Santos

Darwin Pipeline Duplication (DPD) Project - Acid Sulfate Soil and Dewatering Management Plan

PROJECT / FACILITY	Barossa DPD Project
REVIEW INTERVAL (MONTHS)	No Review Required
SAFETY CRITICAL DOCUMENT	NO

Rev	Owner	Reviewer/s Managerial / Technical / Site	Approver
	Project Environmental Lead	Project HSE Manager	Project Director

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Rev	Rev Date	Author / Editor	Amendment
A	15/07/2022	RPS	Issued for review.
B	05/09/2022	RPS	Issued for review.
C	16/12/2022	RPS	Issued for review.
D	09/03/2023	RPS	Issued for review.

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Abbreviations and acronyms

Abbreviation/acronym	Definition
~	approximately
%	per cent
%S	percentage sulfur
AASS	actual acid sulfate soils
AHD	Australian Height Datum
ANC	acid neutralising capacity
ASS	acid sulfate soils
ASSDMP	Acid Sulfate Soils and Dewatering Management Plan
bgl	below ground level
$CaCO_3$	calcium carbonate
CRS	chromium reducible sulfur
EC	electrical conductivity
ENV	effective neutralising value
HAT	highest astronomical tide
km	kilometres
LAT	lowest astronomical tide
m	metres
m^3	cubic metres
mm	millimetres
NT EPA	Northern Territory Environmental Protection Agency
PASS	Potential Acid Sulfate Soils
pH_F	field pH
pH_{FOX}	field peroxide pH
pH_{KCl}	potassium chloride pH
Pty Ltd	Proprietary Limited
RPS	RPS Australia West Pty Ltd
Scr	chromium reducible sulfur
S_{POS}	peroxide oxidisable sulfur
TPA	titratable peroxide acidity
TTA	total titratable acidity

1 Executive Summary

1.1 Background

This acid sulfate soils (ASS) and dewatering management plan (ASSDMP) has been prepared for the intertidal / onshore earthworks to be undertaken as part of the Darwin Pipeline Duplication Project ('the DPD Project').

This ASSDMP applies to the proposed earthworks associated with the construction of the pipeline shore crossing, adjacent to the existing Darwin liquefied natural gas ('DLNG') Facility at Wickham Point Road, Wickham, Northern Territory 0822 ('the site') (**Figure 2-1**). The shore crossing earthworks comprises an approximately 533 m linear trench extending from the lowest astronomical tide (LAT) mark to the upstream weld of the proposed beach valve tie-in point at the existing DLNG Facility.

The proposed pipeline shore crossing for the DPD Project is adjacent to the existing Bayu-Undan to Darwin pipeline and within the same disturbance corridor. As part of the construction of the Bayu-Undan Pipeline, natural material was removed and replaced by site-won, non-ASS, fill material across the length of the on-shore pipeline crossing.

Based on this information, this ASSDMP has been prepared on the assumption that material across the proposed development extent at the site is likely to be non-ASS material except within the intertidal zone, where ASS (as lateritic clay) may be present.

1.2 Proposed works

The construction of a duplicated pipeline shore crossing will comprise the excavation of an approximately 533 m long trench, extending inshore from the LAT to a proposed beach valve connection point. The trench is anticipated to be up to 5.0 m deep and 4.0 m wide (at its base).

The site is broadly split into two sections:

+ An 'intertidal' zone, extending from the LAT mark to the shore pull onshore termination point.
+ An 'onshore' zone, extending approximately 206 m from the shore pull onshore termination point to the upstream weld of the proposed beach valve tie-in point.

At the time of writing, the proposed earthworks methodology and schedule for the intertidal and onshore zones was still to be finalised, however the anticipated earthworks plan is as follows:

+ Intertidal zone – where the tide allows (i.e., during periods of high tide), the trench will be excavated via a vessel-based backhoe dredge (BHD) assisted by split hopper barges (SHB). During periods of low tide, the trench will be excavated via conventional land-based methods (tracked excavator)
+ Onshore zone – the trench will be excavated using a land-based backhoe excavator.

The trench will be excavated in a staged approach and will be undertaken from the shore site using an excavator from temporary causeways (up to approximately 131.9 m long and 21.75 m wide either side of the pipeline).

Based upon information presented within the DPD Project's onshore Delivery Management Plan (Downer, 2022), earthworks at the site are anticipated to commence during the following timeframes:

+ Intertidal zone – between Q4 2023 and Q2 2024.

- Onshore zone – between Q2 2024 and Q4 2024.

These timeframes are indicative only and may be revised.

1.3 Objectives

The principal objectives for the ASSDMP are as follows:

1. Present relevant historical ASS investigation data and management measures
2. Detail the proposed soil management programs to be adopted during the site earthworks to mitigate or control potential impacts relating to the disturbance of ASS associated with construction earthworks (i.e., open trench excavations).
3. Detail the proposed dewatering management programs (if required) to be adopted during the excavation and dewatering of soils associated with construction earthworks (i.e., open trench excavations).

1.4 Soil findings

Historical investigation data indicated that prior to the development of the DLNG Facility, ASS material at the site could be found up to 2.5 m below ground level (bgl), underlain by siltstone bedrock.

Based upon a review of historical earthworks undertaken at the site as part of the development of the DLNG Facility, the site has had its natural material removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand) up to a depth of approximately 6 m bgl.

Based on this, ASS associated with the naturally occurring soil material is no longer expected to be present within the onshore zone, however the presence of ASS cannot be completely discounted and may require management.

Based upon data provided within the historical investigations undertaken at the site and surrounds, ASS material previously present at the site was characterised as ‘Lateritic clays with various amounts of sand, silt and quartz gravel’ (estuarine mud) and is present from natural surface level in the intertidal zone.

1.5 Management measures

For the purposes of managing ASS, the following management measures will be implemented:

1.5.1 Intertidal zone

- ASS material, as estuarine mud, is anticipated from surface level.

Management during high-tide periods:

- Excavation via Marine BHD assisted by SHB.
- Disposal of excavated material will be at an offshore spoil disposal ground.

Management during low-tide periods (where dredging vessel draught permits):

- Conventional earthworks plant, namely: backhoe or tracked excavator
- All encountered material (including ASS) will be stockpiled at a predetermined location situated below mean sea level and as close to the LAT mark as possible, resulting in the material being exposed during low tides

- The tidal action would gradually remove the stockpiled material and disperse it to the marine environment
- The excavated material would be removed directly from the trench excavation to the stockpile location and remain saturated at all times due to periodic tidal inundation: thereby limiting the likelihood of drying out and acidification
- This management measure is for material located within the intertidal zone, extending from LAT inshore.

1.5.2 Onshore zone

ASS material, as estuarine mud, is not anticipated in this section of the site.

Should this material be encountered during earthworks for trenching and site preparation works, suspected unexpected ASS material is to be removed from the excavation and stockpiled separately from non-ASS materials on a limestone pad ahead of confirmatory testing. Due to the timing of excavation and construction of the anchor pit (which is to occur during site preparation works), specific management procedures for the anchor pit excavation are detailed below.

The requirements for management of this material are detailed in **Appendix A**.

1.5.2.1 Anchor pit excavation

As excavation and construction of the anchor pit will occur during the site preparation works, should ASS be encountered, such material will be placed as close to the LAT mark as possible (per the intertidal zone management measures above), whilst the causeway in the intertidal zone is available. Once the causeway is unavailable, encountered ASS material, must be treated on a limestone pad as per the onshore zone management above.

Should ASS material be encountered, during the excavation, and present at the base of the anchor pit, as a contingency measure, a thin layer (10 – 20 mm) of limestone should be placed at the base of excavation and on the batters, where ASS is present.

2 Introduction

This acid sulfate soils (ASS) and dewatering management plan (ASSDMP) has been prepared for the intertidal / onshore earthworks to be undertaken as part of the Santos Darwin Pipeline Duplication Project ('the DPD Project').

This ASSDMP applies to the proposed earthworks associated with the construction of the pipeline shore crossing, adjacent to the existing Darwin LNG ('DLNG') Facility at Wickham Point Road, Wickham, Northern Territory 0822 ('the site') (**Figure 2-1**).

The shore crossing earthworks comprises an approximately 533 m linear trench extending from the Lowest Astronomical Tide mark (LAT) to the upstream weld of the proposed beach valve tie-in point at the existing DLNG Facility.

The location and layout of the site is presented in **Figure 2-1** to **Figure 2-3** (overleaf).

2.1 Acid sulfate soils – definition

ASS are naturally occurring soils, sediments and peats that contain iron sulfides, predominantly in the form of pyrite materials. These soils are commonly found in estuarine and river settings and low-lying land bordering the coast.

ASS materials are benign when in a waterlogged state. However, when these soils or sediments are drained or excavated, oxygen from the atmosphere reacts with the iron sulfides in the soil, resulting in the production of sulfuric acid. This acidity releases elements such as metals and nutrients from the soil profile which can then be mobilised/transported to waterways, wetlands and groundwater systems, often with damaging environmental and economic impacts (DER, 2015a).

The oxidation of metal sulfides is a natural weathering process that generally occurs slowly and does not pose an environmental concern. However, excavation and drainage can exponentially increase the rate of acid generation. Additionally, water draining from oxidised ASS can be strongly acidic, which acts upon soils and sediment to produce high solution concentrations of toxic metals, especially aluminium and iron. These high concentrations of metals may have a deleterious effect on human health, the environment and potentially damage infrastructure. Potential Acid Sulfate Soils (PASS) are soils containing iron sulfides or sulfidic materials in an anaerobic environment and therefore have not been exposed to air and oxidised. However, if disturbed and exposed to air and oxidised, PASS become Actual Acid Sulfate Soils (AASS).

For the purpose of this management plan, the term ASS also includes PASS.

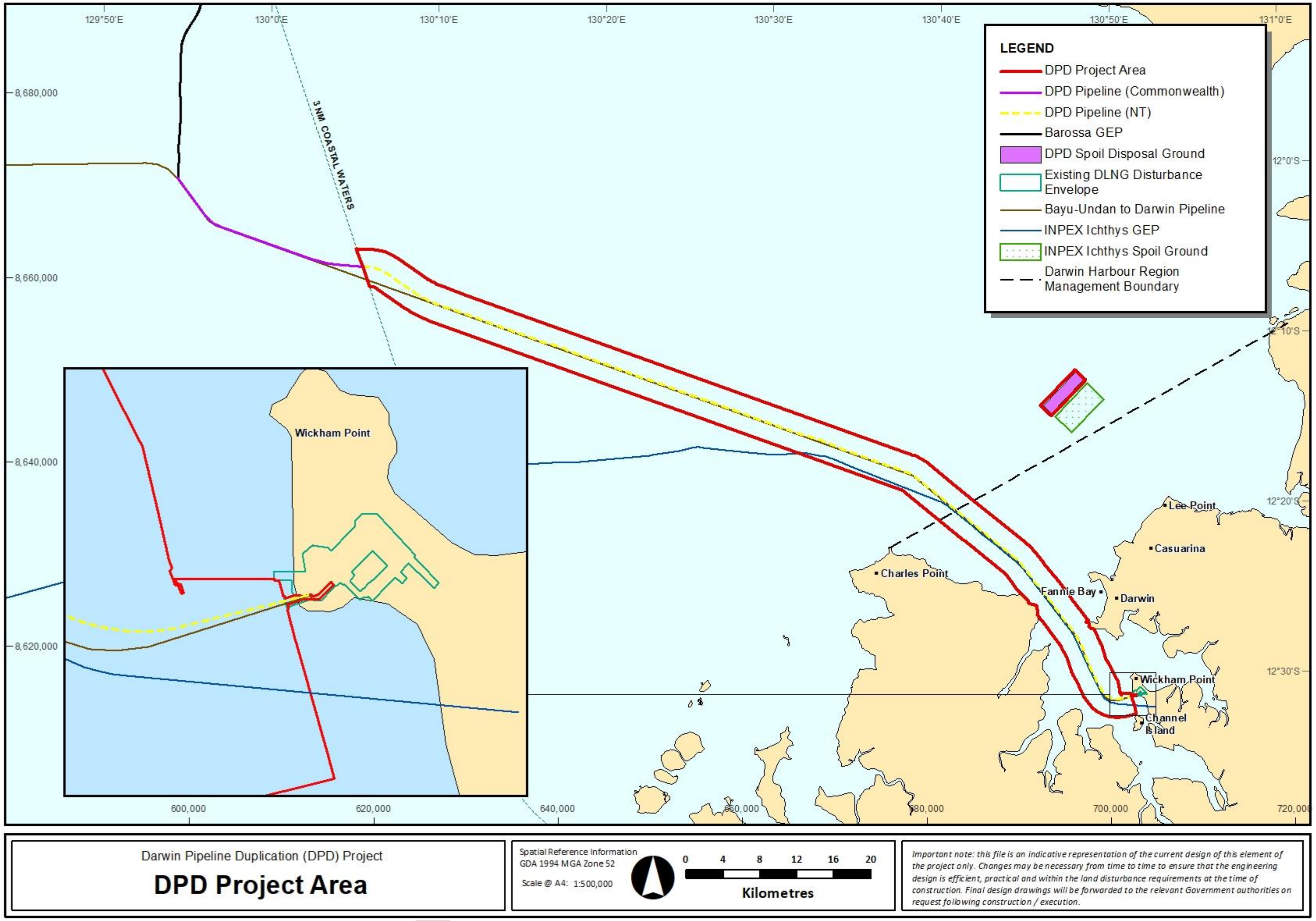

Figure 2-1: DPD Project Area

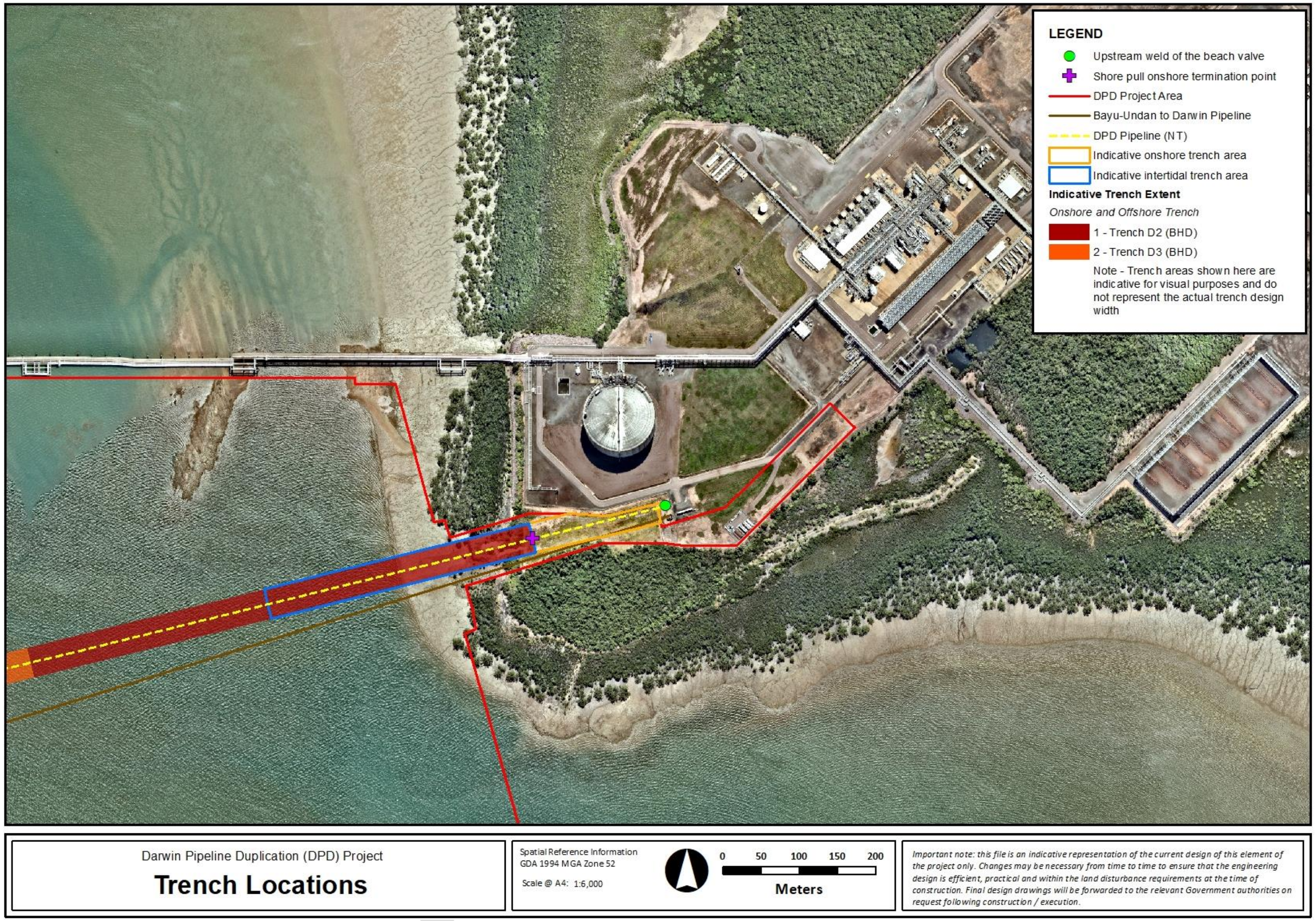

Figure 2-2: DPD shore crossing and onshore Project Area

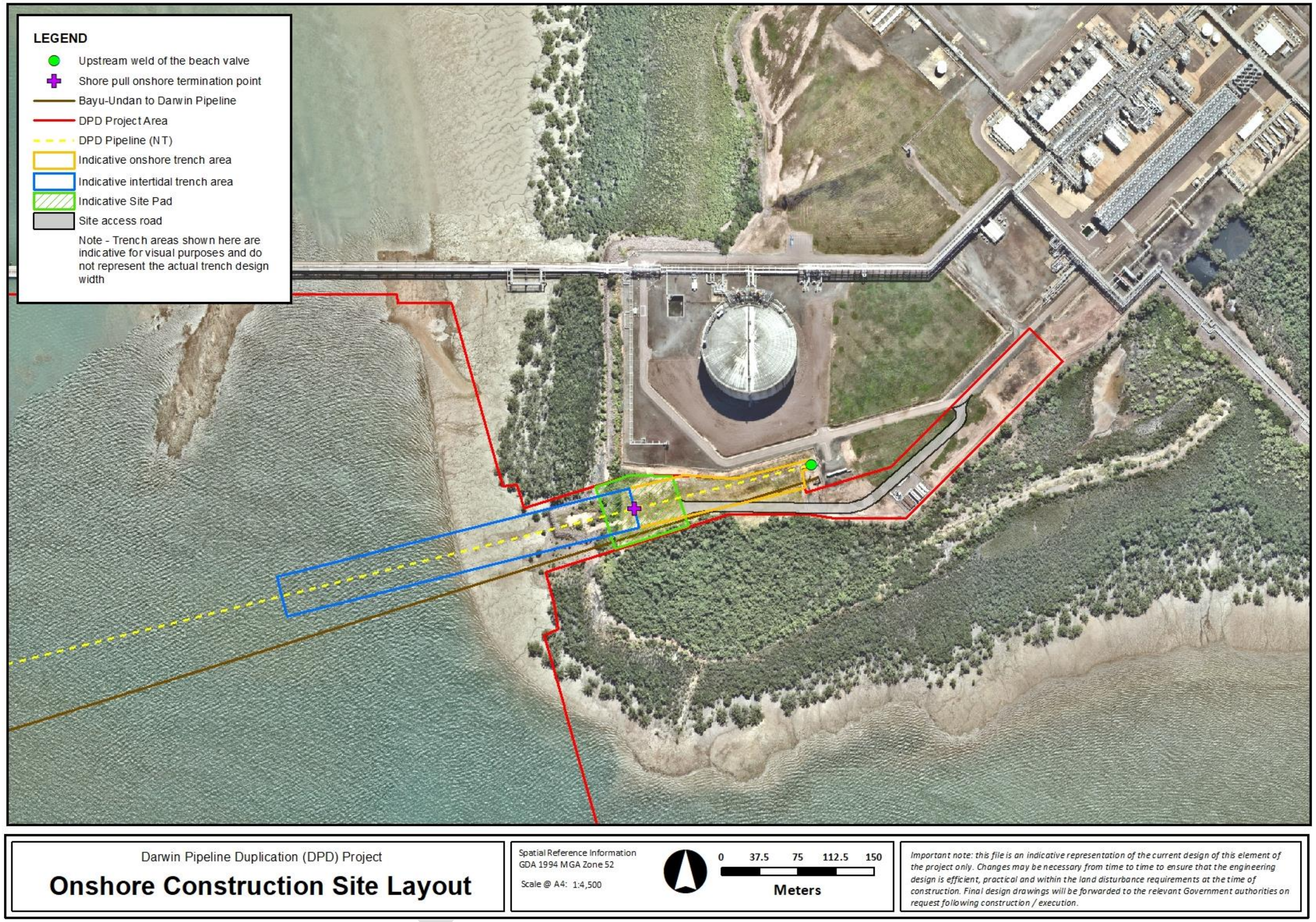

Figure 2-3: Site layout

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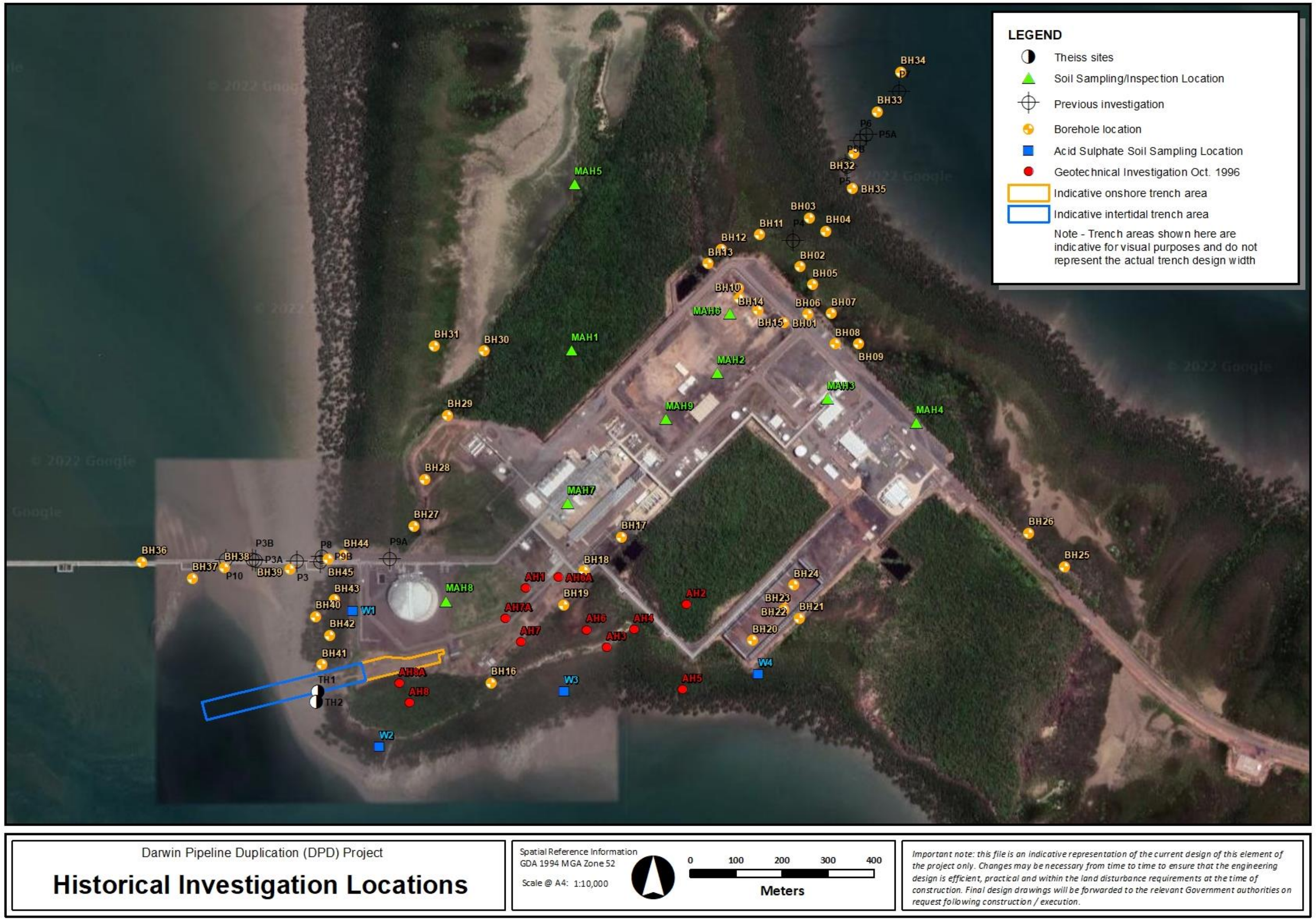

Figure 2-4: Historical investigation locations

2.2 Dewatering – regulatory context

Guidance for the approach to dewatering in shallow groundwater environments is presented in the National Acid Sulfate Soils Guidance document '*Guidance for the dewatering of acid sulfate soils in shallow groundwater environments'* (Water Quality Australia, June 2018d).

The guidance presents management principles to dewatering which '*should be applied across Australia*'. One of the principles is as follows:

'Receiving marine, estuarine, brackish, or fresh waters are not to be used as a primary means of diluting and/or neutralising ASS or associated contaminated waters.'

Given the setting of the site in close proximity to the marine environment, this report presents the dewatering approach that will ensure this guiding principle is adhered to, and that appropriate treatment and management practices for dewatering effluent are followed.

2.3 Project background

The DPD Project involves the construction of a pipeline to connect the existing Barossa Gas Export Pipeline (GEP) to the DLNG. The pipeline will run from where the Barossa GEP approaches the existing Bayu-Undan pipeline to the existing DLNG facility in Darwin Harbour. The DPD Project pipeline includes a ~23 km segment in Commonwealth waters (DPD Pipeline (Commonwealth)) and ~100 km segment in NT waters and lands (DPD Pipeline (NT)).

2.3.1 Report context

This ASSDMP applies to the proposed earthworks associated with the intertidal and onshore project area of the pipeline, covering an area from the LAT mark, to an onshore beach valve tie-in point.

This ASSDMP forms part of a suite of environmental management plans under overarching Construction Environmental Management Plans (CEMPs) for onshore and offshore construction which cover all activities from the 3 nautical mile (NM) Commonwealth/NT waters boundary to the beach valve receipt point:

+ The DPD Project Offshore Pipeline CEMP (BAS-210 0024) addresses all construction activities to be completed from the 3 NM Commonwealth/NT waters boundary to the upstream weld of the proposed beach valve receipt point (Santos, 2022c)
+ The DPD Project Onshore Pipeline CEMP (BAS-210 0025) addresses all onshore construction activities to be completed from the upstream weld of the proposed beach valve to the pipeline shore pull onshore termination point.

The work under the Offshore and Onshore CEMPs will be undertaken by different contractors. Under the offshore CEMP, there are two additional management plans that address specific activities during construction (**Figure 2-5**). These are the:

+ Trenching and Spoil Disposal Monitoring and Management Plan (TSDMMP) (BAS-210 0023) that addresses all trenching and spoil disposal activities from the 3 NM Commonwealth/NT waters boundary to the shore pull onshore termination point
+ Marine Megafauna Noise Management Plan (MMNMP) (BAS-210 0022) that addresses all activities associated with noise impacts to marine megafauna from the 3 NM Commonwealth/NT waters boundary to the shore pull onshore termination point.

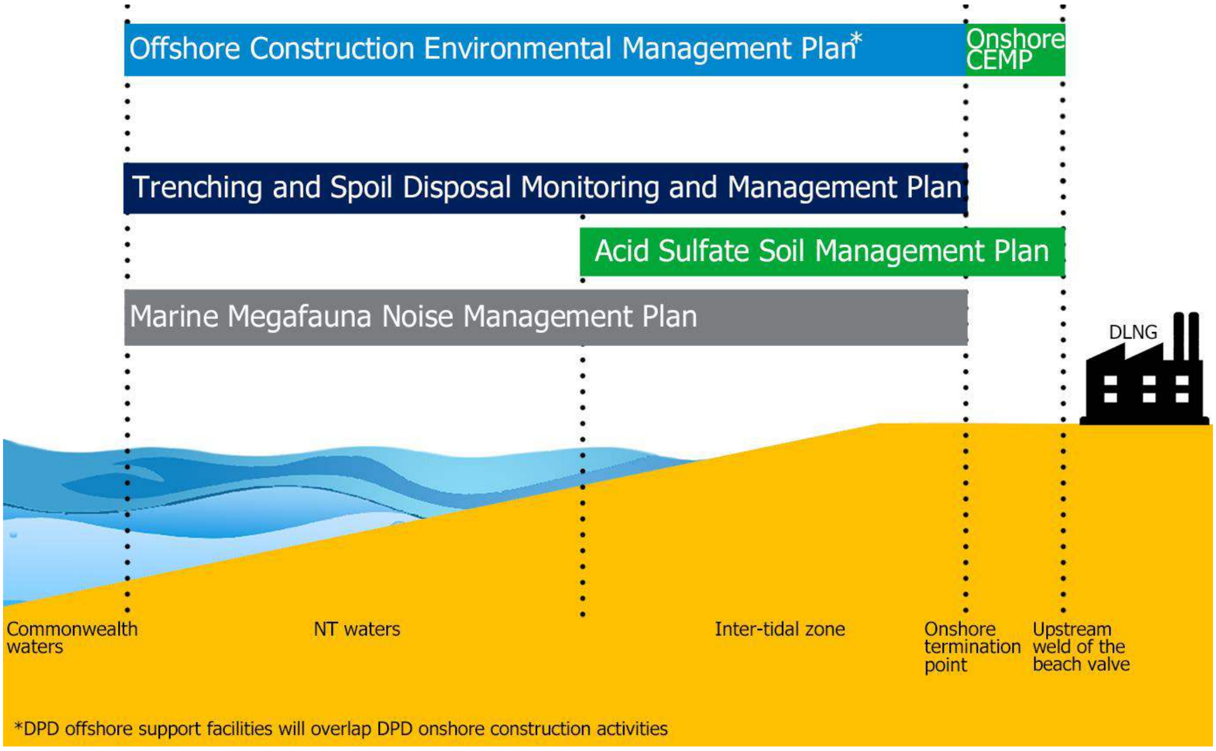

Figure 2-5: Conceptual model of management plan geographical scopes

2.3.2 Site works

The site is broadly split into two sections:

+ An 'intertidal' zone, extending from the LAT mark, to the shore pull onshore termination point.
+ An 'onshore' zone, extending 206 m from the shore pull onshore termination point to the upstream weld of the proposed beach valve tie-in point.

The location of these sections is presented in **Figure 2-2** and **Table 2-1**.

Table 2-1: Trench zone locations

Location	Kilometre point	Coordinates[1]	
		Easting	Northing
Upstream weld of the beach valve	KP122.690	702,472.29	8,614,655.73
Shore pull onshore termination point	KP122.484	702,272.73	8,614,606.40
LAT mark	KP122.157	701,954.81	8,614,527.82

Note:

1. Coordinates are displayed in Geocentric Datum of Australia (1994) (GDA94 MGA Zone 52).

2.4 Site background

The site is located within the DLNG Facility approved disturbance footprint. Santos is the registered owner and operator of the DLNG Facility.

This DLNG Facility and Bayu-Undan to Darwin GEP has been operating since 2006. The shore crossing route for the Bayu-Undan to Darwin GEP is situated to the south-western corner of the DLNG Facility (in the same development footprint as the site).

Several phases of desktop-based and intrusive investigations were undertaken in the vicinity of the site and across the wider area to support the development of the DLNG Facility, including work to assess and manage ASS risks across the development area.

A historical investigation undertaken by URS in 2002 (URS, 2002b) previously identified the presence of ASS across the DLNG Facility development area adjacent to the site. A subsequent ASSDMP (URS, 2004) was prepared for the development of the DLNG Facility and focussed on the presence of ASS across the wider development area.

A review of the 'Darwin 10 MTPA LNG Facility Public Environmental Report' prepared for the development of the DLNG Facility (URS, 2002a) identified the proposed earthworks strategy for the DLNG Facility development included retaining mangrove mud identified to underlie its development footprint.

As part of the construction of the initial Bayu-Undan to Darwin GEP crossing, natural material was removed and replaced by site-won, non-ASS, fill material across the length of the on-shore pipeline crossing.

The extent of historical ground disturbance associated with the development of this pipeline crossing is indicated in aerial imagery from June 2004, presented in **Figure 2-6**: . The image indicates the Bayu-Undan sea-to-shore pipeline crossing site has been subject to extensive ground disturbance, with extensive excavations present.

Based on this information, this ASSDMP has been prepared on the assumption that material across the proposed development extent at the site is likely to be non-ASS material except in the intertidal zone.

Figure 2-6: Aerial image of the site and surrounds – June 2004 (Image source: Google Earth, accessed: 19/08/22)

2.4.1 Scope and objectives

The principal objectives for the ASSDMP are as follows:

+ Present relevant historical ASS investigation data and management measures.
+ Detail the proposed soil management measures to be adopted during the site earthworks to mitigate or control potential impacts relating to the disturbance of ASS associated with construction earthworks (i.e., open trench excavations).
+ Detail the proposed dewatering management programs (if required) to be adopted during the excavation and dewatering of soils associated with construction earthworks (i.e., open trench excavations).

To meet the objectives of this ASSDMP, the following scope of work was undertaken:

+ A desktop review of publicly available information and pertinent historical reports for the site, including summarising the findings of the historical investigations
+ Assessment of ASS risk at the site, based on historical data, including the assessment of potential environmental impacts associated with the proposed earthworks
+ Assessment and presentation of ASS management measures based on historical data
+ Development of management measures, which detail the following:
  - Soil removal, handling and stockpiling operations, including the neutralisation of acidity associated with ASS (if required)
  - Treated soil validation testing programs (if required)

– Contingency measures and appropriate responses that may be implemented to rectify any breaches of the nominated triggers and management measures
– Contingency dewatering strategy.

The control measures presented herein are based on the review of historical reports only.

2.4.2 Assumptions

This management measures presented within this ASSDMP are based on the following assumptions:

+ The site has undergone extensive historical earthworks, and ground disturbance activities associated with the DPD Project will be limited to disturbance of historically imported non-ASS material except within the intertidal zone.
+ The management measures are based on a desktop review of historical information for the site and wider area.
+ The site extends to the upstream weld of the proposed beach valve tie-in point, approximately 205 m inshore of the shore pull onshore termination point. Further onshore works, between the upstream weld of the beach valve and the DLNG Facility process tie-in point are outside the scope of this ASSDMP

2.4.3 ASSDMP format

The remainder of this ASSDMP comprises the following sections:

Table 2-2: Report format

Section	Title	Description
3	Site description	Details the relevant environmental characteristics of the site with respect to ASS management.
4	Proposed earthworks and dewatering program	Outlines the overall earthworks and dewatering operations for the site.
5	Soil results	Assesses the presence and distribution of ASS within the soil at the site.
6	Groundwater quality	Provides a baseline assessment of groundwater prior to construction
7	Groundwater modelling	Details the findings of empirical groundwater modelling undertaken in support of the proposed dewatering program.
8	Assessment of potential environmental impacts	Details the potential environmental impacts from the DPD Project that might result due to disturbance of ASS through the earthworks program.
9	Proposed earthworks operating strategy	Outlines the proposed earthworks associated with the DPD Project.
10	ASS environmental reporting	Presents the environmental reporting requirements associated with the management of ASS at the site.
11	References	Lists the guidance and literature references referred to within this report.

Section	Title	Description
Appendix A	Identification and management of unexpected ASS – onshore zone	Presents procedures for the on-site identification and management of unexpected ASS material in the onshore zone.
Appendix B	Dewatering operating strategy	Presents the proposed options in managing dewatering effluent and containing relevant monitoring requirements for dewatering effluent and groundwater.

2.4.4 Guidance literature

Preparation of this ASSDMP report was undertaken with reference to the following key guidance documents on ASS and water quality:

+ Acid Sulfate Soils Laboratory Methods Guidelines (McElnea, A.E. and Ahern, C.R. 2004)
+ Australian/New Zealand Standard 5667.1:1998, Water quality – Sampling. Part 1: Guidance on the design of sampling program, sampling techniques and the preservation and handling of sampling (Standards Australia, 1998a)
+ Australian/New Zealand Standard 5667.4:1998. Water Quality – Sampling. Part 4: Guidance on sampling from lakes, natural and man-made (Standards Australia, 1998b)
+ Australian/New Zealand Standard 5667.12:1998, Water Quality — Sampling. Part 12: Guidance on Sampling of Bottom Sediments (Standards Australia, 1998c)
+ National Acid Sulfate Soils Guidance. National acid sulfate soils identification and laboratory methods manual. (Water Quality Australia, June 2018a).
+ National Acid Sulfate Soils Guidance. Guidance for the dewatering of acid sulfate soils in shallow groundwater environments. (Water Quality Australia, June 2018d).

3 Site description

3.1 Site details

A detailed site summary is provided in **Table 3-1**, below, with the site locality presented in **Figure 2-1**.

Table 3-1: Site details summary

Reference name	Darwin Pipeline Duplication (DPD) Project	
Address	Darwin LNG Facility, Wickham Point Road, Wickham, NT 0822	
Designated plant and pipeline operator	Santos	
Local government authority	Litchfield Municipality	
Current zoning	Industrial	
Area and elevation	**Area**	**Elevation**
	0.40 ha	DLNG: 12 – 15 m LAT
Site location and layout	**Figure 2-1** **Figure 2-2** **Figure 2-3**	
Coordinates – LAT (GDA 94, Zone 52)	**Easting**	**Northing**
	701,954.81	8,614,527.82
Coordinates – Shore pull onshore termination point (GDA 94, Zone 52)	**Easting**	**Northing**
	702,272.73	8,614,606.40
Coordinates – Upstream weld of the beach valve tie-in (GDA 94, Zone 52)	**Easting**	**Northing**
	702,472.29	8,614,655.73

3.2 Site setting

3.2.1 Climate

Relevant information pertaining to the site's wider setting is presented within the DPD Project's Northern Territory Environmental Protection Authority (NT EPA) referral document (Santos, 2021).

The site's climatic setting can be summarised as follows:

+ The climate is characterised by a tropical monsoonal climate with a distinct dry season (May to September) and wet season (October to March), separately by a relatively short transition period.
+ The average annual rainfall for Darwin is 1,720 millimetres (mm), with the wettest months being January to March.

+ Rainfall is higher than evaporation from December to March and lower from April to November. The mean maximum temperature range is from 30.6°C (July) to 33.3°C (October and November).

3.2.2 Geology

The site's regional geological setting (based on Dames & Moore, 1997) is described as:

+ Quaternary Deposits (Q)
  – Qcl – Sand, silt, clay: colluvial sediments deposited by unconcentrated surface runoff
  – Qca – Mud, clay, silt: intertidal marine alluvium
+ Early Proterozoic Deposits – Finniss River Group – Burrell Creek Formation (Pf)
  – Pfb – shale, siltstone, and phyllite in places, colour banded fine to very coarse sandstone (quartz, arentite, sublitharenite, arkose), quartzite, quartz pebble conglomerate, minor graphitic phyllite, quartz-mica schist and gneiss.

The site's local geological setting (URS, 2002), prior to construction of the DLNG Facility is summarised as follows:

+ Characterised by a strongly foliated and metamorphosed sequence of steeply dipping interbedded sandstone and siltstone
+ Thick lateritic ironstone soil has developed on hinterland areas, whereas marine and mangrove mud characterises the seaward margin
+ The marine and mangrove mud comprises predominantly silty sediments with varying amounts of sand, clay, and lateritic gravel
+ Based on the understanding of the previous earthworks at the site, it is understood the site's geological setting has been highly modified, and the presence of the natural geology at the site is not anticipated.

3.2.3 Intertidal setting

The site is situated in a low-lying intertidal area of the Middle Arm Peninsula, within the wider Darwin Harbour area (**Figure 2-1**).

The clayey nature of the underlying soils and the surrounding area results in localised pooling of rainfall and limited/low infiltration rates. The site is largely cleared of large vegetation due to historical earthworks associated with the installation of the Bayu-Undan pipeline.

The coastline of the site is fringed by mangroves and clayey tidal flats to the north and south of the site.

3.2.4 Topography

The site's topographic profile is largely flat across the onshore half of the proposed pipeline extent, at approximately 12 m LAT, with a maximum height of approximately 15 m LAT. The topography of the site slopes gradually towards the coast extending towards its western extent, to a height of 0 m LAT on its western boundary.

3.2.5 Acid sulfate soil risk

The Australian Soil Information System (ASRIS) is an online data resource provided by the Federal Government's Department of Agriculture, Fisheries, and Forestry, in conjunction with the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

A review of the ASRIS database (accessed: 25/05/2022), based upon an undisturbed site, indicates the site has a 'high probability' of ASS being present, albeit with 'low confidence'.

3.2.6 Groundwater and surface water

Groundwater and surface water information presented within the DPD Project's NT EPA Referral (BAA-201 0003; Santos, 2021) is summarised as follows:

+ There are no permanent freshwater habitats at the shore crossing or the adjacent mainland peninsula. However, there are several small creek lines that flow from upland areas to the harbour during the wet season.
+ Periodic monitoring of groundwater has been undertaken at the DLNG Facility and wider area since 2015. During periodic monitoring, encountered depths to groundwater at monitoring locations closest to the Site (BH05 and BH07) ranged between 1.34 m below top of casing (btoc) (approximately 0.80 m bgl) at BH05 in April 2021; and 3.14m btoc (approximately 2.60 m bgl) at BH07 in April 2021.
+ Periodic groundwater monitoring at the location closest to the site (BH7) has indicated that groundwater levels monitored in 2021 (the latest available annual reporting timeframe) range between approximately 2.4 m AHD (5.4 m LAT) and 4.7 m AHD (7.7 m LAT), dependent upon seasonal rainfall cycles. A higher groundwater level has been noted during the wet season compared to the dry season. This data is based on an historical monitoring location situated to the north of the site, and so groundwater levels at the site may vary.
+ During historical monitoring, the ambient groundwater pH typically varied between 3.9 to 6.7 pH units, whilst the recorded conductivity range varied between 109 to 82,000 micro-Siemens per centimetre (µS/cm). This variation was attributed to the climatic seasonality of the area. Increased rainfall of the wet season presents a freshwater input into the groundwater regime.
+ The Darwin Harbour surface water body is located across the intertidal zone, extending from 0 m LAT to 8.2 m above LAT during periods of high tide.

4 Proposed earthworks and dewatering program

The timing and extent of ground disturbance and dewatering associated with the development of the site can play a large role in the extent of management measures required for the site.

The proposed earthworks and dewatering programs are summarised in the following sections.

4.1 Earthworks program

The following presents a general summary of the anticipated earthworks at the site:

Table 4-1: Summary of proposed earthworks at the site

Earthworks zone	Zone definition	Proposed earthworks
Intertidal zone	Extending from 0 m LAT to the shore pull onshore termination point, over a distance of approximately 327 m (see **Figure 2-2**).	High-tide periods: + Vessel-based backhoe dredge (BHD) assisted by split hopper barges (SHB) + Disposal of excavated material will be at an offshore spoil disposal ground Low-tide periods: + Conventional earthworks plant, namely: land-based backhoe or tracked excavator + Disposal of excavated material will be through stockpiling as close to the LAT mark as possible, as per the procedures presented below.
Onshore zone	Extending from the shore pull onshore termination point to approximately the upstream weld of the beach valve tie-in point over a distance of approximately 206 m (see **Figure 2-2**).	+ The trench, including the anchor pit, will be excavated via conventional earthworks plant, namely: backhoe or tracked excavator + Management of excavated material will be as per the stockpiling and treatment procedures presented in **Appendix A**.

4.2 Proposed ground disturbance

The following presents a general summary of the anticipated ground disturbance extents:

4.2.1 Intertidal zone:

+ Trenching across this part of the site is anticipated to be approximately 327 m long, up to 5.0 m deep, and up to 4.0 m wide at the base.
+ Trenching will be undertaken by means of a combination between excavator and BHD. The exact location where vessel-based excavation and land-based excavation are separated will be determined during the course of the work.

+ This trenching may require the construction of temporary causeways (up to approximately 131.9 m long and 21.75 m wide either side of the pipeline) to enable trenching via conventional earthmoving equipment (excavator and dump trucks).
+ Given the location of this section of trenching, the excavation is anticipated to be periodically inundated by the tide.

4.2.2 Onshore zone:

+ A backhoe excavator will be used for land-based excavation. The excavations will create a trench, approximately 210 m in length, in a staged approach.
+ Based on the anticipated duration of earthworks, the trench may remain open for up to four months.
+ The trench is anticipated to be up to 5.0 m deep, and 4.0 m wide at its base.
+ Excavation pit for the hold back anchor (anchor pit), it is anticipated that the pit will be 25 m x 30 m, with battered sides, and 5 m deep (maximum depth of 8.5 m LAT).

4.3 Proposed dewatering

The use of the term 'dewatering' refers to the removal/pumping of groundwater.

The removal and/or pumping of rainwater from excavations is considered not to be required during construction and as such is not considered within this management plan. As a contingency however, a dewatering management plan has been included (Appendix B) should it be required.

4.3.1 Intertidal zone

Given the intertidal setting of this extent of the trench, no dewatering is proposed for earthworks in this section of the site as it will be subject to periodic tidal inundation.

4.3.2 Onshore zone

The requirement for dewatering is in part dependent on the groundwater levels at the time of excavation, hence varies seasonally with rainfall. Based on the current understanding of the earthworks and associated timeframes, dewatering is considered not to be required across the onshore zone.

Should however groundwater be encountered during the onshore earthworks, dewatering measures should be implemented.

The dewatering measures (if required) are presented within **Appendix B**.

5 Soils

5.1 Previous investigations

The identification and assessment of ASS for the site is based on the following historical reports:

+ D&M, 1997. 'Darwin LNG Plant – Draft Environmental Impact Statement: Appendix G – Wickham Point and Middle Arm Peninsula Terrain Analysis', Dames & Moore Pty Ltd. Ref.: 0053-164-073. July 1997
+ URS, 2002. 'Acid Sulfate Soil Investigation – Wickham Point, Northern Territory', URS Australia Pty Ltd. Ref.: 00533-244-562 R001. 19 July 2002
+ URS, 2004. 'Bayu-Darwin Pipeline Project – Acid Sulfate Soil Management Plan', URS Australia Pty Ltd. Ref.: 561-F6359.1. 6 April 2004
+ BHBJV, 2004. 'ConocoPhillips Bayu-Darwin Pipeline Project: Shore Approach, Dredging & Rock Dumping Subcontract No. BDPP-S-CO-002: Manufacturing Procedure Specification Dry Excavation', Ballast Ham / Boskalis Joint Venture, Ref.: BD-O-PR-1824, 21 April 2004.

5.2 Dames & Moore Pty Ltd, July 1997

Dames & Moore Pty Ltd (D&M) completed a historical investigation of ASS as part of a terrain analysis across the wider Wickham Point area in October 1996 on behalf of Phillips Petroleum as part of the development of the new DLNG facility.

5.2.1 Scope

The investigation comprised the following:

+ Review of desktop data for the area
+ Collection of six soil samples from near-shore locations across the wider area
+ Sample locations were accessed by boat and were collected from depths of up to 1.0 m bgl
+ Laboratory analysis on the collected soil samples.

5.2.2 Findings

Two sample locations (WP-W1 and WP-W2) were in the intertidal area in close proximity to the DPD Project site. The soils were identified as estuarine mud (brown/dark grey/green clayey silts/sands/gravels) and the results of the laboratory analysis are summarised as follows:

+ Sulfate concentrations ranged between 0.21%S (WP-W1 0.0–0.5 m) and 0.34%S (WP–W1 0.1 m).
+ Acid neutralising capacity (ANC) concentrations ranged between 9.91%S (WP-W2 0.0–0.5 m) to 11.9%S (WP–W1 0.1 m).

The report concluded the following:

+ Sulfur concentrations in the samples could give rise to acid generation, however, due to the inherent neutralising capacity of the materials (largely due to the finely disseminated $CaCO_3$ content in the soil most likely generated from shell fragments and/or coral detritus), being an order of magnitude higher than sulfur concentrations "there would not be any nett acid production potential".

5.3 URS Australia Pty Ltd, 19 July 2002

URS completed an historical investigation of ASS across the wider Wickham Point area in 2002 on behalf of Phillips Petroleum as part of the development of the new DLNG facility.

5.3.1 Scope

The investigation comprised the following:

+ Review of historical reports for the area
+ Advancement of 45 boreholes, distributed across six 'sites', spread across the wider Wickham Point area, and installation of monitoring wells
+ Completion of ASS field tests and laboratory analysis (peroxide oxidation combined acidity and sulfur (POCAS) suite analysis and Chromium reducible sulfur (CRS)) on soil samples at 0.5 m depth intervals
+ Collection of soil samples at 0.5 m intervals for laboratory analysis
+ Boreholes were advanced by hand auger to refusal, or to the 'limit of the hand auger'.

5.3.2 Findings

One of the sites (Site 6) was adjacent to the northern boundary of the DPD Project site, and included ten boreholes, of which six were advanced in onshore locations.

+ A review of a geotechnical study (JFA, 2001) for the DLNG Facility, which included Site 6, identified the following:
  - Eight samples were obtained from three boreholes (P8, P9B, and P10) for laboratory (POCAS) analysis, with only Peroxide Oxidisable Sulfur (S_{POS} %S) and Titratable Peroxide Acidity (TPA; %S) reported.
  - S_{POS} concentrations ranged between 0.02 and 0.74%S (in P10_0.55–0.72 m and P9B_0.35–0.50 m respectively).
  - 'Non-detections' of TPA (i.e., 0.01%S) indicate a high acid self-neutralising capacity in all samples tested. This is likely due to the presence of large shell-grit/carbonate content
+ The URS, 2002 investigation encountered the following ground conditions at Site 6:
  - Sediments comprised marine silts, sand, and gravel underlying the shoreline mangrove communities.
  - Hand auger refusal occurred on bedrock at depths ranging from 0.1 to 1.0 m bgl.
  - Field testing was undertaken upon four samples with the test results indicating 'zero to very low' likelihood of ASS.
  - Laboratory analysis was undertaken upon two samples from the Site 6 which indicated:
+ SCR results ranged between 1.26–1.62%S (from sample depths of 0.2–0.6 m and 0.2–0.4 m bgl, respectively).
+ High self-neutralising capacity in the samples, based on the high acidity (pHNaCl – between 8.7 and 8.8), and the concentration of 25–30% fine carbonate/shell content with a particle size of <1mm.

- The laboratory analysis indicated the samples were indicative of PASS.
- The report states that 'no additional lime should be required for neutralisation of acidity if complete oxidation were to occur'.
- These results were broadly consistent across the remaining investigation areas, distributed across Wickham Point.

5.4 URS Australia Pty Ltd, 6 April 2004

URS completed a historical ASSDMP document on behalf of a Multiplex-Saipem Joint Venture. The ASSDMP was prepared to enable the assessment of potential ASS impacts to the Bayu-Darwin Pipeline Project, and to present a contingency plan for unexpected disturbances of ASS.

The context for the document, as presented within the ASSDMP itself, was as follows:

- Although not expected to be present or be of major significance on this site, a detailed ASSDMP has been prepared prior to the proposed pipeline excavation works within estuarine sediments (mudflats). ASS have been identified in areas in close proximity to the proposed mudflat excavation site and on site but based on available site information these sulfidic soils are believed to have the capacity to self-neutralise.

The ASSDMP included a summary of historical investigations at the site, including an additional scope of investigation work undertaken by Thiess Pty Ltd (Thiess) in 2003. Theiss advanced boreholes at two locations within the development footprint of the subject site of this ASSDMP (the site).

The findings of the historical investigations were summarised as follows:

- The encountered sediments were generally marine silts and sand layers, extending to depths of up to 1.0 m bgl.
- Two samples taken from the proposed excavation site confirmed the presence of sulfidic material. The self-neutralising capacity of the soil was found to be such that the net acid generating capacity is negative (i.e., the soil has a high buffering capacity).
- Whilst these samples did not extend down the length of the excavation, they are similar in nature to those collected 100–300 m to the north of the proposed excavation site (Site 6, URS 2002).
- At Site 6 an extensive ASS investigation was carried out with all samples also having a negative net acid generating capacity. Similar ground conditions and results are anticipated at the site.
- The site investigations confirmed that the underlying strongly foliated metamorphosed sequence of interbedded sandstone and siltstone (URS, 2002) does not contain sulfidic material and therefore does not have the potential to generate acid when exposed to the atmosphere, thus does not require ASS management.

5.5 ConocoPhillips, 21 April 2004

The ConocoPhillips, 2004 report presents a Manufacturing Procedure Specification for the construction of the DLNG Facility, as part of the 'Bayu-Darwin Pipeline Project'. The document makes reference to the URS ASSDMP (URS, 2004) as the main reference document for the management of ASS.

The report presents a summary of a Thiess risk assessment undertaken for the interception of ASS material during earthworks. The scope of work undertaken by Thiess included:

- A review of historical ASS investigation data and conclusions
- Additional ASS sampling undertaken in January 2004, comprising:
  - Obtaining one soil sample from ‘centreline’ of the proposed onshore pipeline easement
  - Obtaining one soil sample from ‘south of the centreline’ of the proposed onshore pipeline easement
  - Laboratory analysis for SPOCAS analysis on both samples, which indicated that whilst sulfur concentrations were above management criteria, the soils were identified as self-neutralising.

5.6 Summary

Based upon a review of historical earthworks undertaken at the site as part of the development of the DLNG Facility, the site has had its natural material removed across the onshore zone and replaced by imported (non-ASS) fill material (generally sand).

Based on this, it is understood that ASS associated with the naturally occurring soil material is no longer present within the onshore zone, however its presence in the Onshore and Intertidal Zones cannot be discounted and may require management.

Based upon data provided within the historical investigations undertaken at the site and surrounds, ASS material previously present at the site was characterised as follows:

- ‘Lateritic clays with various amounts of sand, silt and quartz gravel.’ (URS, 2002).
- Generally self-neutralising due to its inherent high buffering capacity, generally associated with its high fine carbonate/shell content.

Historical investigation data indicated that prior to the development of the DLNG Facility, ASS material at the site could be found up to 2.5 m bgl, underlain by siltstone bedrock.

For management purposes, all material at the site should be considered non-ASS unless it matched the visual ASS descriptions, presented within this ASSDMP.

Whilst the majority of material onshore is considered to not require management, vigilance will be maintained during on-site works to identify natural in-situ material PASS (lateritic clays) which may have not been removed during the DLNG Facility construction.

6 Groundwater

This ASSDMP provides a discussion of the site's baseline groundwater conditions recognising the interrelationship between PASS and groundwater quality (e.g., existing ASS impacts), and the potential significance of dewatering management in maintaining shallow groundwater quality in the short and longer terms, i.e., both during and after construction.

Historical groundwater monitoring data undertaken as part of the DLNG Facility's operational license requirements (CDM Smith, 2021) identified the following groundwater quality information for the local area adjacent to the onshore zone:

+ Localised recharge of the groundwater table occurs via infiltration of rainfall through alluvial sediments.
+ Groundwater, if discharging at the coastlines, may be mixing with marine water where it is saline and seeping to near-surface environments where it is fresh.
+ Groundwater monitoring undertaken as part of the July 2021 report identified the following:
  - Groundwater across the monitoring network was identified to be acidic, with the field pH of groundwater in the local area ranging from 4.53 to 6.35 pH units.
  - Field pH values for groundwater across the monitoring well network exceeded the applied Darwin Harbour Water Quality Objectives for the site.
  - Dissolved aluminium concentrations in groundwater ranged from 0.005 mg/L to 0.852 mg/L.

Based upon a review of historical groundwater information, groundwater at the site is anticipated to be acidic and will require treatment, prior to infiltration, should dewatering of groundwater across the onshore zone be necessary.

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7 Groundwater modelling

Dewatering may be required as part of the earthworks in the onshore zone.

Should groundwater be encountered during earthworks, dewatering must be implemented in accordance with the measures presented in **Appendix B**.

To inform the proposed dewatering requirements for the onshore zone, an overall approach to dewatering based on the historical groundwater information for the area is presented below.

7.1 Empirical approach

Based on the information for the DPD Project, no defined timeline or anticipated duration is available for dewatering at the site during the construction and installation of the pipeline.

Groundwater drawdown estimates were conducted utilising the empirical method as outlined in National Acid Sulfate Soils Guidance '*Guidance for the dewatering of acid sulfate soils in shallow groundwater environments*' (Water Quality Australia, June 2018d).

The radius of the cone of depression of the water table was estimated using Sichardt's equation:

$$R_o = 3000 * \mathrm{s} * \sqrt{k}$$

Where:

R_o = radius of influence of an equivalent pumping bore (m)

s = maximum drawdown of ground water (m)

k = hydraulic conductivity of aquifer matrix (units of m/s)

In the absence of site-specific hydraulic data, a K value of 3.5×10^{-4} m/s has been assumed (Water Quality Australia, June 2018d).

Changes in the water table elevation resulting from dewatering activities correlate with the pumping rate, the hydraulic conductivity of the aquifer matrix and the radius of influence of pumping by the following equation:

$$H^2 - h^2 = \frac{nq}{\pi k}(\ln R_o - \ln r_e)$$

Where:

H = saturated thickness of the aquifer undisturbed by pumping (m)

h = saturated thickness of the aquifer at maximum drawdown (m)

re = effective radius of an equivalent pumping bore (m)

q = pumping rate of individual dewatering well points (m^3/s)

n = number of well points used to dewater the excavation

Other parameters have been previously defined

The pumping time required for the cone of depression of the water table to extent out to the radius of influence (Ro) is given by the Cooper-Jacob empirical relationship.

$$R_o = (\frac{2.25 * k * h * t}{S})^{\frac{1}{2}}$$

Where:

t = pumping time (s)

h = specific yield of aquifer sediments

Other parameters have been previously defined

Groundwater dewatering calculations were undertaken to assess potential environmental impacts resulting from the dewatering. The calculations provide guidance and estimations for:

- The extent and magnitude of on- and off-site drawdown arising from dewatering operations and its potential environmental impacts on surrounding areas
- An estimate of the volume of water that will be abstracted to achieve the required on-site drawdown.

7.2 Dewatering scenario

The following scenario for dewatering at the site was based upon the proposed earthworks. The dewatering scenario is based upon the trench having a width of five metres, being conducted in 50 m lengths. A maximum drawdown of 6 m was anticipated.

The calculation adopted the following assumptions, which were biased to being conservative in the estimation of aquifer properties (i.e., tending to over-predict dewatering required):

- The saturated thickness of the aquifer undisturbed by pumping (H): 10.0 m
- The saturated thickness of the aquifer at maximum drawdown (h): 4.0 m
- A well point (n) per 2 metres of length: 10
- The hydraulic conductivity of the aquifer matrix (k) is 1.16×10^{-5} m/s as described in the National Guidance (Water Quality Australia, June 2018a) for clayey sands
- Groundwater is required to be drawdown by 6 m
- The specific yield (S) is 0.1 in the absence of site-specific hydraulic information.

7.3 Results

The following results were obtained based on the assumptions presented above. The results related to each 50 m length of pipeline:

- The radius of influence was 61 m.
- The pumping rate was calculated at 1.6 L/s (per well) taking approximately 16 hours to achieve the drawdown for a 50 m section of the trench.
- A calculated total of 6,327 kL of dewater was estimated to be abstracted requiring disposal to achieve drawdown per 50 m section of the excavation, i.e., cone of depression.

Based on the above, an average pumping rate of ~1.6 L/s per 50 m linear excavation extent was adopted for the site, which equates to an extracted volume of water of 6,327 m^3 over a 16-hour period per day.

7.4 Limitations of empirical method

The empirical method for estimating dewatering volumes is provided in the National Guidance (Water Quality Australia, June 2018d), however it is simplistic and does not take potential hydrogeological complexities into account. This empirical method provides estimated flows from groundwater based upon simplistic geological conditions, default hydraulic conductivity estimates and theoretical calculations.

Similarly, the method does not include the influence of rainfall recharge which can affect groundwater inflow and dewatering rates. For these reasons, the results provided are broad estimates only and may require some adjustment on-site.

8 Assessment of potential environmental impacts

The identified potential environmental impacts associated with earth working and dewatering of ASS for the various proposed construction activities are detailed in **Table 8-1**.

Table 8-1: Potential Environmental Impacts

Potential impact	Description	Predictions	Management measure
Oxidation of PASS			
Soils/sediments (excavated)	+ Generation of ASS through the inappropriate handling, treatment or disposal of excavated soils.	+ PASS in the intertidal zone is anticipated to have suitable self-neutralising capacity to avoid potential ecological damage. + PASS in the onshore zone is not anticipated to be encountered however, if encountered, will require management. + The receiving environment (the surface water) for the disposal of encountered ASS will have a high buffering capacity: minimising potential impacts from ASS disposal.	+ As per the Earthwork Operating Strategy (**Section 9**)
Soils/sediments (*in-situ*)	+ ASS oxidation effects caused through exposure of the soils to air via open excavation.	+ Drawdown of groundwater is not anticipated to impact ASS within the extent of proposed excavations. + Excavated material from the intertidal zone will remain saturated at all times prior to placement at disposal location. + Excavated material from the onshore zone is anticipated to be non-ASS (as historically imported fill). ASS oxidation and impacts associated with this zone are not anticipated.	+ As per the Earthwork Operating Strategy **(Section 9**)
Groundwater	+ Potential for acid and metal leaching through groundwater from oxidised ASS.	+ Drawdown of groundwater, if required, will be managed via the dewatering operating strategy. + Excavated material from the onshore zone is anticipated to be non-ASS (as historically imported fill). ASS oxidation and impacts associated with this zone are not anticipated.	+ As per Dewatering Operating Strategy (**Appendix B**).

Potential impact	Description	Predictions	Management measure
Surface water	+ Potential for acid and metal mobilisation into adjacent surface water (inter-tidal area of Darwin Harbour) from oxidised ASS.	+ Drawdown of groundwater, if required, will be managed via the dewatering operating strategy. + Excavated material from the intertidal zone will remain saturated at all times prior to placement at disposal location.	+ As per Dewatering Operating Strategy (**Appendix B**) and the Earthwork Operating Strategy (**Section 9**).
Sediment plume			
Poor surface water quality	+ Sediment plumes generated in Darwin Harbour during the excavation and placement of sediments/soils from the intertidal zone.	+ Given the low anticipated sediment generation volumes associated with the excavation and dispersals of emplaced PASS material at the site, the risk of adverse impacts on surface water quality is low.	+ None required.
Dewater Discharge			
Impacts to the adjacent surface water body	+ Discharge of acidic groundwater sourced from dewatering of the excavated trench in the Onshore Zone could impact the adjacent surface water body (Darwin Harbour) if not treated appropriately.	+ Should dewatering be undertaken as part of the Onshore Zone earthworks, a dewatering rate of 1.6 L/sec will be required. + This will need to be managed in accordance with the procedures presented in this document in order to avoid impacts to the adjacent surface water body (Darwin Harbour). + Note: discharge of dewatered groundwater from the Onshore Zone directly to Darwin Harbour is not acceptable.	+ As per Dewatering Operating Strategy (**Appendix B**).

9 Earthworks operating strategy

9.1 Overview

For the purposes of managing ASS, the site is spilt into the following zones (as presented in **Figure 2-3**):

- The 'intertidal' zone, extending from the LAT mark to the shore pull onshore termination point.
- The 'onshore' zone, extending approximately 206 m from the shore pull onshore termination point to the upstream weld of the proposed beach valve tie-in point.

For the purposes of managing ASS, the following applies:

- Intertidal zone: ASS management measures will be required for estuarine muds (brown/dark grey/green clayey silts, sand and gravels) material from natural surface level to the top of encountered hard strata.
- Onshore zone: All material is considered non-ASS and does not require active management. There remains the potential, albeit low, for natural in-situ lateritic (red/brown) clays/silt/sand to be present which will requirement management if encountered.

Further information on the identification of ASS *in-situ* is presented in **Appendix A**.

9.2 ASS management measures

This management measure will comprise similar steps to that presented within the ASSDMP for the DLNG Facility (URS, 2004), and is summarised below.

9.2.1 Intertidal zone

- ASS material, as estuarine mud, is anticipated from surface level. Management measures are as follows:

High-tide periods:

- Excavation via vessel-based BHD assisted by SHB
- Disposal of excavated material will be at the DPD offshore spoil disposal ground (**Figure 2-1**).

Low-tide periods:

- Conventional earthworks land-based plant, namely: backhoe or tracked excavator
- All material will be stockpiled at a predetermined location situated as close to the LAT mark as possible, resulting in the material being saturated across most tidal states.
- All material would be removed directly from the trench excavation to the stockpile location and remain saturated during most tidal states due to periodic tidal inundation: thereby limiting the likelihood of drying out and acidification.
- The tidal action would gradually remove the stockpiled material and disperse it to the marine environment.

Visual inspections will be undertaken of the immediate marine environment to ensure adequate dispersal of material placed in the intertidal zone. Where residual material (mounding) is identified during the visual inspection, excess will be transferred via SHB to the DPD offshore spoil disposal ground.

Table 9-1 presents a summary of the performance indicators used to assess the effectiveness of the ASS management. The adherence to these performance indicators should be documented throughout the treatment process for inclusion in the final ASS Closure Report.

Table 9-1: Summary of ASSDMP performance indicators – intertidal zone

Item	Performance Indicator
Soil handling	+ All material will be managed as ASS (or suspected ASS) and will be stockpiled accordingly. + Accurate material movement records kept.
Stockpile all suspected ASS as close to the LAT mark as possible and have it transported to the DPD offshore spoil disposal ground or removed by tidal action.	+ All ASS placed in the intertidal zone removed by tidal action within 2.5 days from being excavated. + Where ASS is still present in a stockpile beyond 2.5 days, the remaining material should be moved via vessel-based BHD assisted by SHB and then disposed of at the DPD offshore spoil disposal ground. + All ASS material is kept saturated from excavation to placement as close to the LAT as possible, for removal via tidal action. + Records are kept for the volume of ASS material disposed of in this manner.

9.2.2 Onshore zone

+ ASS material, as estuarine mud, is not anticipated in this section of the site.

Should this material be encountered during earthworks for trenching and site preparation works, suspected unexpected ASS material is to be removed from the excavation and stockpiled separately from non-ASS materials on a limestone pad ahead of confirmatory testing. Due to the timing of excavation and construction of the anchor pit (which is to occur during site preparation works), specific management procedures for the anchor pit excavation are detailed below.

The requirements for management of this material are detailed in **Appendix A**.

9.2.2.1 Anchor pit excavation

As excavation and construction of the anchor pit will occur during the site preparation works, should ASS be encountered, such material will be placed as close to the LAT mark as possible (per the intertidal zone management measures above), whilst the causeway(s) in the intertidal zone is available. Once the causeway(s) is unavailable, encountered ASS material, must be treated on a limestone pad as detailed above (**Section 9.2.2**).

Should ASS material be encountered, during the excavation, and present at the base of the anchor pit, as a contingency measure, a thin layer (10 – 20 mm) of limestone should be placed at the base of excavation and on the batters, where ASS is present.

10 ASS environmental reporting

10.1 ASS closure report

A closure report will be prepared by an environmental professional and issued to the NT EPA at the completion of earthworks and detail (where required):

+ Management measures undertaken at the site and their effectiveness.
+ Soil validation results, both field and laboratory testing as specified in the ASSDMP (if required; see **Appendix A**).
+ Amount of neutralising agent used during construction (if required; see **Appendix A**).
+ Discussion of potential human health and environmental risk, and any remediation required.
+ Photographic record of the earthworks program.

10.2 Unexpected ASS

Should unexpected ASS be encountered the Contractor's site manager shall be responsible for:

+ Ensuring laboratory analysis is carried out to verify treatment for each identified ASS location at the frequency stipulated in this ASSDMP (see **Table A-2**, **Appendix A**).
+ Applying additional lime/calculating additional liming rates, where soils require further treatment, submitting subsequent verification samples to a laboratory for analysis, and verifying that the results meet the neutralisation criteria.
+ Maintaining a register of testing results and a record of inspections.
+ Compiling a summary report of all test results and inspections at the end each week and submitting to the Santos Project Manager.

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11 References

Literature references

BHBJV, 2003. 'ConocoPhillips Bayu-Darwin Pipeline Project: Shore Approach, Dredging & Rock Dumping Subcontract No. BDPP-S-CO-002: Manufacturing Procedure Specification Dry Excavation', Ballast Ham / Boskalis Joint Venture, ref.: BD-O-PR-1824, 21 April 2004

CDM Smith, 2021. 'Darwin LNG Groundwater Interpretive Report 2021', CDM Smith Pty Ltd. ref.: DLNG-1001034-RPT-001-1', 19 November 2021

D&M, 1997. 'Darwin LNG Plant – Draft Environmental Impact Statement: Appendix G – Wickham Point and Middle Arm Peninsula Terrain Analysis', Dames & Moore Pty Ltd. ref.: 0053-164-073. July 1997

Downer, 2022. 'Barossa Onshore Tie-In Project - Delivery Management Plan', Downer, ref: 158888-PLA-0001 RevA, 17 May 2022

Santos, 2021. 'Darwin Pipeline Duplication (DPD) Project NT EPA Referral', ref.: BAA-210 0003', CDC Smith on behalf of Santos Pty Ltd, Rev0, 8 December 2022

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Santos, 2022b. 'Darwin Pipeline Duplication Project – Basis of Approval', ref.: BAA-210 0005', Rev2, 27 May 2022

URS, 2002a. 'Darwin 10 MTPA LNG Facility Public Environmental Report' prepared for the development of the DLNG Facility

URS, 2002b. 'Acid Sulfate Soil Investigation – Wickham Point, Northern Territory', URS Australia Pty Ltd. ref.: 00533-244-562 R001. 19 July 2002

URS,2004. 'Bayu-Darwin Pipeline Project – Acid Sulfate Soil Management Plan', URS Australia Pty Ltd. ref.: 561-F6359.1. 6 April 2004

Guidance documents

Acid Sulfate Soils Laboratory Methods Guidelines (McElnea, A.E. and Ahern, C.R. 2004)

Australian/New Zealand Standard 5667.1:1998, Water quality – Sampling. Part 1: Guidance on the design of sampling program, sampling techniques and the preservation and handling of sampling (Standards Australia, 1998a)

Australian/New Zealand Standard 5667.4:1998. Water Quality – Sampling. Part 4: Guidance on sampling from lakes, natural and man-made (Standards Australia, 1998b)

Australian/New Zealand Standard 5667.12:1998, Water Quality — Sampling. Part 12: Guidance on Sampling of Bottom Sediments (Standards Australia, 1998c)

Northern Territory Environmental Protection Act, 2019

National Acid Sulfate Soils Guidance. National acid sulfate soils identification and laboratory methods manual. (Water Quality Australia, June 2018a)

National Acid Sulfate Soils Guidance. Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management (Water Quality Australia, June 2018b)

National Acid Sulfate Soils Guidance. Overview of management of monosulfidic black ooze (MBO) accumulations in waterways and wetland (Water Quality Australia, June 2018c)

National Acid Sulfate Soils Guidance. Guidance for the dewatering of acid sulfate soils in shallow groundwater environments. (Water Quality Australia, June 2018d)

'Guidelines for the Siting, Design, and Management of Solid Waste Disposal site in the Northern Territory', Northern Territory Environmental Protection Authority, January 2013. (NT EPA, 2013)

Appendix A: Identification and management of unexpected ASS – onshore zone

General

The procedures outlined below are provided for the identification and management of unexpected ASS material that may be exposed during onshore ground disturbance activities (open excavations in the onshore zone).

Suspected unexpected ASS material is to be removed from the excavation and stockpiled separately from non-ASS materials on a limestone pad ahead of confirmatory testing as outlined below.

Identification of ASS at the site

Vigilance should be maintained during on-site works to assist with the identification of potential unexpected silt/clay or suspected ASS material encountered at the site during the course of earthworks.

Suspected ASS materials are often fine grained and located near the water table and may exhibit a "rotten egg" odour. Based on the results of previous investigations, material which appears to be clayey should be assumed to ASS.

The following visual indicators can be used to assist with the on-site identification of ASS:

- Unusually clear or milky green drain water
- Extensive rust coloured iron stains on any drain surfaces
- Iron-stained drain water
- Butter coloured jarosite present in surface spoil
- Iron oxide mottling.

Other indicators, where none of the above is present, are waterlogged estuarine sands or silty sands having:

- Mid to dark grey to dark greenish grey in colour; or
- Soft and buttery clay consistency.

Material that is suspected ASS material and possesses the above traits can be confirmed by suitably qualified personnel or consultant.

If encountered the material should be stockpiled separately and treated in accordance with the management measures presented below.

Training

Equipment operators and supervisors shall be trained in the basic recognition of ASS as part of induction training. It is recommended that an experienced ASS practitioner shall be appointed to conduct site inspections and assist in the identification of ASS on an as required basis.

Auditing

An experienced ASS practitioner shall make weekly site inspections for the first two weeks of the works (dependent upon the proposed earthworks duration). The frequency of inspections required following this initial inspection period would be reviewed based on specific requirements of the ground disturbance works. The frequency may be reduced once a high level of compliance has been demonstrated.

Unexpected ASS management procedure – onshore zone

ASS is not anticipated within the proposed earthworks extent at the onshore zone. Given this, the requirements of this management measure (as an 'unexpected ASS' management procedure) are summarised below with specific procedures for the anchor pit:

Roles and responsibilities

The following responsibilities for the monitoring requirements are outlined below. All formal reporting to the Regulator will be undertaken by a suitably qualified person.

Table A-1: Monitoring Roles and Responsibilities

Monitoring activity	Parameters	Responsibility
Validation of Treated PASS Soils		
Collection of soil samples upon notification from site contractor	+ Laboratory: pHF and pHFOX, and SPOCAS[1]	+ Environmental Consultant
Review of results and notification to site contractor	+ -	+ Environmental Consultant

Note

1. Suspension Peroxide Oxidation and Combined Acidity and Sulfate.

Excavation and stockpiling of unexpected ASS material

+ Suspected ASS should be excavated and kept separate to non-ASS material.
+ The suspected ASS should be transported to a defined, bunded limestone pad for stockpiling.

Details on the construction of the treatment pad are provided below:

+ The limestone pads will be constructed in accordance with National Acid Sulfate Soils Guidance (2018b); i.e., ~300 mm thickness, with 150 mm high perimeter bunds and graded to corner/sump to capture any leachate/runoff from the drying vegetation.
+ A 'suitably qualified person' should undertake confirmatory sampling and assessment of the material to confirm the presence of ASS and required treatment rate.
+ ASS field screening (pH_F and pH_{FOX}) and CRS suite analysis with the inclusion of TPA is to be conducted at a minimum rate of 2 per 250 m^3 of recovered suspected ASS material (as per National Acid Sulfate Soils Guidance. [WQA, June 2018a]).
+ Based on the outcome of this testing, i.e., Net Acidity > 0.03%S, the 'suitably qualified person' will determine the appropriate aglime treatment rate.
+ Where aglime is applied, the 'suitably qualified person' will be notified to allow visual inspection and sampling and analysis (i.e., pH_F and pH_{FOX} per the Validation Sampling requirements).

- Based upon the results of the sampling:
  - If the treated material does not comply with the validation criteria the material should be treated with additional aglime as determined by the ’suitably qualified person’. Should the results indicate partial treatment then the liming rate, based upon SPOCAS analysis results, may be reduced to ensure that material is not over limed.
  - If treated material complies with relevant validation criteria, then no addition treatment will be necessary.
- Treated ASS materials should not be used as backfill within excavations below the groundwater table. Only non-ASS materials shall be used to backfill below the water table.
- Alternatively, ASS material can be removed from the site and disposed of to a suitably licensed waste disposal facility that is licensed to accept untreated ASS, in accordance with the waste classification guidelines (NT EPA, 2013). Sampling and disposal requirements should be confirmed with the chosen waste disposal facility prior to removal off-site.

Anchor Pit

As excavation and construction of the anchor pit will occur during the site preparation works, should suspected ASS be encountered the following is to be implemented depending on whether the intertidal zone causeway(s) is available or not:

- Causeway(s) available:
  - Suspected ASS material will be placed as close to the LAT mark as possible and allowed to disperse with the tide (per the intertidal zone management measures (Section 9.2.1).
- Causeway(s) not available
  - suspected ASS should be transported to a defined, bunded limestone pad for stockpiling or removed from the site and disposed of to a suitably licensed waste disposal facility (as detailed above),

Should ASS material be encountered, during the excavation, and present at the base of the anchor pit, as a contingency measure, a thin layer (10 – 20 mm) of limestone should be placed at the base of excavation and on the batters, where suspected ASS is present.

Stockpile management

Specifications for the preparation of the bunded treatment area and the monitoring of collected runoff are provided below.

It is important to note, as stated in the relevant guidelines (WQA, June 2018b) ‘Stockpiling of soils is not to be used as an alternative to soil neutralisation, and all soils that are to be replaced in an excavation should be appropriately treated.’

Table A-2 presents the duration that ASS materials may remain untreated in medium-term stockpiles, i.e., those stored on a limestone pad (WQA, June 2018b). Exceedances of these timescales will result in non-conformances with this ASSDMP. Irrespective of how long material a stockpile, all ASS material must be treated prior to reuse onsite.

Table A-2: Indicative maximum periods for medium-term stockpiling

Type of material		Duration of stockpiling	
Texture (AS 17626-1993)	**Approx. clay content (%)**	**Days**	**Weeks**
Coarse Texture Sands to loamy sands	<5	14 days	2 weeks
Medium Texture Sandy loams to light clays	5 - 40	21 days	3 weeks
Pyritic Peat	N/A	21 days	3 weeks
Fine Texture Medium to heavy clay with silty clays	≥40	28 days	4 weeks

Preparation of a temporary treatment facility

As part of the on-site treatment of ASS, a bunded treatment area with crushed limestone pad (a dedicated facility for stockpiling and treatment of soils) shall be prepared as follows:

+ An area of at least 2 m width shall be left between the treatment areas and bunds to allow collection of runoff and direction to sumps.
+ The treatment area shall be bunded using compacted low permeability materials. The bund wall shall be of sufficient height to contain and collect runoff from stockpiled materials. the treatment pad should be constructed from crushed limestone (minimum of 300 mm in thickness).
+ Bunds will be constructed to allow collection of run-off directed to sumps (shallow drains may be employed to assist in directing flow to sumps). sumps shall be sized to allow containment of stormwater runoff from treatment areas with due consideration of possible treatment and discharge limitations.
+ The treatment areas shall be divided into a series of identifiable treatment lots. where possible, treatment lots should consist of the same lithological unit to allow for uniform liming rates. each treatment lot shall be large enough to treat up to 250 m^3 of material. stockpile height is not to exceed 2.5 m in height.

Liming rate

Should unexpected ASS be encountered, it is recommended that stockpiled material is sampled to enable the calculation of a suitable liming rate.

The calculation of liming rates is generally based upon a bulk density of 1.6 tonne/m^3, a safety factor of 1.5, and effective neutralising value (ENV) of 50%. The liming rate has been calculated as follows:

$$LR = \%S * \rho_{soil} * CF * SF * (\frac{100}{ENV})$$

Where:

LR = liming rate

S = percentage sulfur

ρ_{soil} = bulk density of soil (tonne/m^3) assumed at 1.6 tonne/m^3

CF = conversion factor (%S to kg pure $CaCO_3$/tonne) = 31.202

SF = safety factor of 1.5 as National Acid Sulfate Soils Guidance (2018a)

ENV = effective neutralising value

Sampling protocol

Samples should be collected for ASS field screening (pH_F and pH_{FOX}) testing on all samples, and the CRS Suite with TPA on all samples to enable Acid Base Accounting and the calculation of a suitable lime treatment rate.

The number of samples required (**Table A-3**) will be in accordance with the sampling densities as specified in National Acid Sulfate Soils Guidance, National acid sulfate soils sampling and identification method manual (Water Quality Australia, June 2018a).

Table A-3: Validation sampling numbers

Volume (m^3)	Number of samples
<250	2
251-500	3
1000	4
>1,000	4 plus 1 per additional 500 m^3

Quality Control and Assurance

A minimum of one field duplicate sample will be collected per 20 primary samples.

Validation criteria

In order to verify the success of the treatment, ASS field screening (pH_F and pH_{FOX}) shall be completed on all samples, and the SPOCAS suite shall be conducted on 25% of the total samples to confirm net acidity by Acid Base Accounting.

As per national acid sulfate soils identification and laboratory methods manual. (Water Quality Australia, June 2018a), the following verification conditions must be achieved to confirm the successful treatment of ASS material:

+ Net Acidity (Potential Acidity + Existing Acidity – Acid Neutralisation Capacity) ≤ 0
+ pH_{KCL} >6.5
+ TPA < laboratory's limit of reporting (LOR).

Additional lime treatment and further verification testing shall be conducted where adequate neutralisation is not initially indicated. Where additional treatment is required, the liming rate would be based on the results of the CRS verification results.

Validation and reuse of treated material

Upon completion of lime treatment, validation samples should be collected to confirm the successful treatment of the stockpiled ASS.

Once successful on-site treatment has been undertaken, the soil may be:

+ Used as backfill in excavated areas of the **onshore zone** of the site (in accordance with specification requirements including but not limited to embedment, compaction, and hygiene), or
+ Reused on-site.

The reuse of treated ASS materials on-site must be supported by sampling and laboratory analysis (in accordance with NEPM, 2013) to confirm the material's geochemical suitability for re-use on-site (i.e., to confirm the material is not contaminated).

The reuse of treated ASS materials as backfill must not include the placement of treated ASS beneath the groundwater table; the placement of treated ASS must be at unsaturated depths only.

Treatment of excavation areas – onshore zone

Upon excavation of suspected ASS material, the walls and base of the trench should be evenly covered by a thin layer of aglime at a rate of 2 kg per linear metre.

Photographic evidence of this coverage, along with detailed written records of the amount and location of aglime application, should be kept.

This applies to the onshore zone only.

Treatment performance indicators

Table A-4 presents a summary of the performance indicators used to assess the effectiveness of treatment.

The adherence to these performance indicators should be documented throughout the treatment process for inclusion in the final ASS Closure Report.

Table A-4: Summary of ASSDMP Performance Indicators – Unexpected ASS

Item	Performance Indicator
Identification of ASS Units	+ Inspections conducted by suitably qualified person + Unexpected ASS units are identified correctly + All contractors/contractor personnel responsible for identification of ASS have received appropriate training.
Soil handling	+ ASS (or suspected ASS) has been stockpiled separately from non-ASS material + Accurate material movement records kept
Suitably prepared treatment area	+ Treatment areas to be constructed as per measures presented in this appendix (i.e., treatment pad, bunding, sump, stockpile height) + Guard layer used between pad and stockpile + Treatment areas collecting runoff efficiently with no seepage to surrounding environment (i.e., bunding, drains, sumps)
Liming rates	+ Correct liming rates are applied through mixing of lime into soil.
Lime Addition	+ Lime addition to be undertaken based on the rate to be calculated by the Environmental Consultant.
Treatment verification	+ Verification of treatment on each treated lot

Item	Performance Indicator
	+ Correct verification laboratory analysis used + If verification shows material has a positive net acidity, additional treatment has been employed.
Non-conformance	+ All non-conformances are reported and rectified.

Responsibilities

With regards to the monitoring and reporting of treatment, the Contractor's site manager shall be responsible for:

+ Ensuring the treatment areas are constructed as described above
+ Maintaining records of all materials being disposed of or treated at the site
+ Maintaining a register of the construction details of each treatment area prepared at the site including photographs
+ Ensuring laboratory analysis is carried out to verify treatment at the frequencies presented in **Table A-3**. Where soils require further treatment, the Contractor's Site Manager shall be responsible for calculating additional liming rates, submitting subsequent verification samples to a laboratory for analysis, and verifying that the results meet the neutralisation criteria
+ Maintaining a register of testing results and a record of inspections
+ Compiling a weekly summary report of all test results and inspections for submission to the Santos Project Manager.

Appendix B: Dewatering operating strategy

The use of the term 'dewatering' refers to the removal/pumping of groundwater.

The removal and/or pumping of rainwater from excavations (where required) is not considered within this management plan.

Given the broadly-acidic state of localised groundwater at the site and the setting of the site with regards to the marine environment, **off-site discharge of acidic groundwater without treatment should not be undertaken.**

Administrative requirements

The Dewatering Operating Strategy presented in the sections below is based on National Guidance (Water Quality Australia, June 2018d) and describes how the groundwater dewatering (where required) will be managed within the site to ensure minimal impact to the environment.

This operating strategy should be reviewed by a groundwater professional upon confirmation of the extent of ground disturbance and dewatering requirements.

The groundwater potentially encountered during the proposed trenching is a superficial aquifer system. Groundwater levels in the superficial aquifer will be monitored and reviewed, during construction, by a groundwater professional.

Dewatering treatment method and materials

Table B-1 presents the dewatering effluent treatment method and neutralising agent should dewatering be required in the onshore zone.

Table B-1: Dewatering treatment method and materials

Dewatering element	Requirement
Dewatering treatment method	Automated Dosing Unit
Neutralising agent	Calcium-based neutralising agent, the use of sodium-based neutralising agents will not be permitted.

Dewatering treatment set-up

Where dewatering is undertaken, the following management procedures will be applied to the management of dewatering effluent:

+ Effluent will be pumped into a passive lime dosing (treatment) unit for the duration of the dewatering and earthworks program, to increase the pH level. Lime dosing will be manually controlled and based upon the results of monitored pH, acidity and alkalinity.
+ Treated dewater effluent discharged from the passive lime treatment unit will be directed to a settlement basin, lined by compacted limestone. Sufficient retention time will be provided to enable the precipitation of trace metals and settlement of solids from the dewatering effluent.
+ The capacity of the passive lime treatment unit and settlement basin will be maintained such that overflow does not occur to surrounding land. A small percentage of water is expected to recharge into the superficial aquifer via the settlement pond, where compacted limestone is used as a liner.

+ Treated effluent will then be directed to a bunded recharge area, constructed into in situ soils, to recharge the treated effluent to the superficial aquifer.

Figure B-1 presents the general configuration and component parts of the typical treatment system. Prior to discharging the water into a settling basin, the dewatering effluent is processed through a passive lime treatment unit. Aeration occurs upon discharge to the settling basin and is then discharged into the recharge trench/basin system.

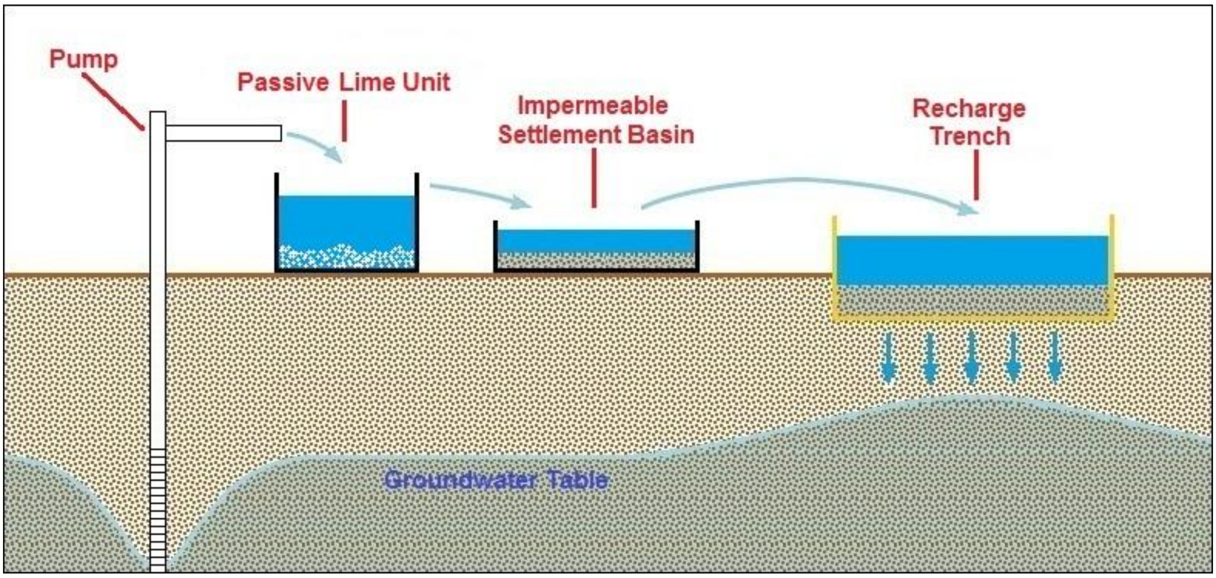

Figure B-1: Typical treatment system configuration for dewatering discharge

Should there be deterioration in the water chemistry observed at the time of construction, i.e., increase acidity and decrease in pH, then an automated lime dosing may be used in replace of the passive lime dosing unit.

Operating guidance

Table B-2: Dewatering strategy operating guidance

Dewatering element	Guidance
Criteria for Source Use	+ Potential short-term dewatering of superficial groundwater to allow the excavation of soil for the installation of the pipeline.
Dewatering Program	+ Dewatering will be limited (where required) and, if required, will be, at relatively low pumping rates, depending on the water level at the time of construction.
Timing of Pumping	+ Pumping if required will occur 24 hours a day when dewatering is required. Pumping may be temporarily suspended if dewatering is not required.
Method of Dewatering	+ The excavations are potentially to be dewatered using either groundwater spears or sump pumps. Dewater will be treated on site before being recharged to the superficial aquifer.
Abstraction Rate	+ The abstraction rate for earth works is predicted to be an average rate of 1.6 L/s, with higher initial rates.

Dewatering element	Guidance
Dewatering Effluent Treatment	+ It is recognised that the quality of abstracted dewater might differ from the monitored shallow baseline groundwater results presented in this ASSDMP. However, using the baseline data available (CDM Smith, 2021), it would appear likely that dewater would have a pH of 5.4–6.3, the total titratable acidity (TTA) will potentially exceed 40 mg/L and the alkalinity potentially be below 40 mg/L. Hence treatment for pH, acidity and alkalinity will potentially be required + Dewater treatment for pH, acidity and alkalinity correction (as necessary) would be in accordance with National Guidance, which specify that dewater having pH <6.0 and/ or TTA >40 mg/L and/or alkalinity <40 mg/L shall be subject to lime neutralisation.
Dewatering Effluent Treatment Material	+ Dewatering effluent is required to be treated with a calcium-based product.
Dewatering Effluent Disposal	+ The primary option for disposing of dewatering effluent is via recharge to the superficial aquifer.

Roles and responsibilities

The following responsibilities for the monitoring requirements, if dewatering occurs, are outlined below. Note: the baseline groundwater monitoring event is required to completed, as a contingency should dewatering occur. All formal reporting to the Regulator will be undertaken by a suitably qualified person.

Table B-3: Monitoring Roles and Responsibilities

Monitoring activity	Parameters	Responsibility
Dewatering monitoring		
Daily	+ Field analysis: pH, electrical conductivity (EC), TTA, and total alkalinity, standing water level	+ Site Contractor
Weekly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Environmental Consultant
Fortnightly	+ Laboratory: Full Dewatering Analytical Suite[1]	
Groundwater Monitoring		
Baseline monitoring event, prior to construction	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Every second day	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Site Contractor
Fortnightly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Immediately After Dewatering		
Post-Construction		
Accumulated Sediments		

Monitoring activity	Parameters	Responsibility
Upon completion of dewatering	+ Heavy metals	+ Environmental Consultant

Note

1. Total and dissolved metals, total acidity, total alkalinity, sulfate, chloride, total suspended solids (TSS), total dissolved solids (TDS), and nutrients. Field parameters including pH, EC, TTA, dissolved oxygen and redox are recorded during sampling.

All formal reporting to the Regulating Body (NT or National) will be undertaken by a suitably qualified environmental consultant.

Dewatering effluent monitoring and groundwater monitoring

Dewatering effluent monitoring:

During and following the completion of dewatering operations, monitoring will be undertaken for dewatering effluent and groundwater with reference to the applicable National Guidance (Water Quality Australia, June 2018d).

In recognition of the groundwater quality at the site, based upon the historical monitoring, the schedule for dewater having total titratable acidity (TTA) between 40–100 mg/L ($CaCO_3$ equivalents) and pH between 4–6 has been adopted and is detailed below (Table B-4). Monitoring will incorporate analysis of dewater samples collected both prior to, and following any treatment process, prior to discharge.

Table B-4: Dewatering Effluent Monitoring Program and Responsibilities

Monitoring activity	Parameters	Responsibility
Daily	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Civil Contractor
Weekly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Environmental Consultant
Fortnightly	+ Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant

Note:

1. Total and dissolved metals, total acidity, total alkalinity, sulfate, chloride, cations, total suspended solids (TSS), total dissolved solids (TDS), and nutrients. Field parameters including pH, EC, TTA, dissolved oxygen and redox are recorded during sampling.

Upon the commencement of works, the quality of the pre-treatment dewatering effluent will be assessed, and the monitoring regime amended, if required, in line with National Guidance (Water Quality Australia, June 2018d).

Groundwater monitoring:

Per National Guidance (Water Quality Australia, June 2018d), a minimum of three groundwater bores will be monitored during the works: this will require wells from the wider DLNG Facility monitoring network to be monitored.

Based upon a review of the existing well monitoring network, the proposed monitoring wells are as follows:

+ BH5
+ BH6
+ BH7.

The location of these wells is presented below.

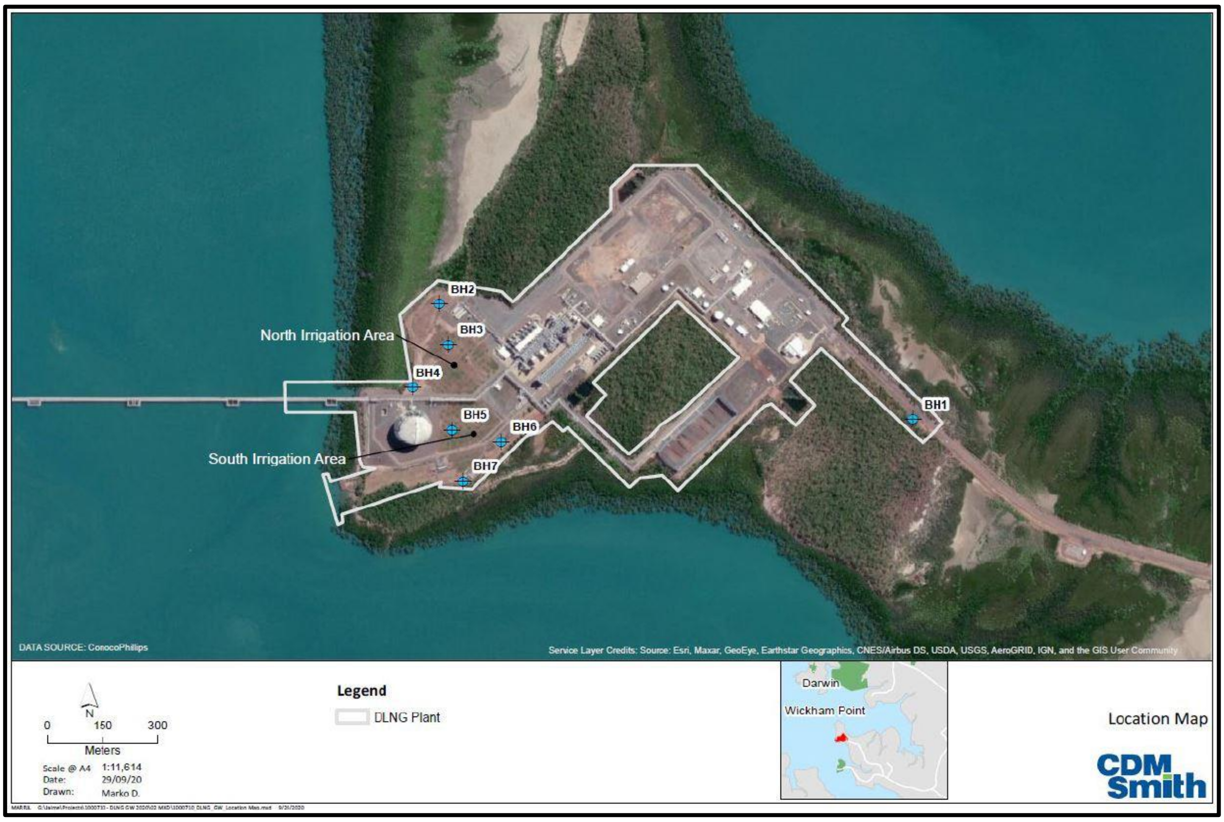

Figure B-2: Aerial image of the DLNG Facility groundwater monitoring well network (Image source: CDM Smith, 2021)

The monitoring schedule will comprise:

Table B-5: Groundwater Monitoring Program and Responsibilities

Monitoring activity	Parameters	Responsibility
Baseline monitoring event	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Every second day	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level	+ Civil Contractor
Fortnightly	+ Field analysis: pH, EC, TTA, and total alkalinity, standing water level + Laboratory: Full Dewatering Analytical Suite[1]	+ Environmental Consultant
Immediately after dewatering		
Post-dewatering monitoring		

Note:

1. Total and dissolved metals, total acidity, total alkalinity, sulfate, chloride, cations, total suspended solids (TSS), total dissolved solids (TDS), and nutrients. Field parameters including pH, EC, TTA, dissolved oxygen and redox are recorded during sampling.

Should dewatering be required for greater then four weeks in total, groundwater will be collected every second month for six months (three sampling events) from the groundwater monitoring network for the full ASS groundwater laboratory suite. Post-construction monitoring will commence once all dewatering works for the site has been completed.

Methodology:

Where possible for the groundwater monitoring events, groundwater samples submitted for laboratory analysis will be recovered using a low-flow bladder pump in accordance with USEPA (1996) guidance (as referenced by Australian Standard, AS/NZS 5667.11:1998). Low-stress (low-flow) purging and sampling is recommended by VEPA (2000) as samples returned are considered to be most representative of aquifer conditions, as disturbances that affect inorganic and organic contaminants are minimised.

Prior to sampling, groundwater will be purged to stability (reference parameters being pH, EC, DO, redox and temperature), measured using electronic probes. Groundwater samples will then be collected into appropriately preserved laboratory supplied containers (being field filtered for dissolved metals, as applicable). All groundwater samples will be chilled and submitted to the primary NATA accredited laboratory, for analysis within 24 hours of collection.

Quality control:

Quality control samples will be collected during each groundwater monitoring event, including a field duplicate, equipment rinsate and field blank. The full analytical suite will be conducted on the duplicate with the total and dissolved metals only from the aforementioned suite conducted on the rinsate and blank.

Water quality reference and trigger criteria

Groundwater level (drawdown) triggers:

Groundwater level triggers (below) are developed to control the depth of groundwater extraction across the site, and thereby to manage the dewatering of PASS soils.

The basis for setting the trigger levels is defined below:

+ The estimated maximum dewatering drawdown at the bore, in addition to a tolerance of 0.2 m (modelled tolerance).
+ At least three nominated groundwater monitoring wells will be monitored during the installation of the pipeline, with additional bores installed where required by the environmental consultant (e.g. should existing wells be damaged or destroyed or if monitoring indicates additional bores are required). These nominated groundwater wells will include three monitoring wells located near the site as part of the DLNG Facility monitoring network, namely: BH5, BH6, and BH7.
+ The depth to groundwater in the monitor bores and the groundwater level determined prior to the commencement of earthworks, and based upon the estimated maximum dewatering drawdown at the bore, in addition to a tolerance of 0.2 m, the drawdown triggers revised where required.

Dewatering effluent and groundwater quality reference criteria:

The criteria nominated below are consistent with targets established in National Guidance literature and have been standardised across all bores. It is noted that ASS criteria had exceeded the guidelines during the DLNG routine groundwater monitoring. It can therefore be expected that these reference criteria will likely be exceeded during the construction program.

The reference criteria will serve as a value, against which contingency responses would be considered, when taken in the wider context of “monitored data trends” over time, i.e., trends identifying deteriorating conditions.

The bore reference criteria for all bores are as follows:

+ Minimum pH: 6.0 pH units.
+ Maximum total acidity: 40 mg/L ($CaCO_3$ equivalents).
+ Maximum dissolved aluminium: 1 mg/L.

Dewatering effluent discharge reference criteria:

Presented below is a summary of the dewatering discharge criteria for groundwater dewatering effluent, as specified in National Guidance (WQA, 2018d).

Table B-6: Dewatering effluent quality

Analyte	Discharge Reference Criteria
Acidity	<40 mg/L ($CaCO_3$ equivalents)
pH	7.5 to 8.0 pH units
Alkalinity	>30 mg/L ($CaCO_3$ equivalents)

Contingency responses

The contingency responses provided below are examples of operating measures that can and may[1] be applied where water quality/levels in the receiving environment is compromised. The approach to determining a contingency response is based upon identifying, managing and addressing the specific cause of the water quality impact.

Groundwater pH and drawdown:

Where the drawdown triggers or pH refence criteria are exceeded, the following contingency measures may be implemented in consultation with the Regulator:

+ Monitoring frequency increased to daily.
+ The addition of a comprehensive suite of groundwater monitoring at an appropriate frequency may be required where dewater discharge varies significantly from pre-dewatering conditions.
+ Pumping rates may be reduced.
+ The area under abstraction at any one time may be reduced.
+ The groundwater recharge infrastructure may be modified.
+ Where a reduction in pumping rate or area under abstraction does not abate drawdown, pumps shall be suspended to allow groundwater levels to recover above the nominated trigger thresholds, unless otherwise agreed with the Regulator / project engineers.

Dewatering discharge:

[1] The word “may” is used because more than one appropriate response might apply. In any case, where a breach occurs, the incident would be reported to the Regulator and advice given and received regarding the appropriate course of action to take.

Where the dewatering effluent discharge reference criteria (Table B-6) are exceeded, the following contingency measures may be implemented in consultation with the Regulator:

+ Increased liming of dewater, and or adjustment/enhancement of existing infrastructure.
+ Pumping rates decreased.
+ Reducing the area under abstraction.
+ Modifications to the settlement basin infrastructure to promote improved settling, and precipitation of metals.

Dewatering management:

The dewatering settlement and infiltration infrastructure should be maintained in such a state to ensure the integrity of the ponds, and all dewater is contained within the ponds.

Where the integrity of the ponds is compromised and or effluent is not contained within the ponds, the following measure may be implemented in consultation with the engineers and regulators (if necessary):

+ Reduce pump rates or cease all dewatering.
+ Reduce the area under abstraction.
+ Modifications to the settlement and infiltration pond infrastructure to ensure all dewater is contained in bunded areas. This may include the addition of extra ponds, increasing the area of the bunded infiltration and or utilising storage bladders to allow slower infiltration rates.
+ Pumping of effluent from the settlement pond to the infiltration area. Any pumping should be minimal and pumping occurring the furthest distance from any treatment (i.e., lime dosing) as possible.

Where any breaches occur, the environment/groundwater consultant and engineer are required to be notified immediately and the aforementioned contingency measures implemented under direction from the Regulator.