PERDAMAN INDUSTRIES

CHEMICALS & FERTILISERS

Surface Water Management Plan

Perdaman Urea Project

Burrup Peninsula, Western Australia

CW1055600

Prepared for Proponent:

Perdaman Chemicals and Fertilisers Pty Ltd.

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Date: 17 March 2020

Assessment No:

2184 (WA)

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Summary

Proposal Title	Perdaman Urea Project
Proponent name	Perdaman Chemicals and Fertilisers Pty Ltd.
Assessment Number	2184 (WA) & 2018/8383 (Commonwealth)
Purpose of the SWMP	The diversion, collection, conveyance, treatment, recycling and discharge of surface water are fundamental and of priority for the Project. Inappropriate management could result in an unauthorised discharge into the environment, erosion, sediment deposition or a modification of normal chemistry in soil and waterways. The purpose of the SWMP is to provide a framework which describes how the project will assess, manage, monitor and mitigate impacts to surface water and receiving waterways during the construction, operation and decommissioning phases of the project in accordance with the applicable regulatory requirements, permit obligations and industry best practice.
Key environmental factors and objectives	The key environmental factors and objectives relevant to the Project include: ▪ Coastal processes - To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected. ▪ Marine environmental quality - To maintain the quality of water, sediment and biota so that environmental values are protected. ▪ Marine fauna - To protect marine fauna so that biological diversity and ecological integrity are maintained. ▪ Flora and vegetation - To protect flora and vegetation so that biological diversity and ecological integrity are maintained. ▪ Terrestrial fauna - To protect terrestrial fauna so that biological diversity and ecological integrity are maintained. Ecological integrity is the composition, structure, function and processes of ecosystems, and the natural range of variation of these elements. ▪ Inland waters - To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.
Condition clauses	To be determined.
Key provisions in the plan	The SWMP's key provisions are included in *Section 6 Environmental Mitigation and Management Measures.* This section details the outcome and management based actions, that will be applied for the life of the Project.

Foreword

This Surface Water Management Plan (SWMP) is a sub-plan of the overarching Project Environmental Management Plan (PEMP) for the Perdaman Urea Project. An overview of the structure of the CEMP and sub-plans is illustrated in Figure 0-1.

This plan shall be reviewed and updated as necessary throughout the construction, operation and decommissioning phases of the project. The review process is detailed in *Section 15 Review and Continual Improvement* of the PEMP.

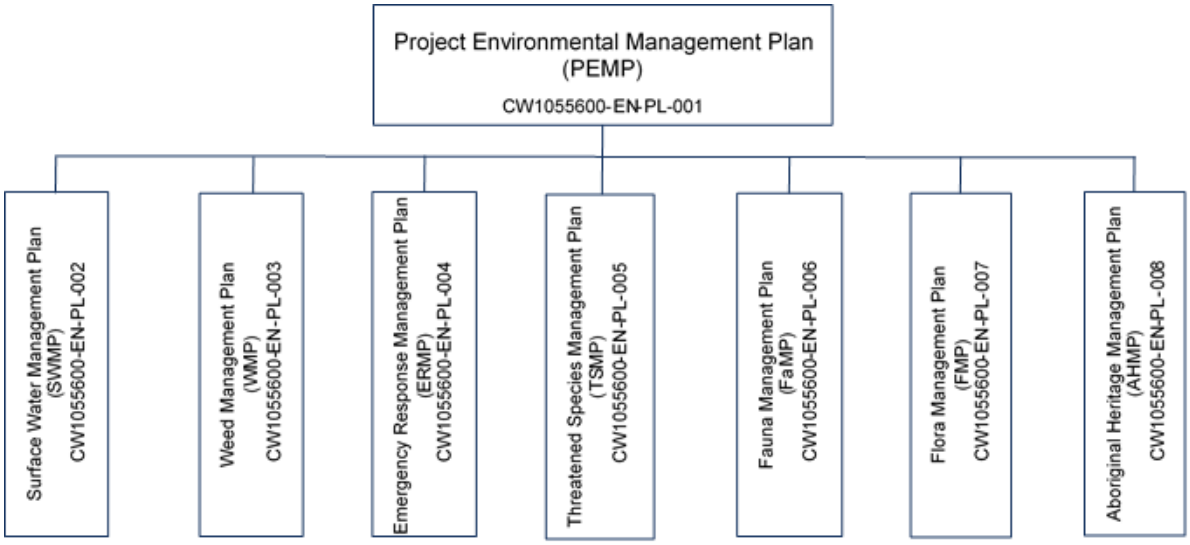

Figure 0-1: Structure of the Project Environmental Management Plan and supporting sub-plans.

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1 Introduction

Perdaman Chemicals and Fertilisers Pty Ltd (Perdaman) proposes to establish a state-of-the-art urea production plant within the Burrup Strategic Industrial Area (BSIA). The site is situated approximately 8 km from Dampier and 20 km north-west of Karratha on the north-west coast of Western Australia.

The key elements of the Project include the design, engineering, construction and operation of the main urea production facility, administration, maintenance and storage infrastructure, conveyor and port storage and shiploading facilities.

The main potential surface water impacts on the Project include surface water management within the Project footprint, diversion of surface water run-off around the site and the disposal of effluent and process waters from the production, transport and storage facilities. The primary strategies that will be implemented to address these impacts include treatment systems, surface water surface water, storage and discharge infrastructure. Where practicable, treated process water and effluent, and the site's clean stormwater will be reused within the process plant. Contaminated water which cannot be treated to a satisfactory standard, will be removed off site and disposed at a suitable waste facility.

This Surface Water Management Plan (SWMP) provides the environmental management requirements for the control, containment, treatment and disposal of the aforementioned surface water impacts. It includes a series of specific management strategies that will be applied across the construction, operation and decommissioning phases of the project.

1.1 Purpose

The diversion, collection, conveyance, treatment, recycling and discharge of surface water are fundamental and of priority for the Project. Inappropriate management could result in an unauthorised discharge into the environment, erosion, sediment deposition or a modification of normal chemistry in soil and waterways.

The purpose of the SWMP is to provide a framework which describes how the project will assess, manage, monitor and mitigate impacts to surface water and receiving waterways during construction, operation and decommissioning phases of the project in accordance with the applicable regulatory requirements, permit obligations and industry best practice as outlined in Section 3 of this document.

1.2 Scope

This SWMP applies to all Project sites during the construction, operation and decommissioning phases. This includes, but is not limited to, works at Site C, Site F, the causeway, the conveyor corridor, Port side storage, product transfer and ship loading areas. Specifically, the SWMP applies to:

- Design considerations for controls based on rainfall statistics and site conditions including geology, gradient and ground cover;
- All ground disturbing activities associated with site establishment;
- All earthworks and cut and fill activities including batter formation and stabilisation;
- All surface water systems including cut-off drains, table drains, swale drains and sediment basins;
- Any dewatering activities including treatment and temporary storage;
- Establishment and use of internal access tracks and associated surface water;
- Establishment and operation of site compounds including administration, maintenance, servicing and laydown facilities;
- Establishment and operation of temporary concrete batching plants;
- All sediment control measures including silt fences, rock checks, baffles and sediment basins;
- Stockpiles and soil management;
- All erosion control measures;
- All pollution control measures;
- All stormwater and wastewater management measures;
- Culverts at the causeway;

- Outlet discharge structures; and
- Site rehabilitation activities.

1.3 Responsibility

The responsibility for surface water management sits primarily with Perdaman, which will ensure appropriate inductions, training and communication of this plan is provided to all Project Personnel.

It is the responsibility of all Project Personnel to understand their scope of works and how surface water management applies to their activities.

2 Project Overview

Perdaman plans to construct and operate a state of the art urea plant with a production capacity of approximately 2 million tonnes per annum (Mtpa) on the Burrup Peninsula in the North West of Australia (Figure 2-1) (the Project).

The Project infrastructure including the main production facility (urea plant), administration, maintenance and storage infrastructure, conveyor and port storage and shiploading facilities are situated within the Burrup Strategic Industrial Area (Burrup SIA). The estate's close proximity to gas, port and other key infrastructure makes it an ideal location for the Project.

The Burrup SIA is located in close proximity to the Murujuga National Park which covers an area of 4,913ha on the Burrup Peninsula. The area is considered to host the largest concentration of ancient rock art in the world. As such, the Project will apply effective management strategies that minimise or abate, actual or potential impacts on the environment, heritage and cultural values of the region.

The Project involves piping natural gas from the nearby Woodside operated LNG facility to the project site under a long term commercial off-take agreement. Natural gas is converted to urea and the final granulated product is transported by conveyor to the Dampier Port by closed conveyor along the East West Service route, where new facilities will include an enclosed stockpile shed and ship loading facilities.

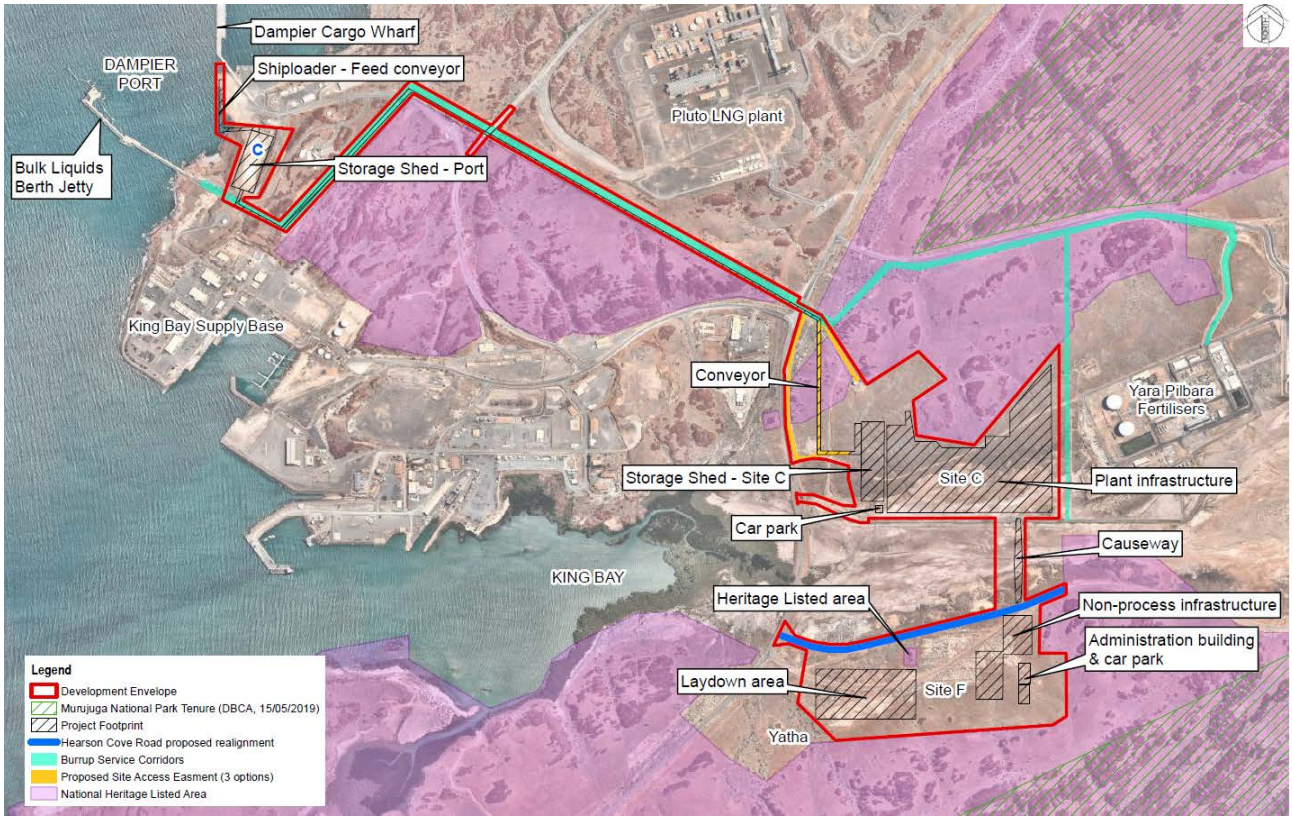

Figure 2-1 Project site layout and adjoining facilities.

Proven Urea production technology underpins each of the key stages of this project. The technologies being applied to the plant are equivalent to the industry best for the specific applications and successfully operate elsewhere in the world. The processing plant can be broadly considered in four sections, or Blocks, namely:

- Gas Block
- Product Block
- Utility Block
- Infrastructure and Logistics

Each of the Process Blocks is made up of a number of process units or physical sections of the plant. The major process sections are described in Figure 2-2.

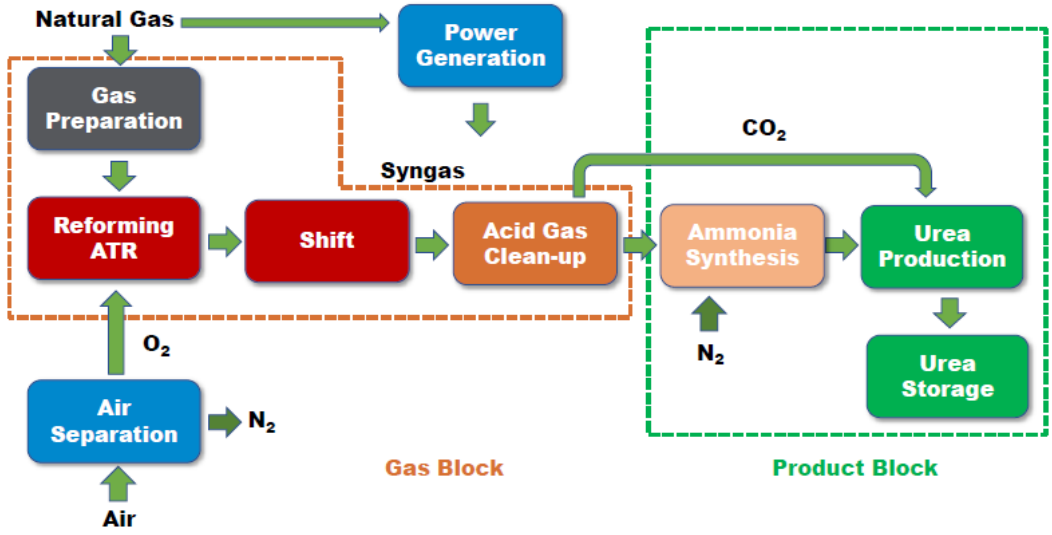

Figure 2-2 Process Block Diagram

3 Legislation, Commitments and Other Obligations

3.1 Regulatory Obligations

Legislation relevant to surface water management on the Project includes, but is not limited to:

- Environmental Protection Act 1986
- Environment Protection and Biodiversity Conservation Act 1999 (Cwth)
- Rights in Water and Irrigation Act 1986
- Soil and Land Conservation Act 1945
- Waterways Conservation Act 1976
- Dangerous Goods Safety (Storage and Handling of Non-explosives) Regulations 2007
- Environmental Protection (Concrete Batching and Cement Product Manufacturing) Regulations 2004
- Environmental Protection (Unauthorised Discharge) Regulations 2004
- Planning and Development (Local Planning Schemes) Regulations 2015

In addition to the above legislation, this SWMP will be developed and regularly reviewed to comply with the commitments and legal obligations arising from the Project's environmental approvals process.

3.2 Project Approvals

The Project must comply with all of the conditions included in its granted approvals. Perdaman will be responsible for ensuring all statutory approvals required for activities or infrastructure specific to Project needs are attained in a timely manner.

Table 3-1 below includes indicative licenses and approvals potentially required for the Project, which may apply or contain conditions specifically related to surface water management. This list is provided as a guide only, and is subject to change throughout the life of the Project.

A detailed approval register will be maintained by Perdaman to monitor the implementation and progress of conditions, and the achievement, renewal and surrender of all licenses throughout the life of the Project.

Table 3-1 Project statutory approvals and agreements relevant to surface water management.

Approval / Agreement	Purpose	Agency / Jurisdiction
EP Act 1986 - Part IV Approval - Ministerial Statement	EPA assessment of strategic proposal.	EPA
EP Act 1986 - Part V - Works Approval & Licence - Cat 12. Screening plant	For establishment and operation of screening plant.	DWER
EP Act 1986 - Part V - Works Approval & Licence - Cat 31. Chemical manufacturing.	Chemical manufacturing (Operations).	DWER
EP Act 1986 - Part V - Works Approval & Licence - Cat 54A or 85B. Desalination plant	For construction and operation of desalination plant.	DWER
EP Act 1986 - Part V - Works Approval & Licence - Cat 73. Chemical storage	For construction and operation of bulk storage of chemicals.	DWER
EP Act 1986 - Part V - Works Approval & Licence - Cat. 54 or 85 Sewage facility	For construction and operation of sewage facility with discharge to land or waters.	DWER
EP Act 1986 - Part V - Works Approval & Licence - Cat. 77 Concrete batching	For construction and operation of concrete batching.	DWER

EP Act 1986 - Part V - Works Approval & Licence - Cat 58 or 86. Material loading.	For construction and operation of bulk material loading onto vessels by material loading system.	DWER
Department of Health - Apparatus for treatment of sewage - installation and permit to use	Needed to install and operate sewage system.	City of Karratha and Department of Health
Approval – Discharge into Water Corporation's Multi User Brine Release Line (MUBRL).	Approval required to discharge into the MUBRL	Water Corporation
Dangerous Goods Safety Act 2004 - Dangerous Goods Site Licence (Construction)	Storage of fuel during the construction phase.	DMIRS
Dangerous Goods Safety Act 2004 - Major Hazard Facility License (Class A)	Storage of dangerous goods over threshold quantities during the operational phase.	DMIRS

3.3 Ground Disturbance Permits

A Ground Disturbance Permit (GDP) is a permit issued by Perdaman, enabling ground disturbing Works within defined battery limits which will impact native vegetation, heritage or other environmentally sensitive values.

The GDP provides Project Personnel with a summary of the key approval commitments and legal obligations issued to Perdaman by regulators, tenure holders and other third parties. It also includes Perdaman's own Project standards and management commitments developed throughout the life of the Project.

Activities covered in the GDP include, but are not limited to, clearing and grubbing, grading open ground, movement of plant, equipment and vehicles and any other activity which will disturb or damage soil, waterways, habitat and, or vegetation.

4 Performance Objectives

The surface water management performance objectives of the Project are to prevent the unmanaged discharge of surface and process waters to the surrounding environment. This will be achieved through:

- Minimising ground disturbance and implementation of progressive erosion and sediment controls;
- Construction of adequately sized onsite retention basins;
- Controlled release of water from the site after water quality testing;
- Preventing leaks or spills of chemicals and other contaminants (oily water) from entering surface water and groundwater;
- Treating contaminated water for reuse or approved disposal;
- Timely rehabilitation of disturbed areas;
- Resurfacing with stored top soil; and
- Revegetation of the disturbed areas as soon as practicable.

5 Site Description

5.1 Location and Regional Setting

The Project area, including Sites C & F, the causeway, conveyor and Port storage and loading facilities, extends east-west approximately 3.4km covering about 105 hectares in area. As illustrated in Figure 2-1 above, the Project area can be separated into five key areas. Each area has specific surface water issues associated with its location and, or proposed Project activities.

5.1.1 Site C

Site C is relatively undeveloped with the exception of a few access roads. The site is situated adjacent to the Yara Ammonia Plant to its east, to the north are steep rocky outcrops and to the south the supra-tidal flat area. Surface water from the site flows in a southerly direction towards the supra-tidal flat between Hearson Cove and King Bay.

Once developed Site C will include the main process plant and a 75,000 tonne urea storage shed.

5.1.2 Site F

Site F is situated to the south of Site C, on the opposite side of the supra-tidal flat area. It includes Hearson Cove Road and a significant proportion of previously disturbed area (now rehabilitated). Surface water from this area flows primarily north into the supra-tidal flat.

During the construction phase of the Project, this area will be used as laydown for equipment and modules. The east portion of Site F will be developed to include the Project's administration, maintenance, storage and warehousing facilities.

5.1.3 Causeway

The causeway, which links Sites C and F, extends across the supra-tidal flat area.

The causeway will be built up above the supra-tidal flat area to a road height of approximately 6m AHD with regular culverts to ensure the structure does not impede natural surface water or tidal flows.

5.1.4 Conveyor

The 3.2km conveyor will transport urea from the storage shed at Site C to the Port loading shed.

From Site C the conveyor will be constructed on relatively undisturbed land, to the west of the existing Water Corp pipeline corridor. It will extend north, connecting to the existing Burrup East West Services Corridor (EWSC).

The EWSC is a bitumen sealed corridor which already includes the Yara Pilbara Fertiliser's ammonia pipeline which extends to the bulk liquids jetty adjacent to the Project's Port facilities. The Project's conveyor will be positioned within this corridor and where possible use existing culverts to avoid roads and other infrastructure. Where the conveyor crosses Woodside's Haul Road the road will be built up to allow the conveyor to pass under.

Surface water in the EWSC will be managed via existing surface water systems which form part of the EWSC infrastructure.

5.1.5 Port Area

The Port Area includes a 75,000 tonne storage shed, covered conveyor and ship loader. The storage shed will be located within an existing quarry and the shiploader on a wharf which will be constructed by Pilbara Port Authority (PPA). The Conveyor will be situated on cleared area associated with the new wharf and quarry, and a small section of rocky ground between these two areas.

To maintain product integrity, it is imperative that urea is kept dry throughout the storage, transfer and loading process. As such, urea will remain isolated from rainfall and stormwater which will be managed through existing surface water channels.

5.2 Hydrology

Regional hydrological mapping shows a number of watercourses flowing into King Bay to the east of Sites C and F. These ephemeral streams only flow occasionally, typically as a result of major rainfall events between December and April.

Whist there are no permanent natural watercourses or wetlands within the site, two ephemeral watercourses cross the south west corner of site F and are reported to be deeply incised indicating potential to convey large flows in storm events.

On Site C, stormwater runoff is reported to flow primarily from the north, where willow bedrock hinders infiltration, runoff is typically conveyed in small flows, potentially resulting in small alluvial deposits at the base of the slopes.

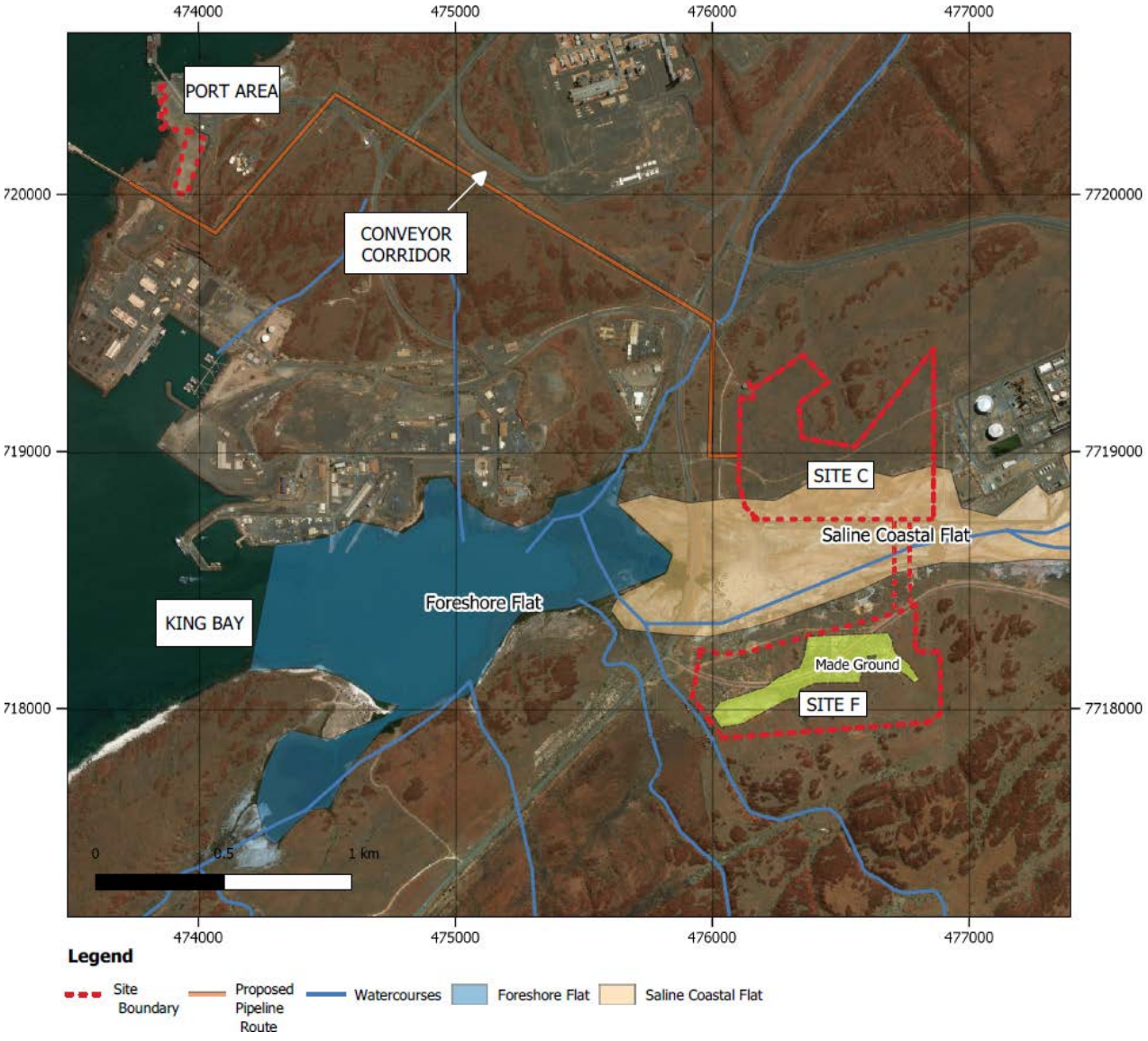

Figure 5-1 Hydrology Map (Geoscience Australia, 2018)

5.3 Geotechnical Information

Geotechnical information for all Project areas can be found in 140436-0000-4GER-0001 – Geotechnical Desktop Study (Attachment C) of this plan .

5.4 Elevation and Slope

5.4.1 Site C

Site C slopes from approximately 28m AHD in the north west to 2m AHD at its lowest point on the southern boundary. As shown in Attachment A Project Surface water Schematic and Plot Plan the battery limits of the Project will avoid the steeper and higher areas in the north west.

During the earthworks phase, the majority of the Site C which will contain the urea production plant and storage shed will be cut and filled to a level of approximately 6m AHD. The north east sector which includes the desalination and demineralisation plants will be tiered at approximately 10m AHD.

The catchment area to the north of the site drains towards the southern boundary and an ephemeral creek line on the west portion of the site.

Initial earthworks will include a surface water diversion system to redirect natural runoff around the Project site and into the supra-tidal flat area.

5.4.2 Site F

Site F slopes generally from south to north from approximately 12m to 28m AHD along the southern boundary, down to approximately 6m and 10 m AHD respectively at the northern boundary, adjacent to the supra-tidal flat area.

Where possible permanent infrastructure and the laydown area will avoid the higher, steeper areas along the southern boundary.

5.4.3 Causeway

The supra-tidal flat area slopes from about 4m AHD at its lowest point. The causeway will be a formation built up to approximately 6m AHD as it extends across the supra-tidal flat area and is then graded to join at the finished levels of Sites C and F.

5.4.4 Conveyor

The eastern segment of the conveyor route starts at approximately 8m AHD at the southern transfer station, up to 18m AHD as it extends north, then back down to approximately 8m AHD at the northern transfer station. At this point it is routed through an existing culvert under Burrup Road where it follows the EWSC which rises from 8m up to approximately 62m AHD at its highest point.

The conveyor will follow the EWSC which drops down to approximately 21m AHD where it borders the southern section of the existing quarry which will contain the Project's Port storage shed.

5.4.5 Port Area

The floor level of the Port storage shed located in the existing quarry will be built up from natural ground level of approximately 5m AHD up to approximately 10m AHD.

The shiploader will be constructed on the wharf which will be built by PPA.

5.5 Site Rainfall Characteristics

The average rainfall in the Burrup region is 259.9mm per annum. The wettest months of theyear are January, February and March averaging 47.7mm, 75.4mm and 47.3mm respectively (see Table 5-1). The most extreme rainfall events are a consequence of the tropical cyclones which generate between 25% and 34% of the annual rainfall near the Pilbara coast.

Cold fronts moving east across the southern section of Western Australia can reach as far north as the Pilbara resulting in light winter rains in May and June.

Table 5-1 Rainfall statistics for Karratha Aero (Source: Bureau of Meteorology).

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	47.7	75.4	47.3	17.3	27.7	36	14	4.1	1.3	0.4	1.4	13.6
Median	19.4	42.2	31.4	6.2	8.2	11.9	4	0.2	0	0	0	0.6
Highest Daily	212.4	210.6	190.8	107.0	107.4	209.4	66.6	28.2	15.4	6.0	37.8	112.8

5.6 Groundwater

Limited groundwater data is available for the Burrup Peninsula.

However, 140436-0000-4GER-0001 – Geotechnical Desktop Study (attachment C) reported that the water quality within the mudflat region located in Site F was significantly saline which is typical given the intertidal nature of the supra-tidal flat, at levels ranging from 76,000 to 78,000 µg/cm.

Historical investigations undertaken for Site C by Soil and Rock Engineering in 2000 found that groundwater levels ranged from 0.7 to 2.8m below ground surface. The shallowest reading of 0.7m was located within the supra-tidal flat area.

The potential impact on groundwater, as a consequence of the Project's activities, include percolation of contaminants into groundwater from the stormwater sump on Site F and unsealed areas across the site. Should groundwater be contaminated there is also the potential to contaminate the supra-tidal flat through seepage.

5.7 Acid Sulphate Soils

Acid sulphate soils (ASS) are naturally occurring soils, sediments and peats that contain iron sulphides, predominantly in the form of pyrite materials. These soils are most commonly found in low lying land bordering the coast, in estuarine and saline wetlands, and in freshwater groundwater dependent wetlands throughout Western Australia.

In an anoxic state, these materials remain benign, and do not pose a significant risk to human health or the environment. However, the disturbance of ASS within the Project area and its exposure to oxygen, has the potential to cause significant environmental and economic impacts including fish kills and loss of biodiversity in waterways, contamination of groundwater by acid, arsenic, heavy metals and other contaminants and corrosion of concrete and steel infrastructure by acidic soil and water.

The possible presence of ASS is reported to be located within the southern section of Site C and within the supra-tidal flat area. It is categorised as Class 1 nature with a high to moderate disturbance risk (<3m from the surface). Due to the historical disturbance of native soil and rock for laydown area in Site F, there is minor potential for ASS to exist or develop in that area.

A detailed geotechnical investigation will be undertaken prior to the commencement of construction. This will include an assessment of potential ASS areas where ground disturbance will occur as part of the construction phase.

6 Environmental Mitigation and Management Measures

During the construction phase a range of site activities will potentially impact the flow and quality of the surface waters across the Project's sites and adjoining areas. These include:

- Grubbing, clearing, and cut and fill works;
- Concrete batch plants;
- Stockpiling imported raw materials, and local topsoil and subsoils;
- Storage and handling of chemicals, hazardous materials and wastewater;
- Access tracks, laydown areas and hardstands.

Throughout the Project's operational phase specifically engineered surface water, containment and treatment systems across all project sites will be appropriately monitored and maintained.

The following section provides general guidance on the management measures that will be implemented to avoid or minimise any detrimental impacts associated with surface water on the site.

6.1 Progressive Erosion and Sediment Control Plans

A site-specific Erosion and Sediment Control Plan (ESCP) will be developed for each Project area prior to construction. The plan will address, as a minimum, the following key points and any other issues which may be specific to the site:

- Site battery limits;
- Soil and general geotechnical description;
- Existing and planned contours including location of cut and fill banks;
- Existing and final overland flow surface water paths;
- Limits of clearing or land disturbance allowed for the proposed scope of works and or the broader Project;
- Location of vegetated buffer strips;
- Stabilised entry / exit point (rumble pad);
- Location of soil and sand stockpiles;
- Location of all proposed temporary surface water control measures;
- Location of all proposed erosion control measures including installation sequence and maintenance requirements;
- Permanent site stabilisation measures; and
- A statement of who is responsible for establishing and maintaining all erosion and sediment measures.

6.2 Surface water, Erosion and Sediment Pollution Controls

The following controls will be installed prior to commencement of construction to prevent contamination of surface water and receiving environments.

6.2.1 Surface water Controls

- Existing surface water lines will be protected and any diversion of these lines should be kept to a minimum.
- Flow management across the site will prevent the concentration and diversion of waters onto steep or erosion prone slopes.
- Any diversion of surface water lines will be directed to slopes that are not prone to erosion.
- External water flows entering the Project's battery limits will be diverted around the construction footprint, using surface water structures such as catch drains and bunds.
- Temporary surface water structures will be designed to reduce run-off velocities by using wider inverts, flat bottomed drains rather than V-shaped drains, check dams (or similar), silt fencing and

revegetation of completed areas.

- All surface water lines likely to receive run-off from disturbed areas, such as those downstream of worksites, will be fitted with geotextile silt fences. Rock checks should also be used in drains to slow flows and provide a lining to prevent scouring of underlying surfaces. Sediment basins will be added to surface water lines as necessary. Basins will be designed relative to the catchment and likely flow levels for higher rainfall events.
- Where silt fences are installed for sediment control, they must be constructed with a centre section lower than the ground levels at the end of the silt fence to avoid outflanking during heavy rainfall events; and
- Silt and sediment fences will be maintained until the areas above them have been adequately stabilised to minimise the erosion risk such that the controls can be removed.

6.2.2 Erosion and Sediment Pollution Controls

Sediment controls are designed to prevent the transportation of sediment and other pollutants from work sites to waterways. They will be installed across the Project sites in areas where land is disturbed. In order to minimise the land exposure and potential risk of erosion, all land disturbances should be confined to a minimum practical working area and within the vicinity of the identified work areas.

Where possible, existing vegetation surrounding the construction site will be used as a buffer zone to help filter surface runoff and should not be disturbed unless necessary for the purpose of construction.

To ensure that silt from batters, cut-off drains, table drains and road works is retained on site and replaced as soon as practicable, sediment controls will be installed downstream of any disturbed land such as worksites, prior to that work being undertaken.

Run-off controls will be developed and maintained to the following standards:

- Controls will be designed to take predicted flows, based on 140436-0000-41EG-0001 – Standard Specification Geographic, Climatic and Wind / Seismic Data;
- Exposed ground will have control measures that minimise the level of erosion;
- Drains will be installed across the site to divert clean surface water to stable areas and away from parts of the site where soil is exposed;
- Installation of sediment traps and basins with a riser pipe or flexible pipe and spillway to avoid adverse flood risk to adjoining properties. These systems will allow for the gradual discharge of the clearest water during a storm event as detailed in 6.1.3;
- Geotextile silt fences will be installed in surface water flow areas to minimise the sediment discharge from the site (refer to Attachment B);
- Should hay bales be used for sediment control, they will be made of straw sourced from cereal crops and be free of weed seeds;
- If any areas of localised erosion develop, they will be remediated as soon as practicable to prevent further erosion or sediment deposition in offsite areas; and
- Regularly inspect stormwater surface water and sediment control structures to ensure hydraulic integrity and erosion and pollution control effectiveness. If the control structures are obstructed or have their capacity reduced by 30% or more through the accumulation of silt, litter, vegetation and other debris, they will be cleared, with silt returned to a stabilised part of the project.

Sediment control structures at waterway crossings will be developed during the detailed design process before any such work takes place.

Throughout construction, rehabilitation of disturbed areas will be progressively undertaken, or as soon as practicable, following completion of specific works.

6.3 On Site Wastewater Management

6.3.1 Wastewater Management During Construction

During construction the main wastewater sources will be:

- Staff amenities including toilet, shower and crib facilities;
- Any areas where fuel and chemicals are stored, used or decanted; and
- Dewatering wastewater from excavations.

Wastewater from these areas will need to be managed in line with the following conditions:

- Wastewater storage systems are to be appropriately bunded and located a minimum of 100m from any watercourse;
- The design of the wastewater management system will be sufficient to handle the anticipated loads of the project's peak number of construction staff; and
- A monitoring and maintenance schedule, approved by the Contractor's Environment amd Heritage Manager, is to be established based on the specifics of the wastewater management system chosen.

6.3.2 Stormwater and Wastewater Management During Commissioning and Operations

The Project will bring on-line five primary wastewater streams during the construction phase. These will come into operational effect towards the end of the construction phase, during commissioning of the plant and associated facilities. These include:

- Black / grey water from staff amenities including toilets, shower, washing and kitchen facilities. After onsite treatment, this wastewater will be discharged to the Water Corp Multi User Brine Release Line (MUBRL) for offsite disposal.
- Brine water generated as part of the desalination plant can be discharged to two locations, depending on the salt content of the brine stream:
  - Brine from the desalination plant will normally be discharged to the MUBRL for offsite disposal after being diluted and mixed with the seawater blowdown stream from the plant cooling tower, which meets the discharge specifications; and
  - Brine can also be sent to the brine evaporation pond for local disposal, if brine / seawater does not meet the MUBRL specification.
- Stormwater generated on site will be managed as two separate streams:
  - Stormwater that could be contaminated by spills or leaks from process activities will be directed to holding ponds for pre-treatment, prior to reuse as a component of the seawater used on site for cooling; and
  - Uncontaminated stormwater will not be treated, but will be pumped directly from the stormwater holding pond into the seawater used for cooling on site or used to dilute seawater at inlet of desalination plant.
- Seawater will be recirculated with a small component (approximately 1%) blown down and discharged off site via the MUBRL.
- Process condensate will be polished before being added back into the demineralised water and reused on site.

6.3.3 Wastewater Discharge

No wastewater will be discharged on to, or off site, without written approval of the Environment and Heritage Manager.

If discharging wastewater, the following conditions will apply:

- If not used on site, all stormwater proposed for discharge will first be contained in an appropriately lined sediment basin, to allow sediment to settle out; and
- Any discharge to the MUBRL must comply with the conditions, including water quality standards, of the Water Corporation operating license that applies to the discharge (See Table 6-1).

Contaminated wastewater which is not able to be treated on site, such as black and grey water generated

during the construction phase, will be removed off site by a licensed controlled waste contractor and disposed of at a licensed waste facility.

Table 6-1 Indicative Wastewater Acceptance Criteria to MUBRL for the Project.

Parameter	Target
Water temperature	Effluent discharge temperature to be less than 2°C above the inlet seawater temperature for 80% of the time and exceeding a maximum limit of 5°C above.
pH	6.9 – 8.3 pH units
Conductivity (TDS)	75 mS/cm
Oxidation-reduction potential	228 mV
Ammonia	1,700 µg/L
Turbidity	63 NTU
Arsenic III	140 µg/L
Arsenic V	275 µg/L
Cadmium	36 µg/L
Chromium III	459 µg/L
Chromium IV	8.5 µg/L
Cobalt	61 µg/L
Copper	11 µg/L
Lead	134 µg/L
Mercury	1.4 µg/L
Nickel	427 µg/L
Selenium	183 µg/L
Silver	49 µg/L
Vanadium	3,050 µg/L
Zinc	419 µg/L
E. Coli	13,000 MPN/100ml
Thermotolerant coliforms	910 CFU/100 ml

6.3.4 Dewatering

Any dewatering that is undertaken on site, must comply with the Acid Sulphate Soils and Dewatering Management Plan. Prior to undertaking any dewatering the Contractor managing the works will submit to Perdaman for approval an Acid Sulphate Soils Treatment Plan which will detail the methods to be used for dewatering, containment, treatment, reuse or discharge of wastewater.

6.3.5 Water Reuse

In Site C uncontaminated stormwater runoff will be collected in a sediment basin and used for dust suppression and other construction needs. This measure will be implemented as part of the early works, once the site's fill works has been completed. Prior to its construction, the requirements for sediment and erosion control outlined in Section 7 will be maintained.

Where practicable, water reuse opportunities will also be sought in other project areas.

6.4 Storage and Handling of Fuels and Hazardous Chemicals

Management of hydrocarbons and hazardous substances must be undertaken in accordance with the requirements of CW1055600-EN-PL-001 Project Environmental Management Plan (PEMP).

7 Summary of Sediment, Erosion and Water Quality Mitigation Measures

Stormwater moving across each of the Project sites (ie: Site C, Site F, causeway, conveyor and Port) will be managed in accordance with the specific project areas' sensitive receptors. The following general mitigation measures will apply to all areas.

Table 7-1 Summary of Sediment, Erosion and Water Quality Mitigation Measures

Item No.	Requirements
1.	Disturbance to watercourses, riparian vegetation and flood plains will be avoided or minimised, wherever practicable, and managed in accordance with CW1055600-EN-PL-002 Surface Water Management Plan.
2.	Water emanating from disturbed areas will be treated to ensure discharge from these areas is clean and consistent with naturally occurring water quality from nearby creeks or surface runoff. Establish sediment, erosion and water quality control measures including silt fences, clean and dirty water diversions, sediment basins and stockpile areas down gradient of the disturbed areas. Where possible, diverted water is to be discharged into remnant sections of natural water courses downstream of the Project work area.
3.	Any disturbance of watercourses should be completed during dry, non-flow periods.
4.	Stockpiles including overburden, clean fill and topsoil are to be established to minimise erosion and prevent movement of material outside the stockpile footprint.
5.	Clearing of sloping ground is to be managed, where possible, to avoid wet periods, to minimise erosion of unstable ground.
6.	Natural surface water channels will be reinstated wherever possible following disturbance to a watercourse.
7.	Establish access routes for site vehicles and deliveries to minimise disturbance of cleared areas.
8.	Surface water diversion structures will be designed, installed and managed to enable uncontaminated water to be directed around disturbed and construction areas. Dispersion systems at discharge points of diversion drains will be engineered to reintroduce sheet flow minimising the impact on the downstream environment.
9.	Diversion channels will be constructed with similar gradients to the natural surface water systems in the Project area.
10.	Rock armouring and other erosion controls will be utilised in areas of high erosion potential (eg: steep gradients and bends).
11.	Where possible, stormwater will be captured and used for construction activities and will be treated to meet regulatory discharge requirements before it leaves the Project boundary. Potentially contaminated stormwater (eg: runoff which contains hydrocarbons) will not be discharged into the environment.
12.	Storm water collected from construction areas that is considered not to be at risk from hydrocarbon contamination will be kept separate from natural surface water and reused on site or discharged via sediment reduction controls.
13.	Sedimentation controls will be constructed prior to the clearing of any large areas at risk of generating runoff.

Item No.	Requirements
14.	Equipment servicing will take place in designated areas. Field servicing will be undertaken in a manner that facilitates containment of all hydrocarbons and chemicals.
15.	Stabilisation of disturbed areas and new surface water lines will be completed prior to the wet season. Stabilisation of the banks of any open diversion channels is to be undertaken with direct seeding of native vegetation species endemic to water courses in the region, or through the use of weed free, excess topsoil from a similar area previously cleared from the project site.
16.	As far as practicable, works in water ways will be conducted during the dry season to minimise environmental impacts.
17.	Causeway construction works will be completed over the shortest time practicable to minimise the period of environmental disturbance in the saline coastal flat.
18.	All sediment basins / ponds will be regularly inspected and cleaned of debris and sludge so that their effective volume is maintained.
19.	Containment bunds around facilities such as vehicle servicing facilities, chemical / fuel storage areas and concrete batch plants will be designed to minimise flood water entry and be inspected on a regular basis.
20.	A progressive erosion and sediment control plan (ESCP) will be developed for each project area and submitted for review and approval as part of the GDP process. The plan will consider the changes that will be required throughout the Project construction phase to ensure adequate management of surface water flows.
21.	Run-off collected from hardstand surfaces, conveyor and product storage sheds in the production plant and the port areas will be managed to minimise impacts on surrounding environments, including marine environmental quality.
22.	The Project's stormwater surface water system in the main process area (Site C) will direct stormwater from hardstand areas into two separate streams which enable the containment and use of the run off: • Stormwater that could be contaminated by spills or leaks from process activities will be directed to holding ponds for pre-treatment, prior to reuse as a component of the seawater used for the process plant's cooling systems; • Uncontaminated stormwater will not be treated, but will be pumped directly from the stormwater holding pond into the seawater used for cooling on site or used to dilute seawater at the inlet of desalination plant.

8 Monitoring and Maintenance

Perdaman will undertake regular reviews of construction and environmental management systems. Site inspections to assess the effectiveness of all sediment, erosion and pollution controls will be undertaken and corrective actions implemented.

8.1 Review of Procedures

This SWMP will be reviewed periodically throughout the life of the Project (approximately every 12 months) to assess effectiveness of its measures and maintain relevance to current works or operations. Should performance of controls be inadequate then the measures will be updated to achieve performance objectives. Additional review will be required in the event of an environmental incident or change in activities.

8.2 Inspections, Monitoring and Maintenance

Regular inspections and audits are required to assure the environmental protection outcomes outlined in this SWMP. Inspection and maintenance activities will follow the Monitoring and Compliance requirements outlined in the PEMP and will include:

- Review of ESCPs and validate that the proposed erosion and sediment controls have been implemented and, where relevant, revised to accommodate the changing environment;
- Inspections to observe and record any scouring/erosion, any sediment transfer particular beyond the footprint;
- Cleaning of sedimentation basins when the accumulated sediment has reduced the basin capacity by more than 30%, as indicated by depth pegs;
- Cleaning of all drains to remove silt, vegetation (where capacity is reduced) and litter;
- Weekly inspection of access roads and hardstand areas to identify erosion damage in need of maintenance. Remediation is to occur within one month or earlier if heavy rains are likely;
- Discharge from any oily water separator will be monitored to ensure it contains less than 5ppm TRH and is in compliance with Project approval conditions before it can be used on site or discharged. Written approval from the Environment and Heritage Manager must be obtained prior to reuse or discharge.

Where erosion or sediment deposition occurs rehabilitation corrective actions will be implemented as soon as practicable.

Where sedimentation occurs the source of the sediment should be determined to identify likely erosion in up gradient areas. The sediment should be removed and deposited, if possible, as part of remediating erosion areas.

If erosion is identified and requires rehabilitation the impacted area will be filled, compacted and contoured to merge with the surrounding landscape. This area should then be stabilised using erosion controls outlined in section 6.4.

8.3 Monitoring and Management Plan

Prior to construction, a monitoring and management plan for surface and groundwater quality will be developed. This will include the monitoring locations, frequency, measurement protocols, assessment protocols, management commitments and reporting arrangements to demonstrate that the water quality targets are met.

9 Reporting

Compliance with this SWMP will be reported in a timely manner to the Environment and Heritage Manager after each inspection and audit. Corrective actions will be recorded and monitored as per the non-conformance tracking system to ensure continual improvement and enable the close out of incidents.

Any stormwater, surface water, erosion or sedimentation incidents resulting in offsite impacts will be reported to the Environment and Heritage Manager (or their representative) as soon as possible.

Annual reports will be prepared by Perdaman for submission to the appropriate Regulators. These will include general conformance, new risks and hazards identified, corrective actions implemented, sampling results and incident and investigation reports.

10 Definitions

Bund

A bund is a barrier constructed from material that is able to adequately contain contaminated material such that, should a spill, leak or loss occur, it prevents contamination of the environment. It will serve the dual purpose of containing contaminated material or wastewater within a confined area, whilst excluding external stormwater runoff.

Contractor

The Contractor on the Project is any individual or party engaged directly or indirectly by Perdaman, that is not an employee of Perdaman, to carry out the Project.

Environmental Representative

The Environmental Representative includes Perdaman's Environment and Heritage Manager, the Environmental Coordinator or their delegated representative.

Environment and Heritage Manager

The Environment and Heritage Manager is Perdaman's site based Environmental Representative who has the authority and responsibility for managing the implementation, compliance and effectiveness of the Project's environmental and heritage requirements.

Ground Disturbance Permit

A Ground Disturbance Permit (GDP) is a permit issued to a Subcontractor, by the Contractor, enabling Works within defined battery limits to manage any impacts on native vegetation, heritage or other environmentally sensitive values. It includes the key approval commitments and obligations obtained by or issued to the Contractor or Owner by regulators, tenure holders and other third parties.

May

Indicates that the Subcontractor is permitted to do something or the Contractor reserves the right to do something according to the text.

Perdaman

Perdaman Chemicals and Fertilisers Pty Ltd is the proponent of the Project.

Project Personnel

Project Personnel includes all persons working on the Project directly employed by Perdaman, or its Contractors.

Project Work Sites

The Project work sites include Area C, Area F, the causeway linking these two areas, the conveyor corridor to the Port and the Port storage and loading infrastructure. It can also include any other Project relevant location under operational control of Perdaman.

Should

Indicates a recommendation.

Subcontractor

A Subcontractor is any organisation, consultant or supplier engaged, or to be engaged by SNC- Lavalin.

Will

Indicates that a statement is mandatory.

Works

Works includes all work which Perdaman and or its Contractors are required to perform to comply with its obligations under their relevant scope of works pertaining to the Project.

Water Corporation

Water Corporation is the principal supplier of water, wastewater and surface water services throughout the state of Western Australia. It will provide potable water during construction, and seawater and brine disposal facilities for the commissioning and operations phase.

11 Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
ASS	Acid Sulphate Soils
BSIA	Burrup Strategic Industrial Area
EMP	Environmental Management Plan
EPC	Engineering, Procurement and Construction
ESCP	Erosion and Sediment Control Plan
EWSC	East West Services Corridor
FEED	Front End Engineering and Design
Mtpa	Million tonnes per annum
MUBRL	Multi User Brine Release Line
PEMP	Project Environmental Management Plan
PPA	Pilbara Ports Authority
PPM	Parts per million
SWMP	Surface Water Management Plan
TRH	Total Recoverable Hydrocarbons

12 Reference Documents

Document Number	Document Title
140436-0000-4GER-0001	Perdaman Project Destiny – Geotechnical Desk-Top Study
CW1055600-EN-PL-001	Project Environmental Management Plan
140436-0000-41EG-0001	Standard Specification Geographic, Climatic and Wind / Seismic Data

13 Codes and Standards

Document Number	Document Title

14 Project Delivery Applicability

☐ Proposals	☒ EPC	☒ Construction
☐ Studies	☒ Project Management	☒ Commissioning
☒ Preliminary Engineering	☒ Technical Services	☐ Site Services
☒ FEED	☒ Procurement	☒ Ops and Maintenance
☒ Detailed Design	☒ Construction Management	☐

Attachment A. Project Surface Water Schematic and Plot Plan

DATE PLOTTED: 19 March 2020 9:38 AM BY : ASHLEY PEARCE

DIVERTED RUNOFF SITES "C" AND "F"

255,440 / 89,280

DISCHARGE STRUCTURES DS01, DS02 &DS03 FROM SITES "C"&"F"

255,440 / 89,280

TO ENVIRONMENT 1A

WATER CORP

- / 80

POTABLE WATER STORAGE TANK 8.4m dia x 6.4m H

(2x) POTABLE WATER DISTRIBUTION PUMPS 7.5m³/h @ 20m HEAD

7.5 / 1.5

SITES "C" GATE HOUSE AND CONTROL ROOM

DESIGN DEVELOPMENT ADDITION

(2x) GRINDES SEWAGE PUMPS 7.5m³/hr @ 3.75kW

SITES "F" GATE HOUSES, MAINTENANCE, WAREHOUSE ADMINISTRATION, LAB BUILDINGS

7.5 / 1.5

7.5 / 1.5

(2x) GRINDES SEWAGE PUMPS 7.5m³/hr @ 3.75kW

7.5 / 1.5

PERMANENT STP RBC 36 m³/day

7.5 / 1.5

(2x) EFFLUENT WATER DISTRIBUTION PUMPS 7.5m³/h @ 2.1kW

RECYCLE PROCESS 3

DESALINATION UNIT

FIRE WATER TANK CAPACITY: 5,400m³ 21m dia x 16.9m H

900 / 0

DIESEL PUMP 900m³/h @ 90m HEAD

ELECTRIC PUMP 900m³/h @ 90m HEAD

JOCKEY PUMP 20m³/h @ 90m HEAD

DESIGN DEVELOPMENT SPLIT INTO (2) (2x) 450m³/h @ 90m HEAD

SITES "C" & "F"

RECYCLE PROCESS 3

OILY WATER PUMP 5m³/h @ 16m HEAD

UREA UNIT 1

UREA UNIT 2

AMMONIA UNIT SUMP 1

AMMONIA UNIT SUMP 2

ASU

POWER PLANT

BoU

5 / 0

OILY WATER TREATMENT UNIT

OFFSITE OIL FOR TREATMENT AND DISPOSAL

50 / 0

AMMONIA STORAGE TANK

UREA UNIT 1

UREA UNIT 2

AMMONIA UNIT

ASU

POWER PLANT

COOLING TOWER AREA

WATER TREATMENT

PCWS PUMP 50m³/h @ 25m HEAD

(2x) BLOWDOWN PUMPS 50m³/h @ 25m HEAD

COOLING TOWER BASIN

SUBMERSIBLE PUMP 100m³/h @ 25m

SALINE WATER POND STORAGE CAPACITY 14000m³

MUBRL 2

(2x) SUBMERSIBLE PUMPS (2x) 800m³/h @ 25m

PROCESS RECYCLE 3

CLEAN RAIN WATER ON SITE "C"

PLANT SITE "C"

1995 / 720

SITE "C" RUNOFF WATER COLLECTION POND STORAGE CAPACITY 8000m³

EMERGENCY SPILLWAY FOR 1:100 YEAR FLOWS

DISCHARGE STRUCTURE DS04 TO ENVIRONMENT 1B

CLEAN RUNOFF FROM ROADS AND ROOFS

SITE "F"

3525 / 612

SUBMERSIBLE PUMP 50m³/h @ 25m

SITE "F" STORM WATER BACK-UP POND STORAGE CAPACITY 1250m³

PROCESS RECYCLE 3

EMERGENCY SPILLWAY FOR 1:100 YEAR FLOWS

PERIMETER DITCH SITE "F" TO DS03 1C

LEGEND

- PROCESS LINE AND FLOW DIRECTION
- BACKUP LINE AND FLOW DIRECTION
- 255,440 / 89,280 PEAK FLOW (m³/h), AVERAGE FLOW (m³/h)

ABBREVIATIONS

MUBRL	-	MULTI USER BRINE RETURN LINE SINGLE CONNECTION POINT
BoU	-	BOIL OF UNITS AT AMMONIA STORAGE TANK

XREFs:
CAD File: Y:\CW1055600_Perdaman_Chemicals_and_Fertilisers_Permits_and_approvals\5_Technical\Civil\CAD\00\CW1055600-FIG01.dwg

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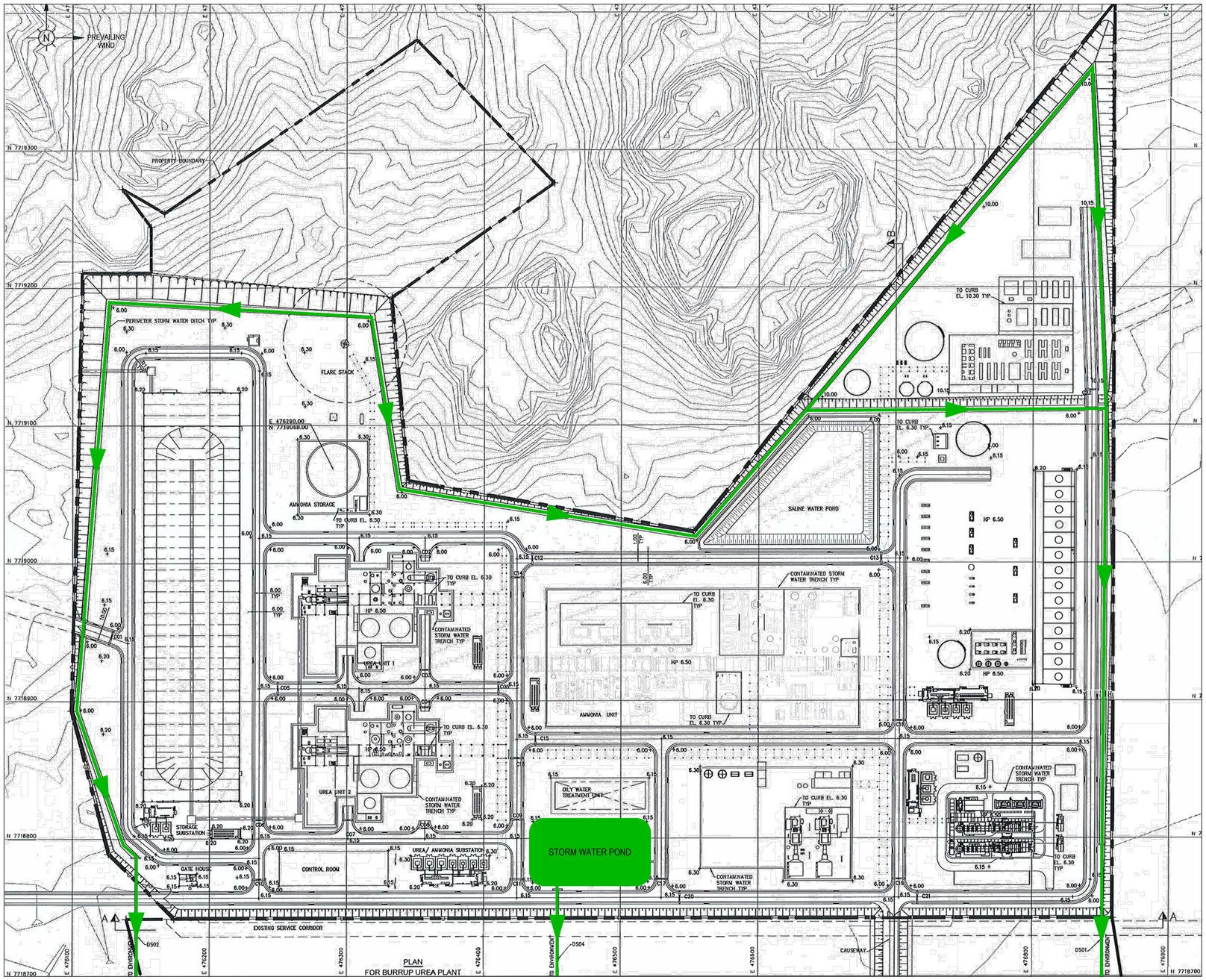
Figure 5 - Water Balance Flow Sheet

PERDAMAN
BURRUP - UREA PROJECT
FLOW SHEET
WATER BALANCE / RETICULATION

Date	Scale	Size
19.03.2020	N.T.S.	A1

CW1055600-CI-SD-001 (Drawing Number)

B (Revision)



PLAN
FOR BURRUP UREA PLANT

LEGEND

STORMWATER FLOW PATH

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PERDAMAN
BURRUP - UREA PROJECT
SITE C - FLOW SHEET
WATER BALANCE / RETICULATION

Date	Scale	Size
12.03.2020	N.T.S.	A1

CW1055660-CI-ST-001
Drawing Number

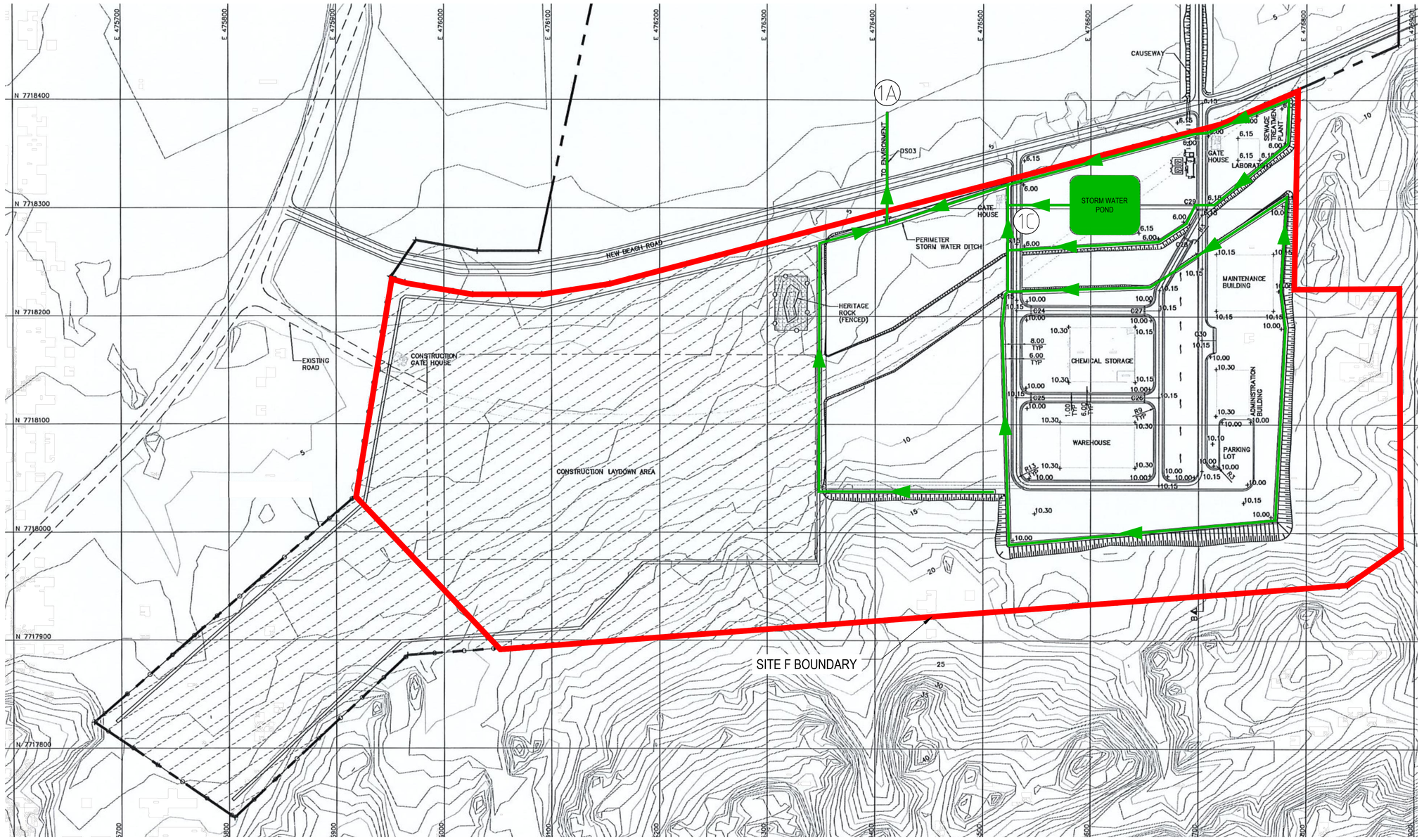
A
Revision

DATE PLOTTED: 18 March 2020 11:34 AM BY : ASHLEY PEARCE

NORTH

LEGEND

STORMWATER FLOW PATH



0 50 100 150 200m

SCALE 1:2000 @A1

PERDAMAN
BURRUP - UREA PROJECT
SITE F - FLOW SHEET
WATER BALANCE / RETICULATION

Date	Scale	Size
12.03.2020	1:2000	A1

Figure 7 - Site F Stormwater Flow

CW1055660-CI-ST-002
Drawing Number

A
Revision

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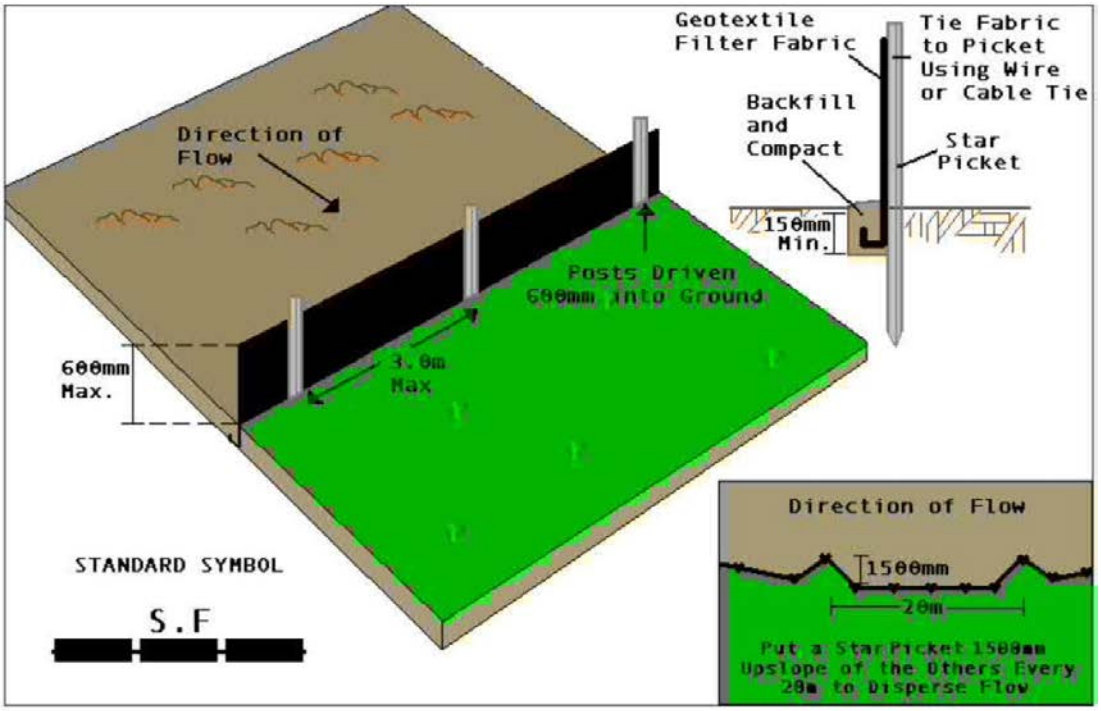
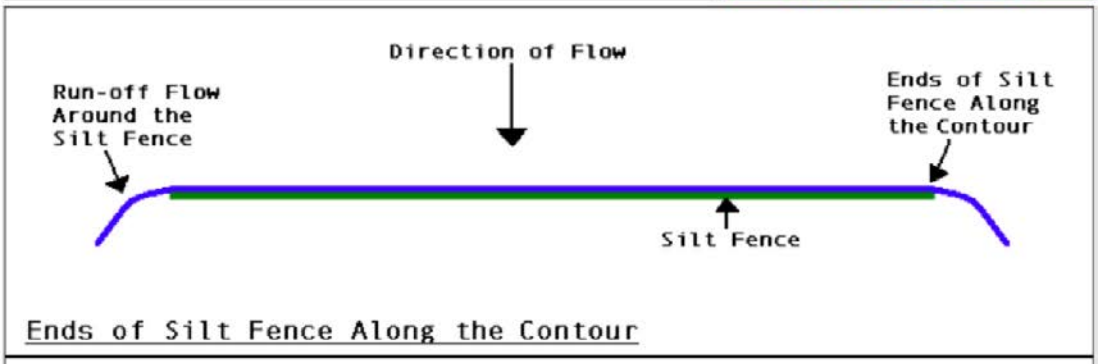
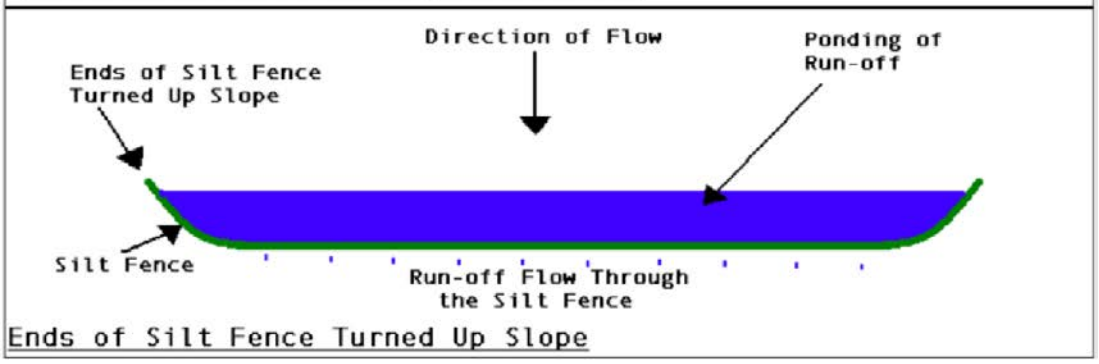
XREFs:
CAD File: Y:\CW1055600_Perdaman_Chemicals_and_Fertilisers_Permits_and_approvals\5_Technical\Civil\CAD\00\CW1055600-FIG03.dwg

Attachment B. Silt Fence Design







Attachment C. Geotechnical Desktop Study

GEOTECHNICAL DESK-TOP STUDY

Document No: **140436-0000-4GER-0001**

1 OF 6

Revision **: B1** Date **: 8-APR-2019**

B1	8 Apr 2019	Issued for Information	M. LEE & T.PERRIMENT	S.J.MOORE	N/A	EC
A1	29 Mar 2019	Draft for internal review	M. LEE & T.PERRIMENT	S.J.MOORE	N/A	EC
REV	**DATE**	**ISSUE DESCRIPTION**	**AUTHOR**	**CHECKER**	**HSSE/Q**	**APPROVER**

PERDAMAN INDUSTRIES
CHEMICALS & FERTILISERS

FOREWORD

CLARIFICATION OF PROJECT AREA

Some technical reports, including this one, were completed in the early planning and design phases of the Project. As such, some of the maps / and aerial views depict the following anomalies associated with the actual Project area:

i. The Project boundary of Site F does not have an extension from the south west corner.

ii. The southern alignment of Hearson Cove Road is not applicable. Only the alignment on the north side of Site F will apply to the Project.

iii. The footprint of the port area is limited to the area depicting the *Storage Shed – Port* and *Shiploader – Feed Conveyor.* It does not extend out along the Bulk Liquids Berth Jetty.

Figures A and B below provides further clarification of this discrepancy.

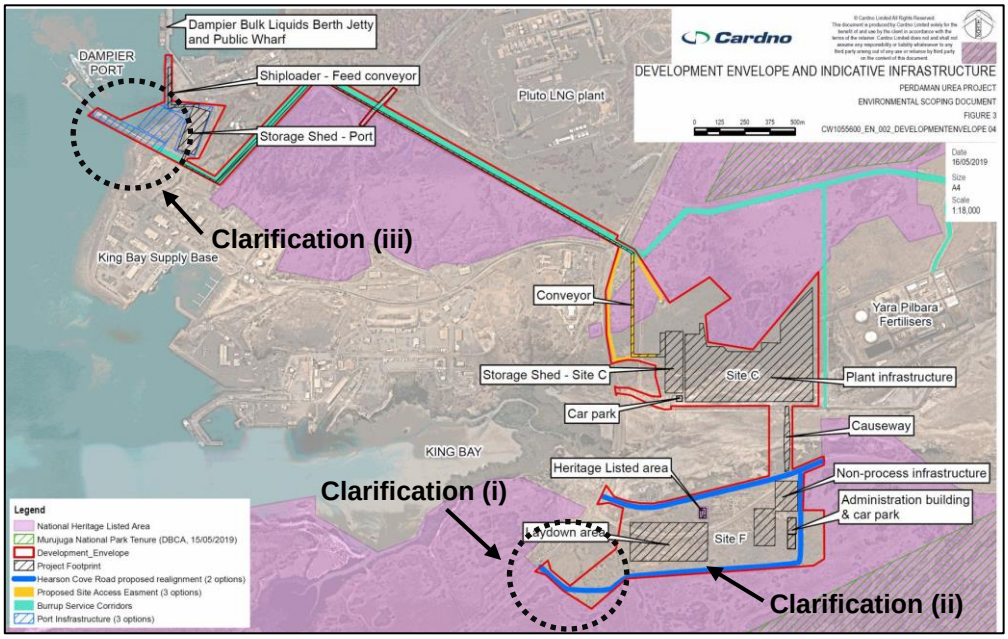


Figure A: Incorrect / superseded Project Area.

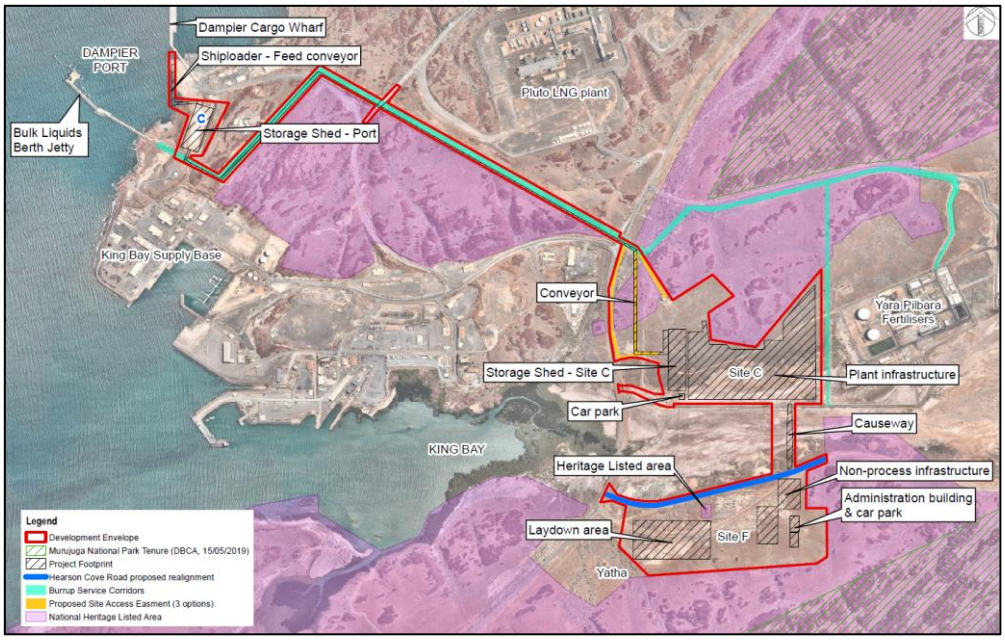


Figure B: Correct Project Area.

TABLE OF CONTENTS

1.0 INTRODUCTION

Perdaman Group (Owner) is seeking to develop a gas based urea plant located on the Burrup Peninsula, approximately 10km from Dampier and 20km north-west of Karratha on the north-west coastline of Western Australia. The Project's urea plant will be developed on Site C and F with a causeway linking between the two sites, which allow for the existing natural channel for the inter-tidal flow of seawater to remain relatively unchanged. In addition, the Project will also leverage the existing pipeline easement for the construction of a new conveyor corridor linking between the urea plant and the port. A new warehouse structure will constructed at the disused quarry of the port area.

1.1 Purpose

The desktop study has been undertaken for the purpose of informing the geotechnical design of the Project. The intention of the desktop study is to provide an initial indication of the potential geotechnical risk and requirements of the development as well as inform the gaps in the geotechnical analysis in previous investigation at or near the site. The work presented herein does not represent a design and any recommendation are indicative and further assessment Ground Investigation shall be undertaken prior to detailed design.

The desktop study will specifically:

- Provide a description of the site history, ground conditions, and environmental setting;
- Develop a preliminary conceptual site model (CSM);
- Identify ground related risks associated with the development; and
- Provide recommendations in relation to design aspects.

1.2 Scope

The scope of this desktop study is to provide a review of the existing available relevant information. Data sources to be examine should include as a minimum:

- Geology and Soil Maps;
- Acid sulfate soils maps;
- Any existing geotechnical reports that may be made available by the client;
- Council held records;
- Aerial photographic imagery; and
- Any nearby wellbore information.

2.0 SOURCES OF INFORMATION

Table 2-1 presents the information sources used to inform this desktop study report.

Table 2-1 - Sources of information

Class of Information	Data Obtained	Source
Memorandum	Cut and Fill Methodology	Woolnough, W. Memo to Benjamin Rankin SLI Engineering Manager. SNC-Lavalin, Toronto Ontario, Canada. 6 February 2019.
Report	Site History Geology Acid Sulphate Soils Groundwater	HLA Envirosciences Pty Limited. 1999. *Proposed Gas to Synthetic Hydrocarbon Plan Burrup Peninsula, Western Australia – Consultative Environmental Review.* GHD. 2010. *Dampier Nitrogen Pty Ltd – Ammonium Nitrate Project Public Environmental Review.* BHP Engineering. 1996. *Methanol Plant Site – Burrup Pensinsula Peliminary Geotechnical Design Criteria*. King Bay/ Hearson Cove and Maitland Industrial Estates, Phase 2 Geotechnical Investigation Report, by Soil and Rock Engineering, August 1999. Site Survey data provided by SNC-Lavalin, recorded March 2019.
Satellite Imagery	Historical Imagery	Google Earth. 2017. Google Earth Pro V 7.1.8.3036 (accessed on 26 March 2019) ESRI (2018-2019)
GIS Data Formats	Acid sulphate Maps Geological Maps Soil Maps Contours Hydrology	Government of Western Australia. 2018. Acid Sulfate Soil Risk Map, Pilbara Coastline (DWER-053).https://catalogue.data.wa.gov.au/dataset/acid-sulfate-soil-risk-map-pilbara-coastline-dwer-053/resource/f3fb78ab-0864-33ae-84ba-840041c40153 (accessed on 26 March 2019) Government of Western Australia. 2000. 1:100 000 geological map – DAMPIER (2256), first edition. Geological Survey of Western Australia. Australian Government. 2011. 1 second SRTM Derived Hydrological Digital Elevation Model (DEM-H) Version 1.0. Geoscience Australia.

Laboratory Data Report	Historical Laboratory Data	King Bay/ Hearson Cove and Maitland Industrial Estates, Phase 2 Geotechnical Investigation Report, by Soil and Rock Engineering, August 1999.

3.0 SITE LOCATION AND DESCRIPTION

The Perdaman project is located on the Burrup Peninsula in northwest of Western Australia, approximately 1,300km north of Perth, with the nearest address being 314 Griffin Road, Dampier WA 6713. The coordinates for the approximate centre of site C is 476477E, 7718888N, and likely wise site F's coordinates are 476355E, 7718112N and the port area 473965E, 7720146N. The site is approximately 105 hectares in area and is relatively undeveloped with the exception of a few access roads running through the site. A site location map for the proposed development is presented as Figure 3-1 where the site boundary is outlined in red.

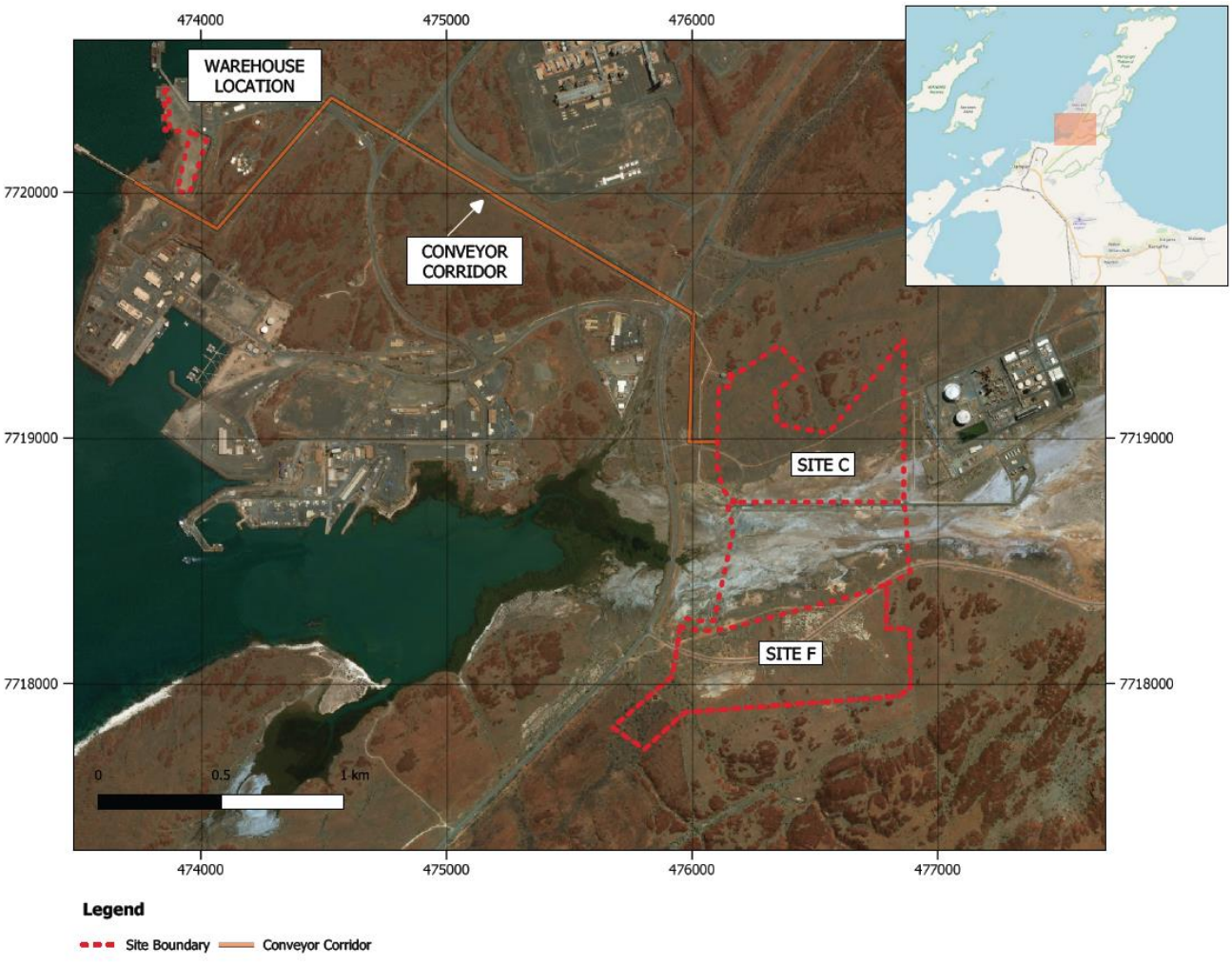


Figure 3-1 – Proposed site location plan with inset map showing location within the Burrup Peninsula, Western Australia

Site access to the following key infrastructure are:

- Site F: Hearson Cove Road, Burrup WA 6714 (runs throughout Site F);
- Site C: Unnamed Road off Burrup Road, Burrup WA 6714 (Towards Yara Pilbara Fertilisers); and
- Port Area: Mof Road, Burrup WA 6714.

4.0 DEVELOPMENT HISTORY

4.1 Historical Development

A review of the site history and surrounds has been carried out through the Google Earth imagery database and shows that the site has remained relatively unchanged since 2006.

Table 4-1 summarises the information obtained from reviewing the available historical images.

Table 4-1 – Historical development

Year	Site Description
Early 1980's	Site F was used for pipeline-weight coating operation, pipe laydown, concrete batching operations and stockpile of marine dredging spoils. Construction of a cement hardstanding using iron ore fines was required for the pipe weight coating yard (BHP Engineering, 1996).
1980 - 1990	Rehabilitation of the site which included import of fill material (potentially from Hearson Cove, course grained sand, shells and coral fragments) (BHP Engineering, 1996).
Early 1990's	Construction of new tourist road to Hearson Cove (BHP Engineering, 1996).
2006	Existing wharf facilities present approximately 3km west of the site. Existing Yara Pilbara Fertiliser plant to the east of the proposed Site C (construction began in 2003).
2009	No major changes.
2011	Development of Woodside Energy's Pluto LNG Park located approximately 1.5km northwest of Perdaman's proposed Site C.
2012	No major changes.
2013	No major changes.
2015	No major changes.
2017	No major changes.
2018	No major changes.

4.2 Previous Investigations

Previous ground investigation conducted at or nearby the site includes:

Reference	Details
Borrow Areas Selected for Road Construction for Main Access Road Northwest Shelf Development Project, Phase 2 Geotechnical Ground Investigation Report; Soil and Rock Engineering; August – September, 1980.	Report is referenced in BHP (1996) but was unavailable at the time of this review. 86 No. test pits to unknown depth. 17 No. boreholes to unknown depth.
Access Roads for Northwest Shelf Development Project, Evaluative Report; Soil and Rock Engineering; September, 1980.	Report is referenced in BHP (1996) but was unavailable at the time of this review.
BHP Petroleum Methanol Plant Site – Burrup Peninsula, Preliminary Geotechnical Design Criteria; BHP Engineering; May, 1996.	Engineering geological ground model.
Syntroleum Proposed Gas to Synthetic Hydrocarbon Plant, Consultative Environmental Review; HLA Envirosciences; November, 1999.	Environmental review only.
King Bay/Hearson Cove and Mailtland Industrial Estates, Phase 1 Geotechnical Investigation Report; Soil and Rock Engineering; February, 1999.	Geotechnical Investigation Report
King Bay/Hearson Cove and Maitland Industrial Estates, Phase 2 Geotechnical Investigation Report; Soil and Rock Engineering; August, 1999.	6 No. boreholes terminating between 6m to 9.15m 10 No. testpits ranging from 0.3m to 2.5m 40 No. Dynamic Cone Penetration tests
Burrup West Service Corridor, Geotechnical Reconnaissance memo, Soil & Rock Engineering, September, 2001.	Geotechnical Reconnaissance.
Dampier Nitrogen Site, Public Environmental Review by GHD, December, 2010.	Public Environmental Review.

5.0 SITE WALKOVER RECCONAISSANCE

A site walkover was undertaken by a Principal Geotechnical Engineer from SNC-Lavalin on 6 March 2019 in order to assist with preparing the desk-top study report and enable scoping of the geotechnical investigation. The reconnaissance was carried out at Site C and Site F and the intertidal flats area inbetween. Access into the pipeline corridor for the conveyor or the port area for the storage warehouse was not possible at the time of the visit, however Lidar survey images of these sites were subsequently made available.

The Hearson Bay Cove Road transects the low lying area of Site F where colluvial materials are visible at the surface. The colluvium was observed to typically comprise a sandy silty soil with gravel and scree cobbles and boulders. Where the site rises gently up to the south small surface outcrops of granophyres geology are visible on the colluviums slopes. Figure 5-1 illustrates the nature of the colluvial material and shows the southern part of site F rising up to the southern boundary where a weathered granophyre rock outcrop is visible beyond the site boundary.

Figure 5-1 - Plate 1: View of southern aspect of Site F from bottom of slope

To the north of the Hearson Bay Cove Road the level area of Site F drops down by around 1m to 2m to the tidal flats area between sites C and F. Clayey gravel outwash materials and cemented horizons forming calcrete were visible in these slope adjacent to the tidal flats. Figure 5-2 shows the tidal flats area to the north of Site F.

Figure 5-2 - Plate 2: View of northern aspect of Site F from Hearson Bay Cove Road.

The low lying inter-tidal area was observed to comprise predominantly sandy silt that was dry at the surface but became moist when penetrated. Slightly elevated areas of surface gravel/cobbles and sandy dune type features were observed at the margins and across the flats.

The southern portion of Site C comprises the low lying intertidal area as is shown to the left of the pipeline in Figure 5-3 below.

Figure 5-3 - Plate 3: View of southern aspect of Site C near existing gas pipeline.

North of the flats, Site C rises up in elevation where colluvium similar to Site F is present and granophyres rocks outcrop at the margins of the site. The rock outcrops are jointed and weathered to form rounded block piles at the surface. The rock blocks are assessed to be of very high strength. Figure 5-4 shows the slopes of Site C rising up in elevation to the north.

Figure 5-4 - Plate 4: View of northern aspect of Site C from low laying inter-tidal area

A LiDAR image from the quarry site at the port shows the slopes to comprise batter angles of between around 45 degrees to near vertical. The geological mapping for the area indicates that the quarry consists of granophyres rocks. Well defined jointing is apparent as is scree debris at the toe of cuts, suggesting slope degradation and rockfall may be an ongoing process. The upper reaches of some batters appear to have been laid back at shallow angles in weathered material – see Figure 5-5.

Figure 5-5 - Plate 5: Lidar imagery from the quarry site at the port.

The geological map for the area indicates the pipeline easement that will form the conveyor route to comprise of predominately granophyres rocks with minor sections of the route underlain with colluvium material. Cuts excavated into the slopes to form the pipeline corridor suggest a thin soil mantle overlying fractured rocks beneath. Figure 5-6 - Plate 6: shows the pipeline corridor cut into the rock geology. In low lying areas, some portions of the corridor may have been constructed in fill although the majority of the route is likely in rock.

Figure 5-6 - Plate 6: Excavated cuts along the pipeline corridor

6.0 GROUND CONDITIONS

This section of the report summarises the currently available information that is considered relevant to the geotechnical elements of the proposed works. This information is used in the later sections as background information to aid the identification and determination of geotechnical constraints and hazards that could impact the proposed works.

6.1 Topography and Soils

The site lies either side of a tidal inlet bounded by gently sloping hills leading up to ridges where the granophyre bedrock is exposed. Figure 6-1 and Figure 6-2 show 3D-models of Site F (left) and Site C (right) with a 5x vertical exaggeration, and the Port Area site and conveyor route with a 2x vertical exaggeration, respectively. The site boundary is outlined in red, whilst the conveyor route is outlined in orange.

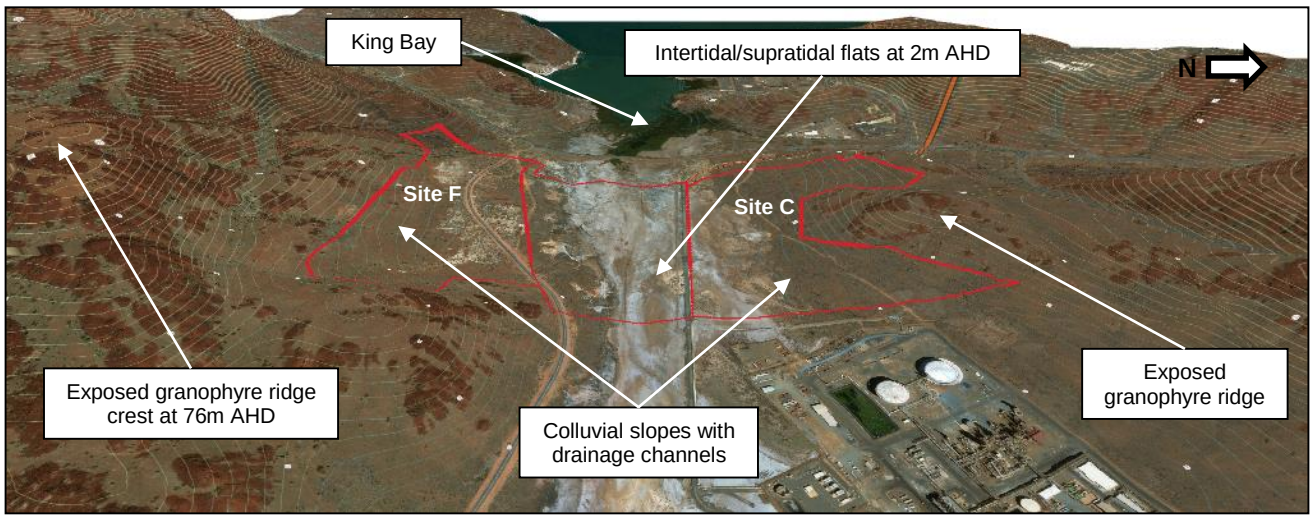


Figure 6-1 - 3D-model of site orientated west (270 °) with 5x vertical exaggeration

The reddish-brown vegetation dominating the ridges in Figure 6-1 demarcates the extent of the granophyre outcrops, whilst the extent of the light grey soil cover demarcates the high-tide mark of the intertidal flats at approximately 4m AHD. The intertidal flats extend into the site from King Bay, the source of inundation. Some overland flows may also occur from the direction of Hearson Cove to the east.

A survey of the site boundary was conducted by SNC-Lavalin in March, 2019 (Figure 6-3). Site C slopes southward from the northern ridge at 28m AHD in the north-west, and 21m AHD in the north-east, to approximately 2.4m AHD along its southern extent. Site F slopes from the south-east at 28m AHD, to approximately 6.3m AHD in the north-east, and approximately 3.2m AHD in the north-west. The intertidal flats lie at approximately 2m AHD.

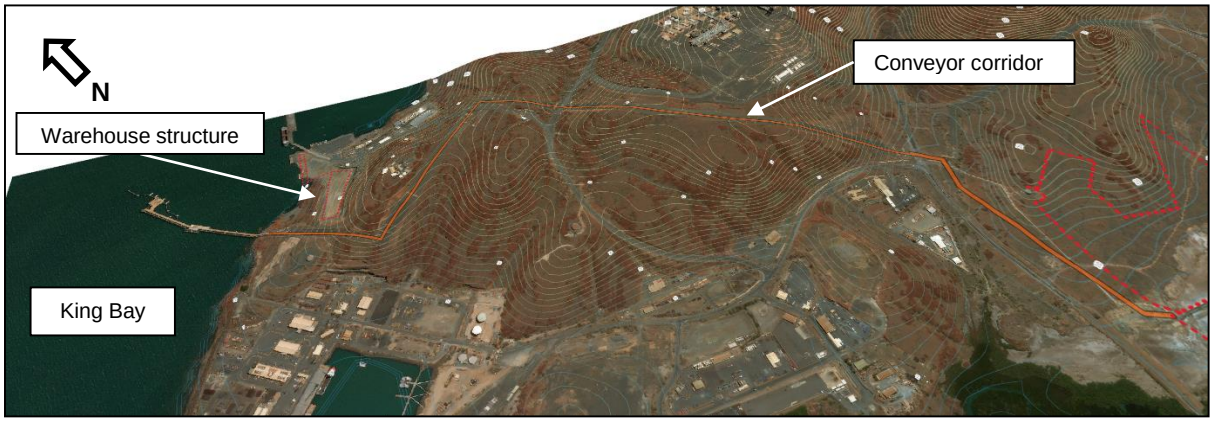


Figure 6-2 - 3D-model of the conveyor corridor and warehouse structure location, orientated north-east (45°) with 2x vertical exaggeration

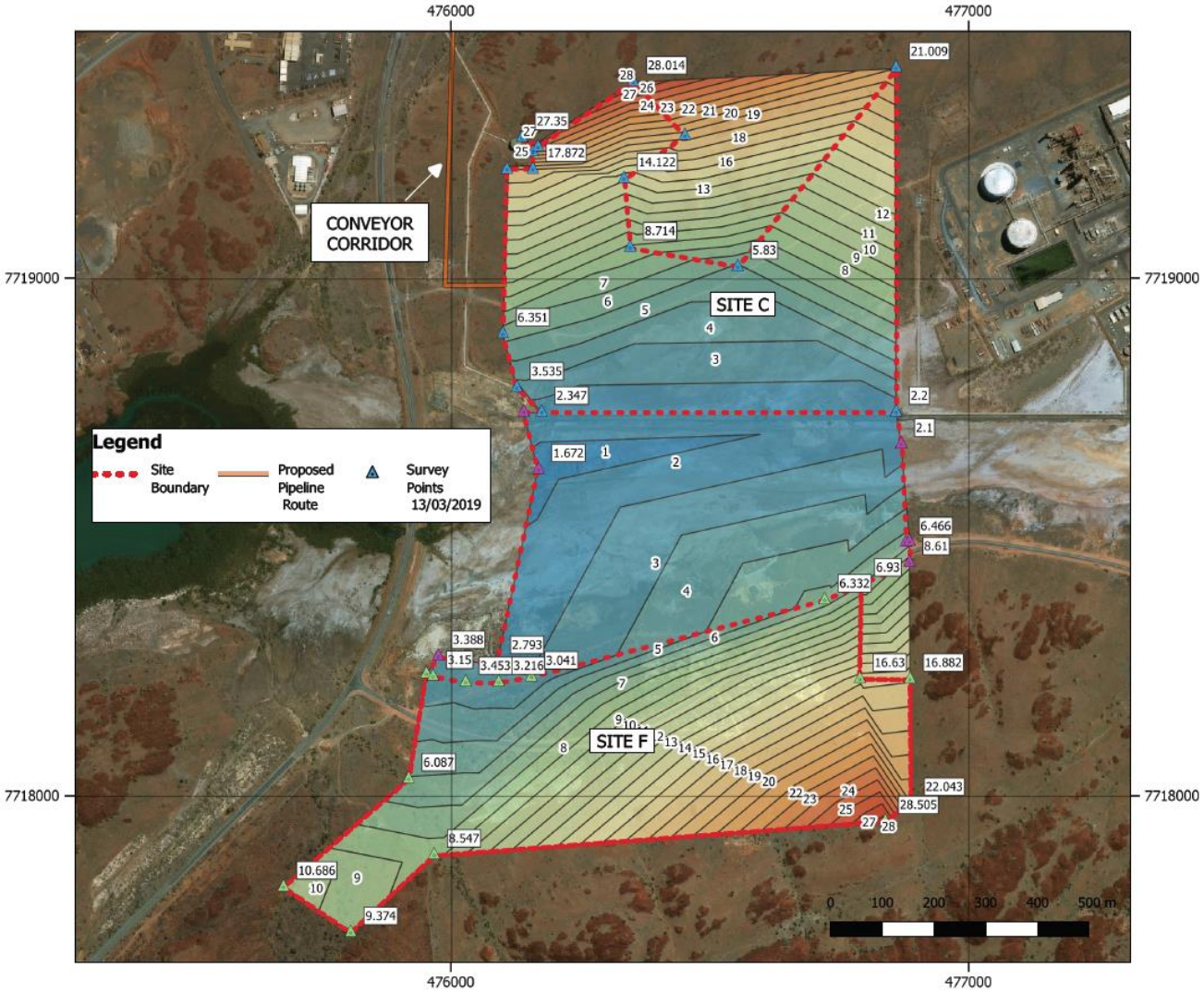


Figure 6-3 - Site elevation map generated from March 2019 survey data

6.1.1 Land Units and Soils

Figure 6-4 shows the soil landscape of the site and surrounding area:

- The Department of Primary Industries and Regional Development (DPIRD) (2018) classify the intertidal flats as a Littoral Land System, characterised as a bare coastal mudflats, supporting samphire low shrub lands and sparse acacia shrub lands at the northern and southern banks, and mangrove forests at the western extent where the intertidal flats meet King Bay.
- The slopes between the granophyre ridges and intertidal flats are classified as a Granitic Land System, characterised as rugged granitic hills, supporting shrubby hard and soft spinifex grasslands.

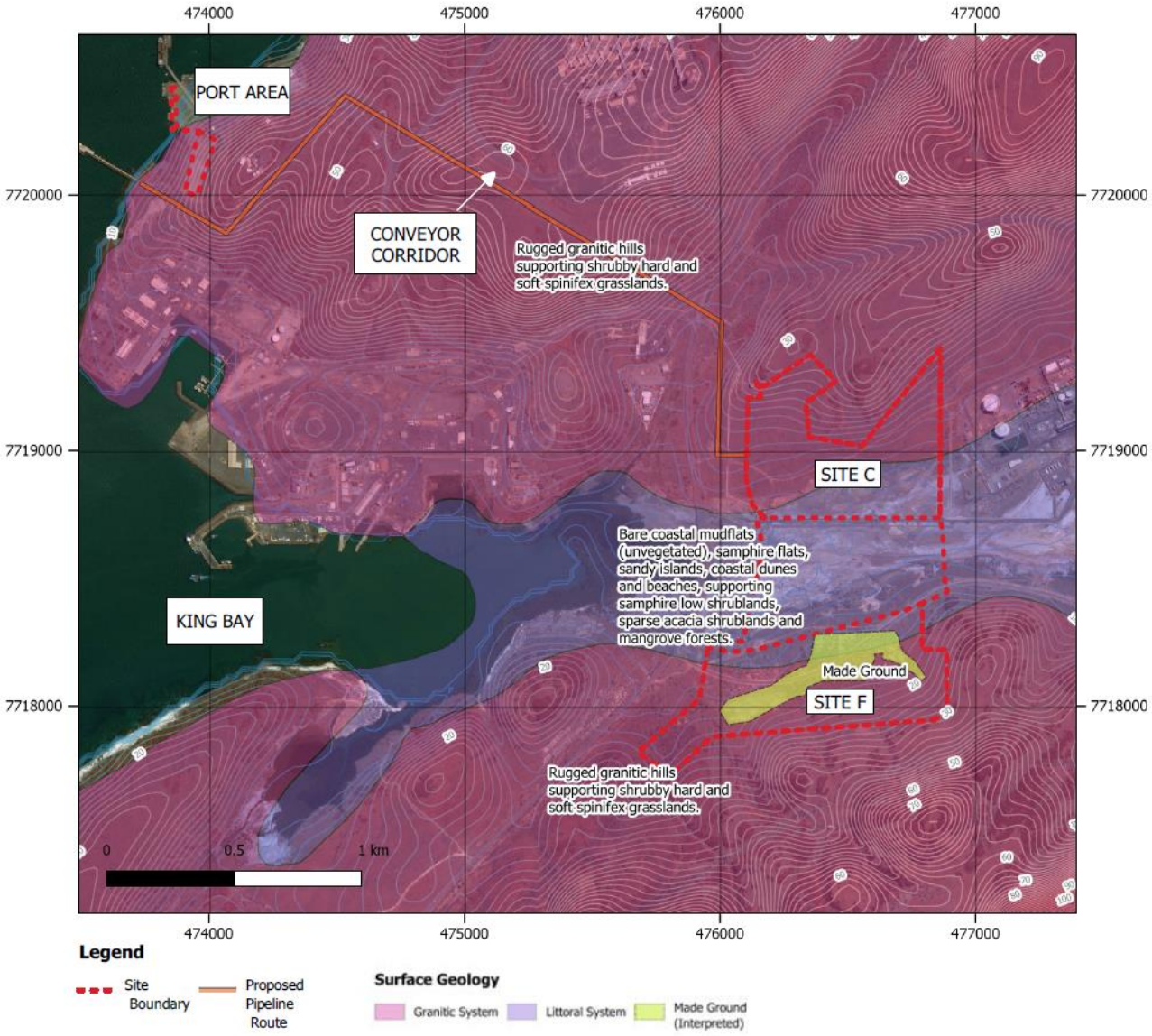


Figure 6-4 – High-level soil landscape of proposed site (after DPIRD, 2018)

6.1.2 Hydrology

Regional hydrological mapping (by Geoscience Australia, 2018) (Figure 6-5) shows a number of watercourses flowing into King Bay, east of Site C/F. These ephemeral streams only flow occasionally, typically in association with major rainfall events between December and April (GHD, 2010). Whilst there no reported permanent natural watercourses or wetlands within the site, two ephemeral watercourses appear to cross the south-west corner of Site F, and are reported to be deeply incised indicating potential to convey large flows in storm events (GHD, 2010). Stormwater runoff is reported to flow primarily from the north (URS, 2006), where shallow bedrock hinders infiltration; runoff is typically conveyed in small flows, potentially resulting in small alluvial deposits at the base of the slopes.

The two major hydrological units include the intertidal flats, classified by Geoscience Australia (2018) as a saline coastal flat, and the foreshore flat of King Bay.

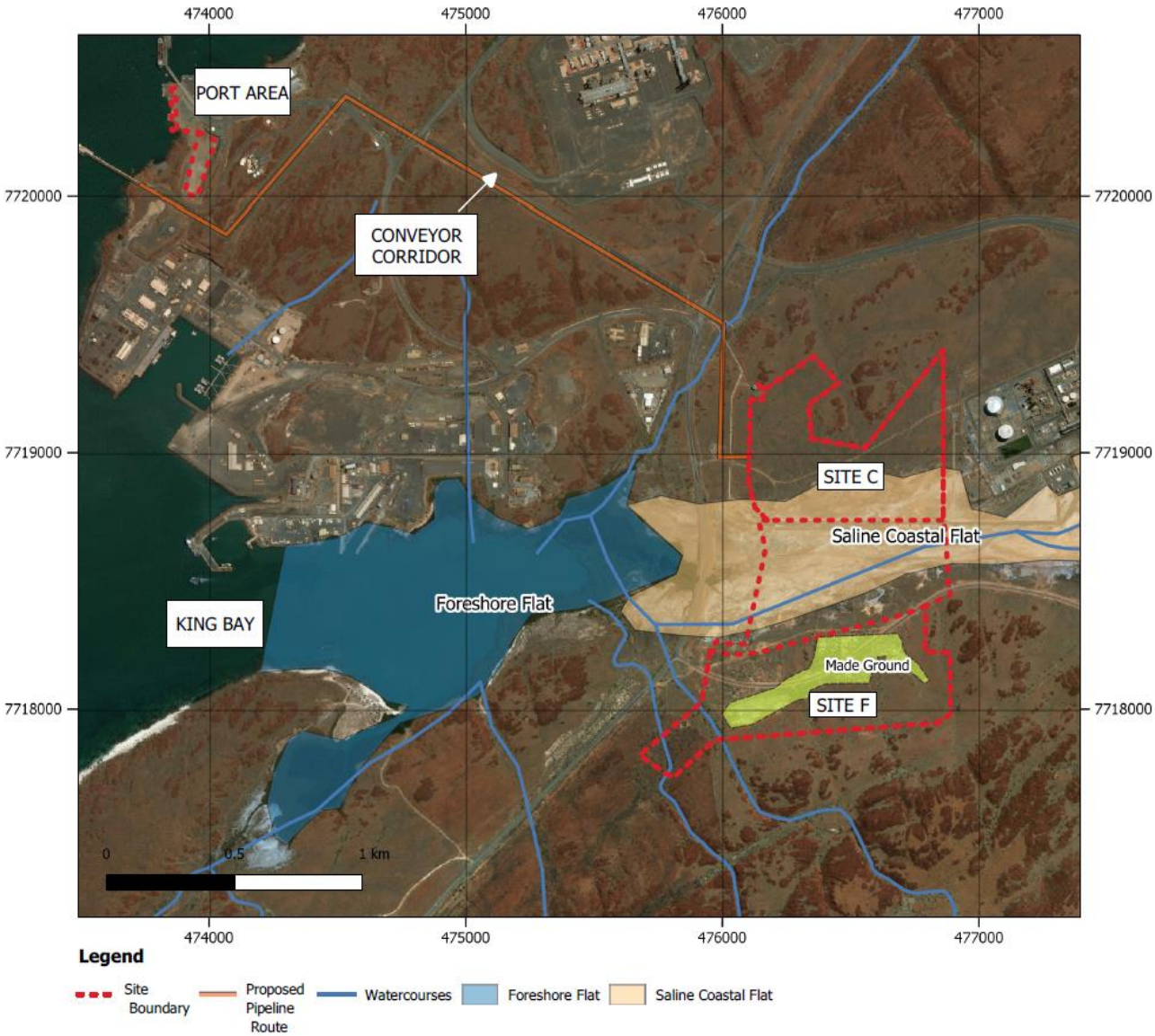


Figure 6-5 - Hydrology map (Geoscience Australia, 2018)

6.2 Geological Map

Regional surface geology from the Department of Mines (1997) is presented in Figure 6-6, whilst Table 6-1 presents descriptions for the geological units shown.

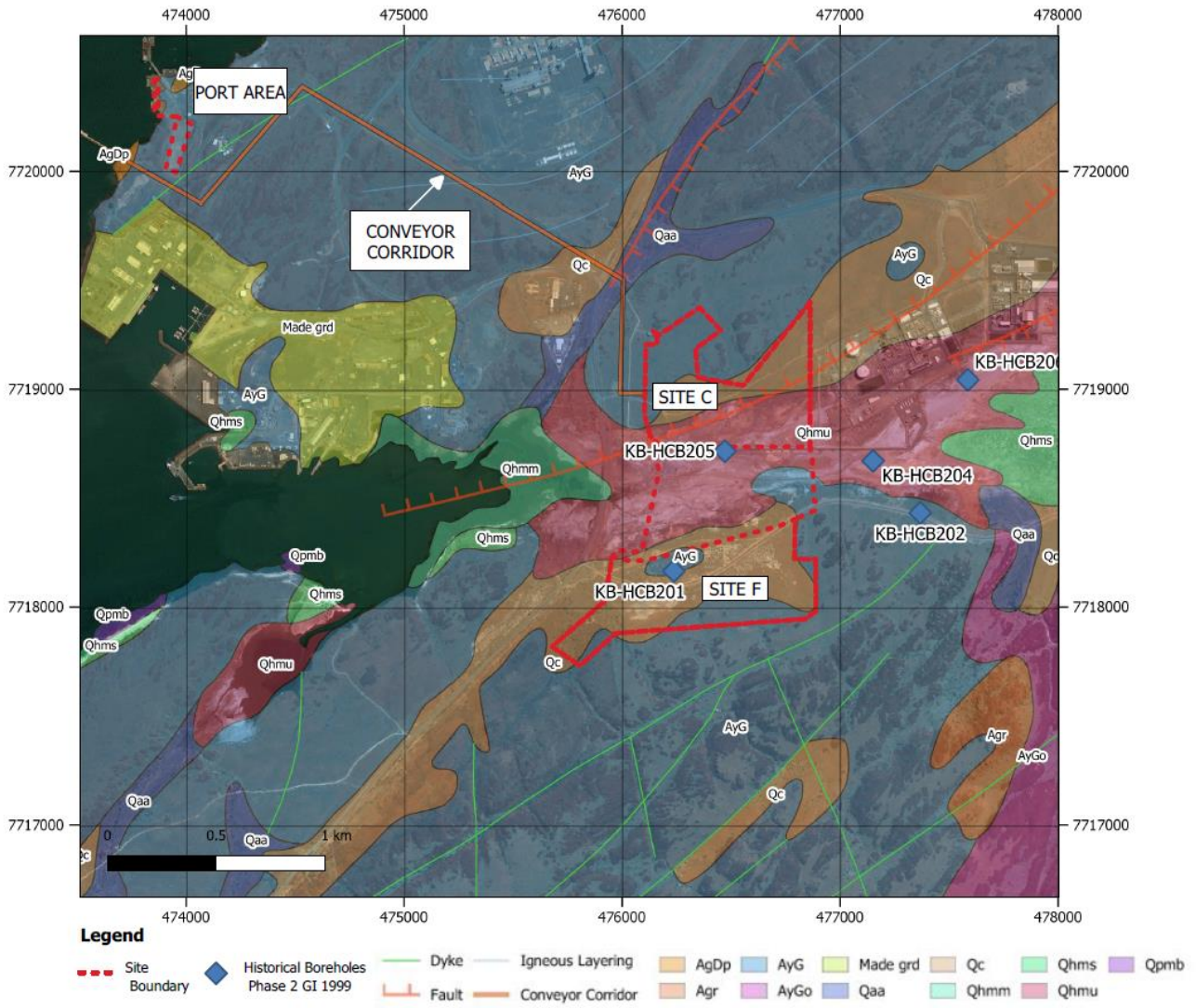


Figure 6-6 - 1:100k surface geology of proposed site (after Department of Mines, 1997).

Table 6-1 - Description of regional geological units (after the Department of Mines, 1997)

Symbol	Name	Description	Age
On Site:			
Qhmu	Saline Coastal Flat (intertidal)	Silt and mud in supratidal to intertidal flats and lagoons.	Cainozoic

Qc	Colluvium	Colluvium-sand, silt, and gravel in outwash fans and scree.	Cainozoic
AyG	Gidley Granophyre	Fine- to medium-grained granophyre, commonly porphyritic.	Archaean
Made grd	Made Ground	Made ground: highly variable, typically comprising clay, slit, sand, and gravel.	Recent
Near Site:			
Qhms	Hearsons Cove Beach Deposits	Shelly sand in coastal dunes and old beach deposits; contains Anadara granosa.	Cainozoic
Qhmm	King Cove Deposits	Marine mud and silt; intertidal with mangroves.	Cainozoic
Qaa	Alluvium	Alluvium - sand and gravel in rivers and creeks; clay, silt, and sand in channels on floodplains.	Cainozoic
Qpmb	Coastal Limestone	Coastal limestone; lime-cemented shelly sand, dune sand, and beach conglomerate.	Cainozoic
AyGo	Gidley Granophyre (Gabbro)	Gabbro.	Archaean

The geological map indicates that the site has three distinct geological areas:

- Archean **fine to medium grain granitic rock** (Gidley Granophyre), situated in the northern and southern-most higher elevation areas;
  - The Gridley Granophyre bedrock is an extremely hard mafic intrusive rock with a series of faults trending south-west/north east across the Burrup Peninsula. One large fault extends from King Bay west of the site, through Site C to Cowrie Cove to the north-east. The formation was intruded by a number of dolerite dykes, trending south-west/north-east, and exhibits igneous layering trending south-west/north-east.
- Phanerozoic (Cainozoic to Quaternary) **colluvial (and minor alluvial) sediment** comprising sand, silt, and gravel as outwash fans and scree, forming the gentle slopes between the granophyre ridges and the low-lying intertidal flats;
  - The colluvial and minor alluvial sediments were deposited by stream runoff, minor rockfall, and low energy tidal flooding.
- Phanerozoic (Cainozoic to Quaternary) **supratidal to intertidal sediments** comprising silt and mud, situated in the low-lying intertidal flats separating Site C and Site F.

Approximately 200m west of the site boundary (and 600m east of the site boundary) are Cainozoic to Quaternary deposits comprising intertidal deposits of marine muds and silts (Qhmm), and shelly sand as coastal dunes and ancient beach deposits (Qhms).

6.3 Reported Stratigraphy

The majority of studies on the project site have passed comment on the geology/soils of the area, however only two have geotechnical information available:

- BHP (1996) Methanol Plant Site – Burrup Peninsula Preliminary Geotechnical Design Criteria, located at Site F, based on data obtained from the following preliminary field and laboratory investigations:
  - Large Scale Instrument Plate Load Test at the Woodside facility north-west of the site (1986);
  - Engineering Geological Appraisal at the Methanol Plant Site (Site F) (1995);
  - Feasibility Geotechnical Investigation at the Methanol Plant Site (Site F) comprising 18 No. test pits to supplement previously excavated environmental test pits (1996); and
  - Unspecified older projects on the Burrup Peninsula.

- Soil and Rock Engineering (1999) King Bay/Hearson Cove, Desk Study (Phase 1) and Geotechnical Investigation (Phase 2) located at in Site F and the intertidal flats, commissioned by the Department of Resources Development and Landcorp for the development of the King Bay/Hearson Cove and Maitland Industrial Estates.

Following a review of geological descriptions and geotechnical data presented in the aforementioned studies, a cross-section trending north-south through the centre of Site C and Site F is presented in Appendix 2. Based on this interpretation, the anticipated stratigraphy for Site C and Site F is presented in Table 6-2.

Table 6-2 - Anticipated stratigraphy at Site C and Site F described in accordance with AS1726:2017

Strata Name	Description of Strata	Thickness (m)
INTERTIDAL FLATS	Silty clayey SAND to silty sandy CLAY: light grey to light orange brown, fine to coarse sand, medium to high plasticity (non-plastic where loose), trace of fine gravel, with coarse shell fragments, dry to moist (MC < PL to MC ~ PL), loose to medium dense (increasing with depth) where SAND, soft where CLAY (intertidal and supratidal). Plasticity index ranges from 4-21% between KB-HCB201.	0.2 – 1.0
COLLUVIUM	Clayey sandy GRAVEL with cobbles: bluish greenish grey, fine to coarse slightly weathered to distinctly weathered granophyre gravel, sub-angular to sub-rounded, fine granophyre and shell fragment sand, wet (MC > PL), medium dense to dense (colluvial). Plasticity index reported as 15-17% in KB-HCB201.	0.5 – 2.0

BRECCIATED CALCRETED GRANOPHYRE	BRECCIATED CALCRETED GRANOPHYRE: fine to medium grained fragmented and brecciated with a calcrete cement, whitish grey, orange brown to greenish black, very low (matrix) to high (clast) strength, slightly weathered to extremely weathered, moderately to highly altered, massive, infilled clay seams are closely to widely spaced, open, clasts are fine to medium grained predominantly dark mafic minerals of coarse gravel to cobble size, matrix is sandy clay. RQD ranges from 0-70 with no apparent trend. Rockmass weathering grade estimated at III.	0.5 – 3.5
GRANOPHYRE	GRANOPHYRE: grey, fine to medium grained fragmented quartz cemented, bluish grey to orange brown low to very high strength, fresh to extremely weathered[1], locally massive with large scale igneous layering approximately 250m apart, infilled clay seams are widely spaced, moderate incidence, open, sheared zones are widely spaced but exhibit close sub-horizontal to steep incidence fractures, rarely sub-horizontal to sub-vertical wispy discontinuous calcite veinlets, very low strength in seams and factures, high strength in rock. RQA ranges from 0-100, aphantic to porphyritic, contains mafic minerals and feldspar with minor quartz. Rockmass weathering grade estimated at I to II.	N/A
NOTES: 1 – Weathering profile within the granophyre is typically moderately to extremely weathered <5m bgl, reducing to fresh to slightly weathered below 5m bgl.		

Groundwater was encountered in all boreholes in Soil and Rock Engineering's 1999 geotechnical investigation, ranging from 0.15m bgl to 0.6m bgl (approximately 2m AHD to 6m AHD). Groundwater level is considered to be at ground level in the intertidal flats, and within 0.5m of ground level in the lower slopes. There is no available information on groundwater level at the granophyre ridge crests, however the presence of dry ephemeral channels and low permeability of the bedrock indicate that groundwater level may rise rapidly in adverse weather.

No historical geotechnical investigation data was available for the warehouse structure location (disused quarry), however photographs taken on site as presented in the Site Description (Figure 5-5) show a thin residual soil underlain by weathered granophyre.

The residual soil is estimated to be <0.5m thick, and the granophyre exhibits a distinct weathering profile where <3m bgl (original ground level, pre-quarry) appears to be moderately to extremely weathered, whilst >3m bgl and current ground level of the quarry appears to be slightly weathered.

6.3.1 Made Ground

Roads/former roads traversing the site will be underlain by sub-base fill materials, in some places possibly from the borrow pit located to the west of the main Burrup Road.

Syntroleum (1999) remarks on historical operations by Woodside Petroleum in the early 1980's at the location of Site F, where there was pre weight pipe coating and concrete batching operations. Associated with these operations are large flat slabs of iron ore concrete, however in some places the slabs have been ripped by dozer tynes during rehabilitation. The stabilised ground pads are up to 150mm thick and are approximately 150m by 15m in size (BHP, 1996).

A soil dump exists beneath Hearson Cove Road (cutting through Site F) comprising imported dredged marine (saline) mangrove muds (exact extent unknown). The material is described as blue grey sandy silt with shells and nodular calcrete cobbles and boulders.

6.4 Reported Laboratory Test Results

An intrusive ground investigation was conducted by Soil and Rock Engineering (1999b) comprising of six boreholes. However, it should be noted that only two boreholes are located within the Project's site, and within the warehouse structure location. Borehole KB-HC201 is located towards the northern boundary of Site F within the colluvium and granophyre, and KB-HC205 is located at the southern extent of Site C within the intertidal flats. Table 6-3 provides a summary of the laboratory test results from the Phase 2 Geotechnical Investigation undertaken by Soils and Rock Engineering (1999b). No laboratory or *in-situ* test data was available for the Made Ground or Engineered Fill at Site F.

Table 6-3 - Summary of Laboratory Test Results (Soils and Rock Engineering 1999b).

Laboratory Test Type	Stratigraphic unit			
	Intertidal Flat	Colluvium	Brecciated Calcreted Granophyre	Granophyre
Standard Penetration Test 'N' Value	4-7	14	Refusal	36
Atterberg Limits	LL 27-35%, PI 4-19%	LL 38%, PI 15%		
Uniaxial Compressive Strength (MPa)			0.9	2.33[2] – 76.5[3;4]
Point Load Strength Is_{50} (MPa)			1.14	1.18[2] – 7.01[3]
Youngs Modulus (GPa)				19.6[2] – 94.6[3]
Poissons Ratio				0.155[2] – 0.194[3]
1D Consolidation Test[1]	Cr = 0.00014 Cc = 0.00034			
Internal Friction Angle (°)	1			
Cohesion (kPa)	4			

NOTES:

Laboratory test data was only available for limited samples from the King Bay/Hearson Cove Phase 2 Geotechnical Investigation Report (1999).
1 – Cc and Cr calculated from 1-D Consolidation Test performed on an Intertidal Flats tube sample from KB-HCB201 at 1.5m depth, available in Soil and Rock Engineering (1999).
2 – Granophyre sample exhibited moderate to extreme weathering.
3 – Granophyre sample exhibited fresh to slight weathering.
4 – UCS test sample exhibited blocky failure planes (likely along joints).

6.5 Preliminary Geotechnical Characteristics

It is recommended that the geotechnical parameters outlined in Table 6-5 be used for preliminary design purposes. Parameters have been based on site specific laboratory results, published data, know empirical relationships and engineering judgement.

All available geotechnical data is at least 20 years old, therefore stress states and groundwater regimes may have changed, and whilst conservative estimates have been presented, the data below must be considered provisional and characteristic only.

The rationale for derivation of the geotechnical parameters is summarised in Table 6-4. Where possible, a common approach has been applied, however, due to disparities in the type of data available variances may be required as set out below.

Table 6-4 - Rationale for Preliminary Geotechnical Characteristic Values

Parameter	Rationale
Bulk Unit Weight	Burt Look (2007) provides an indicative range of bulk unit weight for soil and rock, Table 7.3 and 9.2. Weathering in granitic rocks can reduce unit weight by 2kN/m^3.
Undrained Shear Strength (C_u)	An approximation of Cu = 5 * SPT'N' is common, however this correlation is known to vary from 2 – 8 (Burt Look, 2007). Stroud and Butler's (1975) graph indicates that for lower plasticity clays (PI=~15%), 8N is appropriate, in line with the approximation given in AS1726:2017.
Cohesion	Laboratory data.
Internal Friction Angle	Burt Look (2007) provides an indicative correlation between SPT N values and internal friction angle in Tables 5.3, 5.4, 5.5, and 7.9 reduced by 5° for clayey sand, and increased by 5° for gravelly sand. Where SPT data is unavailable, a range has been provided in line with the strength descriptor of the geological unit. For granitic rocks with an RQD of 0-70 as the granophyre does, internal friction angle of the **rock mass** can be reduced from 45-55° to 30°.
UCS	Laboratory testing data.
Coefficient of Volume Compressibility (m_v)	Empirical correlation using SPT N value and Burt Look (2007), Tables 11.8 and 11.9.
Undrained Elastic Modulus (Eu)	BHP Petroleum (1996) provides indicative geotechnical design criteria based on historical geotechnical site investigation (not currently available), also empirical correlation using SPT N value and Burt Look (2007), Tables 11.12, 11.13, and 11.15,
Drained Elastic Modulus (E')	BHP Petroleum (1996) provides indicative geotechnical design criteria based on historical geotechnical site investigation (not currently available), also empirical correlation using SPT N value and Burt Look (2007), Tables 11.12, 11.13, and 11.15. For soft clays at 10-30% PI, E' = C_u*270, or alternatively E'/N = 0.6-0.7.
CBR	BHP Petroleum (1996) provides indicative geotechnical design criteria based on historical geotechnical site investigation (not currently

	available). DCP data provided by Soil and Rock Engineering (1999) has also been used to correlate to *in situ* CBR using Table 5.11 of Burt Look (2007).
Bearing Capacity	BHP Petroleum (1996) provides indicative geotechnical design criteria based on historical geotechnical site investigation (not currently available).

Table 6-5 - Preliminary Geotechnical Characteristic Values

Parameter[1]	Intertidal Flats	Colluvium	Brecciated Calcreted Granophyre	Granophyre
Bulk Unit Weight (kN/m^3)	**16** (14-18)	**20** (19-21)	**20** (19-21)	**27** (25-29)
Undrained Shear Strength (C_u) (kPa)	**32** (32-56)	N/A	N/A	N/A
Effective Cohesion (kPa)	**4** (4-20)	N/A	N/A	**30** (30-50)
Effective Internal Friction Angle (°)	**15** (12-30)	**30** (30-45)	**36** (35-45)	**40** (30-55)
UCS (MPa)	N/A	N/A	**0.9** (0.5-15)	**30** (2.33[2] – 76.5[3])
Coefficient of Volume Compressibility (m_v)	**0.5** (0.5-2)	**0.08** (0.05-0.1)	N/A	N/A
Undrained Elastic Modulus (Eu) (MPa)	**8** (5-15)	**40** (20-50)[4]	**40** (20-50)[4]	**100** (100-500)[4]
Drained Elastic Modulus (E') (MPa)	**6** (5-15)	**28** (20-40[4]	**28** (20-40)[4]	**70** (70-350)[4]
Poisson's Ratio	**0.5**	**0.4**[5]	N/A	N/A
CBR (%)	**5** (2-15)	**40** (20-50)	**40** (40-60)	**100**
Bearing Capacity (kPa)	N/A[6]	**150**[4]	**150**[4]	**1000**[4] (500[2]-2000[3])

Notes:
1 – Preliminary geotechnical parameters are given in bold, with a typical range for the strata in brackets where there is significant variability or lack of reliability.
2 – Granophyre exhibiting moderate weathering.
3 – Granophyre exhibiting slight weathering to fresh.
4 – In accordance with BHP (1996).
5 – Colluvium is predominantly gravel with rare thin clay lenses.
6 – Not suitable as bearing strata.

6.6 Geo-Environmental Considerations

6.6.1 Acid Sulphate Soils

Acid sulphate soil (ASS) are naturally occurring soils containing iron sulphides. These soils are usually not harmful when left undisturbed in the anaerobic environment. However, when they are exposed to the air and water through disturbance, the soil undergoes oxidisation forming sulphuric acid which has the ability to break heavy metal bonds and release heavy metals such as aluminium, iron and arsenic into the water.

The presence of ASS is reported to be located within the southern section of Site C (GHD, 2010). The ASS is categorised as Class 1 nature with a High to Moderate disturbance risk (< 3m from the surface). Whereas, there is minor potential for ASS to exist and/or develop in Site F (HLA Envirosciences, 1999) due to the historical disturbance (excavation) of native soil and rock, as mentioned in Section 4.1 of this report.

Acid Sulphate Soil mapping information based on published data is presented in Figure 6-7. The previous geotechnical investigation reports are in line with the published data source.

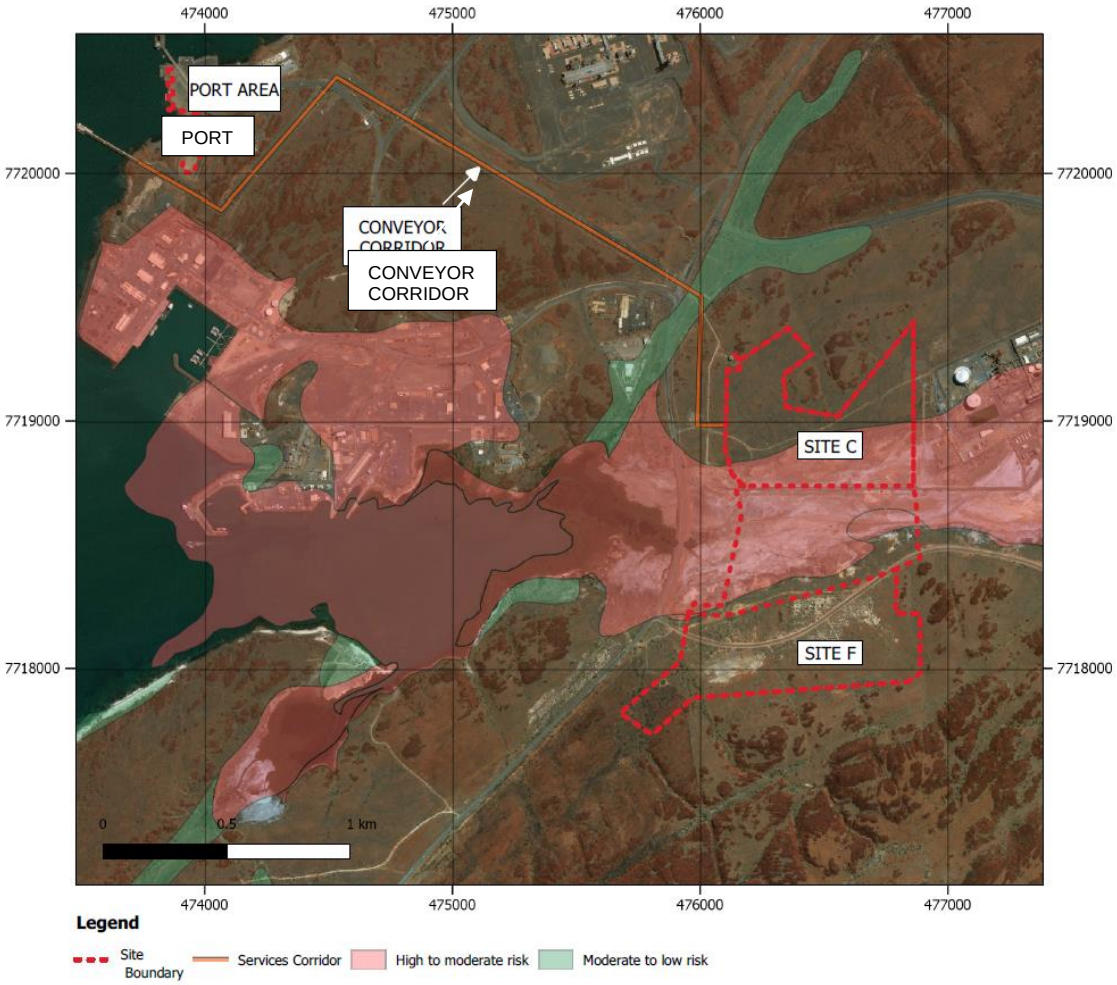


Figure 6-7 - Published Acid Sulphate Soil Data (Government of Western Australia, 2018).

The associated construction and environmental risk and consequences of disturbing the ASS especially during the construction earthworks is detailed in Section 7.10 of this report.

6.6.2 Groundwater Quality

According to sample test results taken from the two groundwater monitoring bores installed within the mudflat region located in Site F, the water quality is uncontaminated with no hydrocarbon or organic compound detected and all metal concentrations, sulphates and pH are within regulatory guidelines (HLA Envirosciences, 1999). However, the water quality were shown to be significantly saline which is typical given the intertidal nature of the mudflat region.

7.0 PRELIMINARY GEOTECHNICAL CONSIDERATIONS

This section of the desk-top study report seeks to set out the main geotechnical aspects that will require consideration during preliminary design. The discussion provided below and the derivation of geotechnical parameters is based upon limited available information that has been provided from nearby sites. No intrusive investigation, insitu testing or laboratory testing for the proposed Perdaman sites has been carried out and therefore design recommendations should be treated as preliminary and subject to revision when the results of the geotechnical investigation and geological mapping exercises become available.

A risk register is presented in Appendix 3.

7.1 Excavation Conditions

Preliminary design indicates that excavations up to 11 m deep are required at Site F and up to 6m deep at Site C. This will require excavation through surface colluvial deposits and a weathered rock profile that will likely become increasingly difficult to excavate with depth.

Conventional plant such as bulldozers, hydraulic excavators and backhoes should be adequate for the excavation of the soils comprising the intertidal flats and colluvial hillslopes. Similar plant may be suitable for excavating the blocky granophyre rock on the surface only. Excavations deeper than the fractured and weathered surface rocks will likely require ripping using the tyne of a dozer. Excavation difficulty will increase with depth as rock material strength and fracture spacing increases and extremely hard ripping conditions should be allowed for. The use of an impact hammer fitted to an excavator is likely to significantly improve productivity. Ripping may even prove impractical in the deepest excavations and blasting may be required. Should blasting not be permitted then chemical expansive grout may be an option.

7.2 Suitability of Materials for Re-use

The soils comprising the intertidal flats will very likely be unsuitable for re-use as fill given the highly saline and potential acid sulphate soils environment. Slope colluvial materials comprising silt/sand with gravel, cobbles and boulders should be suitable provided any topsoil and organic material is discarded. Excavated rock will be suitable for use as rock fill at the site. Crushing will likely be required following excavation to achieve a rock fill specification. Extremely high strength rock should be expected when considering crushing plant.

7.3 Slope Batter Angles

The soils comprising the inter-tidal flats will be subject to a high groundwater table and tidal inundation and as such the saturated sandy silty soils will not remain stable at anything but very shallow batters. Where excavation is required in these materials which could be over 2m in thickness, excavation support should be considered along with groundwater control measures.

The colluvial materials on the lower slopes are not expected to be much thicker than around 1m. Temporary batters of 1V:2H and permanent batters of 1V:3H should be suitable above the groundwater table. Cobbles and boulders that could roll down slopes should be removed from slope faces and crests.

Rock cut slopes may be battered back to 1V:1.5H through upper weathered materials, say to 2m deep, and a steeper 1V:0.2H in more competent rock beneath. An allowance should be made for rock netting and spot bolting in rock cuts. Drainage should be conveyed away from the toe and crest of slopes in drainage channels.

7.4 Slope Stability

No evidence of slope instability processes were observed at the site during the walkover other than erosion and minor slumping of the colluvium/ calcrete terrace slope bordering the tidal flats on the south side of the inlet.

Cut rock platforms may be assumed to be stable for preliminary design purposes however slope stability analyses should be undertaken where heavily loaded structures are founded close to the edge of platforms. Similarly, factor of safety analyses will be required where loading close to the edge of constructed fill slopes will occur.

7.5 Erosion Protection

Erosion protection measures should be allowed for on any cut soil slopes and constructed fill slopes. It is likely that the climatic environment is unsuitable for sustaining vegetation on slopes. Fill slopes constructed for raised platforms at Site C and the causeway embankment within the intertidal area will require rip-rap protection with a geotextile beneath. The rock excavated from within the site should be suitable for rip-rap subject to block shape and durability requirements being satisfied. The fill within any slopes subject to inundation should be designed to a specification such that collapse settlement is mitigated against and the wash-out of fines does not occur.

7.6 Foundation Conditions

The superficial deposits comprising the intertidal flats will be highly variable in composition and low in strength. These soils should not be considered as a suitable founding material and it is recommended that they are removed down to weathered rock beneath the footprint of the causeway embankment and fill platform at Site C. Dewatering or groundwater exclusion will likely be required for these areas to enable cleaning of the base, inspection and backfilling.

Any structures that are to be located outside of the platforms that are to be excavated into rock may be founded on the colluvial material where allowable bearing capacities of 150-200 kPa should be available assuming the site is not sloping. Where overturning forces are to be resisted, anchoring or piling into the underlying rock will be necessary.

For footings on weathered rock a presumed allowable bearing capacity of 500 kPa is recommended. For less weathered material at least 1000 kPa should be available. For structures that are required to resist uplift or lateral forces, rock anchors or piles will be necessary.

7.7 Conveyor Route

It is anticipated that the conveyor route will be underlain by rock within the pipeline easement where shallow cutting into the landscape appears to have occurred over much of the pipeline corridor. Adequate bearing capacity should be available for conveyor footings and where tie-down anchors or piles are required to resist uplift and lateral forces subject to confirmation by site investigation. Should the pipeline corridor be constructed in fill over any sections within low lying terrain then conveyor footings should be taken beneath the fill to found within the rock strata beneath.

For the conveyor route adjacent to Site C (i.e. not within the existing pipeline easement) footings should be taken through the colluvium to found in the rock strata beneath. A site walkover of the route should be undertaken to confirm these assumptions and borehole investigations should be undertaken at the location of critical structures.

7.8 Warehouse Structure within the Port Area

Lidar imagery shows batter angles vary from around 45 degrees to near vertical in the old quarry. These slopes appear stable however some loose blocks are visible and scree at the base of slopes indicates ongoing minor degradation. For preliminary design purposes, slopes that are not required to be excavated to facilitate the warehouse footprint can remain at existing slope angles assuming space is available at the toe for a rock trap ditch or fence to collect falling debris. Where space is not available the scaling of loose material from slope faces and slope netting should be allowed for.

Where excavation of the existing quarry wall is necessary a cut slope face of 1V:0.2H may be allowed for with say the upper two metres of weathered material being laid back to 1V:2H. For high slopes, mid-slope benches 3m wide should be constructed at every 6m in height. Slope face netting and spot bolting should be allowed for unless adequate space is available to collect falling debris at the toe of the slope. Drainage should be constructed at the toe and crest to convey flows away from the slopes. Geological mapping of the rock slopes should be undertaken to enable adequate detailed design.

7.9 Seismicity

Based on AS1170.4–2007, Structural design Actions Part 4; Earthquake Actions in Australia, the Hazard Factor (Z) for the Burrup Peninsular 0.12. Assuming soils are removed and all structures are founded on rock then Sub-soil Class Be – Rock should apply.

7.10 Acid Sulphate Soils

Given the proposed construction earthworks for the site which includes a Cut and Fill methodology for the northern section for Site C (as per memo: William Woolnough, SNC-Lavalin, 2019). It is recommended that field screening during investigation and laboratory testing for the presence ASS, should be conducted in low lying areas of the site.

8.0 CONCLUSION AND RECOMMENDATIONS

This desk-top study report has been prepared using information available at the time of writing and should be considered preliminary only. Following completion of the geotechnical site investigation and geological mapping, an interpretive geotechnical report should be prepared. The interpretive report will supersede the desk-top study and the project design should then be revised in light of the site specific geotechnical information.

One of the main geotechnical risks is the excavation of the rocks at the site as this can only be determined from strength and joint spacing information recovered from rotary cored boreholes. There has been much industrial development in the area including the adjacent ammonia plant, construction of the pipeline easement and the quarry at the port. Enquiries should be made to these organisations and if geotechnical information is available for these sites then this desk top study should be updated with the relevant details.

A significant part of the site is to be constructed on a platform raised above the inter-tidal flats. The design of the platform and the specification of the bulk fill will need to take cognizance of the loading intensity, including dynamic loads of structures and also consider the potential for fluctuating groundwater levels associated with the inter-tidal flats.

Significant quantities of unsuitable materials, both saline and potentially acidic, may be required to be removed from beneath fill platforms and causeways if excavation of the alluvial soils is to occur prior to construction of the fill platform over much of site C and the causeway. Costs for disposal off-site may therefore be high. Characterisation of the alluvial soils will be required as part of the geotechnical site investigation in terms of both chemical composition and grading e.g. clay, silt, sand and gravel. This will enable other options to be assessed as an alternative to excavation, disposal off-site and replacement. Other options to be considered could comprise; consolidating compressible soils insitu with surcharge, treating the soils insitu to improve bearing capacity (ground improvement with cement and admixtures) or excavation and on-site treatment within treatment pads to mix and neutralise soils and improve engineering fill characteristics such that the materials may be re-used as fill. The most cost effective solution can only be determined once the results of the site investigation are received.

9.0 REVISION HISTORY

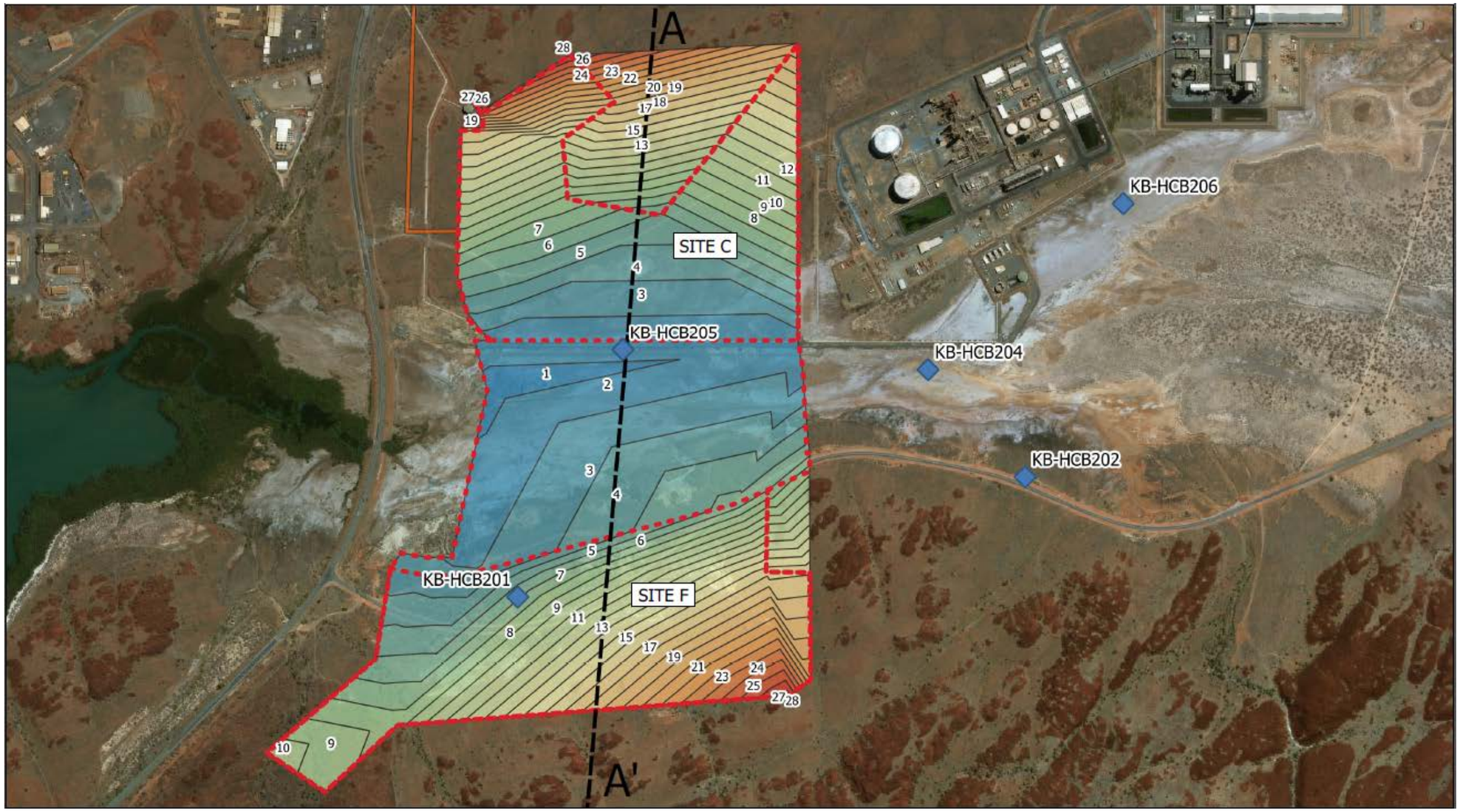
REVISION	COMMENTS/NOTES
A1	Draft for internal review
B1	Issued for Internal Review

APPENDIX 1 – PROJECT DELIVERY APPLICABILITY

☐ Proposals	☐ EPC	☐ Construction
☒ Studies	☐ Project Management	☐ Commissioning
☐ Preliminary Engineering	☐ Technical Services	☐ Site Services
☐ FEED	☐ Procurement	☐ Ops and Maintenance
☐ Detailed Design	☐ Construction Management	

APPENDIX 2 – PRELIMINARY GEOLOGICAL SECTION

PERDAMAN DESTINY PROJECT: Site C and F Preliminary Geological Section



LEGEND:

Anticipated groundwater level

INTERTIDAL FLATS: silty clayey SAND grading to silty sandy CLAY with depth.

COLLUVIUM: clayey sandy GRAVEL with cobbles and boulders.

BRECCIATED CALCRETED GRANOPHYRE: fine to medium grain fragmented and brecciated calcreted granophyre, extremely weathered to highly weathered.

GRANOPHYRE: fine to medium grain fragmented and quartz cemented granophyre (light red indicates moderate weathering, darker red indicates slight weathering to fresh).

NOTES:

1. The geological profile presented is schematic only based upon limited desk study information and should not be used for detailed design.
2. Some features may appear exaggerated due to different V:H scales.
3. Ground level based on SNC-L survey data collected in March 2019.
4. Drawing to be read in conjunction with the attached Geotechnical Desk Study Ref. 140436-000-41EW-0001.

DRAWN BY: M. LEE
REVIEWED BY: S. MOORE
PRODUCED: 08/04/2019

IN ASSOCIATION WITH:
140436-0000-41EW-0001

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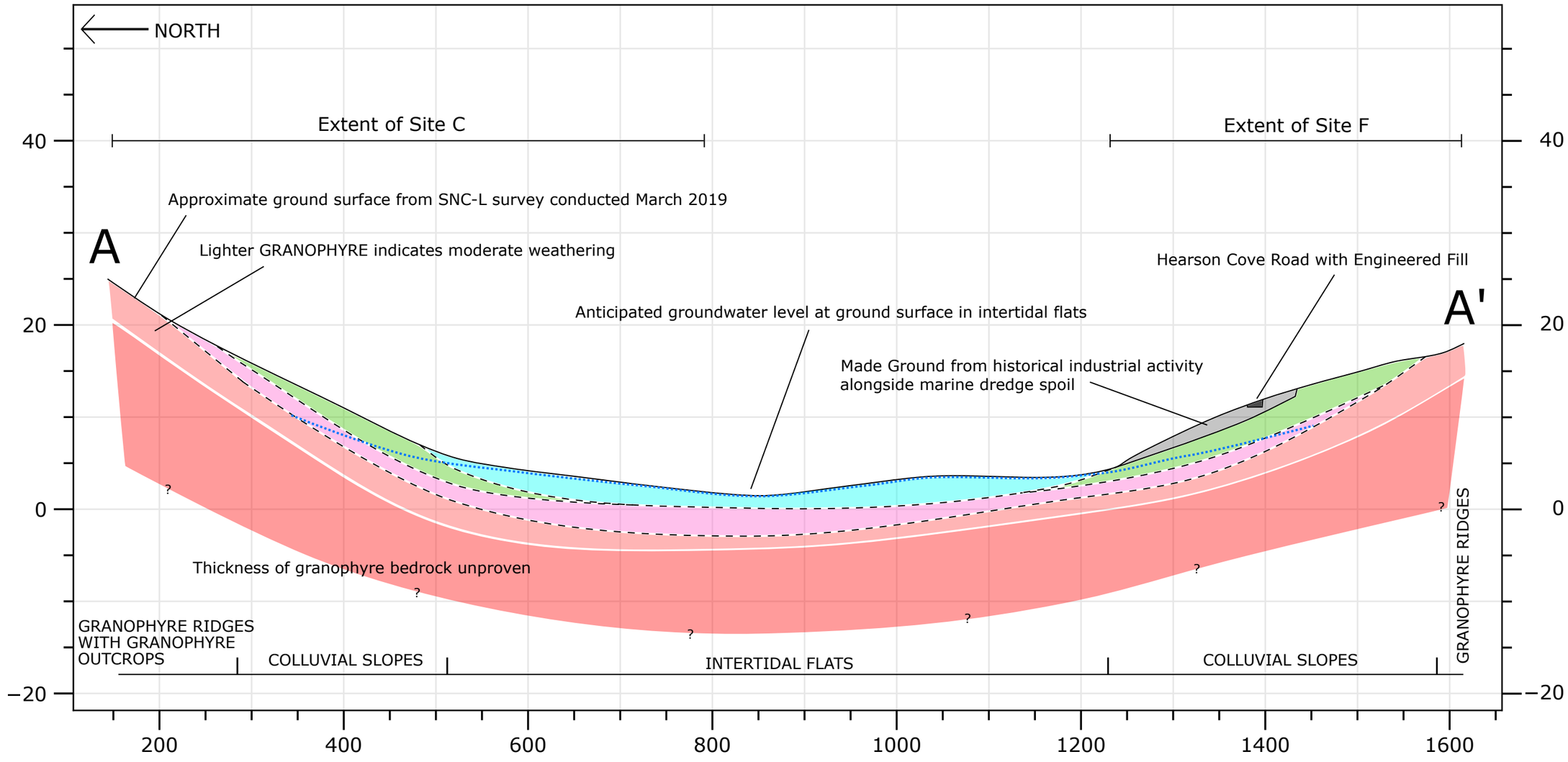
PERDAMAN DESTINY PROJECT: Site C and F Preliminary Geological Section

SHEET 2/2



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- Anticipated groundwater level
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- COLLUVIUM: clayey sandy GRAVEL with cobbles and boulders.
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APPENDIX 3 – RISK REGISTER

Key to probability and severity ratings.

Probability and severity ratings

Probability		Severity	
5	Almost certain. May occur many times.	5	Multiple fatality / Major environmental incident threatening public health and criminal liability. Unsustainable costs and programme delay.
4	Probable, not surprising. May occur more than once.	4	Fatality / Environmental incident causing criminal liability. Significant increase in construction costs and delay to programme.
3	Possible. Likely to occur sometime.	3	Major injury > 3 days / Environmental incident triggering damage or complaint. Increased construction costs and programme delay.
2	Remote, though conceivable.	2	Major injury < 3 days / Environmental incident requiring management response. Small impact to costs and minor programme delay.
1	Improbable.	1	Negligible.

Risk Matrix

Severity						
	5	M	H	S	S	S
	4	M	H	S	S	S
	3	L	M	H	S	S
	2	L	M	H	H	H
	1	L	L	M	H	H
		1	2	3	4	5
		Probability				

Action Required

Risk Level		Action by Designer
S	Severe	Amend design to reduce risk, or seek alternative option. Only accept option if justifiable on other grounds.
H	High	
M	Medium	Check that risks cannot be further reduced by simple design changes.
L	Low	

General geotechnical and geoenvironmental risks.

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
Generic risks												
1	Access to site	Collision with live traffic at entry/egress, risk of injury or death to site personnel and the public	Ground investigation and construction	3	4	S	1. Personnel to receive appropriate training. 2. Vehicles/plant to be suitably marked/signalled. 3. Only approved vehicles to be used to access sites in official access/egress points. 4. Personnel to wear suitable Personal Protective Equipment (PPE) at all times, including high visibility clothing (trousers and long sleeve jacket).	2	4	H	Y	Active
2	Access to/ working on or adjacent to slopes or uneven ground	Toppling of plant while driving/operating on uneven slope, risk of injury to site personnel	Ground investigation and construction.	2	3	H	1. Contractor to consult with personnel who has been on site to obtain the appropriate measures prior to commencement of ground investigation works. 2. Contractor to raise awareness of uneven/unstable slopes. 3. Personnel to wear suitable PPE at all times, including lace up steel mid sole and toe capped boots. 4. Contractor to establish safe working area and set up exclusion zone around work site. 5. Setting up on / traversing slopes to be avoided where possible. 6. Entry/egress points situated to minimise slope traversing. 7. Contractor to be suitably qualified to operate machinery. 8. All staff to attend induction and tool box talks as appropriate.	2	2	L	Y	Active

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
3	Access to/working in floodplain	Vehicles and towed plant losing traction in flooded/muddy floodplain, potential for minor differential settlement causing imbalance	Ground investigation and construction	2	2	M	1. Contractor to consult with personnel who has been on site to obtain the appropriate measures prior to commencement of ground investigation works. 2. Contractor to raise awareness of flooded ground. 3. Understanding of topography and geology prior to mobilization.	2	2	M	N	Active
4	Driving	Collision whilst driving to/from and around site. Risk of injury or death to site personnel and the public.	Ground investigation and construction	3	4	S	1. Only suitably qualified personnel with appropriately marked up vehicles may enter site during works period. 2. Staff to take suitable breaks whilst driving and stop if tired. 3. Staff to hold a full Australian driving licence and undergo any internal driver safety awareness courses.	2	4	H	Y	Active
5	Personnel working in close proximity to plant	Collision with moving plant. Risk of injury or death to site personnel.	Ground investigation and construction	4	4	S	1. Contractor to provide training to personnel before commencing work on site. 2. Personnel to wear PPE at all times, including high visibility clothing and hard hat. 3. All personnel operating machinery to be competent and hold appropriate competency cards. 4. A safe working distance is to be maintained by all staff from moving machinery and equipment. 5. Acknowledgment from machine operator should be received and machine stopped before staff enter safety zone of plant or machinery.	3	3	H	Y	Active

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
6	Public access	Confrontation with aggressive members of the public. Risk of intimidation and injury to site personnel.	Ground investigation and construction	3	2	H	1. All personnel to be calm and polite if confronted by any member of the public. 2. In the event of aggressiveness or safety concerns for site personnel, Police are to be called immediately. 3. No valuables are to be left visible in vehicles at any time.	2	2	M	Y	Active
Ground risks												
7	Buried and overhead services.	Striking buried and overhead services. Gas pipes, electricity cables, water main, communications cables and fuel infrastructure on site. Health and Safety of contractor's personnel.	Ground investigation and construction.	3	4	S	1. Ground Investigation Specification to provide a utilities map for overhead and buried services. 2. A Dial-Before-You-Dig (DBYD) should be conducted for the site area prior to any excavation. 3. Contractor to positively locate services before commencing excavation via a service utility locator contractor.	2	4	H	Y	Active
8	Ground conditions differ to that expected (e.g. historical landfill sites, infilled sand and gravel pits and embankment fill material for berm).	Redesign, programme delays, cost implications.	Ground investigation, construction and maintenance.	3	2	H	1. Understanding of the ground conditions via the desktop study to assess the ground conditions. 2. Geotechnical supervision required for the duration of geotechnical site activities. 3. Should the design change significantly or should uncertainties in the ground conditions arise following assessment, it is advised that supplementary ground investigation be performed and a ground model of the site be produced. 4. Results from the site specific ground investigation to be used in the GDR and to determine if a second phase of ground investigation is required.	2	2	M	Y	Active

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
9	High groundwater table, water ingress, and perched groundwater	Redesign, programme delays, cost implications.	Ground investigation, construction and maintenance.	4	2	H	1. Understanding of the ground conditions via the desktop study to assess the ground conditions. 2. Geotechnical supervision required for the duration of geotechnical site activities. 3. Should the design change significantly or should uncertainties in the ground conditions arise following assessment, it is advised that supplementary ground investigation be performed. 4. Results from the site specific ground investigation to be used in the GDR.	3	2	M	Y	Active
10	Presence of ground conditions with shrink-swell potential	Redesign, programme delays, cost implications, long term maintenance costs, disruption.	Ground investigation, construction and maintenance.	4	2	H	1. Understanding of the ground conditions via the desktop study to assess the ground conditions. 2. Geotechnical supervision required for the duration of geotechnical site activities. 3. Ground improvement to be designed and implemented if deemed necessary.	3	2	M	Y	Active
11	Encountering extremely soft/low strength ground conditions (e.g. Made Ground, Head Deposits, Alluvium, infilled sand and gravel pits, berm embankment material) and weathered bedrock	Redesign, programme delays, cost implications.	Ground investigation, construction and maintenance.	5	2	H	1. Understanding of the ground conditions via the desktop study to assess the ground conditions. 2. Geotechnical supervision required for the duration of geotechnical site activities. 3. Perform targeted geotechnical sampling and laboratory testing to facilitate design. 4. Produce a site specific ground model. 5. Use ground improvement techniques where appropriate.	4	2	H	Y	Active
12	Encountering hard layers in the Made Ground, gravel strata, bedrock and tree roots.	Redesign, programme delays, cost implications.	Ground investigation and construction.	4	2	H	1. Understanding of the ground conditions via the desktop study to assess the ground conditions. 2. Geotechnical supervision required for the duration of geotechnical site activities.	3	2	M	Y	Active

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
							3. Perform targeted geotechnical sampling and laboratory testing to facilitate design. 4. Produce a site specific ground model. 5. Use appropriate equipment during ground investigation and construction to allow for efficient and effective excavation.					
13	Any presence of contaminated ground and groundwater, and ground gas (including from historical landfill sites, infilled sand and gravel pits, berm material, and stockpiled material)	Sickness, injury or fatality to personnel if ingested / inhaled / dermally absorbed or other human and/or controlled waters receptors. Waste disposal and/or treatment costs. Programme delays and potential redesign.	Ground investigation and construction.	4	3	S	1. Perform a site specific ground investigation with targeted contamination sampling and laboratory testing to determine the presence and extent of any contamination 2. Geotechnical supervision required for the duration of geotechnical site activities. 3. Based on the findings of the ground investigation, contamination risk assessments should be carried as necessary out to determine if there is a risk from the contamination and appropriate remedial actions / measures where required. 4. Contractor to provide training to personnel. 5. Personnel to wear PPE, including appropriate gloves and safety glasses. 6. Should contamination be encountered, works should cease until further instruction is sought from either the Designer's site representative or Client's representative. 7. Supplementary ground investigation and testing to better delineate areas of significant contamination assess the risk.	2	2	M	Y	Active
14	Destabilisation or settlement of existing	Injury or fatality to Site personnel, programme delays, damage of	Ground investigation and construction.	3	2	H	1. Perform a site specific ground investigation. 2. A bearing capacity and slope stability, and seepage assessment should be produced.	2	2	M	Y	Active

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
	slopes due to excavation or berm improvements.	reputation, cost implications.					3. A competent Contractor should be employed to carry out Site works. 4. Geotechnical supervision required for the duration of geotechnical site activities.					
15	Unidentified existing infrastructure and services (including wells, disused utilities etc.).	Redesign, programme delays, cost implications.	Ground investigation and construction.	3	2	H	1. Contractor to carry out risk assessment to include voltage and height of overhead services, works being carried out close to overhead services, size and reach of machinery, safe clearance distance, site conditions and competency of staff. 2. Ground Investigation Specification to provide a utilities map for overhead and buried services. 3. Contractor to locate services via utility service locator contractor before commencing excavation via a utility clearance contractor.	2	2	M	Y	Active
16	Re-use of material	Redesign, programme delays, cost implications.	Ground investigation and construction.	4	3	S	1. Perform a site specific ground investigation with targeted contamination sampling and laboratory testing to determine the presence and extent of any contamination 2. Geotechnical supervision required for the duration of geotechnical site activities. 3. Based on the findings of the ground investigation, contamination risk assessments should be carried as necessary out to determine if there is a risk from the contamination and appropriate remedial actions / measures where required.	2	3	H	Y	Active

(1)	(2)	(3)	(4)	(5)			(6)	(7)			(8)	(9)
Hazard Reference	Activity/Process/ Material/Element	Hazard (also indicate who is at risk and how)	Stage of Work	Initial Risk Level			Risk Control Measures: Design action taken, record of decision process including option considered, design constraints and justification for options/actions not having been taken	Residual Risk Level			Is there a 'significant' residual risk to be passed on? (Y/N)	Status (Active / Closed)
				Probability	Severity	Risk Level		Probability	Severity	Risk Level		
17	Cutting of slopes and temporary stockpiling of material	Toppling of boulders and slope instability. Health and safety risk.	Ground investigation and construction.	3	3	H	1. Geotechnical supervision required for the duration of geotechnical site activities. 2. Temporary stockpiling of material is to follow the recommended gradient slopes and inspected by a geotechnical engineer. 3. If necessary, rock netting and spot bolting into rock cuts to mitigate toppling of boulders.	3	3	H	Y	Active
18	Erosion of material	Erosion of constructed fill slope, collapsed settlement, wash-out fan.	Ground investigation and construction.	3	4	S	1. Rip-rap protection and geotextile fabric to be installed during the compaction of engineered slopes 2. Fill material should be blocky in shape and durability requirement being satisfied . 3. Geotechnical supervision required for the duration of geotechnical site activities.	3	3	H	Y	Active
19	Adequate load resistance	Collapsed settlement, up-lift and lateral movement.	Ground investigation and construction.	3	3	H	1. Geotechnical supervision required for the duration of geotechnical site and construction activities. 2. Adequate and suitable design parameters. 3. Utilisation of tie-down anchors to resist uplift.	3	2	H	Y	Active
20	Acid Sulphate Soils	Creation of sulphate acid when disturbed, causing damages to waterway, aquatic life and vegetation	Ground investigation and construction.	3	4	S	1. Geotechnical supervision required for the duration of geotechnical site and construction activities. 2. Produce risk maps to predict the location and depth of acid sulphate soils. 3. Conduct simple field testing when excavating as a form of monitoring when encounter acid sulphate soils	3	3	H	Y	Active