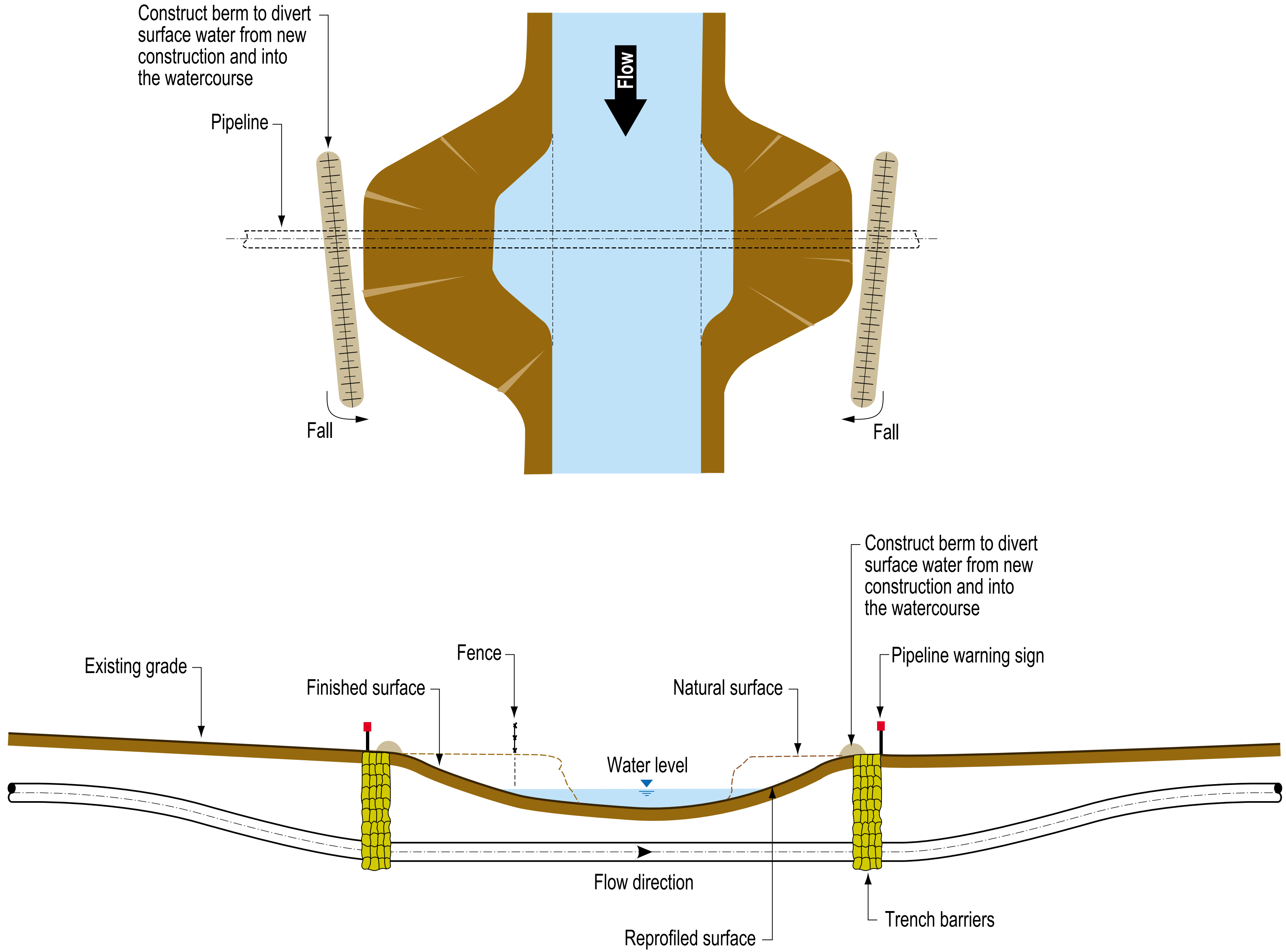

PNG LNG	Job No: 1284	Esso Highlands Limited	Pipeline watercourse crossing erosion and sediment control and rehabilitation
	File Name: 1284_09_F03.06_HB	PNG LNG Project	Figure No: 3.6

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– The grade of rehabilitated banks will generally be 1V:3H and will merge smoothly with adjoining undisturbed banks. The width of bank disturbance will be minimised.

– Watercourse beds will be rehabilitated to the preconstruction profile to the extent practicable to ensure smooth transitions to adjoining undisturbed beds upstream and downstream.

– Trench barriers and cross berms will be installed to divert surface water from new construction.

– Scour protection will be installed where required.

3.4.4.5 Horizontal Directional Drilling

Horizontal directional drilling methods will be used for watercourse crossings where the watercourse is considered too large and fast flowing for conventional trenching. Pipestrings installed by horizontal directional drilling will be hydrotested prior to pulling.

There are four locations where drilled crossings are being considered (Tagari, Mubi, Wah and Kikori rivers, however, trenching may be used as an alternative method if feasible). Areas of 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 watercourse, respectively. Figure 3.7 shows the main stages of pipe hole drilling construction and Figure 3.8 shows a typical horizontal directional drilling construction site. An example of a horizontal directional drilling site and rig are shown in Plate 3.9 and 3.10, respectively. A vegetation buffer set back from the watercourse will be maintained at horizontal directional drilling sites to reduce sedimentation impacts into the watercourse.

The crossing is established by first drilling a pilot hole, which is then progressively reamed out to the final diameter using a number of different sized reamers. If poor ground conditions require, a pre-welded casing is first pulled into the hole, followed by the tested pipestring (see Figure 3.8).

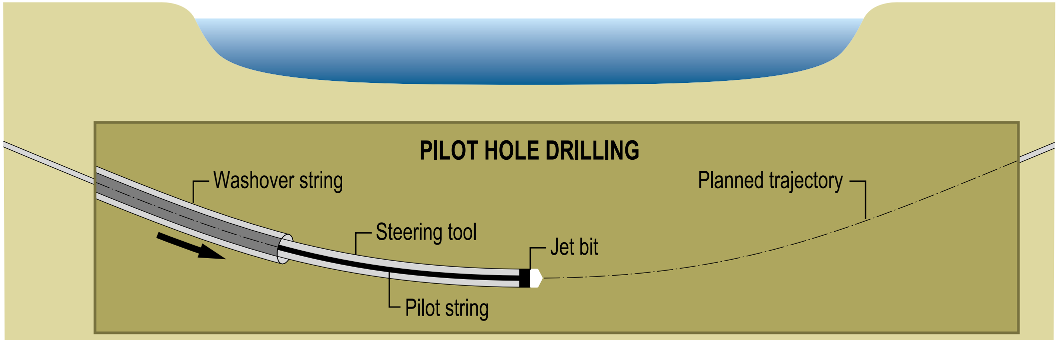
At the rig side the drilling muds and cuttings are contained within a closed system that recirculates the drill fluid through a holding tank (slurry mixing tank) while a series of shakers is used to separate the drill cuttings before recirculating drill fluid down the hole. At the rig and pipe sides of the horizontal directional drilling site, slurry containment pits contain the drilling mud. Drill cuttings are captured in cuttings settlement pits at the rig and pipe sides of the horizontal directional drilling site. Management procedures will be developed for the disposal of the drill cuttings and the water-based waste drilling fluids and will be detailed in the waste management plans.

3.4.4.6 Delta Swamp Construction

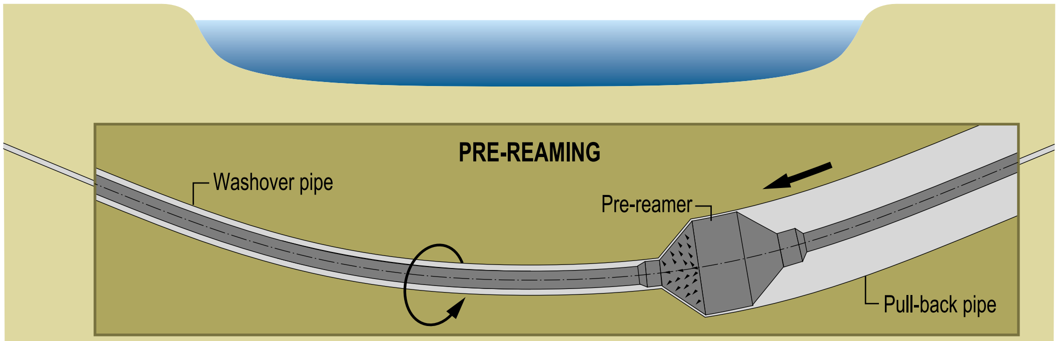
The first 13 km of the LNG Project Gas Pipeline ROW inland from the Omati River Landfall across low-lying swamp forest will be raised in order to provide a working platform from which to install the pipeline in an adjacent trench. The working bench is likely to be formed by a combination of soil, rock and, in some places, timber cleared from the ROW. Culverts will be used to allow drainage across the working bench. The formation will typically be 8 m wide, with an allowance for the pipeline trench to be excavated along one side.

The concrete-coated pipe will be strung out on the access track and welded into strings up to 1 km long and the joints coated. A vee-shaped trench 4 m wide at the surface and 1.5 m deep will be excavated 2 m from the access way either by excavators working from the formation or

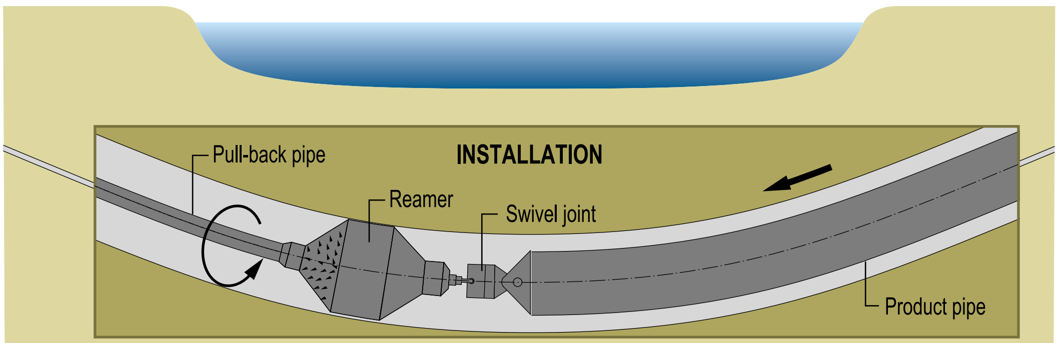
Drilling the profile



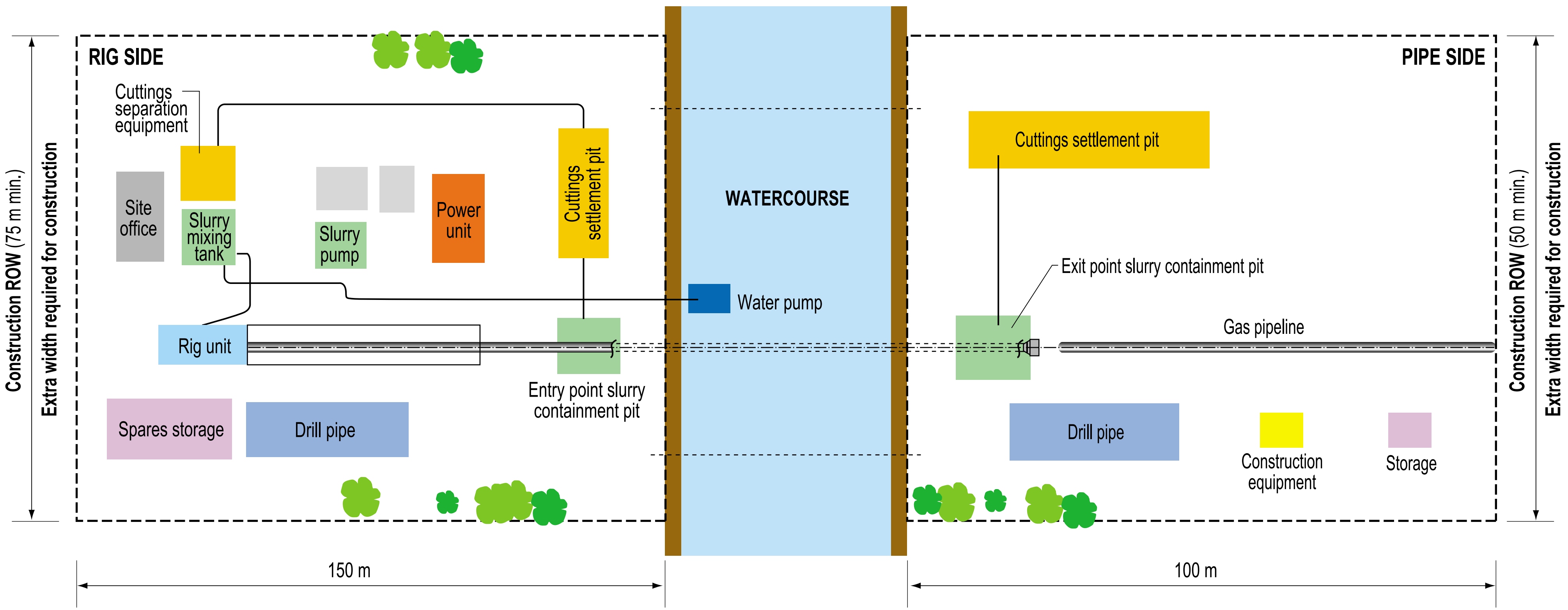
Enlarging the hole



Installing the pipe



PNG LNG	Job No: 1284	Esso Highlands Limited	Stages of horizontal directional drilling construction	Figure No: 3.7
	File Name: 1284_09_F03.07_HB	PNG LNG Project		



Note: Not to scale.	PNG LNG	Job No: 1284	Esso Highlands Limited
		File Name: 1284_09_F03.08_HB	PNG LNG Project

Typical horizontal directional drilling construction site

Figure No: 3.8

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Plate 3.10
Example of horizontal directional drilling

Plate 3.11
Example of a pipeline swamp crossing

Plate 3.12
Example of timber riprap installation
across a marsh area

mounted on a pontoon. The trench will be left full of water to improve the stability of the trench walls. The pipe will be lowered into the trench using side-boom tractors with tie-ins completed outside the trench. The trench will then be backfilled.

Alternate methods exist. The push/pull method involves welding the pipe sections at the edge of the swamp and launching the pipestring into a prepared trench. In some situations, a floating dredge and lay barge may also be used. There will be further optimisation of the pipelaying method as FEED progresses into detailed design.

An example of a pipeline swamp crossing is shown in Plate 3.11.

Post rehabilitation monitoring of vegetation will be undertaken in swamp areas between Kopi and Omati River to determine whether additional remediation is necessary to maintain hydraulic flows in the area of project works.

3.4.4.7 Above-ground Fault Crossings

Project pipelines will cross major faults that could, if movement along the fault plane occurred, damage or even rupture the pipeline. There are seven potentially active faults (15 splays) along the pipeline route between Hides and Kopi, which are shown in Figure 3.9. Pipelines will be designed to withstand earthquakes with a return frequency of 300 years, but with sufficient ductile strength to deform without rupturing under more severe shaking with a return frequency of 1,500 years. In order to minimise the risk of damage, in the vicinity of the fault, the pipeline will be constructed above ground and include an expansion loop sized to take into account predicted vertical movements of the fault.

3.4.4.8 Existing Pipelines

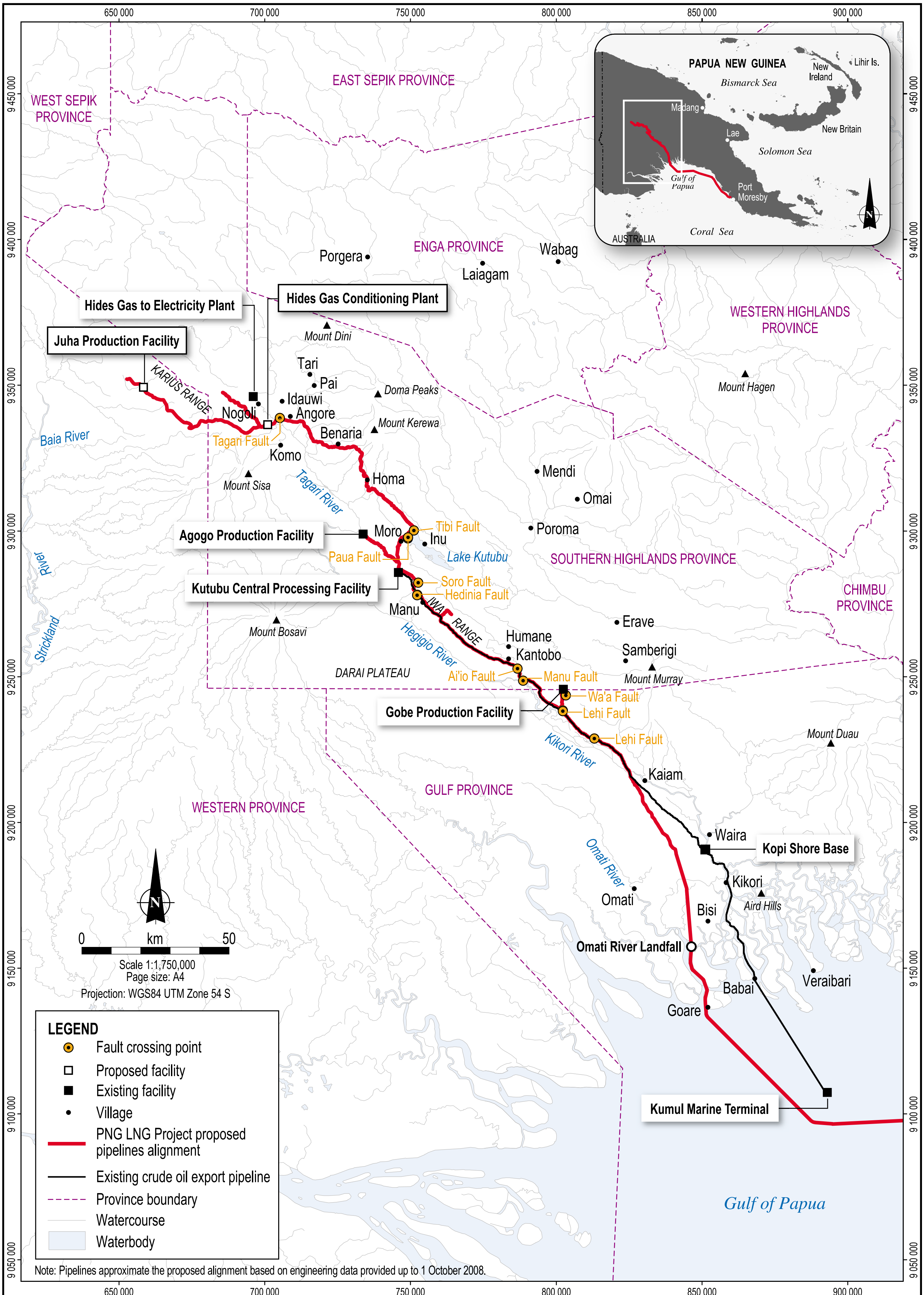
The LNG Project Gas Pipeline will cross below the crude oil export pipeline at 17 locations. The mainline crew will leave these crossings to a specialist crew. At these locations, the following construction management measures will apply:

- Written approval and advice from the operator of the existing pipeline regarding the proposed crossing.
- Application of safeguards to eliminate damage to the existing coated pipeline, e.g., hand (in lieu of mechanical) excavation within 1 m of the existing pipeline.
- Application, where necessary, or safeguards (such as the installation of temporary supports) to eliminate additional stresses on the existing pipeline caused by increasing its span length.
- Using tie-in to facilitate below pipeline crossing, where necessary.

3.4.5 ROW Reinstatement and Rehabilitation

ROW clean-up and rehabilitation will be undertaken progressively, immediately behind the backfilling crew. Clean-up will involve removal of all temporary infrastructure and machinery while rehabilitation aims to reinstate a stable, vegetated land surface for local plant species.

The ROW will be returned to its natural contour and grade to the extent practicable. The construction sites and equipment laydown areas will be ripped to relieve compaction if necessary.



PNG LNG	Date: 26.09.2008 MXD: PNG_LNG_Project_GIS.mxd File Name: 1284_09_F03.09_GIS_HB	Esso Highlands Limited PNG LNG Project	Fault crossing points	Figure No: 3.9

Topsoil, where stockpiled, will be replaced over areas to be revegetated and salvaged vegetation stockpiled on one side of the ROW will be spread over the surface to assist with erosion control and assist natural revegetation. Erosion and sediment control measures, such as diversion berms and sediment traps, will be put in place as appropriate to protect water quality and divert runoff away from potentially unstable rehabilitation areas. Where necessary, active works to re-establish vegetation will be undertaken and assessed during FEED and detailed design, in particular for areas that may be slow or difficult to regenerate naturally, difficult to stabilise or prone to erosion.

The success of rehabilitation will be monitored until a stable vegetation cover has been established and the soil profile stabilised (local seismicity notwithstanding). As part of the preparation of the EMP, detailed rehabilitation plans will be prepared to enhance protection for particularly sensitive areas due to topography (steep slopes, karst landforms, erosion-prone soils and watercourse crossings) and high ecological values. Mitigation measures that will be applied during construction and rehabilitation are further discussed in Section 18.1.2, Types of Impacts.

ROW rehabilitation activities are shown in Figure 3.4 and Plates 3.12 and 3.13.

Ground and aerial markers with kilometre indicators will be installed along the pipeline route to aid in aerial inspection, maintenance and possibly emergency response.

As discussed in Section 3.4.1, Right of Way Design Criteria and Standards, a 15-m-wide pipeline operations easement will be maintained so that trees with extensive root systems do not develop. All of the remaining construction ROW will be allowed to regenerate or to return to its former use after construction activities cease.

3.4.6 Pipeline Cleaning, Gauging and Testing

A specialised crew will carry out systems completion functions to ensure that the now-buried pipelines are clean and ready to enter service.

The pipeline pre-commissioning processes begin with the controlled water filling of the pipeline, using a train of pigs. The pipeline will then be cleaned, gauged, hydrotested, dewatered and dried. These processes are discussed below.

3.4.6.1 Water Source Selection and Water Treatment

Water is required for both the cleaning and hydrotest procedures and it is standard practice to protect the internal surface of the pipeline by the addition of a small amount of an oxygen scavenger and a biocide. It is considered unlikely that any additional corrosion inhibitor will be required:

- Oxygen-scavenger chemicals:
  - Reduce the dissolved oxygen in the water so as to prevent corrosion.
  - Create the anaerobic conditions in which the biocide can control sulfate-reducing bacteria.

  Commercial oxygen-scavenger chemicals include sodium sulfite, sodium bisulfite and ammonium bisulfite solutions, all of which oxidise to sulfate. The dosage rate will depend on the amount of dissolved oxygen in the water.

Plate 3.13
Example of a reinstated ROW

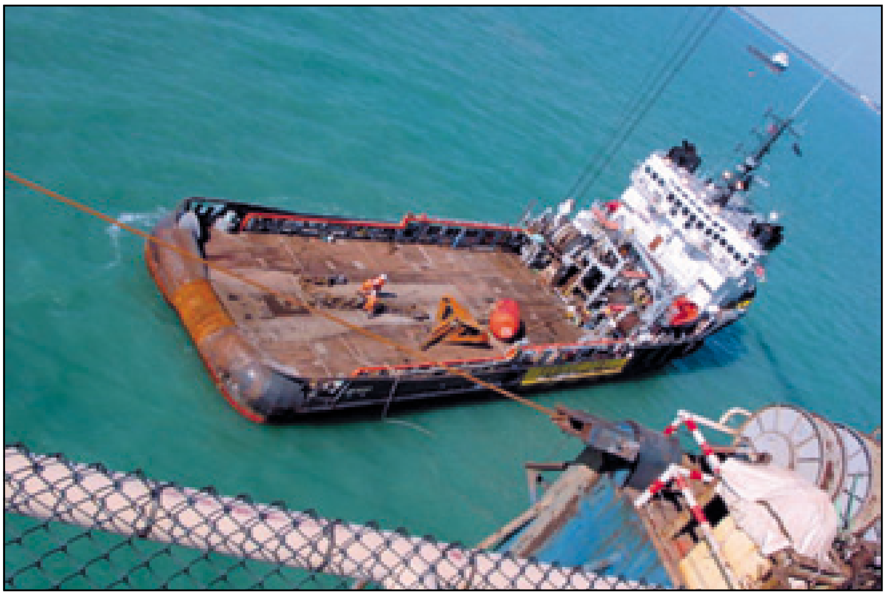


Plate 3.14
Typical anchor-handling tug

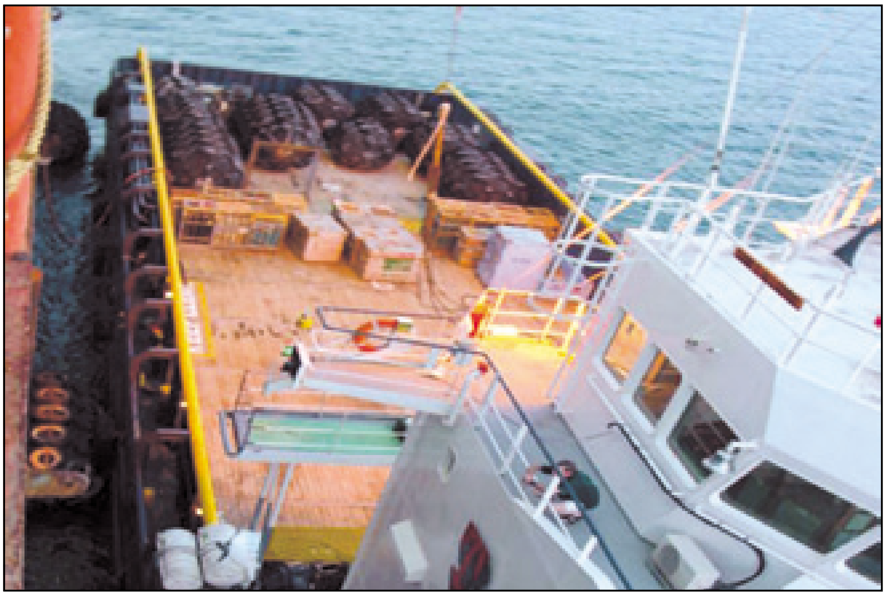


Plate 3.15
Typical general supply vessel

- Biocides control sulfate-reducing bacteria, which can form hydrogen sulfide and corrode the wall of an anoxic, water-filled pipeline. As well, a failure to control biological activity can allow tenacious deposits to form, which can be hard to shift after the pipeline has been dried.

  Common biocides used include polymeric biguanide hydrochloride, quaternary ammonia and glutaraldehyde.

Water for hydrotesting of the onshore pipelines will generally be drawn from convenient rivers, provisionally identified as: Kikori River, Wah River, Mubi River, Ai'io River and the Tagari River.

A sample of water from each offtake point will be tested prior to its introduction into the pipeline to determine particle contamination and sizing. This will enable appropriately sized, mesh filters to be selected, in order to remove particles from the test water.

The dissolved oxygen and sulfate-reducing bacteria content of the water will determine the optimum water treatment design.

The oxygen scavenger and biocide will be mixed in an enclosed tank onshore or added separately at the suction side of the pumps used to fill the pipeline during the hydrotesting process. Appropriate bunding will be constructed as necessary to contain any accidental spillage of chemicals or treated water.

The once off water intake for hydrotesting from these rivers is expected to have minimal effect on the natural water volumes and flow regimes of these large rivers. None the less, the project will undertake additional study of water intake volumes during FEED and detailed design to meet project water use permit requirement (see assessment of water abstraction impacts in Section 18.4, Water Resources and Hydrology).

3.4.6.2 Cleaning

The protection of the interior condition of the pipe is an ongoing process. After welding, the contractor will remove rust, dust and other fine debris from each pipe joint using an industry-standard swabbing procedure. Thorough cleaning at this stage simplifies post-lay cleaning.

There are three main options for pipeline cleaning. They are:

- Brush pigging.
- Gel cleaning.
- High-velocity flushing.

A brush pigging cleaning process comprising a train of six to eight brush pigs, nominally 500 m apart and travelling at approximately 0.50 m/s to 0.75 m/s and is likely to be required to optimise the cleaning process. Other types of cleaner pigs may be used depending on the condition of the pipeline and the need to protect internal pipe coatings.

The brush pigging cleaning process normally begins by injecting a volume of treated water equivalent to approximately 500 m of pipe length ahead of the first pig in order to wet and reduce friction in the pipe. Some turbulence in the water flow is required to keep any loose particles in suspension and to reduce the risk of the pigs becoming stuck if debris builds up ahead of them. As an alternative to water, the cleaning pigs may be propelled by compressed air.

Gel cleaning combines the cleaning action of brush pigs with the debris pick-up capability of a carrier gel. The water-based gel is non-hazardous and biodegradable.

High-velocity flushing involves passing water at high velocity through the pipeline. This method is mainly effective on small-diameter pipeline and not likely to be used in this case.

3.4.6.3 Gauging

Gauging checks the pipeline for deformation of the cross-section (ovality) and dents. It normally occurs concurrent with cleaning, with the penultimate pig at the rear of the cleaning train fitted with one or two aluminium gauging plates. The pipeline is ready to be hydrotested once it has been cleaned and has accepted the gauging plates.

3.4.6.4 Hydrotesting

Hydrotesting involves pressurising the pipeline to confirm the integrity of the welds. The treated water used for cleaning will be reused for the hydrotest process, but will require topping up. Testing will be done in sections of the pipelines, generally between valve sites.

3.4.6.5 Dewatering and Drying

The preferred course of action is to recycle hydrotest water from one section to another. If this is not feasible, hydrotest water will be tested, then discharged to land (see Section 3.4.6.6, Hydrotest Waste Disposal below).

Following hydrotesting, the pipeline is then dried by vacuum extraction.

3.4.6.6 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 to a project landfill facility**.** Hydrotest water will contain traces of corrosion-inhibitors and biocides and will typically be safe to discharge to land or large water courses with high rates of dilution. Esso’s first preference will be to recycle hydrotest water from one section to another. Once no longer required, all hydrotest water will be tested, then discharged at a controlled rate to a site. Land disposal is likely to be into infiltration beds or percolation ponds, incorporating erosion control measures, such as energy dissipaters.

Due to the uncertainty regarding actual recycling of hydrotest water, firm volumes of water cannot be provided; however, assuming no recycling occurs, the maximum amount required will be approximately 150 to 180 ML for the onshore pipeline.

Specific arrangements for hydrotest water disposal require details of the locations of the hydrotest sections and local conditions, which will be determined as FEED advances into detailed design. When these locations are known additional risk based studies will be undertaken to demonstrate the wastewater will be acceptable for receiving water and meet environmental (waste discharge) permit requirements.

Esso’s water management standards for hydrotest water discharge require no visible oil sheen to be present on receiving water. Preliminary environmental assessment of disposal of hydrotest water in the Omati River delta was conducted for this EIS and is discussed in Sections 3.6.5, Precommissioning Activities, and 19.3, Sea Water Quality and Hydrology.

3.4.6.7 Gas Introduction

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

3.5 Constructing the Common Onshore Pipeline Infrastructure

3.5.1 Cathodic Protection

Sacrificial magnesium anodes will be placed at intervals to protect the buried pipeline until the impressed current cathodic protection stations are operating.

It is estimated that twelve stations will be required in all, comprising a rectifier, solar panels, a cleared area 5 m wide for an underground electrical powerline of between 150 m and 200 m long and trenched away from the pipeline and a 10 m by 150 m ground bed in which to shallowly bury the anodes. A total area of each station and cleared surrounds could total up to 0.6 ha. Protection circuitry will be connected to the pipeline leads and tested.

Some cathodic protection stations can be co-located with valve stations.

3.5.2 Valve Stations

Mainline valve stations will comprise a communications building, tower and solar power in a fenced area of approximately 50 m by 50 m overlapping the ROW, an additional area cleared to keep the trees away from the fence and solar panels, a vent line run of 10 m by 35 m away from the valve and a blowdown vent area of 30 m by 30 m. The total area would be approximately 0.5 ha (or up to 1 ha for a co-located cathodic protection station).

Check valves operate passively within the pipeline without surface infrastructure.

3.5.3 Scraper Station

Pig launcher and receiver stations require only a small area next to the pipeline of less than 0.1 ha. The pipelay crew will leave the pipeline exposed above ground and configured to allow direct connection to the prefabricated launching and receiving equipment.

3.6 Constructing the Offshore Pipeline

This section describes the construction of the offshore section of the LNG Project Gas Pipeline from the Omati River Landfall across the Gulf of Papua to the Caution Bay Landfall. The timing of the offshore pipeline construction is given in Section 3.6.1, Construction Timing. The activities involved in the offshore pipeline construction are: pipelaying (Section 3.6.3, Offshore Pipeline Installation), construction of landfalls (Sections 3.6.2, Omati River Landfall Construction and 3.6.4, Caution Bay Landfall Construction) and pre-commissioning activities (Section 3.6.5, Precommissioning Activities). Details are also provided on workforce and accommodation (Section 3.6.7, Offshore Construction Crew and Accommodation) and site cleanup and rehabilitation (Section 3.6.6, Clean-up and Regeneration of Landfall Sites).

3.6.1 Construction Timing

The indicative timing of offshore pipeline construction is shown in Figure 1.3.

Offshore pipeline construction is anticipated to take approximately 19 months in total. The activities include pipelaying; pipeline protection and stabilisation; and pre-commissioning activities (i.e., cleaning, hydrotesting and dewatering). Pipeline protection and stabilisation activities are during the same timeframe as pipelaying.

Construction of the offshore pipeline is expected to progress at a rate of 300 to 720 m per day in the Omati River and Caution Bay. The offshore pipelay progress across the Gulf of Papua is expected to be 2 to 3 km per day.

3.6.2 Omati River Landfall Construction

The Omati River Landfall has a minimum tidal river depth of approximately 2 m and a diurnal tidal range of 4 m. The onshore section is swampy and floods frequently when high tides coincide with high flows in the Kikori and Omati rivers.

A dry working environment is required for the landfall section of the pipeline. A cofferdam of 4-m-wide sheet piling is envisaged from a point approximately 60 m onshore to approximately 20 m into the river. The cofferdam concept may change during detailed design, but the objectives and principles applied will remain to provide a stable excavated trench through the river bank into which the pipestring can be pulled ashore.

Two methods of pulling the pipeline through the landfall have been considered. The offshore-pull method uses a barge anchored in the river to haul a long, welded pipestring floating in the trench from a pipeline-stringing facility on firm ground inland. The alternative (and currently preferred method) is the onshore pull, whereby a winch onshore pulls welded pipestring from a laybarge anchored immediately offshore. This method negates the need for an onshore pipeline-stringing facility, as the pipe can be welded, the welds coated and the pipestring launched from a lay barge (which will in any case be on hand for the shallow-water offshore pipelaying (see Section 3.6.7, Offshore Construction Crew and Accommodation). The sequence of onshore-pull landfall construction is shown schematically in Figure 3.10.

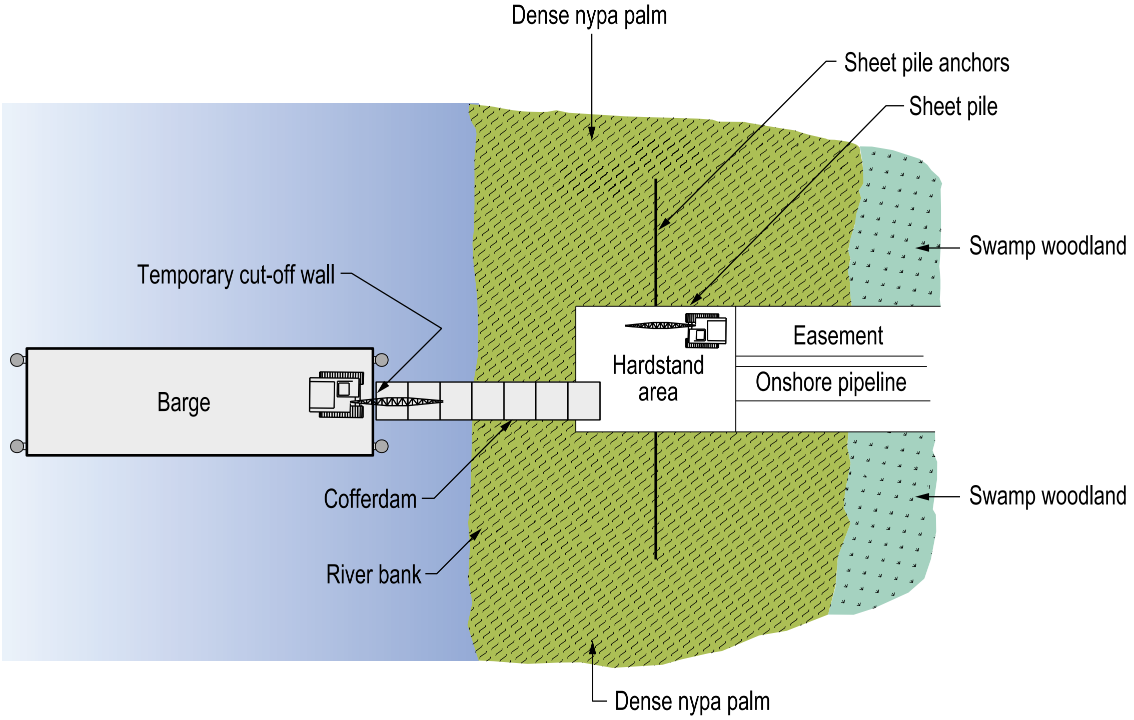
3.6.3 Offshore Pipeline Installation

The 407-km-long offshore pipeline will be installed within a surveyed, 600-m-wide corridor. The area of direct disturbance will be that of the pipeline centreline and the laybarge anchor pattern (if an anchored laybarge is used).

3.6.3.1 Pipelaying

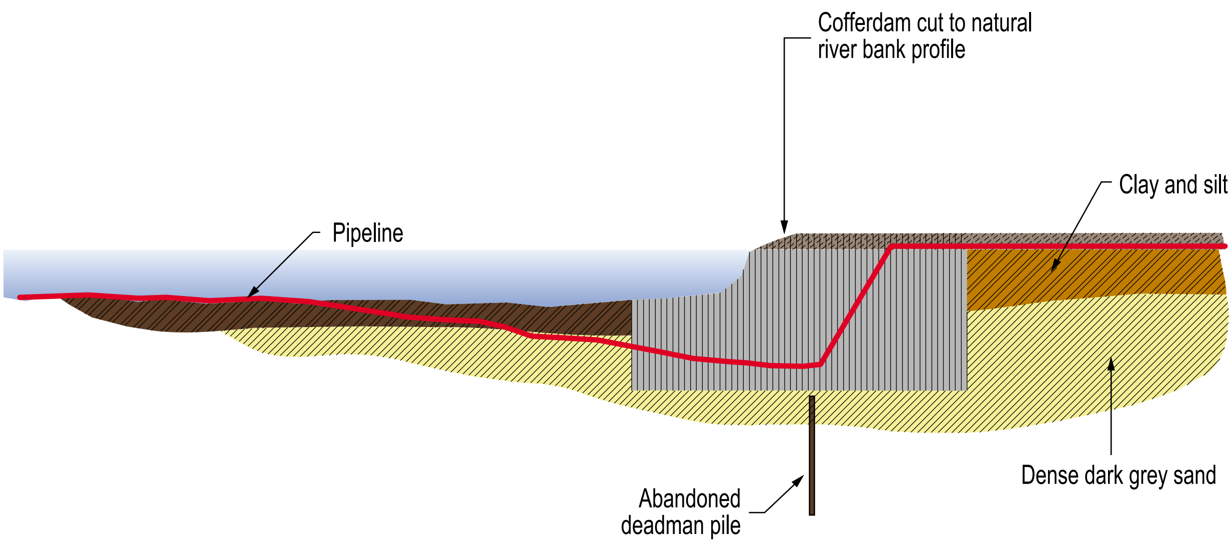
It is envisaged that pipelaying vessels will install the offshore gas pipeline (as opposed to towed pipestrings). Vessels of this type typically operate as follows:

Complete sheet pile installation and construct hardstand area from onshore.
Seal cofferdam and dewater.



PLAN VIEW

Backfill to natural profile and cut-off sheet piles to natural profile.



PNG LNG	Job No: 1284	Esso Highlands Limited	Omati River onshore-pull landfall construction method	Figure No: 3.10
	File Name: 1284_09_F03.10_HB	PNG LNG Project		

- Sections of pipe with anti corrosion material and concrete coating are stacked on the pipelaying vessel.
- Pipe ends are prepared for welding.
- Successive joints of pipe are lined up and welded together.
- Welds are subject to non-destructive testing and repaired as necessary.
- Anti-corrosion material (fusion-bonded epoxy) and a field joint infill are applied to the welded joints.
- The pipeline is lowered to the seafloor.

A constant tension is applied to the pipeline as it is progressively lowered from the vessel to the seabed along a stinger, which extends from the stern of the pipelaying vessel to prevent the pipeline from bending excessively between the vessel and the seabed.

Offshore pipelaying is a continuous process. Barges (either towed by tugs or self-propelled) bring the pipe and other supplies to the pipelaying vessel. An offshore pipelay spread typically comprises:

- A pipelaying vessel.
- Up to three anchor-handling tugs (depending on vessel type).
- A general supply vessel.
- Pipe supply vessels in sufficient numbers to ensure a continuous supply to the pipelaying vessel.
- Bulk carriers to 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 personnel to and from shore bases.

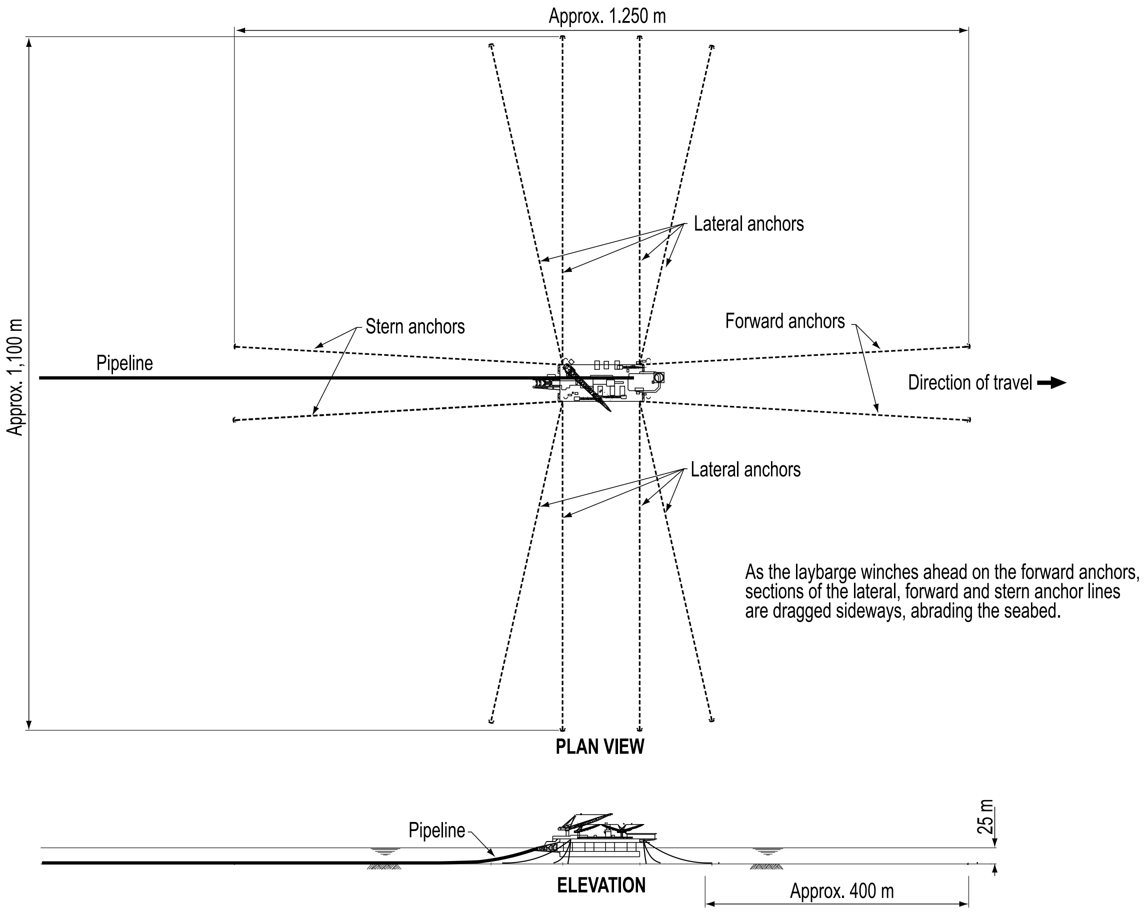
These vessel types and their roles in pipeline installation are described below.

Pipelaying Vessel

Anchored laybarges are commonly used for installing long-distance, large-diameter marine (i.e., 34”) pipelines in relatively shallow water like much of the Gulf of Papua. Typically, 10 to 12 anchors are deployed by up to three dedicated, anchor-handling tugs. Lateral and forward/stern anchors are placed on each side of, in front of and behind, the laybarge respectively. The anchored laybarge moves forward along the pipelaying route by simultaneously winching on the forward anchors and paying out on the stern anchors. The anchors are picked up one by one and moved forward by the anchor-handling tugs as the laybarge progresses forward. The type and size of anchor is largely a function of the seabed material and holding capacity required to generate the lay tension.

Figure 3.11 shows a typical anchored laybarge, pipe supply vessel and a typical anchor pattern. The length of anchor line in contact with the seabed depends on the tension, which varies as the

Typical anchored laybarge (above) and pipe supply vessel.



PNG LNG	Job No: 1284	Esso Highlands Limited	Typical anchored laybarge, associated pipe supply vessel and anchor layout	Figure No: 3.11
	File Name: 1284_09_F03.11_HB	PNG LNG Project		

laybarge progressively takes up slack on the forward lines and pays out line on the stern lines. During this process, some portions of the anchor lines are dragged along the seabed and disturb the seafloor in an overlapping scallop pattern.

A flat-bottomed variant of the anchored laybarge is typically used in tidal rivers and other shallow waters, like the Omati River and Caution Bay. These maintain position and forward movement by utilising anchors and spud piles penetrating the seafloor.

Alternatively, a dynamically positioned laybarge may be used, which holds position using thrusters with no need for anchors and anchor-handling tugs and no anchor abrasion of the seabed. However, they generally use more fuel and emit more underwater noise than anchored laybarges.

Support Vessels

Anchor-handling Tugs

Anchor-handling tugs are ocean-going vessels with sufficient deck space and winch capacity to pick up, lie down and reposition laybarge anchors (Plate 3.14). They operate under the direction of the laybarge.

General Supply Vessel

The general supply vessel continuously moves between the pipelaying vessel and the onshore support base to:

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

Plate 3.15 shows a typical general supply vessel.

A supply base, comprising facilities such as a wharf, crane, lay-down area, ablution, office facilities, etc., may be required for the offshore pipeline construction activities. If so, existing facilities or facilities that will be built for other project purposes will be used (i.e., there will be no purpose built facility).

Pipe Supply Vessel

Pipe will be shipped from the coating yard to offshore holding locations as close as possible to the pipelaying vessel**.** The pipe supply vessels (Plate 3.16) will bring the pipe to the pipelaying vessel. The pipeline coating yard location will require an area of up to 25 ha to store the pipe required for the offshore section of the pipeline. The pipeline is expected be coated at the same location as the onshore pipe, which is discussed in Section 3.4.3.1, Mobilisation.

Survey Vessel

A dedicated survey vessel (Plate 3.17) will accompany the pipelaying spread to conduct the pre-lay survey ahead of pipelaying and subsequently survey the as-installed position of the pipeline**.**

Plate 3.16
Typical pipe supply vessel, showing pipe sections on deck and a pipe section being transferred to the pipelaying vessel by crane

Plate 3.17
Typical survey vessel

Plate 3.18
Natural revegetation near the Omati River Landfall

3.6.3.2 Pipeline Stabilisation and Protection

Stabilisation

The specific intention of the concrete weight coat is to ensure that the pipeline is stable on the seabed under all design environmental conditions. Additionally, the weight coating provides protection against natural and or third party impact. Due to the prevalence of soft deltaic sediments in the Gulf of Papua, the pipeline is expected to embed in these sediments for most of its length. However, where the seabed is hard or the sediments thin, the pipeline may only partially self-bury. If there are strong enough lateral currents to scour the seabed underneath the pipeline, localised sections of the pipeline may become unsupported (this is called spanning). Spanning represents the greatest risk of snagging of trawling equipment or anchors and to the stability of the pipeline structure.

The detailed geophysical survey completed in late 2008 and future pre-lay survey will identify areas where spanning in excess of design guidelines might occur and where span lengths need to be reduced by methods, such as post trenching or grout-bag support. The post-installation survey inspection (and subsequent routine survey inspections over the life of the operation) will identify any further spanning that needs remediation.

Protection from Vessels and Anchors

The offshore pipeline will be buried for protection against impacts from vessels and anchors in the Omati River (and for some distance beyond the river mouth to a water depth of between 5 and 10 m) and seaward from the landfall in Caution Bay to a water depth of 15 m. In addition, the pipeline will be trenched and buried for the shipping channel crossing offshore from the LNG Facilities site. The depth of cover to the top of the pipeline in the trenched sections is still to be determined but could be achieved using one of the trenching methods described below.

Methods of Protection and Stabilisation

Pipeline protection and stabilisation depends upon seabed conditions. Trenching in harder substrates, using techniques such as dredging and cutting, is typically undertaken before the pipe is laid and the pipe is then laid directly into the trench. Trenching in softer substrates, using techniques such as ploughing and jetting, is typically undertaken after the pipe has been laid.

Dredging

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

- Suction dredging, which works like a vacuum cleaner and 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 depths of up to 30 m.
  - *Trailing Suction:* this method is most effective for softer seabeds and water depths up to 80 m.

- Dipper/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, and may be used in Caution Bay. A typical mechanical cutter and its trench profiles are shown in Figure 3.12.

Ploughing

This technique buries pipelines that have already been laid and is similar to 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 (Figure 3.13). 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 soil around the pipeline and deposit the soil adjacent to the pipeline while the pipestring falls under its own weight through the liquefied sediments (Figure 3.14). Trenches excavated by jetting will normally backfill naturally. This method may be used in the Omati River and Caution Bay.

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 then filled with a cement-grout slurry, which then sets.

Spoil

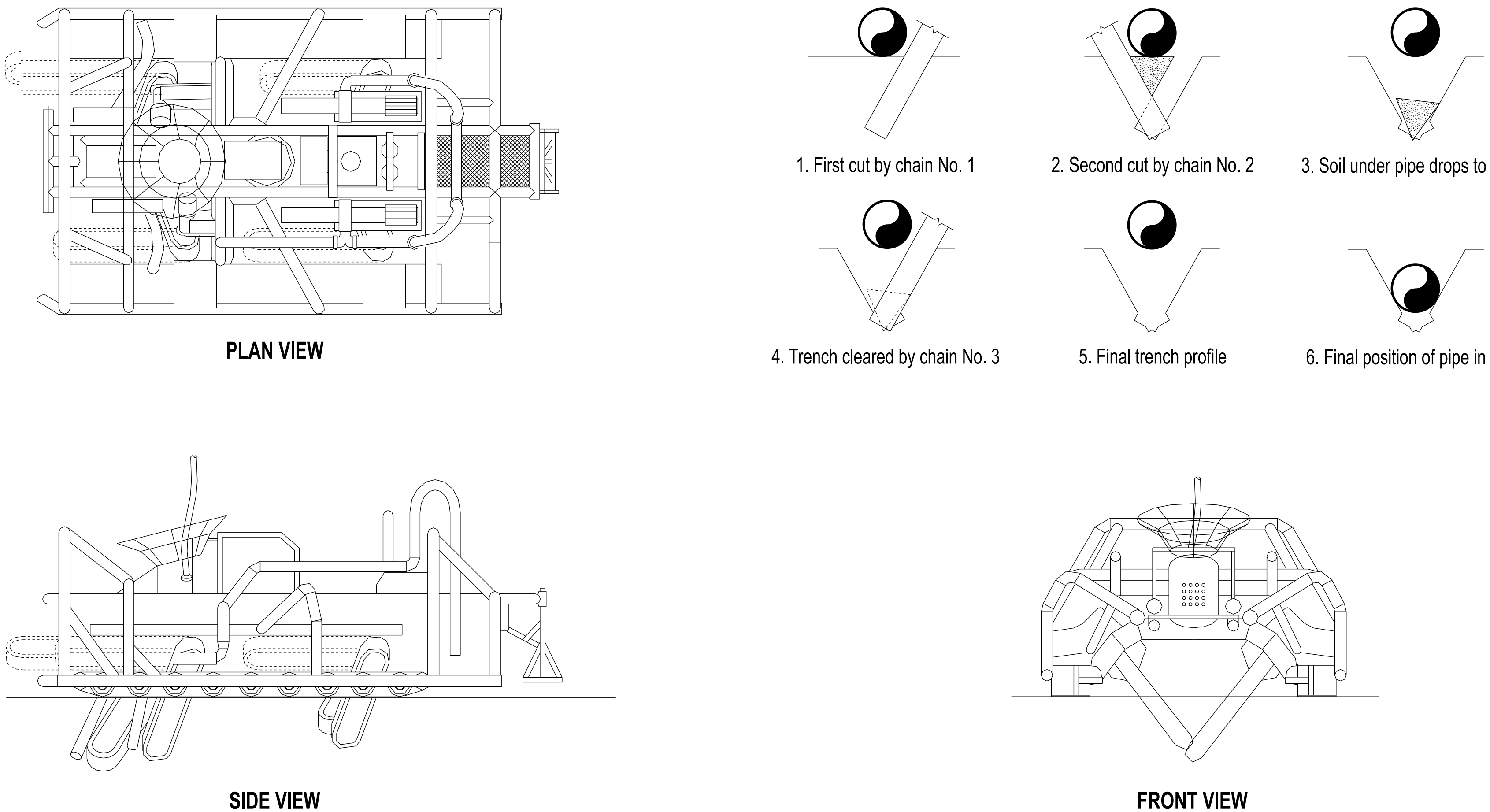
Trenching spoil will settle near the trench or disperse with the currents.

Protection from Prawn Trawls

In the prawn trawling grounds of the Gulf of Papua (see Section 6.4.5.2, Segments 18 to 23: Omati River Mouth to Caution Bay), self-burial of the pipeline in the soft sediments will reduce or avoid the risk of contact with trawl gear. Moreover, the pipeline's concrete coating will protect the pipeline from the 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 spanning between raised areas of seabed is unlikely in the soft sediments of the prawn grounds, but it is in any event the purpose of the pre- and post-installation surveys respectively to identify and remedy potential or actual spanning.

3.6.4 Caution Bay Landfall Construction

The method currently preferred for installation of the pipeline through the Caution Bay Landfall is generally similar to the Omati River Landfall, i.e., the onshore-pull method described in Section 3.6.2, Omati River Landfall Construction. However, sheet piling may not be needed, and



Notes:
1. Sketch based on Allseas Digging Donald.
2. Trench depths in excess of 2 m are possible.
3. Cutters may be replaced by blades or other tools for different seabed conditions.
4. Typical cutter dimensions: length, 17 m; width, 10 m; height, 7 m.

PNG LNG	Job No: 1284 File Name: 1284_09_F03.12_HB	Esso Highlands Limited PNG LNG Project	Typical mechanical cutter and its trench profiles	Figure No: 3.12

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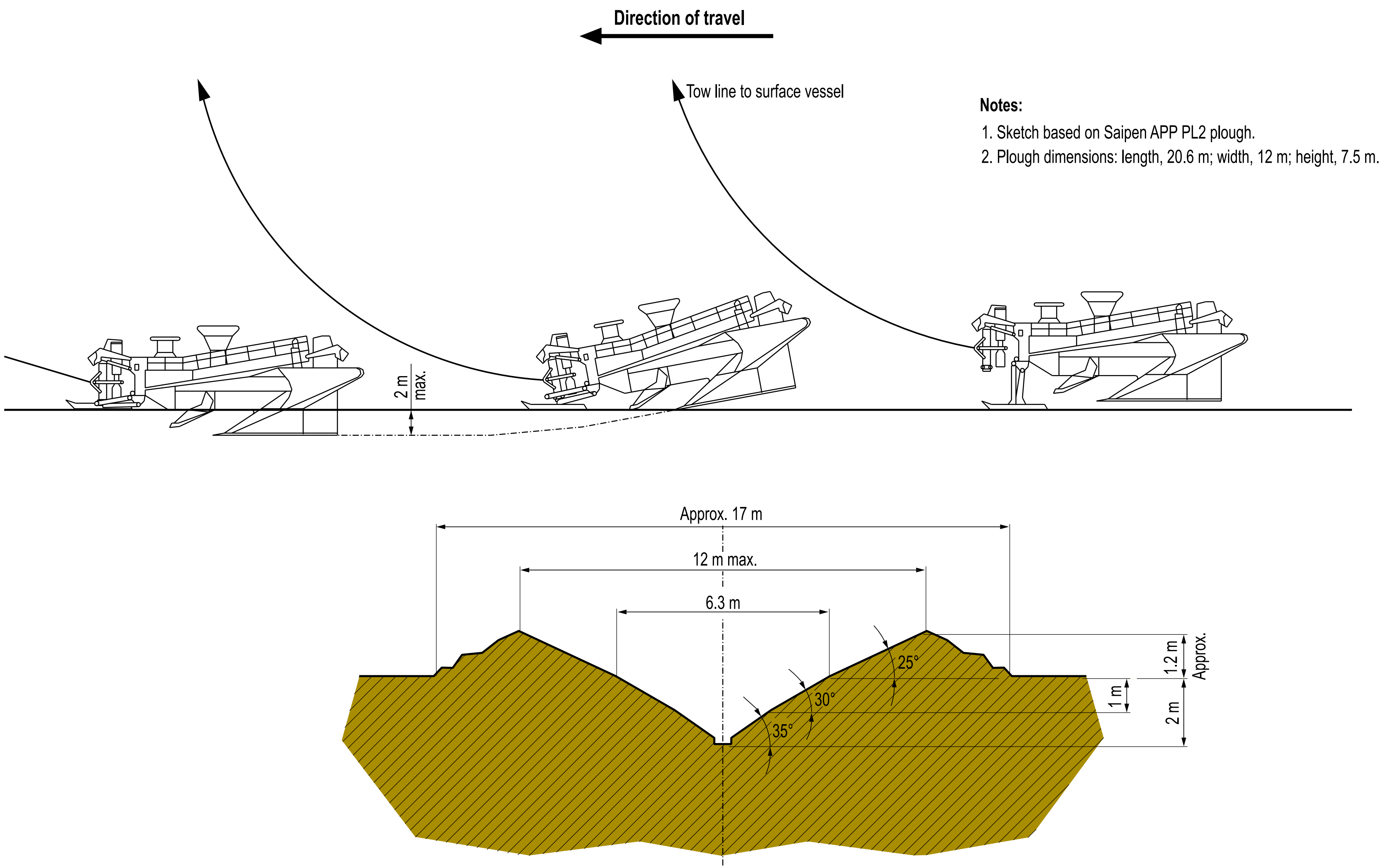

PNG LNG	Job No: 1284	Esso Highlands Limited	Typical plough and its trench profile
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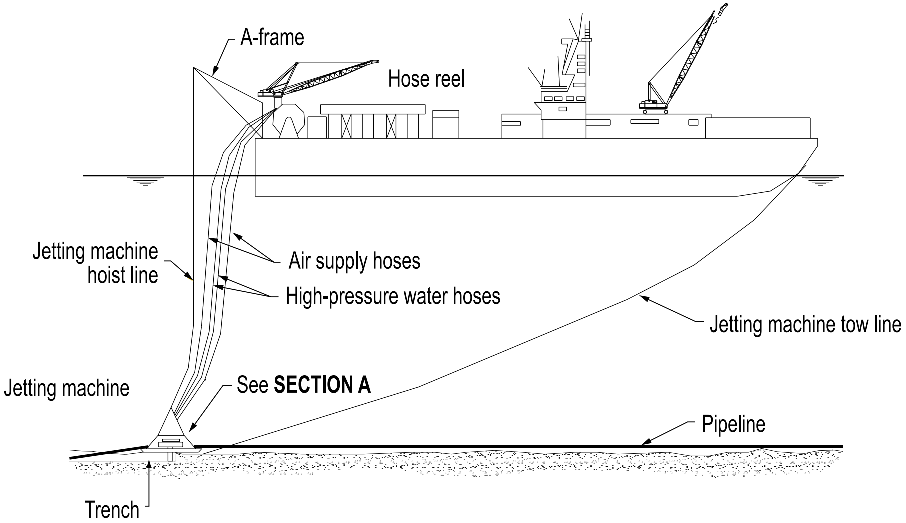
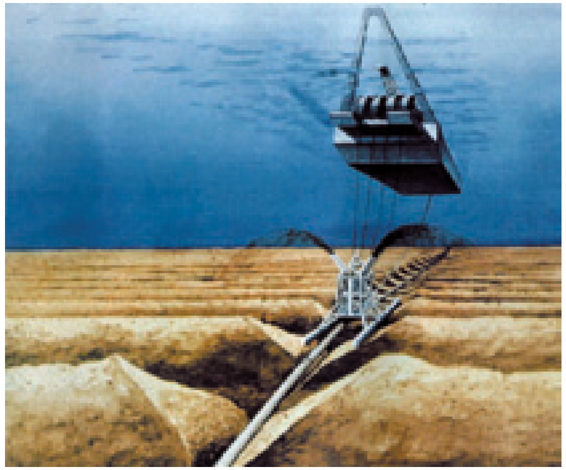
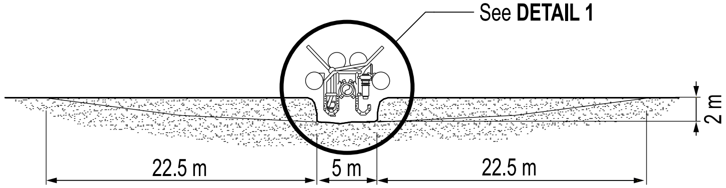
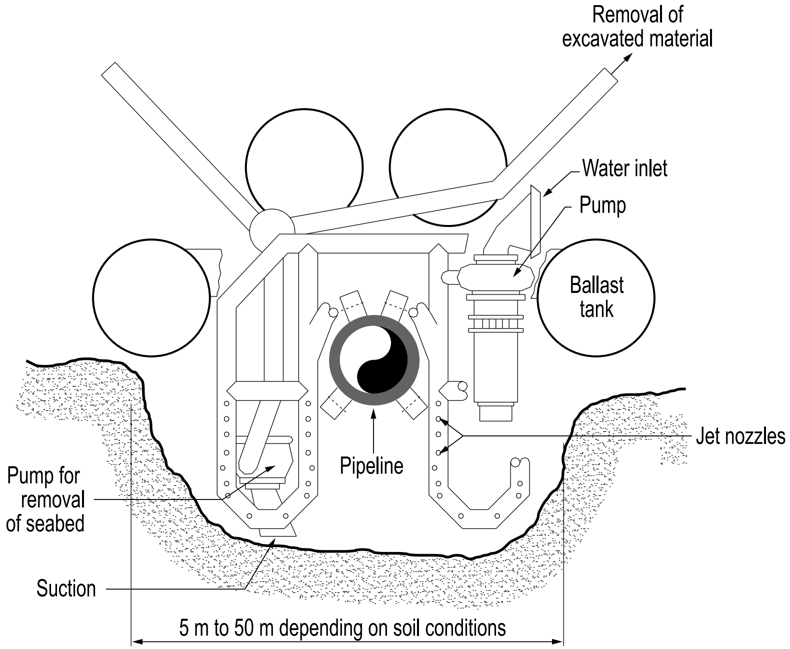


SIDE VIEW OF CONVENTIONAL JETTING BARGE AND MACHINE





END-ON VIEW OF JETTING MACHINE (SECTION A)



TYPICAL JETTING MACHINE (DETAIL 1)

Notes:

1. Sketch based on Land and Marine jetting machine.
2. Typical jetting machine dimensions: length, 7 m; width, 5 m; height 4 m.

PNG LNG	Job No: 1284	Esso Highlands Limited	Typical jetting machine and its trench profile, and an artist's impression of a jetting machine in use	Figure No: 3.14
	File Name: 1284_09_F03.14_HB	PNG LNG Project		

geotechnical investigations will be conducted as part of FEED and detailed design to establish if this is the case.

3.6.5 Precommissioning Activities

3.6.5.1 Post-installation Survey

A post-installation survey will confirm the pipeline's installation to be in conformance with specifications. This can be achieved using several methods, including video and bathymetric surveys. Video surveys would not be suitable for areas with low visibility, such as in the Omati River. Pipeline free spans in excess of specification criteria will be rectified by one of the methods described in Section 3.6.3.2, Pipeline Stabilisation and Protection.

3.6.5.2 Cleaning, Gauging and Hydrotesting

The pipeline will then be cleaned and gauged, hydrotested, dewatered and dried before gas is introduced, generally as set out in Section 3.4.6, Pipeline Cleaning, Gauging and Testing.

Cleaning of the pipeline uses a water-based (either freshwater or seawater) gel that is non-hazardous and biodegradable. However, as the gel's composition can change as it passes through the pipeline, used gels are typically stored and analysed before being disposed in accordance with environmental (waste discharge) permit requirements.

The water is required for both the cleaning and hydrotest procedures and may be drawn from the Omati River at the landfall or from Caution Bay (seawater). It is expected that approximately 220 ML of water will be required to hydrotest the offshore pipeline.

The options under consideration for the discharge of the hydrotest water are in the vicinity of the Omati River Landfall and Caution Bay. The discharge rate will depend on the speed of the dewatering train. This is typically held at 0.50 m/s to 0.75 m/s, resulting in a discharge rate of 15 m^3 to 23 m^3 per minute over a period of 7 to 10 days via one or more discharge lines. Environmental assessment of potential impacts to water resources and aquatic ecology relating to disposal of hydrotest water is given in Section 19.3, Sea Water Quality and Hydrology. Following removal of hydrotest water, the pipeline is then dried with compressed air (passed through driers) until the specified dewpoint is reached at the outlet.

3.6.6 Clean-up and Regeneration of Landfall Sites

The landfall sites will be cleared of construction equipment and leftover construction materials. The sheet piling used in the construction of the landfall will be removed either by crane or, cut off at, or below, the level of the riverbed or seafloor. Risk assessment during FEED and detailed design will be used to determine the best option.

Unused construction materials that are unable to be recycled will be disposed of in accordance with project waste management strategy procedures described in Chapter 25, Waste Management.

The Omati River Landfall is part of a naturally prograding delta and under a continuous process of vegetation colonisation. Plate 3.18 was taken in April 2008 and shows the natural revegetation of a site close to the Omati River Landfall that was cleared in 2005. When construction is complete, it is intended to rehabilitate the river bank and then allow the natural revegetation processes to resume.

The area of disturbance around the Caution Bay Landfall will also be rehabilitated and stabilised, but mangroves will not be allowed to regrow where their roots could interfere with the pipeline.

3.6.7 Offshore Construction Crew and Accommodation

Table 1.1 shows the staffing requirements for the construction of the offshore pipeline. Most are likely to be accommodated offshore (mainly on specific accommodation vessels), while those required for precommissioning at the Caution Bay end of the pipeline will be accommodated in the construction camp at the LNG Facilities site (see Section 4.6.4, Constructing the Temporary Construction Camps).

3.7 Operating the Pipelines

Properly designed and constructed pipelines are normally operated by a small team using standard systems and procedures to ensure pipeline integrity is maintained.

3.7.1 Monitoring and Control

Both the Hides Gas Conditioning Plant and the LNG Plant will have control rooms that can monitor and control the overall pipeline system, so that in the event of an emergency situation there is an operable, reliable back-up system that can be used.

Pipeline, process and well flowrate adjustments will be made to ensure daily nominations are met. An on-line analyser with read-out in the Hides Gas Conditioning Plant control room will be used to monitor and control gas quality, and pipeline shutdown will occur automatically should the LNG Project Gas Pipeline gas quality specifications be exceeded.

3.7.2 Inspection and Maintenance

An inspection and maintenance program for the PNG LNG Project pipelines will be in place at the start of operations in accordance with an environmental management plan that will be developed prior to operations starting.

Once the new pipelines are installed, the area in the vicinity of the pipelines will be kept clear of tall vegetation (i.e., trees) and deep-rooted vegetation. Routine ground and/or aerial patrols will be undertaken to monitor the pipeline ROWs for operations and maintenance issues, such as tree regrowth, soil erosion and pipeline marker sign maintenance. In particular, the pipelines will routinely be visually inspected from helicopters or fixed-wing aircraft to monitor for threats to pipeline integrity. Pipeline valve stations will be visited for routine inspections.

Ground and aerial markers with kilometre indicators will be installed along the pipeline route to aid in maintenance and possible emergency response.

In-line inspection tools (i.e., intelligent pigs) will be passed through the pipelines at programmed intervals to internally test the integrity of the pipeline wall. The exception to this is the Hides–Juha MEG Pipeline, which is too small in diameter. Pipeline pigging is expected to be on a very low frequency basis (i.e., approximately every 10 years). Pipeline integrity may also be monitored using corrosion coupons. These coupons and the external inspections may result in a reconsideration of the frequency of pigging, and will be determined during detailed design.

Mainline valve and pig launcher and receiver sites along the pipelines will be located inside fenced areas, along with the associated instrumentation and electrical systems. Functional and maintenance checks will be conducted on these sites on a regular basis.

Full-time staff members or contractors based at the Hides Gas Conditioning Plant and LNG Plant will be trained in, and have a responsibility for, pipeline inspection and maintenance, including revegetation and erosion control. Attention will be paid to possible third-party use of the pipeline ROW easement.

The offshore pipeline will be subject to routine external surveys to confirm that it is fast on the seabed with no excessive spanning. The initial and pre-lay surveys will identify the seabed processes that could pose a risk to the pipeline, which in turn, will determine the appropriate long-term inspection frequency.

3.8 Decommissioning the Pipelines

3.8.1 Onshore Pipelines and Spinelines

Pipeline decommissioning requires the pipelines and spinelines to be made safe by:

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

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

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

Closure plans will be prepared for the pipelines and spinelines approximately one year prior to any decommissioning activities taking place. The plans will be based on standards and technology that exist at that time and will be documented in the project's environmental management plan (see Chapter 30, Environmental Management, Monitoring and Reporting).

3.8.2 Offshore Pipeline

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

- Flush the pipeline of hydrocarbon liquids and vapour.
- Flood the pipeline with seawater.
- Seal the pipeline openings with mechanical plugs.

- Abandon all offshore sections of pipeline in place to minimise the disturbance of removal.
- Update navigation charts for offshore areas to show what remains.

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.