Port Kembla Gas Terminal

Acid Sulfate Soils Management Plan Stage 2A Marine Berth Construction and Onshore Receiving Facilities

Australian Industrial Energy

24 December 2021

→ **The Power of Commitment**

GHD Pty Ltd | ABN 39 008 488 373

133 Castlereagh Street, Level 15

Sydney, New South Wales 2000, Australia

T +61 2 9239 7100 | **F** +61 2 9239 7199 | **E** sydmail@ghd.com | **ghd.com**

Printed date	24/12/2021 8:56:00 AM
Last saved date	24 December 2021
File name	N:\AU\Sydney\Projects\21\27477\Tech\MP update\Stage 2A\Spoil Management Plan\App A - Acid Sulfate Soils Management Plan\PKGT-AIE-ASSMP-Stage-2A_RevD.docx
Author	Nathan Alexander
Project manager	Karl Rosen
Client name	Australian Industrial Energy
Project name	East Coast Gas Project
Document title	Port Kembla Gas Terminal | Acid Sulfate Soils Management Plan
Revision version	Rev 0
Project number	2127477
AIE document number	PKGT-AIE-PLN-024

Document status

Status Code	Author	Reviewer		Approved for issue		
		Name	Signature	Name	Signature	Date
A	N Alexander	K Rosen		K Rosen		20/09/21
B	N Alexander	K Rosen		K Rosen		29/10/21
C	N Alexander	K Rosen		K Rosen		23/11/21
0	N Alexander	K Rosen		K Rosen		24/12/21

Acronyms

Acronym	Definition
AIE	Australian Industrial Energy
ANC	Acid Neutralising Capacity
ASS	Acid Sulfate Soils
ASSAC	Acid Sulfate Soils Action Criteria
ASSMAC	Acid Sulfate Soils Management Advisory Committee
ASSMP	Acid Sulfate Soils Management Plan
ASS Waste Guidelines	Waste Classification Guidelines Part 4: Acid Sulfate Soils
$CaCO_3$	Calcium carbonate
CSSI	Critical State-Significant Infrastructure
EIS	Environmental Impact Statement
EMS	Environmental Management Strategy
EPA	NSW Environment Protection Authority
EP&A Act	Environment Protection and Assessment Act
EPL	Environmental Protection Licence
FSRU	Floating Storage and Regasification Unit
GHD	GHD Pty Ltd
H_2O_2	hydrogen peroxide
HM	Harbour Muds
HS	Harbour Silts
HSE	Health, Safety and Environment
KCl	potassium chloride
KPI	Key Performance Indicators
LNG	Liquefied Natural Gas
MBD	Marine Berth Construction and Dredging
MLAs	Marine Loading Arms
National ASS Guideline	National Acid Sulfate Soils Guidance: National acid sulfate soils sampling and identification methods manual (DAWE, 2018)
NSW ASS Manual	Acid Sulfate Soil Manual (ASSMAC, 1998)
NV	Neutralising Value
ORF	Onshore Receiving Facilities
PASS	Potential Acid Sulfate Soils
PKCT	Port Kembla Coal Terminal
PKGT	Port Kembla Gas Terminal
PKGT EIS	Port Kembla Gas Terminal Environmental Impact Statement
PKHD	Port Kembla Height Datum
POEO Act	*Protection of the Environment Operations Act 1997*
SCR	Chromium Reducible Sulfur
SMP	Spoil Management Plan

Acronym	Definition
SPOS	Peroxide oxidisable sulfur
SRD SEPP	State Environmental Planning Policy State and Regional Development
TAA	Total Actual Acidity
The Project	Port Kembla Gas Terminal Project
TPA	Total Potential Acidity
TSA	Total Sulfidic Acidity
WQMP	Water Quality Management Plan

Contents

Table index

Figure index

Appendices

1. Introduction

1.1 Overview

This Acid Sulfate Soil Management Plan (ASSMP) has been developed as a sub-plan to the Port Kembla Gas Terminal Project (the Project) Spoil Management Plan (SMP). The SMP is sub-plan to the Project's overarching Environmental Management Strategy (EMS). This ASSMP has been prepared by GHD Pty Ltd (GHD) on behalf of Australian Industrial Energy (AIE) to apply to construction activities associated with Stage 2A construction of the Project. It has been prepared by a set of consultants with extensive experience in the identification, treatment and management of acid sulfate soils, including team members from GHD and Fox Consulting.

This ASSMP interfaces with the other associated sub-plans, which together describe the proposed structure for environmental management and monitoring requirements for the Project. This ASSMP addresses the requirements of the Port Kembla Gas Terminal Environmental Impact Statement (PKGT EIS) and associated Infrastructure Approval (SSI 9471) and Environmental Protection Licence (EPL) No. 21529.

1.2 Background

AIE is developing the Project which involves the development of a liquefied natural gas (LNG) import terminal at Port Kembla, south of Wollongong, NSW. The Project will be the first of its kind in NSW and will provide a simple and flexible solution to the state's gas supply challenges.

NSW currently imports more than 95 percent of the natural gas it uses from other eastern states. In recent years, gas supplies to the Australian east coast market have tightened, resulting in increased natural gas prices for both industrial and domestic users.

The Project provides an immediate solution to address the predicted shortages and will result in significant economic benefits for both the Illawarra region and NSW. The Project will have a capacity to deliver more than 100 petajoules of natural gas, equivalent to more than 70 percent of NSW gas needs and will provide between 10 to 12 days of natural gas storage in case of interstate supply interruption. LNG will be sourced from worldwide suppliers and transported by LNG carriers to the gas terminal at Port Kembla where it will be re-gasified for input into the NSW gas transmission network.

The Project has been declared Critical State Significant Infrastructure (CSSI) in accordance with Section 5.13 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) (NSW) and Schedule 5 of the State Environmental Planning Policy State and Regional Development (SRD SEPP). The Project received Infrastructure Approval from the Minister for Planning and Public Spaces on 29 April 2019.

The construction of the Project is primarily associated with the establishment of a new berth facility at Port Kembla to enable an LNG carrier to berth alongside the Floating Storage and Re-gasification Unit (FSRU) and new infrastructure to connect the terminal to the existing gas network. Excavation and dredging would be required to establish the new berth facility, with spoil deposited in a cell (referred to as the 'Emplacement Cell') in the Outer Harbour.

The development has progressed to Stage 2A works located at Berth 101 (referred to as 'the site' or 'MBD Site Compound'). The Stage 2A works include land-based construction works associated with the Marine Berth Construction and Dredging (MBD) and Onshore Receiving Facilities (ORF). The Stage 2A works include:

- Completion of excavation works undertaken during Stage 1 (including transport of spoil materials to Emplacement Cell Construction Site).
- Construction of the quay wall at the MBD Site Compound.
- Construction of ORF at the MBD Site Compound (including construction of Wharf Topside Area, Utility Area, and Common Area).
- Installation and commissioning of power, communications, and potable water line.
- Installation of gas pipeline within the MBD Site Compound as part of ORF.

1.3 Purpose

This ASSMP has been prepared in accordance with the PKGT EIS and associated Infrastructure Approval (SSI 9471) and EPL No. 21529. It describes how the management measures and commitments in the PKGT EIS, Infrastructure Approval (SSI 9471) and EPL No. 21529 relating to Acid Sulfate Soils (ASS) are to be implemented by the Principal Contractor during Stage 2A construction of the Project.

This ASSMP will address the following, in relation to ASS:

- Occurrence.
- Identification.
- Assessment.
- Disposal.
- Treatment.
- Reporting.

AIE and its contractors acknowledge that maintaining ASS in the vicinity of the MBD Site Compound is paramount to the successful delivery of the construction phase of the Project. AIE is committed to ensuring this ASSMP is implemented, reviewed and updated regularly to ensure its objectives are met and that the approval conditions outlined in the Infrastructure Approval (SSI 9471) and EPL No. 21529 are achieved.

This ASSMP is applicable to all staff, employees, subcontractors, and any statutory service authorities undertaking the Stage 2A works described in Section 2 of this ASSMP. The ASSMP implementation and on-going development will be managed by the Project Team (refer to Section 3).

2. Project overview

2.1 Site description

The site of the Project is situated at Port Kembla within the Illawarra region of NSW, about 80 kilometres south of Sydney. Port Kembla is mainly characterised by an existing import and export terminal and multiple other business, cargo, logistics, bulk goods, and heavy industrial facilities in the vicinity.

Port Kembla is situated about two kilometres south of the centre of Wollongong. Other localities surrounding Port Kembla and the Project site include Mangerton, Mount St. Thomas and Figtree to the north-west; Unanderra to the west; Berkeley to the south-west; and Cringila, Lake Heights, Warrawong and the residential region of Port Kembla to the south.

The zoned land use in the region includes special use and industrial use at Port Kembla and a mix of primarily residential and commercial uses at the surrounding localities. Major infrastructure in the region of Port Kembla includes the Princes Highway, which is a major state and regional highway connecting Sydney and Wollongong and regional areas further south. Princes Highway provides access to Port Kembla through turnoffs at Masters Road, Five Islands Road and Northcliffe Drive and is broadly utilised including by heavy vehicles from the port.

The South Coast railway line runs along the periphery of Port Kembla including the stations Port Kembla, Port Kembla North, Cringila and Lysaghts. The rail line services commuters and is also used to transport bulk solid goods like coal, grain, copper and steel from Port Kembla. The environmental features of Port Kembla and the surrounding region are limited given the extensive industrial, commercial and residential development. Waterways in the region include the Gurungaty Waterway, Allans Creek, American Creek and Byarong Creek. Green space includes JJ Kelly Park and Wollongong Golf Club to the north and a larger open area to the south-west.

The Project will be predominantly located within land zoned for dedicated port and industrial uses. Berth and wharf facilities, as well as the FSRU, would be situated at Berth 101 at the Inner Harbour, while the gas pipeline would extend around the periphery of port operations from Berth 101 to a tie-in point at Cringila. The Emplacement Cell will be located in the Outer Harbour. A site overview is provided as Figure 2.1.

Figure 2.1 Site overview

2.2 Project construction scope of works

2.2.1 Overview

The Project construction scope of work has been divided into the three main packages (with associated activities), as outlined in Table 2.1. This ASSMP applies only to the works associated with Stage 2A.

Table 2.1 Construction stages/work packages

Stage	Package	Proposed commencement	Activities
1	Early Enabling Works	May 2021	Demolition of Berth 101, removal of structures and land based excavation works, and Cone Penetration Testing (CPT) in the Outer Harbour to inform Emplacement Cell design and relocation of Bunker Oil Pipeline.
2A	Marine Berth Construction – Land Based	January 2022	Completion of excavation works undertaken during Stage 1. Transport of spoil materials for storage at the Emplacement Cell Construction Site.
			Quay wall construction.
		February 2022	Installation of communications conduit, potable water line, and 11kV power cable and Padmount Substation within MBD Site Compound.
		April 2022	Construction of the ORF, which comprises three areas: Wharf Topside Area; Utility Area; and Common Area.
		June 2022	Pipeline construction and associated ancillary infrastructure within MBD Site Compound delivered as part of ORF scope.
2B	Marine Berth Construction and Dredging – Land and Marine Based	March 2022	Continuation of Stage 2A with addition of the following activities:
			Excavation/dredging and construction of the Emplacement Cell in the Outer Harbour
			Marine based construction activities including installation of navigational aids and revetment shore protection.
3	Pipeline Installation including tie-ins (NGP)	June 2022	Construction of an 18" onshore natural gas pipeline approximately 6.3km in length from the Berth 101 site boundary to Tie-in Facility at Cringila for connection to the Eastern Gas Pipeline Pipeline construction to occur concurrently with Jemena, subject to separate set of management plans.

The construction of Stage 2A works is located within the former Port Kembla Coal Terminal (PKCT) Bulk Products Berth (Berth 101). As part of the Early Enabling works the removal of existing structures and services and excavation was undertaken to facilitate subsequent development stages of the Project.

The following will be undertaken as part of the Stage 2A land-based works:

– Construction of the quay wall at MBD Site Compound incorporating finalisation of excavation works undertaken during Stage 1 (including transport of spoil materials to Emplacement Cell Construction Site).
– Installation of and commissioning of power, communications, and potable water line.
– Construction of ORF at MBD Site Compound (including construction of Wharf Topside Area, Utility Area, and Common Area).
– Installation of gas pipeline within the MBD Compound site.

An outline of the tasks associated with Stage 2A is provided in Section 2.3 through Section 2.5. The site of the works includes the MBD Site Compound with materials being transported to the Emplacement Cell Construction Site. The location of the Stage 2A works, MBD Site Compound, and the Emplacement Cell Construction Site is shown in Figure 2.2.

Figure 2.2 Stage 2A works and location of MBD Site Compound and Emplacement Cell Construction Site

2.2.2 Traffic

Traffic generated by Stage 2A will be controlled through the gate on Sea Wall Road. Heavy vehicle movements will be generated by the delivery of materials, equipment, and plant to the MBD Site Compound and transport of stockpiled material to the Emplacement Cell Construction Site.

There may be a requirement to transport and tip up to 8000m³ of crushed concrete and up to 2000m³ of crushed heavily bound base course to the Emplacement Cell Construction Site via road to increase the storage footprint area within the East Stockyard and to facilitate for later use during the construction of the Emplacement Cell.

The activities associated with this task will involve loading, road transportation via truck and trailer (approximately 30-tonne capacity), unloading, stockpiling, and management of the stockpiles.

Light vehicle movements will be generated from construction workers accessing the MBD Site Compound. Parking will be provided for up to 76 vehicles on the MBD Site Compound (refer to Figure 2.3).

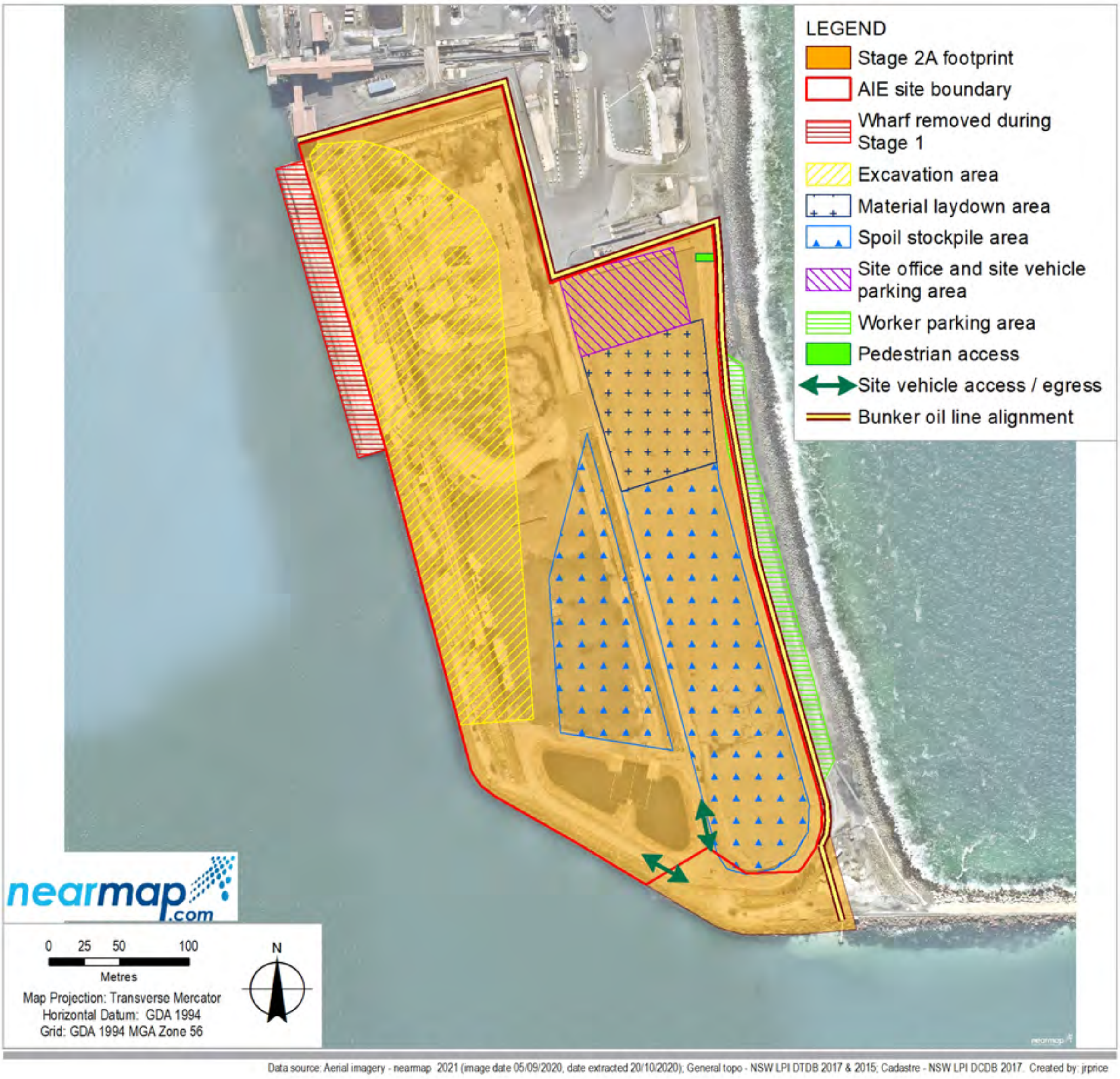


Figure 2.3 Layout of MBD Site Compound

2.2.3 Program

The Stage 2A works are anticipated to commence in January 2022. Stage 2B which includes the continuation of land-based construction and water-based works are then anticipated to commence in March 2022 (refer to Table 2.1).

2.3 Construction of quay wall (MBD – Land Based)

A number of structures will be constructed within the MBD Site Compound to accommodate the FSRU and LNG carrier for the Project. Excavation and stockpiling activities from the Stage 1 Early Enabling Works will continue on-site during Stage 2A to lay the platform for ongoing construction activities at the MBD Site Compound.

The new structures that will commence construction during Stage 2A are summarised in Table 2.2. The location of the quay wall and layout of the marine berth and wharf facilities is shown in Figure 2.4.

Table 2.2 Marine berth and wharf structures to be constructed during Stage 2A

Component	Works required
Earthworks and stockpiles	– Completion of excavation and backfilling works from Stage 1 Early Enabling Works. – A nominal 15-metre-wide section on the northern end and a circa 60-metre 'wedge' at the south- west corner of the excavation zone was left to facilitate contractor access and will required completion at commencement of Stage 2A. – Excavated materials from the Early Enabling Works have been stockpiled within the Eastern and Western Stockyards of the MBD Site Compound and the Emplacement Cell Construction Site. – The excavated materials stockpiled include: • Approximately 15,000m³ of demolished concrete crushed to nominal 70mm minus. • Approximately 30,000m³ of heavily bound base course crushed to nominal -150mm minus. • Approximately 25,000³ of mixed slag, general fill, and coal nominally < 150mm in size. • Approximately 10,000m³ of predominantly sand with some slag and coal. – The excavated materials will be used/reused for quay wall construction and to backfill the landside area of the quay wall or transported to the Emplacement Cell Construction Site for storage and use in construction of the Emplacement Cell.
Quay wall	– Construction of a new piled quay wall keyed into bedrock complete with sheet pile anchor wall, capping beam and tie rods to the south of the existing coal terminal. – Excavated and processed materials from the Stage 1 Early Enabling Works are stockpiled within the MBD Site Compound and will be used during construction of the quay wall and to backfill on landside area of the wall. – Installation of a marine fender system attached to the capping beam along the quay wall to protect the quay wall from berthing and mooring loads. – Installation of a cathodic protection system to the quay wall and associated elements, including assessment of the potential impacts the FSRU and pipeline cathodic protection will have on quay wall. – Backfilling and compaction on landside area of wall utilising the site stockpiled materials.
Mooring dolphins	– Installation of landside mooring dolphin structures on reinforced concrete platforms supported by steel piles. – Mooring equipment will be installed and comprise the following: • 20 load sensing quick release hooks. • Up to four land-based mooring winches on mooring dolphins may be required. • Up to four swivel fairleads may be required to enable each mooring line to land-based winches to be fed in a horizontal alignment.
Marine Loading Arm foundations	Construction of a new reinforced concrete foundation supported on steel piles, located behind the new quay wall.
Gangway tower foundation	Construction of foundation for Gangway tower
Fire monitor foundation	Fire monitor foundations, subject to risk studies.

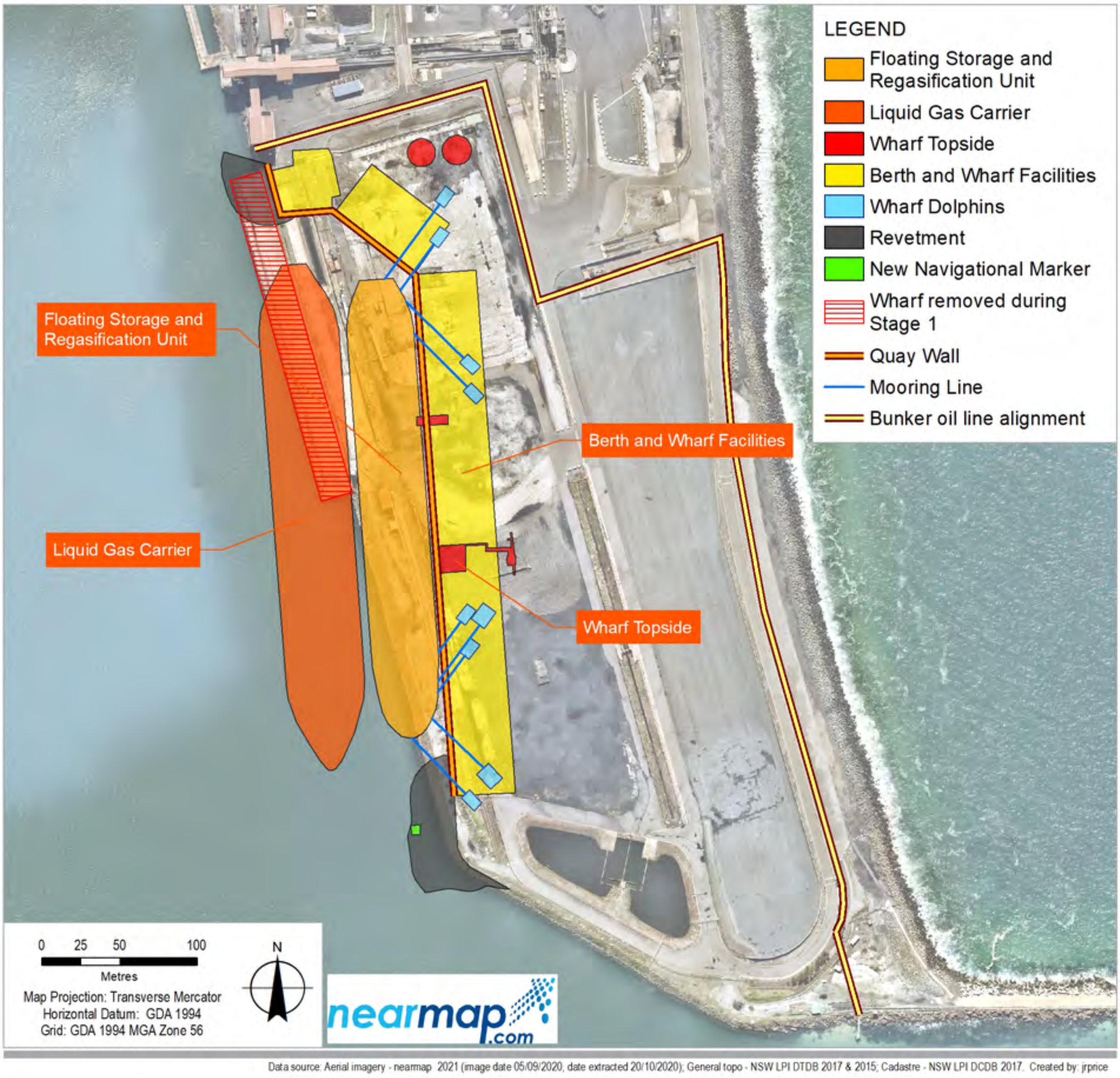


Figure 2.4 Location of quay wall and layout of MBD and ORF

2.4 Power, communications, and water connections

Works required for power, communications, and water connections are summarised in Table 2.3.

Table 2.3 Construction of power connections for Stage 2A

Component	Works required
Power and communications	– Construction and installation of a new 11kV power cable in a buried conduit and Substation. – Energisation of the Padmount Substation and 415kV Temporary Building Supply. – Installation of communication conduit and pits.
Potable water	– Extension of existing potable water line within MBD Site Compound.

2.5 Construction of ORF

The general layout of the ORF areas is shown in Figure 2.4. Works required for the three ORF areas are summarised in Table 2.4.

Table 2.4 Structures to be constructed for ORF during Stage 2A

Component	Works required
Wharf Topside Area	
Marine Loading Arms (MLAs)	Installation of MLAs, including: – Civils and structures. – Associated works such as piping, hydraulics, electrical, instrumentation, and auxiliary systems.
Piping and valving	– All necessary piping and valving. – Odorant injection facilities. – Pig launcher, downstream of the MLAs to tie-in to the Natural Gas Pipeline.
Gangway	– Gangway access tower to provide connection between the wharf and FSRU.
Utility connections	FSRU utilities connections for: – Communications. – Marine Diesel Oil. – Freshwater. – Sewage, bilge, and grey water.
Utility Area	
Site Utilities	Site utilities including: – Potable water and sewerage. – Instrument air and bottled nitrogen. – Diesel storage. – Electrical distribution (including UPS and emergency diesel generators). – Control and instrumentation. – Telecommunications.
Common Areas	
Firefighting systems and equipment	Firefighting equipment including: – Firewater storage. – Pumps – Firewater monitors.
Security systems and equipment	– CCTV. – Fencing and gates. – Security access and monitoring systems.
Equipment housing	Equipment shelters and buildings to house:

Component	Works required
	– Electrical, control, and operating equipment, critical spares, emergency response and site monitoring facilities. – Buildings will include appropriate building services e.g., HVAC, potable water, amenities, sewerage etc.
Site roadways, lighting and drainage	– Roads and car parking areas. – General lighting, earthing, lightning system. – Drainage system to tie into the existing Port Kembla drainage system.
Gas Pipeline	A section of gas pipeline will be installed within the MBD Compound site as part of the Stage 2A works. Final safety studies will be prepared prior to the construction of the gas pipeline and prior to commencement of operation as per Schedule 3, Condition 21 of Infrastructure Approval (SSI 9471).

3. Roles and responsibilities

The Project Team is responsible for all activities associated with Stage 2A, including the implementation and maintenance of the various mitigation/management measures outlined in this ASSMP. Relevant roles and responsibilities of the Project Team are outlined in Table 3.1.

Table 3.1 Roles and responsibilities of Project Team

Project Role	Responsibility
AIE Project Director	– Responsible for the overall funding and direction of civil and environmental works associated with Stage 2A. – Ensuring provision of adequate resources to achieve the environmental objectives for the project including ensuring sufficient resourcing for the Environmental Team, Engineering and Construction Teams.
AIE Construction Manager	– Proactively stewards the effective implementation of Stage 2A in accordance with requirements of the Infrastructure Approval (SSI9471), this ASSMP, EMS, and all related Sub-Plans. – Demonstrate proactive support for environmental requirements.
AIE HSE Manager	– Develops and update all Health, Safety and Environmental (HSE) Management Strategies and Sub-Plans. – Ongoing liaison and engagement with government agencies and point of escalation for any environmental incidents. – Identifying environmental issues as they arise and proposing solutions. – Coordinate and facilitate weekly environmental inspections with the key contractors. – Environmental Reporting.
Principal Contractor Project Manager	– On-site Project management and control. – Decision-making authority relating to environmental performance of the construction program. – Authority over Project construction and site activities in accordance with the EMS. – Ensure relevant training is provided to all Project staff prior to commencing individual activities. – Reports to AIE Construction Manager on environmental matters. – Ensures appropriate Contractor resources are allocated to implement the environmental requirements. – Responsible for planning and scheduling of construction, and to ensure operations are conducted in accordance with statutory requirements and the EMS. – Monitors performance against environmental Key Performance Indicators (KPI's). – Ensures that all environmental objectives associated with the Project are achieved. – Day-to-day decision-making authority relating to environmental performance of construction activities and direct site activities and construction. – To provide resources to ensure environmental compliance and continuous improvement. – Ensure all personnel are aware of any changes to EMS, this ASSMP and improved procedures. – Ensure this ASSMP is implemented for the duration of Stage 2A.
Principal Contractor Construction Foreman	– Implement requirements contained in the EMS and Sub-Plans, work procedures and standard drawings. – Maintaining open and transparent communication with other Project discipline managers and other areas of the Project. – Reporting of hazards and incidents and implementing any rectification measures. – Ensures appropriate contractor resources are allocated. – Orders STOP WORK for any environmental breaches and reports incidents to the Project Manager. – Ensure this ASSMP is implemented for the duration of Stage 2A.
Principal Contractor Environmental Representative	– Delivers environmentally focussed toolbox talks and provides applicable site inductions. – Provides environmental advice, assistance, and direction to Project Manager to ensure construction activities are conducted in accordance with regulatory legislation and this EMS.

Project Role	Responsibility
	– Participate and cooperate with AIE HSE Manager with regards to undertaking of joint weekly environmental site inspections. – Coordinate / undertake wet-weather inspections as per EPL No. 21529 and report accordingly to the AIE HSE Manager. – Develop strong working relationships with the AIE team and Consultants. – Ensure environmental risks are appropriately identified, communicated, and effectively managed. – Ensure communication of relevant environmental information to Project personnel. – Provide specialist advice and input as required. – Ensure construction manager, superintendents and field supervisors fully understand the environmental constraints and how construction practices must ensure any such constraints are considered and mitigated against during construction. – Orders STOP WORK for any environmental breaches and immediately reports incidents to Principal Contractor Project Manager and AIE HSE Manager.
AIE Environmental Representative	– Develop strong working relationships with the Principal Contractor Team and Consultants. – Ensure environmental risks are appropriately identified, communicated, and effectively managed. – Instruct and advise management team on compliance issues. – Provide specialist advice and input as required. – Co-ordinate internal audits of this ASSMP. – Conduct audit review as required. – Reports on the performance of this ASSMP and recommends changes or improvements to Project Manager. – Orders STOP WORK for any environmental breaches and immediately reports incidents to the AIE Construction Manager and AIE HSE Manager. – Conducts investigation and response to environmental complaints and inquiries, where required.
Subcontractors and construction personnel	– Undertake an environmental induction prior to accessing to site. – Comply with legislative requirements. – Participate in weekly inspections and audits. – Follow environmental procedures. – Report all environmental incidents and hazards. – Introduce environmental topics to prestart meetings. – Ensure that all relevant permits and clearances are in place prior to commencing work.
NSW EPA Accredited Site Auditor	– Reviews various documentation associated with the contaminated land aspects of the Project. – Prepares and issues a Section A site audit statement confirming the suitability of the site for its intended use at the completion of dredging, excavation and disposal.

4. Legislative requirements

The legislative requirements applicable to Stage 2A are listed in Table 4.1.

Table 4.1 Legislation and relevant policy applicable to this ASSMP

Legislation and Regulation	Description	Applicability
State		
Protection of the Environment Operations Act 1997 (POEO Act)	The objectives of the POEO Act are to protect and enhance the environment of NSW with regard to the need for ecologically sustainable development. The Act provides the statutory framework for managing pollution in NSW, including the procedures for issuing licences for environmental protection on aspects such as waste, air, water, and noise pollution control. Companies and property owners are legally bound to control emissions (including particulates and deposited dust) from construction sites under the POEO Act.	Exposure of Potential Acid Sulfate Soils (PASS) to oxygen has the potential to result in acid leachate which may constitute a pollution event in not managed appropriately.
Guidelines		
National Acid Sulfate Soils Guidance: National acid sulfate soils sampling and identification methods manual (DAWE, 2018) (National ASS Guideline)	The National ASS Guideline provides technical and practical advice regarding the identification and sampling of ASS in both the field and prior to investigations being undertaken. Requirements of ASS investigation stages are detailed in Section 8, including sampling procedures and indicators.	The good practice management guidance provided in the National ASS Guideline has been implemented into this ASSMP regarding the identification of excavated materials requiring field screening to be undertaken (refer to Section 8.4).
Acid Sulfate Soil Manual (ASSMAC, 1998) (NSW ASS Manual)	The NSW ASS Manual was developed by the Acid Sulfate Soils Management Advisory Committee (ASSMAC) and forms the overarching approach to the management of ASS in NSW. The Manual provides management guidelines, assessment guidelines and management plan guidelines.	As per the Infrastructure Approval (SSI 9471) Schedule 3, Condition 6, the management of ASS during construction of the Project must be undertaken in accordance with the NSW ASS Manual. This ASSMP has been prepared in accordance with the assessment guidelines outlined in the NSW ASS Manual (ASSMAC, 1998).
*Waste Classification Guidelines Part 4: Acid Sulfate Soil*s (NSW EPA, 2014) (ASS Waste Guidelines)	The ASS Waste Guidelines are developed by the NSW Environment Protection Authority (EPA) and provide 'best practice' guidance for planning, assessing and managing activities in areas prone to developing ASS. The guidelines apply to ASS which are unable to be managed on-site and provides guidance for off-site disposal requirements.	Disposal of ASS materials will be undertaken in accordance with the ASS Waste Guidelines (NSW EPA, 2014).

5. Planning requirements

5.1 Conditions of approval

The planning requirements and the corresponding ASS management measures applicable to Stage 2A are listed in Table 5.1. Management measures are detailed in Section 8 through Section 9.

The planning requirements include the conditions set out in the Infrastructure Approval (SSI 9471) dated 24 April 2019, EPL No. 21529 and the mitigation/management measures outlined in the PKGT EIS.

Table 5.1 Approval conditions

Requirement	Reference	Responsibility	Evidence	Applicability to this ASSMP
Infrastructure Approval Requirements (SSI 9471)				
Acid Sulphate Soils The Proponent must ensure that any construction activities in identified areas of acid sulphate soil risk are undertaken in accordance with Acid Sulfate Soil Manual (Acid Sulfate Soil Management Advisory Committee, 1998).	Schedule 3, Condition 6	– AIE HSE Manager – Principal Contractor Project Manager		Applicable
A Dredge and Excavation Management Plan that: – includes an investigation of all reasonable and feasible measures to reduce the road haulage of spoil – describes all activities to be undertaken during dredging, excavation and disposal works – describes in detail the location and depth of disposal areas during all stages of construction, including the final form of the emplaced material – includes procedures for handling, transporting, storing and disposing of dredge and excavated material, including: • potentially acid forming material • contaminated material • asbestos containing materials; and – includes a description of measures that would be implemented to: • minimise the generation and dispersion of sediments during dredging and disposal • minimise soil erosion and discharge of sediment and other pollutants to lands and/or Port Kembla harbour • monitor and manage odours and air emissions during handling of sediments or from stored material prior to emplacement within the disposal area; and – includes contingency measures in the event of a failure of the silt curtains	Schedule 3, Condition 11(b)			Not applicable
PKGT EIS Management Measures				
Preparation of an ASSMP by a consultant experienced in the identification and management of ASS. This will also include appropriate management and/or treatment of ASS. The ASSMP will be developed in line with the requirements of the Acid Sulphate Soils Management Advisory Committee Guidelines (ASSMAC, August 1998 and as updated). The ASSMP will be prepared to identify, manage and treat the ASS encountered during excavation and dredging to minimise the production of acid leachate	EIS Measure C04	– AIE HSE Manager – Environmental Consultant	This plan	Applicable

6. Geology

6.1 Acid sulfate soils

ASS naturally occur in soil and sediment that contain, predominantly, iron sulfides. When these sulfides are disturbed and exposed to air, oxidation can occur, producing sulfuric acid. Unoxidised sulfidic soils are commonly referred to as PASS. These are typical of marine sediments formed below water, such as in Port Kembla.

The 1: 25,000 Port Kembla ASS Risk Map (DLWC, 1998) indicates that Berth 101 (in red outline) is situated in an area mapped as disturbed terrain at an elevation >4 metres (shown in grey shading) (refer to Figure 6.1).

Estuarine sediments exist within the Port Kembla Harbour and are mapped as high probability of ASS. The MBD Site Compound was constructed using fill comprising of sediments originally dredged from the Inner Harbour, which were subsequently placed over existing marine sediments containing ASS.

Figure 6.1 ***ASS risk map***

6.2 Stratigraphic units

A geotechnical assessment completed by Worley Parsons (2012) identified the range of stratigraphic units beneath and adjacent to the MBD Site Compound. The stratigraphic units identified are:

Fill

- Gravelly sand, sand, silt, black, dark brown, grey, some to trace, silts and cobbles.
- Foreign materials, coal wash, coal, slag, steel, wood, concrete.

Unit 1A

- SAND, brown, pale brown, yellow, orange, fine to coarse grained, trace amounts of shell fragments, fine to coarse gravel, silt bands and layers, clayey sand layers, trace iron-stained sand, fine black sand layers (probable heavy mineral sands), rounded to subrounded gravel, clay lenses and layers. Foreign materials: charcoal, wood and coal.

Unit 1B

- SAND pale grey to pale brown, fine- to medium grained occasional coarse-grained SAND may "…contain discrete clay horizons generally less than 1m thick" (interpreted as Unit 1C).

Unit 1C

- Clayey SAND, black, dark grey, grey, fine to coarse grained sand, medium to high plasticity clay, trace silt, shell fragments, gravel.
- Gravelly CLAY, black, dark grey, grey, low to medium plasticity, fine to coarse grained angular to subangular gravel, trace of fine to coarse grained sand.

Unit 2

- CLAY, brown, grey, high plasticity, trace of fine coarse grained, trace of gravel, rounded cobbles.
- Silty SAND, dark brown, grey, brown, fine to coarse sand, trace of fine gravel, shell fragments.

Unit 3/4

- Sandy CLAY with lesser amounts of Silty CLAY, Silty/Clayey SAND and CLAY.
- SILTSTONE with lesser amounts of Sandy SILTSTONE, Silty SANDSTONE and SANDSTONE.

Harbour Muds (HM) and Harbour Silts (HS)

- Upper unit black-brown clayey silt mud (HM) with coarse sand and gravel sized coal and lower unit of grey silty clay (HS).

GHD carried out ASS sampling and analysis of the stratigraphic units within the MBD Site Compound and its surrounds (GHD, 2018). The report found dark grey clayey sands and gravelly clays occurring as discrete layers within Units 1A and 1B. Unit 1C has been defined as thin ASS layers or lenses occurring within Unit 1A and Unit 1B.

7. ASS/ PASS occurrence

7.1 Assessment criteria

The assessment and management of coastal ASS has been based on the NSW ASS Manual (ASSMAC, 1998) and the National ASS Guideline (DAWE,2018).

The action criteria for ASS are based on the sum of existing plus potential acidity. This is calculated as equivalent sulfur (s-TAA+SCr in %S units) or equivalent acidity (TAA + a-SCr in mol H+/tonne). The highest laboratory result is always used to assess against the action criteria.

As clay content tends to influence a soils natural pH buffering capacity, the action criteria are grouped into three broad texture categories: coarse, medium, and fine. For disturbances of more than 1,000 tonnes of ASS, the action criteria are interpreted as 0.03 %S or 18 mol H+/tonne equivalent acidity.

These criteria are from the NSW ASS Manual (ASSMAC, 1998) and are the basis for this ASSMP, as outlined in Table 7.1. The expected volumes of material to be disturbed during the Stage 2A works are <1000 tonnes. Action criteria for greater than 1000 tonnes are included for reference.

Table 7.1 ASS Action Criteria (ASSMAC)

Type of material		Action Criteria 1 - 1000 tonnes disturbed		Action Criteria if more than 1000 tonnes disturbed	
Texture range McDonald et al. (1990)	Approx. clay content (%<0.002mm)	Sulfur trail % oxidisable (oven-dry basis) e.g., STOS or SPOS	Acid trail mol H+/tonne (oven-dry basis) e.g., TPA or TSA	Sulfur trail % oxidisable (oven-dry basis) e.g., STOS or SPOS	Acid trail mol H+/tonne (oven-dry basis) e.g., TPA or TSA
Coarse texture Sands to loamy sands	≤5	0.03	18	0.03	18
Medium texture Sandy loams to light clays	5-40	0.06	36	0.03	18
Fine texture medium to heavy clays and silty clays	≥40	0.1	62	0.03	18

Notes:
Net Acidity calculated using acid base accounting excluding ANC (refer Sullivan et al 2018)
SPOS Peroxide oxidisable sulfur
STOS Total oxidisable sulfur
TAA Total Actual Acidity
TPA Total Potential Acidity
TSA Total Sulfidic Acidity

7.2 MBD Site Compound

Sampling for PASS/ASS was carried out between 20 August and 25 September 2018 and the results were reported in the PKGT EIS (GHD, 2018). 67 samples were tested using the chromium reducible suite (SCR) and the laboratory results are summarised in Appendix C. Location of sample sites are provided in Figure 7.1.

The sampling frequency conducted exceeded that recommended in Appendix B Tables B1 and B2 of the National ASS Guideline (DAWE, 2018) for characterisation of sediments.

The ASS results are summarised below:

– Only nine samples recorded a SCR result above the adopted action criteria (0.03%) The pH potassium chloride (KCl) in these samples was between 4.6 and 12.0, indicating moderately acidic to strongly alkaline conditions.

– Of the nine samples, four samples recorded a net acidity above the action criteria (0.03%). The pH KCl in these samples was between 4.6 and 6.5, indicating acidic conditions.
– The majority of these samples recorded elevated Acid Neutralising Capacity (ANC) resulting in net acidity below the action criteria.
– In the samples that exceeded net acidity, liming rates calculated by the laboratory were between 7.1 kg and 220 kg of calcium carbonate ($CaCO_3$) per tonne.

Table 7.2 summarises these results as per the stratigraphic units encountered during the investigation and as complimented by the findings of GHD in 2019, which are detailed in Section 8.2 of the CSP.

Table 7.2 Summary of ASS risk per stratigraphic unit

Unit	General Description	Corresponding Stratigraphy	ASS Risk following disturbance
Fill	Gravelly sand, sand, silt, black, dark brown, grey, some to trace, silts and cobbles. Foreign materials, coal wash, coal, slag, steel, wood, concrete.	Fill	None
Probably reclaimed sands	SAND, brown, pale brown, yellow, orange, fineto coarse grained, trace amounts of shell fragments, fine to coarse gravel, silt bands andlayers, clayey sand layers, trace iron stained sand, fine black sand layers (probable heavy mineral sands), rounded to sub-rounded gravel, clay lenses and layers. Foreign materials: charcoal, wood and coal	1A/1B	Low
	Clayey SAND, black, dark grey, grey, fine to coarse grained sand, medium to high plasticityclay, trace silt, shell fragments, gravel	1C	High risk ASS are present within occasional pockets and lenses at random locations within units 1A and 1B.
	Gravelly CLAY, black, dark grey, grey, low to medium plasticity, fine to coarse grained angular to sub-angular gravel, trace of fine to coarse grained sand	1C	High risk ASS are present within occasional pockets and lenses at random locations within units 1A and 1B.
Possible Alluvium/ tidal	SAND, brown, pale brown, yellow, orange, fineto coarse grained, trace amounts of shell fragments, fine to coarse gravel, silt bands andlayers, clayey sand layers, trace iron stained sand, fine black sand layers (probable heavy mineral sands), rounded to sub-rounded gravel, clay lenses and layers	1A	Tidal sand units have below net acidity and highANC indicating some self-neutralising
Estuarine	CLAY, brown, grey, high plasticity, trace of finecoarse grained, trace of gravel, rounded cobbles	2	High
	Silty SAND, dark brown, grey, brown, fine tocoarse sand, trace of fine gravel, shell fragments	2	High
Residual	Sandy CLAY with lesser amounts of Silty CLAY,Silty/Clayey SAND and CLAY	3	None
	SILTSTONE with lesser amounts of Sandy SILTSTONE, Silty SANDSTONE and SANDSTONE	4	None
Harbour Silts and Harbour Muds	Silts and Muds with a high probability of contamination. To be placed within the emplacement cell under similar conditions to high-risk ASS material	HS/HM	Unknown

Units 1A and 1B represent former dredged harbour sands, silty sands and tidal sands used to construct the MBD Site Compound. Average chromium reducible sulfur concentration within Units 1A and 1B is 0.024%S and average

ANC in Units 1A and 1B is 6.0%. Based on the low chromium reducible sulfur concentrations (<0.03%S) and the average ANC, the net acidity for these Units is <0.02 %S, indicating that there is sufficient natural buffering capacity within these Units to account for acidification if it were to occur.

The Units 1A and 1B is known to contain occasional pockets and lenses of higher risk PASS/ASS material, which are generally considered to be less than 0.5 m thick and have been defined as Unit 1C. Boreholes where ASS was identified in specific lenses in the GHD sampling round (2018) are as follows:

- Samples BH11 (12.-12.25 metres in depth).
- GBH07 (8.7 – 9.0 metres in depth).
- GBH10 (4.4 – 4.6 metres in depth).
- GBH23 (9.7 – 10 metres in depth).
- GBH24 (4.7-4.9 metres in depth).

These are shown on Figure 7.1.

A summary of laboratory results for each soil unit is included in Appendix C.

The total volume of Unit 1C material has been conservatively estimated as potentially up to 10,000 metres^3. The Unit 1C materials represent less than 4% of the total volume of Unit 1A and Unit 1B sands which recorded net acidities below the adopted ASS Action Criteria (0.03%S) with an average of 0.024%S.(Fox Consulting, 2020).

In addition, the Units have considerable buffering capacity available as measured by ANC, which was on average 6% $CaCO_3$. The small volumes of Unit 1C material is therefore not likely to have adverse impact on acidity levels and separation from Units 1A and 1B is not necessary allowing for stockpiling and / or use during Stage 2B within the bund or capping of the Emplacement Cell.

7.3 ASS/ PASS materials to be managed during Stage 2A

The land-based excavation activities during Stage 2A will generate minimal volumes of Type 1C materials. As discussed in Section 7.2, Type 1C materials are already inter-mixed and cannot practically be segregated from Type 1A and 1B materials. Additionally, the occasional layers of Unit 1C materials are considered to be less than 0.5 metres thick and account for a volume of less than 10,000 metres^3, which represents less than 4% of the total Unit 1 volume.

Due to the low Scr concentrations and average ANC of Unit 1A and 1B materials as outlined in Section 7.2, the natural buffering capacity of these Units will account for any acidification from potential Unit 1C materials and will therefore not be managed as ASS/PASS material during Stage 2A (Fox Consulting, 2020).

Unit 1C will not be separated from Unit 1A/1B and it is noted that all Unit 1 materials (1A/1B/1C) will be stockpiled together as a single unit ensuring any variability in acid generating capacity can be effectively neutralised by the high buffering capacity particularly associated with the Unit 1A material.

Initial validation testing will be undertaken for excavated/ drilled Unit 1 material to verify that any Unit 1C material that may have been mixed with Unit 1A/1B has zero to minimal acidification impact (i.e. verifying the adequacy of Unit 1A/1B neutralising capacity).

During pile installations in Stage 2A, minimal amount of Unit 2 material will be generated (up to 1000m^3).. It is intended that these Unit 2 materials are placed back to the hollow piles and sealed, ensuring that it will not be mixed with other materials, and is retained within its original stratum depth, minimising the risk of oxidation / exposure. Unit 2 materials that cannot be placed back into the hollow piles and sealed (e.g., due to volume limitation within the pile), will require further management as outlined in Section 8.

It is noted that approximately 3,000m^3 of materials (Unit 1, Unit 2, Unit 3) to be excavated during piling activity, of which 500m^3 is considered Unit 3 material (non ASS/PASS). Therefore, there is an adequate spare capacity in the hollow piles for all Unit 2 material.

Figure 7.1 Borehole locations where ASS identified (GHD, 2018)

8. Identification

The process for identifying ASS is described in this section.

Positive PASS/ASS identification will require that the spoil is to be placed in the preceding hollow pile (see Section 8.2 below) or undergo treatment prior to use. If ASS/PASS material is to be placed inside the pile within the following time periods, no visual or field testing is required:

- Coarse Texture (<5% clay): 18 hours
- Medium Texture (5-40% clay): 42 hours.
- Fine Texture (>40% clay): 66 hours.

Monitoring to be undertaken during initial stages of piling activities to confirm the adequacy of these timeframes. Monitoring will include field screening and laboratory testing if necessary, in accordance with the NSW ASS Manual (ASSMAC, 1998). The materials that are tested will be isolated from other materials following testing until results are obtained.

8.1 Training and responsibilities

The Principal Contractor’s Environmental Representative is responsible for managing the ASS issues during excavation activities. If required, a suitably qualified Environmental Consultant will be engaged to assist or train the Principal Contractor in the identification of ASS.

This person should be familiar with:

– Relevant statutory requirements.
– Recognition of excavated ASS sediments.
– ASS testing and treatment procedures.
– Onsite management of ASS materials, including implementing management procedures.

The classification of ASS materials during excavation should be carried out by personnel trained in the identification of ASS. The classification will be based on visual classification and the field screening test. A flow chart (Figure 8.1) has been developed to aid in the identification and appropriate management of ASS..

8.2 Handling

Stage 2A construction activities will initially be undertaken prior to dredging or emplacement cell construction. Any activities such as piling or deeper excavation for construction of the quay wall or foundations for mooring dolphins will have potential to encounter small volumes of ASS.

Direct placement at depth will not be available until the commencement of emplacement cell as part of Stage 2B. Any identified ASS will therefore need to be reburied within a hollow and sealed pile (at depth) or stored separately for treatment and subsequent reuse or removed offsite for treatment and disposal.

The following is an outline of the general principles for mitigating impacts associated with identified ASS as per the NSW ASS Manual (ASSMAC, 1998):

– The disturbance of ASS should be avoided, wherever possible.
– Where disturbances of ASS are unavoidable, preferred management strategies are:
  1. Minimisation of disturbance.
  2. Immediate reburial in the preceding hollow pile (provided a complete seal is created, and structural integrity of pile is not compromised).
  3. Neutralisation of acidity (treatment).
  4. Hydraulic separation of sulfides.
  5. Strategic reburial (reinternment, with treatment of any excess acidity).

The preferred approach for Stage 2A is reburial within hollow and sealed piles of the quay wall for identified ASS/PASS material.. It should be noted that there will be adequate capacity within the piles to be excavated to encapsulate ASS/PASS material planned to be excavated as a part of the project as described in Section 7.3.

8.3 Visual identification

Visual assessment of PASS or ASS begins using the Environmentally Sensitive Area maps, which identify all areas of PASS. As Port Kembla Harbour is situated in a high ASS risk area, vigilant visual monitoring should be undertaken during all excavation and stockpiling activities.

It is also important to be able to recognise indicators of actual ASS to prevent further acidification of land and waterways. These indicators include:

– Cloudy green-blue water.
– Excessively clear water.
– Iron stains.
– Scalded soil.
– Yellow jarosite.
– 'Rotten egg' smell.
– Corrosion of concrete and/or steel structures.
– Oily-looking surface iron bacterial scum.
– Dark grey soils.

The classifications apply to the excavated sediments:

– Unit 1A and 1B: SAND, brown, pale brown, yellow, orange, fine to coarse grained, shell fragments, fine to coarse gravel, silt bands and layers, clayey sand layers, trace iron stained sand, fine black sand layers (probable heavy mineral sands and non ASS), rounded to sub-rounded gravel, clay lenses and layers.
– Unit 1C: Clayey SAND, black, dark grey, grey, fine to coarse grained sand, medium to high plasticity clay, trace silt, shell fragments, gravel. Gravelly CLAY, black, dark grey, grey, low to medium plasticity, fine to coarse grained angular to sub-angular gravel, trace of fine to coarse grained sand. LIKELY TO CONTAIN ASS/PASS.
– Unit 2: CLAY, grey, dark grey and green high plasticity, trace of fine coarse grained, trace of gravel, rounded cobbles, Silty SAND, dark grey, grey, brown, fine to coarse sand, trace of fine gravel, shell fragments. LIKELY TO CONTAIN ASS/PASS.
– Residual soils (Unit 3) and weathered rock (Unit 4) are not classified as ASS. Residual soils and weathered rock are typically stiff to very stiff clays, dark brown mottled dark green-grey, pale brown and brown orange.

8.4 Field screening

A field screening test undertaken in two steps using deionised water (pHf) and peroxide (pHfox) should be performed on the excavated Unit 2 sediments that cannot be placed back to the pile, as described in Section 7.3. The test will be used to assess the potential presence of ASS and is to be performed in accordance with the NSW ASS Manual. A visual assessment flow chart is shown below (Figure 8.1) which will provide additional support in determining the presence of ASS.

Based on additional ASS/PASS assessment (Fox Consulting, 2021), Unit 1A/1B have enough buffering capacity to neutralise Unit 1C. Field screening test will not be undertaken for Unit 1A/1B/1C material as long as these materials remained mixed and visual identification confirmed they are Unit 1A/1B/1C materials.

If Unit 2 and Unit 3 material cannot be placed back into the pile and intended to be re-used on site, field screening will be undertaken to confirm whether it's ASS/PASS material. If confirmed an ASS/PASS material, it can only be re-used on site if treatment has been undertaken and required performance criteria and verification of treatment is satisfactory as detailed in Section 9.2.

Excavated material requiring treatment, as indicated by the field screening test, will be relocated to the treatment area to undergo the process described in Section 9 below.

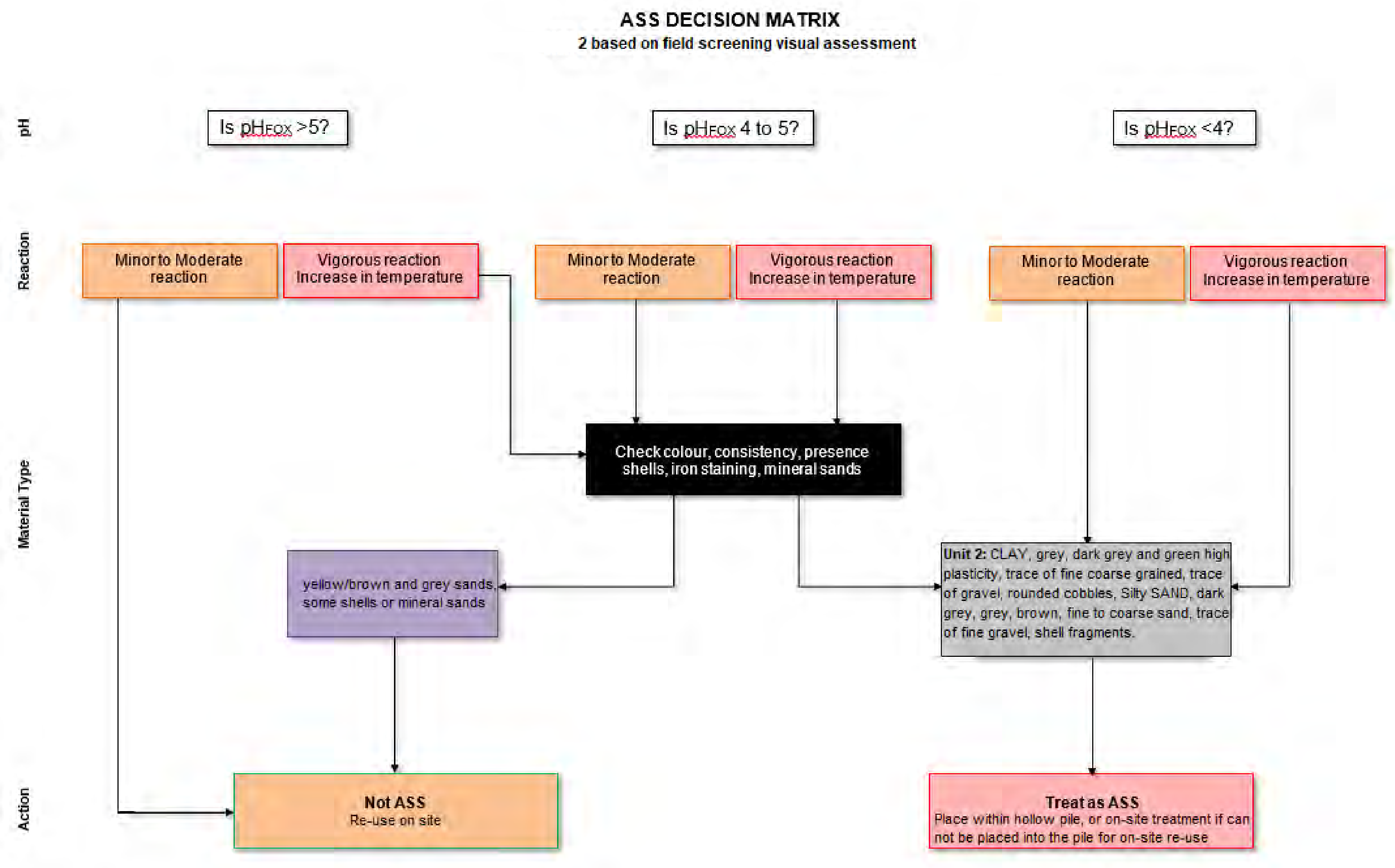


Figure 8.1 ASS decision matrix – field screening visual assessment

9. Treatment

9.1 Overview

ASS treatment will be undertaken on stockpiles that have failed the criteria outlined in Section 8.4. Each stockpile that requires treatment will then be identified and tracked as a 'batch', which will be spread out on a treatment pad.

The type and amount of lime to be applied should be such that a neutralizing value (NV) of at least 95 can be achieved. The NV should be identified prior to mixing. NV relates to the purity of the lime and an NV of 100 is preferred to ensure that the lime is effective in neutralising the potential acid.

Fine powdered agricultural lime ($CaCO_3$, <0.5mm particle size) generally has an NV of 90% to 100%, whilst other manufactured forms of lime can have an NV as low as 80%. Where NV is below 100, the factor of safety, hence the amount of lime, will have to be adjusted accordingly.

Calculation of the quantity of lime required for treatment will be calculated based on rates recommendations made by the laboratory with which the analysis was undertaken, however it should be noted that the following formula from the NSW ASS Manual (ASSMAC, 1998) may also be used for guidance:

$$\text{Lime required (kg } CaCO_3\text{/tonne material)} \cong \text{kg } H_2SO_4\text{/tonne of material x safety factor}$$
$$\cong (\text{oxidisable S \% x } 30.59) \text{ x } 1.5$$

The design of the treatment pad should be in general accordance with Figure 9.1, noting concrete hardstand can be used in place of compacted clay.

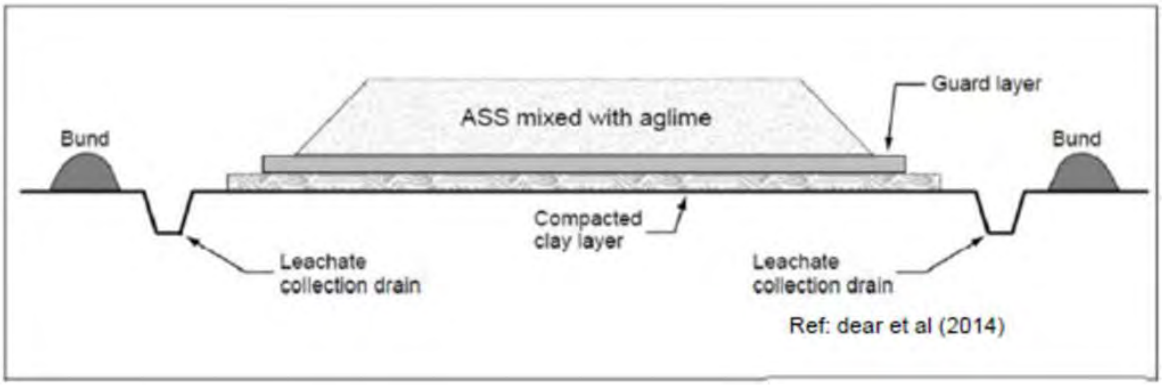


Figure 9.1 ASS treatment pad (example)

The following procedures (or other equivalent) should be undertaken for the treatment pad and liming. It is aligned with the PKGT EIS recommendations, Department of Agriculture and Water Resources National Acid Sulfate Soils Guidance (2018) and the NSW ASS Manual (ASSMAC, 1998):

- The area will be bunded (50 millimetres high bund) and provision made to collect run-off water and be sufficiently robust to avoid impacts to the harbour during storm events.
- Spreading of the soil in thin (<300 millimetres) layers on impervious pads within the boundary of the site works.
- A guard layer of neutralising agents should be provided at the base of the pad prior to the addition of ASS as per page 48 of the Queensland *Acid Sulfate Soil Technical Manual: Soil Management Guidelines* (DSITIA, 2014), which states: *The minimum guard layer rate beneath any treated-in-place ASS will be 5 kilograms fine aglime per m² per vertical meter of fill.*
- Where the highest detected sum of existing and potential acidity is more than 1.0% S equivalent, the rate will be at minimum 10 kilograms fine aglime per m² per vertical meter of fill.
- Addition of lime followed by mixing.
- The amount of lime to be added will be determined based on the results of laboratory analysis taking into consideration existing acidity, potential acidity, retained acidity.

- A factor of safety should also be applied to the lime rate calculation of between 1.5 and 2 and will depend on the likely area of reuse or disposal option for this material and environmental sensitivity.
- Leachate is to be monitored in accordance with the NSW ASS Manual (ASSMAC, 1998).

For the establishment of the location of the treatment pad, this is to determined in accordance with both the NSW ASS Manual (ASSMAC, 1998) and the Queensland *Acid Sulfate Soil Technical Manual: Soil Management Guidelines* (DSITIA, 2014), which establish the following parameters:

- the storage site should be impervious and bunded with adequate leachate collection and treatment systems
- treatment pads should be located on stable ground, away from overland flow paths and preferably in a location where bund and leachate collection pond construction does not disturb in situ ASS.
- keeping treatment pads some distance from surface water bodies will help to avoid instances of accidental release of pollutants to water.
- treatment pads should be set up to allow maximum treatment batch sizes of 500 m3 , as it is difficult to representatively sample larger batches, and re-treatment of large failed batches is expensive."

"

9.2 Performance criteria and verification testing

In order to demonstrate that appropriate quantities of lime have been used, a lime register shall be maintained by the Principal Contractor. The register shall list the amount of lime delivered to the site, verified by delivery dockets, and where/when the lime has been used. The lime usage shall quantify areas limed and soil volumes treated, liming rates and quantities of lime used.

Validation of ASS treatment is based on:

- Minimum four test samples per batch or one sample per 1000 m^3.
- Samples to be tested using the SCR suite with full acid base accounting including retained acidity.
- The performance criteria as outlined in Section 8:
  - No single sample shall exceed a net acidity of 18 mol H+/tonne (0.03% S).
  - If any single sample is between 0 and 18 mol H+/tonne (0.00 to 0.03% S), then the average of any four spatially adjacent samples (including the exceeding sample) shall have an average net acidity of zero or less.
- Field screening at a greater density should also be undertaken to confirm pHf post treatment is > 6.5 (but no higher than 8.5)

Corrective actions for ASS failing treatment criteria include:

- More thorough mixing of the material (particularly if high clay content)
- Retreating soils, by addition of more lime.
- Retesting soils.
- Repeating steps 1 and 2 until SCR suite results are below the thresholds defined in Section 7.1.
- Off-site disposal will be undertaken in accordance with the NSW EPA (2014) *Waste Classification Guidelines Part 4: Acid Sulfate Soils which requires chemical assessment of the material following neutralisation*.. Additional requirements and procedures for off-site disposal are outlined in Section 8.3 and 8.5 of the Stage 2A SMP.

Periodic monitoring will be undertaken in accordance with the NSW ASS Manual (ASSMAC, 1988) if the treated materials are to be stored long term prior to re-use.

10. Monitoring, inspection, and reporting

Ongoing water quality monitoring will be conducted to ensure acid leachate is not entering the harbour. To prevent leachate escaping the treatment area, it will be ensured that the leachate is diverted into the leachate collection drain. Whenever necessary (e.g. prior to wet weather event), periodic collection of leachate and appropriate management (e.g. disposal) of collected leachate and/or covering of the collection drain will be undertaken to prevent overtopping. Full time automated water quality monitoring is outlined in the Water Quality Management Plan (WQMP) and includes pH and dissolved oxygen monitoring at two locations outside the emplacement cell. The WQMP also outlines a tiered trigger level response to limits. Weekly grab samples for contaminants are also included in the WQMP.

Given the anticipated small volumes of leachate to be treated (if any), routine visual environmental inspections are to be undertaken, to include inspections of the bund integrity, in line with the existing inspection regime. Daily inspection as part of the environmental compliance checklist will be carried out to assess the effectiveness of this plan. The aim of the inspections is to identify any non-conformance or improvements that can be made and proposed corrective actions. Environmental checklists will be kept and made available to AIE on request.

The Principal Contractor Environmental Representative will undertake a series of targeted internal audits of environmental controls used during construction to review compliance with the requirements of the ASSMP in accordance with the EMS.

References

Acid Sulfate Soil Management Advisory Committee 1998, Acid Sulfate Soil Manual.

DAWE 2018, National Acid Sulfate Soils Guidance: National acid sulfate soils sampling and identification methods manual.

DLWC 1998, Acid Sulfate Soil Risk Map - Wollongong 1: 25,000, 2nd Ed. Department of Land and Water Conservation.

DSITIA 2014, Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines.

Environmental Protection Licence No. 21529, dated 20 August 2021.

Fox Consulting 2020, Port Kembla Gas Terminal Dredged Emplacement Area- Expert Advice and Literature Review Acid Sulfate Soils.

GHD 2018, Port Kembla Gas Terminal Environmental Impact Statement.

GHD 2019, Port Kembla Gas Terminal Environmental Impact Statement Modification Environmental Assessment.

Infrastructure Approval SSI 9471 dated 24th April 2019.

NSW EPA 2014, Waste Classification Guidelines Part 4: Acid Sulfate Soils.

Worley Parsons 2012, Berth 101 Upgrade Project Marine Assessment Dredge Spoil Contamination Assessment - Stage 2 Detailed Site Investigation (Report Ref: 301015-02809-00-CS-REP-0003, dated 15 October 2012).

Appendices

Appendix A

Acid Sulfate Soil Placement Considerations

FOX ENVIRONMENTAL
CONSULTING

ABN 90 613630676

laurie@foxenviro.com
20 Hawkins Street
New Lambton 2305
0420 961259

9 September 2020

Reference: FEC200106AA-L01 Final

GHD Pty Ltd

Level 11 200 Crown Street

WOLLONGONG 2500

Email: colee.quayle@ghd.com

Dear Colee

RE: Port Kembla Gas Terminal Dredged Emplacement Area- Expert Advice and Literature Review Acid Sulfate Soils

1 Introduction

The Port Kembla Gas Terminal proposal includes the establishment of a Liquified Natural Gas (LNG) Import Terminal at Berth 101 Port Kembla Harbour, Port Kembla NSW. The establishment of the new berth and wharf facilities will involve the removal, via dredging, of fill and sediments from beneath the existing Berth 101 and placement within an engineered cell located within the Outer Harbour.

About a third of the dredged sediments have been classified as high risk acid sulfate soils. Placement of these high risk soils within the engineered cell is proposed to a height of about 0.74m Chart Datum. Schedule 3 Specific Environmental Conditions of Infrastructure Approval (April 2019) states that acid production within the engineered cell must be prevented and concerns have been raised over whether this can be practically achieved.

Fox Environmental Consulting Pty Ltd (FEC) was commissioned by GHD Pty Ltd (GHD) to assess whether the placement of the high risk ASS within the disposal area, will result in the production of acid that could impact the surrounding environment. In order to achieve the objective, FEC has reviewed the following:

- Site specific project information related to the proposed ASS dredging and disposal at Port Kembla including tidal information
- Published and peer reviewed papers related to ASS management in similar scenarios; and
- Recognised national and state ASS guidance with respect to management of ASS.

2 Coastal Acid Sulfate Soils (CASS)

Acid sulfate soils can form in a number of geologic and geomorphic landscapes provided there is a source of iron, sulfate and soil bacteria. Coastal Acid Sulfate Soils (CASS) have formed along the east coast of Australia, since the last glacial period (19,000 to 18,000 years ago), when sea levels were around 120 to 130m below today's levels.

Sea levels rose rapidly to about 7,000 years ago, reaching a height about 1.0m above the present day mean sea level (0.0m AHD), at which time they stabilised (CRC Care 2018). Since that time there has been a slow accumulation of coastal sediments within the intertidal zone, including saline wetlands, salt marshes and as bottom sediments in embayments, coastal rivers, estuaries and coastal lakes. This accumulation is still occurring today (Wilson White and Melville 1999).

CASS are found along most of the coast of mainland Australia, generally found below about 5m AHD where tidal ranges are large, such as northern Queensland. Along coastal areas with smaller tidal ranges, it is rare to find significant accumulations of CASS above about 2m AHD (Simpson et al 2018).

The formation of sulfidic sediments is a natural part of the sulfur cycle where sulfates from sea water, in combination with iron and sulfate reducing bacteria (SRB), combine to produce reduced inorganic sulphides (RIS). RIS can include iron disulfides (FeS_2), pyrite and marcasite, monosulfides (FeS) and elemental sulfur (S^8) (Sullivan et al 2018). Provided these sediments remain in an anoxic state (saturated) they are benign (Wilson et al 1999, Dear et al 2014, Sullivan et al, Simpson et al 2018).

The influence of tides in near shore sediments and the position of the water table on floodplains, are critical to both the formation of CASS and the prevention of widespread acidification under natural conditions (Wilson et al 1999). In near neutral waters (pH 6 to 8) inorganic carbon speciation favours bicarbonate ion (HCO_3-) which provides the buffering capacity for sea water (Luke et al 2012).

At the upper limits of the tidal range (around 0.5m AHD) short term wetting and drying can occur. The acid produced during these periods of wetting and drying is limited and is well buffered by seawater and hence there is negligible environmental harm (CRC Care 2018).

3 ASS Occurrence at Port Kembla

The DLWC (1997) 1:25,000 Wollongong ASS Risk Map (reproduced below as Figure 1) indicates that Berth 101 (in red outline) is situated in an area mapped as disturbed terrain at an elevation >4 m (shown in grey shading). Estuarine bottom sediments exist within the Port Kembla Harbour and are mapped as high probability of ASS.

The majority of Berth 101 was constructed using material comprising an upper fill layer of coal washery reject and slag plus sandy sediments originally dredged from the inner harbour. These hydraulically placed sediments were placed over existing marine sediments containing ASS. The bottom sediments at Port Kembla Harbour are shown by the purple shaded area on Figure 1 below.

Figure 1 Wollongong ASS Risk Map showing bottom sediments (purple shading)

A geotechnical assessment, prepared by Worley Parson (2018), shows the stratigraphic units beneath and adjacent to Berth 101 (Figure 2). With reference to Section E-E' and F-F' in Figure 2 below, the light green shaded area indicates estuarine (Unit 2), high risk ASS underlying tidal sands (Unit 1A and Unit 1B - light orange shading).

The sections show that the Unit 2 material has been truncated by maintenance dredging over time and the more recent (geologically) Harbour Muds (HM) and Harbour Sediments (HS) have accumulated on the harbour side of Berth 101. A Sediment and Contamination report by GHD (2018a) indicated that both HM and HS contain ASS and these deposits are consistent with the high probability area shown by purple shading in Figure 1.

GHD carried out ASS sampling and analysis of six stratigraphic units encountered within Berth 101 and harbour muds and sediments from within the harbour floor, immediately west of Berth 101 (GHD 2018a, 2018b). The combined GHD and Worley Parsons stratigraphic units and ASS results are summarised in Table 1 below which also includes a statistical appraisal based on the number of samples tested per unit.

These stratigraphic units will be excavated/dredged and placed within the Outer Harbour Disposal Spoil Containment Area (OHDSCA), southwest of Berth 101. The ASS hazard (net acidity) was used to semi qualitatively assess the risk posed by these materials. It should be noted that Unit 1B in the Dredging and Excavation Plan has been based on the Worley Parsons interpretation of geotechnical conditions not based on the presence of ASS.

The GHD (2018b) report found dark grey clayey sands and gravelly clays occurring as discrete layers within Units 1A and 1B. In this report Unit 1C has been defined as ASS layers occurring within Unit 1A and Unit 1B (refer to the attached photos).

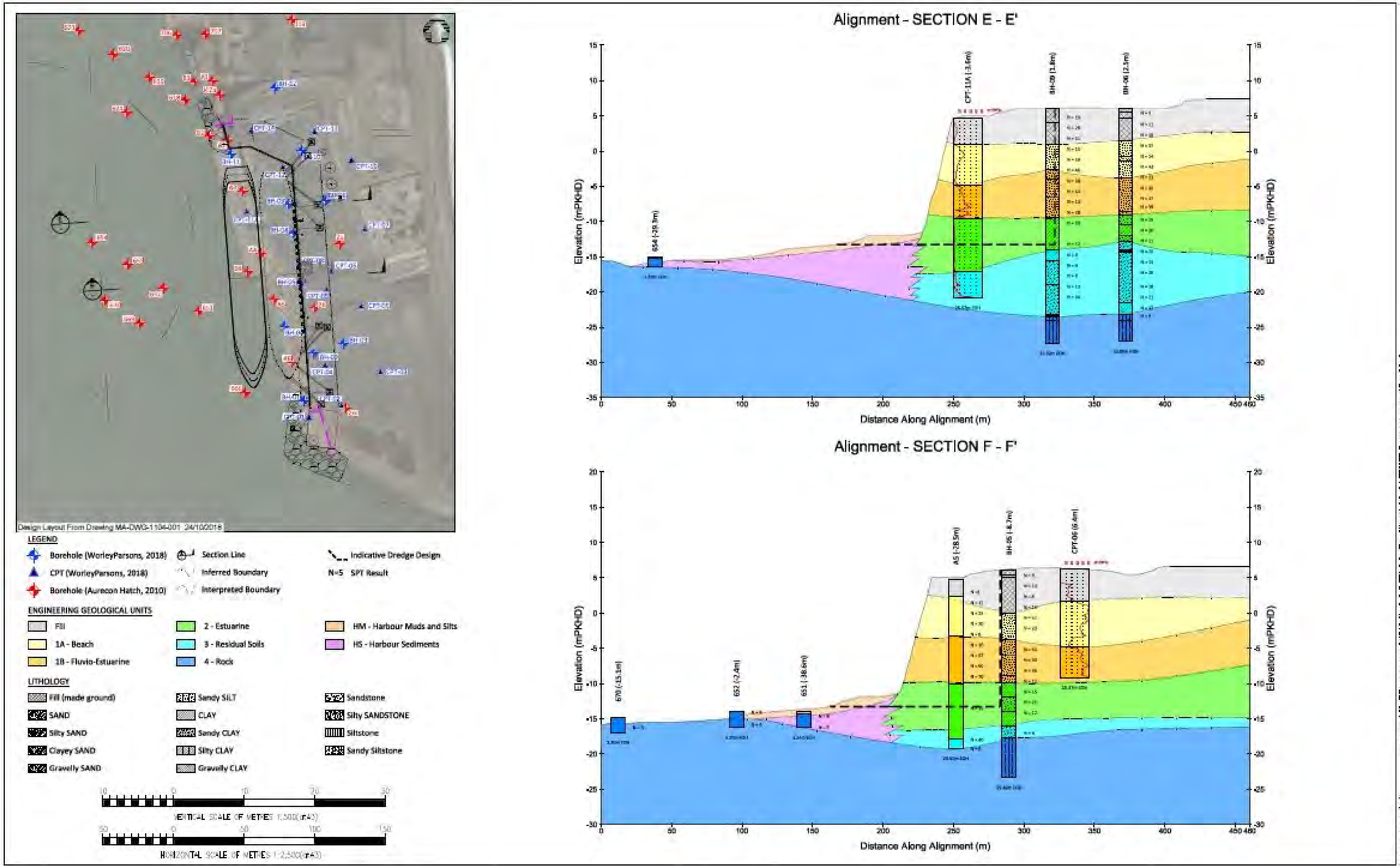


Figure 2 Stratigraphic Cross Sections (Worley Parsons 2019 Geotechnical report)

Table 1 Summary of Laboratory Results for Dredged Sediments

Unit	**Generalised description**	**No of Samples**	pH KCL	TAA (%)	Scr (% S)	ANC % (CaCO3)	Net Acidity (% S)	Estimated Volume (m^3)[1]	ASS Risk category
Fill	Gravelly sand, sand, silt, black, dark brown, grey, some to trace, silts and cobbles. Foreign materials, coalwash, coal, slag, steel, wood, concrete.	2	Range: 9.5 to 9.6	<0.02	Range: 0.008 to 0.011	Range: 3.3 to 9.4	<0.02	89,828	Non ASS
Unit 1A[1]	SAND, brown, pale brown, yellow, orange, fine to coarse grained, trace amounts of shell fragments, fine to coarse gravel, silt bands and layers, clayey sand layers, trace iron stained sand, fine black sand layers (probable heavy mineral sands), rounded to sub-rounded gravel, clay lenses and layers. Foreign materials: charcoal, wood and coal.	52 (includes Unit 1A and 1B)	Range: 7.9 to 9.8 Average: 9.50 Median: 9.70	<0.02	Range: <0.005 to 0.33 Average: 0.024 Median: 011	Range: 0.54 to 15.0 Average: 6.0 Median: 6.3	<0.02	110,708	Low Risk
Unit 1B	SAND pale grey to pale brown, fine- to medium-grained occasional coarse-grained SAND may "*…contain discrete clay horizons generally less*							173,039	Low Risk

Unit	**Generalised description**	**No of Samples**	pH KCL	TAA (%)	Scr (% S)	ANC % (CaCO3)	Net Acidity (% S)	Estimated Volume (m^3)[1]	ASS Risk category
	than 1m thick" (interpreted as Unit 1C).								
Unit 1C	Clayey SAND, black, dark grey, grey, fine to coarse grained sand, medium to high plasticity clay, trace silt, shell fragments, gravel. Gravelly CLAY, black, dark grey, grey, low to medium plasticity, fine to coarse grained angular to sub-angular gravel, trace of fine to coarse grained sand.	5	Range: 8.4 to 12.0 Average: 9.96 Median: 9.70	<0.02	Range: 0.049 to 1.1 - Average: 0.52 Median: 0.42	Range: 4.6 to 55.0 Average: 18.30 Median: 8.50	<0.02	10,000[3] (subset of Unit 1A / 1B)	High Risk
Unit 2	CLAY, brown, grey, high plasticity, trace of fine coarse grained, trace of gravel, rounded cobbles Silty SAND , dark brown, grey, brown, fine to coarse sand, trace of fine gravel, shell fragments	7	Range: 6.0 to 8.4 Average: 6.8 Median: 6.9	<0.02	Range: <0.005 to 0.6 Average: 0.23 Median: 0.065	Range: 0.26 to 0.53 Average: 0.42 Median: 0.5	Range: <0.02 to 0.6 Average: 0.6 Median: 0.6	100,731	High Risk

Unit	**Generalised description**	**No of Samples**	pH KCL	TAA (%)	Scr (% S)	ANC % (CaCO3)	Net Acidity (% S)	Estimated Volume (m^3)[1]	ASS Risk category
Unit 3/4	Sandy CLAY with lesser amounts of Silty CLAY, Silty/Clayey SAND and CLAY SILTSTONE with lesser amounts of Sandy SILTSTONE, Silty SANDSTONE and SANDSTONE	Nil					<0.02	18,573[2]	Non ASS
HM and HS	Upper unit black-brown clayey silt mud (HM) with coarse sand and gravel sized coal and lower unit of grey silty clay	14	Range: 8.2 to 9.0 Average: 8.50 Median: 8.50	<0.02	Range 0.103 to 6.29 Average: 0.92 Median: 0.22	Range 2.7 to 38.8 Average: 8.05 Median: 5.11	Range <0.02 to 4.85 Average: 2.49 Median: 2.49	48,027	High Risk
Action Criteria				**0.03**	**0.03**		**0.03**		

Notes:

[1] *Estimated volumes includes bulking factor from Dredge and Excavation Management Plan (Hall 2019)*

[2] *Includes estimated volume for rock (unit 4)*

[3]. *Refer to calculations in Attachment 1*

TAA *Total Actual Acidity* *ANC* *Acid Neutralising Capacity*

Scr *Chromium reducible sulphur* *Net Acidity includes ANC*

4 Port Kembla Chart Datum and Tidal Fluctuation

The Australian Tides Manual (Version 5 Oct 2018) summarises the various datums used around Australia, to predict tidal behaviour. An understanding of the tidal terminology is required when comparing chart datums, tidal effects on ASS and the potential for acid production. Table 2 below provides a definition of the relevant terminology and gives the average limits observed at Port Kembla and Figure 3 shows the tidal variation at Port Kembla from 1957 to 2020.

Table 2 Explanation of Terms and Datums Used in Australian Ports (BOM website see below)

Term	Purpose	Definition[1]	Port Kembla
Highest Astronomical Tide (HAT)	Landward limit of the tidal interface.	The highest level of water which can be predicted to occur under any combination of astronomical conditions.	2.33m CD (+1.458m AHD)[2]
Lowest Astronomical Tide (LAT)	Baseline for the purposes of defining Australia's maritime boundaries.	The lowest tide level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions.	-0.0217mCD (-0.655mAHD
Mean High Water (MHW)	Common datum for cadastral mapping and common limit for topographic mapping.	The average of all high waters observed	~1.80m CD (+1.458m AHD)[2]
Mean Sea Level	Average limit of tides	Arithmetic mean of hourly heights of sea over a sufficient period of time	~0.910m CD (0.0m AHD)[3,4]
Mean Low Water (MLW)	Used as the limit of Australian States As definition of 'low water'	Arithmetic mean of all low water heights of sea over a sufficient period of time	~0.20m CD (-0.655m AHD)[2]
Australian Height Datum (AHD)	National vertical Datum of Australia and refers to Australian Height Datum 71 for Australian Mainland	AHD71 is a surface that passes through approximate MSL measured between 1966 and 1968 at 30 tide gauges around the Australian mainland	0.0mAHD (0.872m CD)[3,4]
Chart Datum (CD)	Local Port Kembla Sea Level Datum	In use since at least 1957	0.0m CD (-0.872m AHD)[3,4]

Notes

[1] Definitions taken from ICSM (2018) Australian Tides manual v5

[2] Mean High Water and Mean Low Water taken from monthly recorded sea levels for Port Kembla - 1957 to 2020 http://www.bom.gov.au/ntc/IDO70000/IDO70000_60420_SLD.shtml

[3] Chart Datum from http://www.bom.gov.au/oceanography/projects/abslmp/data/data.shtml

[4] MSL at Port Kembla also given as 0.910m CD on http://www.bom.gov.au/ntc/IDO70000/IDO70000_60420_SLD.shtml

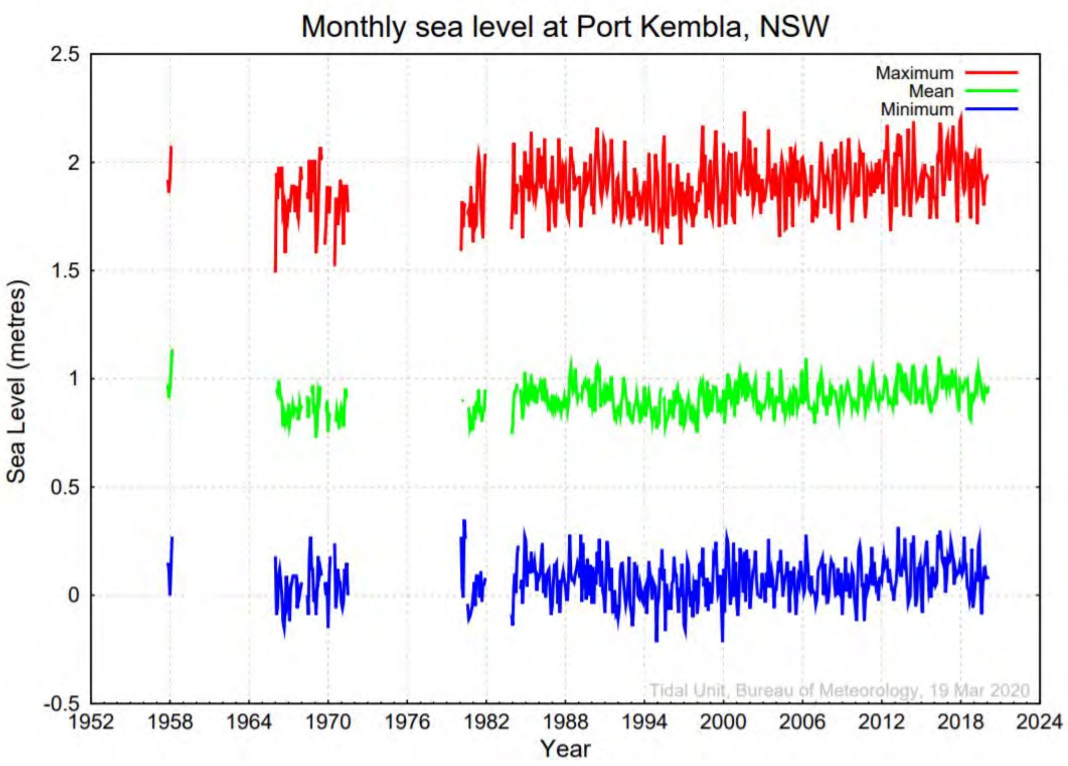


Figure 3 Monthly Tidal Range Port Kembla Harbour (source BOM website)

5 Proposed Dredging and Sediment Disposal

The current dredging plan is outlined within Port Kembla Gas Terminal Dredge and Excavation Management Plan (The Dredge Plan) prepared by Hall Contracting Pty Ltd 2019 (reference PKED-20D-PLA-1020-Rev-C dated 20/08/19).

Material from Berth 101 will be excavated using a combination of conventional land based machinery down to +1.0m CD, then by Barge Hopper Dredge (BHD) to a final depth of -13.3 CD. Units 2, 3 and 4, HM and HS will be transported to the Outer Harbour Disposal Spoil Containment Area (OHDSCA) via barges and placed below water within 24 hours, following excavation (Section 6.5 of the Dredge Plan).

Table 4.1 of the Dredge Plan shows the following:

- The perimeter bund will be constructed using fill material and sandy material from Units 1A and 1B assessed as low risk ASS;
- The maximum crest level for the bund will be 4.0m CD;
- The estimated final height of the high risk ASS, placed within the OHDSCA, will be about 0.74m CD;
- The high risk ASS in the OHDSCA will be capped with about 1.0m of low risk ASS and sandy material from Units 1A and 1B; and
- The final level, after capping, is given in Table 4.1 as about 2.0m CD.

The above information has been used to construct a conceptual model (Figure 4) of the material placement within the OHDSCA using the design heights specified within the Dredge Plan. Figure 4 includes the Port Kembla Chart Datum shown for MHW, MLW and MSL as well as the equivalent AHD levels.

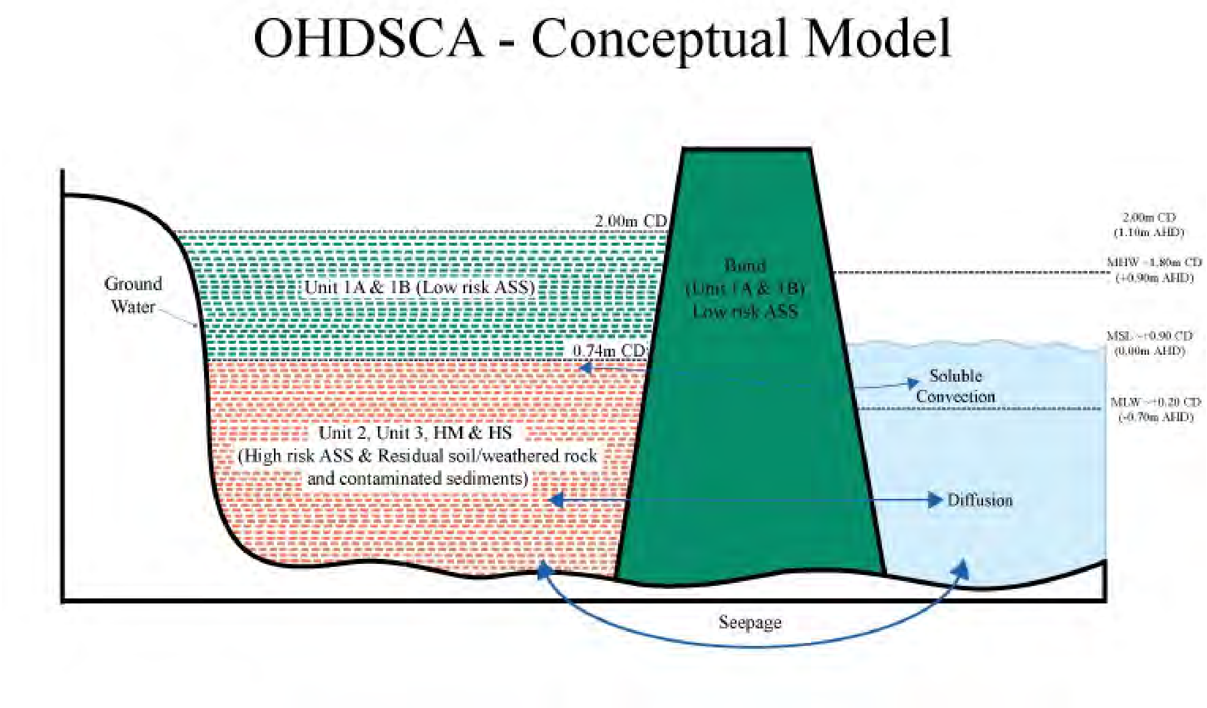


Figure 4 Conceptual Model for OHDSCA Port Kembla NSW

6 Discussion - ASS Management at the OHDSCA

6.1 Use of Low Risk ASS Units 1A and 1B in OHDSCA

Units 1A and 1B have been classified based on their ASS characteristics as shown in Table 1. These deposits represent former dredged harbour sands, silty sands and tidal sands used to construct Berth 101. There are occasional layers of higher risk ASS within these two units (referred to as Unit 1C), but these are considered to less than about 0.5m thick and represent a volume of less than about 10,000m^3 (refer Attachment A for volume calculations)

Average chromium reducible sulphur (Scr) concentration within Units 1A and 1B is 0.024%S and average ANC in Units 1A and 1B is 6.0%. Based on the low Scr concentrations (<0.03%S) and the average ANC, the net acidity for these Units is <0.02 %S, indicating that there is sufficient natural buffering capacity within these Units to account for acidification if it were to occur.

Worley Parsons noted clayey sand and silty sand layers up to about 1.0m thick within these Units but it is not known if these layers were ASS (Section 4.2.3 Worley Parsons 2018). It should be noted that Worley Parsons has interpreted Unit 1B from a geotechnical perspective, not based on the presence of ASS.

The high risk ASS layers (interpreted as Unit 1C) will be segregated and placed below mean sea level within the OHDSCA. This is consistent with the SCSB -JV (2020) Acid Sulfate Soil Management Plan (ASSMP rev C) Section 3.2.1. This section of the ASSMP indicates that about 3,600m^3 of high risk ASS (interpreted as Unit 1C in this letter report) will be segregated during land based and marine dredging. Should additional Unit 1C material (estimated as about 6,400m^3) be encountered, it will be managed as an unexpected find. A flow chart and management procedures for identification of Unit 1C material, are included in Attachment 2.

Units 1A and 1B will be removed from Berth 101 using excavators and the barge hopper dredge, then immediately transferred on barges and placed at the OHDSCA within 24 hours. This material will be used in the following ways:

- As structural fill forming the bund for the OHDSCA; and
- As a capping layer over the high risk ASS within the OHDSCA from about +0.74m CD to a maximum of +2.0m CD

Placement of the Units 1A and 1B at the OHDSCA presents the following risks:

- There is a risk of separation of finer grained silts and clays from the more alkaline sands and shell grit during placement of Units 1A and 1B at the OHDSCA meaning that ASS layers may not be able to take advantage of the buffering capacity of the sandy material. Considering that the majority of these sediments were originally dredged and placed to form Berth 101, there is no reason to suggest that removal and placement at the OHDSCA will alter their buffering capacity.
- Units 1A and 1B contain considerable shell grit which accounts for the high buffering capacity. Use of shell grit to treat ASS on land is not generally recommended given the large surface area and the tendency for the shell fragments to coat with iron deposits (Simpson et al 2018). This is considered only an issue where Units 1A and 1B will be placed above mean sea level. It is considered that the shell grit within Unit 1A and 1B will continue to be effective in the long term, regardless of where they are placed. The high percentage of ANC and the relatively low amount of ASS within these Units should negate the formation of significant iron deposits.
- There is a risk that the alkaline pH conditions within Units 1A and 1B would no longer be effective, once dredged and emplaced at the OHSDCA. The pH of the sands within Units 1A and 1B ranges between 7.9 and 9.8. Groundwater wells installed within these Units at Berth 101 gave a pH range from 7.5 to 8.5, indicating neutral to slightly alkaline conditions, which is consistent with sea water (pH 8.5). This indicates that the shells and carbonates within the sandy Unit 1A and 1B sediments has been effective in maintaining an alkaline pH over time.

The proposed management and placement of Unit 1A and Unit 1B is considered appropriate from the point of view of acid generation, for the following reasons:

- The acid neutralising capacity (ANC) of these Units can be up to 100 times the potential acidity (as shown by converting ANC to %S for Units 1A and 1B and comparing to Scr %S results). Simpson et al (2018) notes that when selecting site specific Action Criteria, a buffering capacity greater than 1.5 times the potential acidity, would be effective using a Factor of Safety of 1.5; and
- The effectiveness of the buffering capacity within the Units should not diminish as a result of excavation and placement at the OHDSCA and should remain adequate to account for oxidation of ASS, if it were to occur. There should be no excess export of acidity from either the perimeter bund or the capping layer.

6.2 Placement of High Risk ASS at OHDSCA

According to the 2019 Dredge Plan, high risk ASS will be placed below about +0.74m CD (-0.26m AHD) which is about 0.25m below mean sea level. The material to be placed at this level will comprise stratigraphic Unit 1C, Unit 2 (estuarine), Unit 3/4 (residual soil and weathered rock), Harbour muds (HM) and Harbour sediments (HS). Unit 1C, Unit 2, HM and HS are classified as high risk ASS and are likely to comprise about 80% of the dredged material placed below mean sea level (0.9m CD).

Figure 3 shows that mean low water is about +0.2m CD indicating that the sediments placed below about +0.74m CD will be subjected to a diurnal tidal range of about 0.5m. During part of the tidal cycle, the material above about +0.2m CD will therefore be subject to partial saturation, whereas material below about +0.2m CD will remain fully saturated.

6.3 Short and Long Term Process

6.3.1 Potential Short Term Acidification Process during Emplacement

There are two process that could cause short term oxidation and hence lead to acid production within the partially saturated zone, namely, advection and physical separation. Advection, or bulk movement of material by flow, is likely to be short lived and occur immediately as the material is end dumped within the OHDSCA. Physical separation is the process whereby clays and silts become separated from coarser material as they settle through the water column.

The risk of oxidation occurring through these two processes is greatest as the material is being placed and prior to placement of the capping layer. The potential for oxidation rises if sulfidic fines are re-suspended, or kept in contact with oxygenated water as in the tidal zone (Dear et al 2014).

The dredging programme is to last about 5 months and the sediments are to be capped with about 1.0m of material from Units 1A and 1B. It is assumed that within this time the fines would have settled and that the capping layer would restrict re-suspension. Given this timeframe and construction methodology, significant oxidation of the sediments during placement is considered unlikely.

Simpson et al (2018) notes that field studies have shown minimal pH changes during dredging as a result of buffering effects of sea water. Similarly, studies have shown that mixing with sea water results in low dissolved oxygen concentrations in dredged sediments (Simpson et al 2018).

The harbour muds will likely contain monosulphidic black ooze (MBO). Mono sulphides are known to be reactive if disturbed (Sullivan et al 2018). Given the dredging and placement time frames involved (24 to 48 hours), the risk from MBO is de-oxygenation of the water column during placement, rather than acidification.

Given that Port Kembla represents a large body of sea water open to the ocean and tidal influences, it is unlikely that deoxygenation as a result of disturbance of MBO, will occur. Routine monitoring of water quality, particularly dissolved oxygen, both inside the emplacement cell will be carried out during dredging and placement to access the impact from dredging of MBOs. It should be noted that maintenance dredging in Port Kembla and other Ports in Australia, regularly encounter MBOs and there is generally little impact on water quality.

6.3.2 Potential Long Term Acidification Processes

There are three long term process that could lead to oxygen transport and hence acidification:

- Diffusion on a molecular level.
- Increased dissolved oxygen through tidal fluctuations and transport of acid products via soluble convection.
- Oxidation of iron species (Fe II) and the mobilisation of acid.

Dear et al (2014) note that risk of oxidation can increase when oxygen transport mechanisms are not limited to diffusion. Generally oxygen will reach sulfide minerals in natural sediments via diffusion which, in the absence of marine biota, is a slow process (Huettel and Webster 2001, Precht et al 2004, Simpson et al 2018). Diffusion within the OHDSCA could lead to long term oxidation of sulphides but at rates that would easily be accounted for by sea water buffering resulting in no net acid production.

Convective flow requires a pressure gradient and it is possible that some oxidation of sulphides could occur above the Mean Low Water (MLW) via the transport of oxygen within pore spaces via tides.

The sediments are unlikely to completely dry out as a result of tidal movements and the amount of oxidation is considered minimal particularly following capping and consolidation of the sediments.

The potential influx of oxygen into the partially saturated sediments is unlikely to lead to long term export of acid products for the following reasons:

- The buffering effect of sea water;
- The additional buffering provided by the bund material (Units 1A and 1B);
- The clayey nature of the high risk ASS which means the risk of rapid drying is lessened;
- Long term settlement and consolidation of the sediments. Consolidation under the cap will likely decrease porosity forcing oxygen out of the sediments further reducing the potential of acidification. Settlement over time should also mean that the height above the MLW will lessen with time and lower the risk of partial saturation.

Based on the results, there is little evidence of sulfuric soils (pH below 4, jarosite or iron staining, TAA >18moles H+/tonne) within the high risk ASS sediments (Unit 1B, Unit 2, HM and HS). This suggest that they contain solid phase Fe II (ferrous iron) rather than Fe (III), ferric iron. Should Fe III species exist within the sediments, these would be reduced under tidal conditions (Johnson et al 2009) and therefore a negligible risk of further acidification from the presence of Fe III within the sediments.

6.4 Buffering Effects of Sea Water at the OHSCDA

Once placed, the material most at risk of acidification will be that which is placed last, above the MLW. This material will comprise a combination of Units 2 (high risk ASS) and Units 3 and 4 (non ASS), assuming that Unit 1C, HM and HS had been placed at a lower depth within the OHDSCA. Volume calculations (refer Attachment 1) indicate that about 55,000m^3 of excavated material from Berth 101 will be placed above MLW.

Placing the material at or below mean sea level (+0.9m CD) will result in partial saturation for material above the MLW and below +0.9m CD. Some oxidation of this partially saturated material is inevitable as it is a natural part of the sulphur cycle and occurs in similar tidal environments along the east coast. In natural tidal environments the rate of oxidation is usually less than the buffering effects of sea water.

Predicting oxidation rates for ASS can be difficult given the differing environments in which they form, differing oxygen pathways, moisture contents and pyrite concentrations. Sediments that are permanently kept below the water table for instance would be expected to have lower oxidation rates to those on a floodplain that are above the water table.

A paper prepared by Cook et al (2004) calculated a pyrite oxidation rate of 10 tonnes H_2SO_4/ha/year from a research site located about 25m inland from the Gold Coast in Queensland. The research was carried out on "*a heavy clay loam texture in the top 0.3 m, fine sandy light clay from 0.3 to 0.9m on top of silty clay. The top 2m of soil show signs of oxidation with a field pH of 3.5–4, in contrast to a pH >5 below 2 m".* These rates of oxidation concurred with other studies carried out at the Shoalhaven River floodplain in NSW (Blunden B, Indraratna B (1999).

Given that the Port Kembla sediments are unlikely to completely dry out and will remain within the tidal zone, the use of the Cook et al 2004 oxidation rates of 100 tonne H_2SO_4 per year are considered appropriate. Therefore, it is unlikely that these oxidation rates would be exceeded at Port Kembla.

Attachment 1 gives the calculation of sea water buffering and the parameters used. Based on the calculations, about 14% of Port Kembla Harbour (about 1,178 ML per year or 3.2ML per day) would be required for buffering the acid export. As Port Kembla Harbour is not a closed system, but open to the Pacific Ocean, a twice daily tidal exchange (assuming 1.0m tidal range) occurs which is about 16% or 1,383ML (8,439ML over 6.1m depth). The daily tidal exchange would be expected to be more than sufficient to negate the effects of oxidation. Based on the above, it is considered unlikely that oxidation of the material above MLW and below +0.9m CD, would have a detrimental effect on water quality within Port Kembla Harbour.

6.5 Buffering Effects of The OHSCDA Bund

The bund will be constructed using Units 1A and 1B. These units contain ANC (average 6.0% $CaCO_3$) and it is expected that the bund will supply additional buffering should oxidation of the material above MLW occur.

Attachment 1 includes calculations to show the effect of available buffering above MLW. Based on the average ANC within Units 1A and 1B and an assumed bund configuration (700m long X 10m wide X 0.55m depth), the bund material placed above the MLW and below +0.9 CD, will have sufficient capacity to account for an oxidation rate of about 100 tonnes of acid per year. The amount of buffering includes a factor of safety (FoS) above 4, which is in excess of FoS of 1.5 recommended by Simpson (2018).

6.5 Precedent and Scientific Principles

6.5.1 Port Of Gladstone

Placement of the high risk ASS below the mean sea level has been successfully achieved in the past. Simpson et al 2018 presents a case study from Gladstone Harbour, Queensland where dredged ASS sediments were successfully placed up to, but not exceeding the mean sea level (0.0m AHD). The Port of Gladstone required new port facilities for expansion and dredging comprised deepening and widening of existing channels, swing basins, and berth pockets. Further information is contained within Chapter 5 of the Environmental Impact Statement (EIS) prepared by GHD in 2009.

Table 3 provides a summary of the main parameters measured at the Port of Gladstone related to ASS. It should be noted that these results have a similar range and average as the Port Kembla sediments.

Table 3 Summary of Laboratory Results Sediments Gladstone Harbour Project

	pH_{KCL}	pH_{OX}	Scr (%S)	ANC (%)
Minimum	5.00	0.40	0.02	0.01
Maximum	9.80	9.40	1.62	55.4
Average	8.53	5.26	0.40	5.14
Mean	8.70	5.77	0.38	4.48

It was recognised that oxidation was a risk should the sediments dry out and management procedures were in place to ensure sediments were kept moist throughout the dredging process. Sediments with an ANC 1.5 to 3 × %S concentrations were placed without neutralisation, either below water or above the mean seal level. Materials with greater ANC tended to be placed above the mean sea level.

The higher risk ASS were placed within a containment cell below mean sea level (0.0m AHD) where it was considered that drying out and hence sulfide oxidation, would be minimal and buffered by sea water.

The management plan for the dredged sediments at Gladstone Harbour was similar to that proposed at Port Kembla. Sediments with sufficient buffering capacity were placed, without neutralisation, above mean sea level (similar to that proposed for Units 1A and 1B). High risk ASS were dredged and placed in such a way as to minimise exposure time and then deposited below mean sea level in a similar way to that proposed for the Unit 2 material, HM and HS at Port Kembla.

6.5.2 Scientific Principles

In addition to the above precedent, the CRC Care Technical Document No 41 (CRC Care 2018) noted the following scientific principles upon which the East Trinity ASS remediation at Cairns Queensland, was based. Whilst there was some acid export initially when the tidal influence returned, the overall effect of tidal inundation was successful in reversing the trend. The experience at East Trinity showed that the buffering effects of sea water, based on a diurnal tides, was an effective and successful method in remediating acidic environments. The tidal effects were measured up to 0.5m AHD (CRC Care 2018).

The scientific principles are considered relevant to the placement of the high risk ASS at the OHDSCA. This is because of the similar tidal setting and the use of high buffering capacity material within the bund and capping layer at the OHDSCA corresponds in some way to the addition of hydrated lime to the impacted waterways at East Trinity.

The CRC Care (2018) established scientific principles were:

- *“tidal exchange was expected to hydraulically suppress acid export from the soil and buffer existing water acidity;*
- *maintenance of daily tidal exchange will raise the level of the permanent water table and hence ultimately halt the process of oxidation of the pyritic layers, thereby preventing the generation of more acid from these areas;*
- *the addition of hydrated lime ($Ca(OH)_2$) to the waterways will not only enhance the buffering capacity of tidal waters but will counteract the acidity being transported off-site if or when an adverse event is detected;”*

7 Conclusion

Placement below mean sea level (0.0m AHD) is a proven and successful management technique for disposal of high risk ASS, provided that the sediments remain saturated during excavation, transport and placement. The disposal method has been successfully achieved in Gladstone Harbour Queensland for disposal of ASS during capital dredging works.

In addition the scientific principles related to ASS remediation of formerly degraded wetlands are relevant to the Port Kembla Harbour emplacement, particularly as the perimeter bund, which will contain the material has considerable buffering capacity, similar to the addition of hydrated lime to waterways.

Based on the current configuration of the OHDSCA, it is considered that placement of the high risk ASS below mean sea level 0.9m CD (0.0m AHD) will not lead to significant oxidation of sulphides and hence long term environmental harm. The mechanisms that could produce acidification during excavation, transport and placement, are not considered probable given the short duration of exposure. Once placed, the combined buffering effects of both sea water and the material used as the bund, have been shown to be sufficient to account for the anticipated acid load..

It has been noted through this review that an estimate of long term settlement of the material within the OHSDCA has not been made. The estimate of long term settlement is a critical factor in assessing the long term potential for acidification. Should the material below the cap settle below the MLW level, then the material will remain saturated and have no potential for acidification.

8 References

Australian Tides Manual Special Publication No 9 Version 5 2018 prepared by Permanent Committee on Tides and Mean Sea Level

Blunden B, Indraratna B (1999) Pyrite oxidation model for assessing ground-water management strategies in acid sulfate soils. *Journal of Geotechnical and Geoenvironmental Engineering* **127**, 146–157.

CRC CARE 2018, *Remediating and managing coastal acid sulfate soils using Lime Assisted Tidal Exchange (LATE) at East Trinity, Queensland*, CRC CARE Technical Report no. 41, CRC of Contamination Assessment and Remediation of the Environment, Newcastle, Australia

Cook F.J, Dobos S.K, Carlin G.D, and Millar G.E. 2004, *Oxidation rate of pyrite in acid sulfate soils: In situ measurements and Modelling* Australian Journal of Soil Research, 2004, **42**, 499–507 CSIRO Publishing

Dear, S-E., Ahern, C. R., O'Brien, L. E., Dobos, S. K., McElnea, A. E., Moore, N. G. & Watling, K. M., (2014). *Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines*.

GHD Report Reference 42/15387/52021 (2009) *Western Basin Dredging and Disposal Project EIS Chapter 5 Lands* prepared for Gladstone Ports Corporation

GHD *Sediment and Contamination Assessment Report Port Kembla Gas Terminal* dated November 2018a

GHD *Contamination Assessment Report East Coast Gas Project* Prepared for Australian Industrial Energy Report Reference 2127477 dated October 2018b

Luke C. Jeffrey & Damien T. Maher & Isaac R. Santos & Ashly McMahon & Douglas R. Tait *Groundwater, Acid and Carbon Dioxide Dynamics Along a Coastal Wetland, Lake and Estuary Continuum* in Estuaries and Coasts 39:1325–1344 (2016

Hall Contracting Pty Ltd Port Kembla Gas Terminal, *Dredging and Excavation Plan* Report Reference PKED-20D-PLA-1020-Rev C dated August 2019

Huettel M., Webster I. T., *Pore Water Flow in Permeable Sediments* Part Chapter 7 in Benthic Boundary Layer eds Boudreau, B. P and Jorgensen B. B. Oxford University Press 2001

Scott G. Johnston, Richard T. Bush , Leigh A. Sullivan, Edward D. Burtona, Douglas Smith , Michelle A. Martens, Angus E. McElnea, Col R. Ahern, Bernard Powell, Luisa P. Stephens, Steve T. Wilbraham, Simon van Heel *Changes in water quality following tidal inundation of coastal lowland acid sulfate soil landscapes* in Estuarine, Coastal and Shelf Science Journal 81 (2009) 257–266

Precht E., Franke U., Polerecky L., and Huettel M. *Oxygen dynamics in permeable sediments with wave-driven pore water exchange* 49(3), 2004, 693-705 American Society of Limnology and Oceanography.

Scott G. Johnston, Richard T. Bush, Leigh A. Sullivan, Edward D. Burton, Douglas Smith B, Michelle A. Martens, Angus E. McElnea, Col R. Ahern, Bernard Powell, Luisa P. Stephens, Steve T. Wilbraham, Simon van Heel *Changes in water quality following tidal inundation of coastal lowland acid sulfate soil landscapes* Journal of Estuarine Coastal and Shelf Science 81 (2009) 257–266

SCSB-Joint Venture Port Kembla Gas Terminal Acid Sulphate Soil Management Plan Reference SCSB-AIE-PKGT-ENV-EMP-008 Rev C dated 5th June 2020

Simpson, SL, Mosley, L, Batley, GE and Shand, P 2018, *National Acid sulfate soils guidance: Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management,* Department of Agriculture and Water Resources, Canberra, ACT.

Sullivan, L, Ward, N, Toppler, N and Lancaster, G 2018a, *National Acid Sulfate Soils guidance: National acid sulfate soils sampling and identification methods manual,* Department of Agriculture and Water Resources, Canberra ACT.

Sullivan, LA, Ward, NJ, Bush, RT, Toppler, NR, Choppala, G 2018b, *National Acid Sulfate soils Guidance: Overview and management of monosulfidic black ooze (MBO) accumulations in waterways and wetlands,* Department of Agriculture and Water Resources, Canberra.

Sullivan, L, Ward, N, Toppler, N and Lancaster, G 2018c, *National Acid Sulfate Soils Guidance: National acid sulfate soils identification and laboratory methods manual* Department of Agriculture and Water Resources, Canberra ACT

Thompson T.G. and Bonnar R.U *The Buffer Capacity of Sea Water* Department of Chemistry and Oceanographic Laboratories, University of Washington, Seattle. Published in the Journal of Industrial and Engineering Chemistry, October 15 1931.

Wilson B.P., White I., Melville M D*. Floodplain hydrology, acid discharge and change in water quality associated with a drained acid sulfate soil,* in Marine Freshwater Research published by CSIRO 1999

Worley Parsons Geotechnical Investigation Interpretative Report Port Kembla Gas Terminal Report ref 401010-01496 - MA-REP-1404 October 2018

Websites consulted

http://www.bom.gov.au/ntc/IDO70000/IDO70000_60420_SLD.shtml

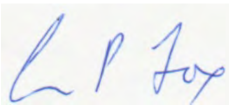
https://www.environment.nsw.gov.au/Topics/Water/Estuaries/Estuaries-of-NSW/Port-Kembla

http://www.bom.gov.au/oceanography/projects/abslmp/data/data.shtml

*   *   *

We trust the information provided in this letter is suitable for your current needs. If you have any questions please do not hesitate to contact the undersigned.

For and on behalf of



Laurence Fox (Director) CPSS CSAM

Fox Environmental Consulting Pty Ltd

Attachment 1 Volume Calculations

Attachment 2 Management Procedures Units 1A and 1B

Attachment 1

1. Unit 1 C Volume Calculations

Unit 1C occurs as lenses, pockets or a minor component throughout Unit 1A and Unit1B. This occurrence was recorded on borehole logs as a thickness or percentage that was observed at the time of drilling. Based on the logs from GHD's contamination assessment and Worley Parsons' geotechnical investigation, an average thickness of Unit 1A and Unit 1B was calculated and the ratio of these two thicknesses was then used to estimate a percentage of Unit 1C.

This percentage was multiplied by the estimated volume of Unit 1A and Unit 1B, which was provided in the Dredge and Excavation Management Plan prepared by Hall dated 23/8/2019. The table below provides a summary of these calculations based on individual data sets, that is GHD or Worley Parsons, and a combined data set. Individual data sets were considered to assess potential sensitivity that may exist and influence the estimated volumes. Because Worley Parsons boreholes were deeper, the average thickness of Unit 1A and 1B will be greater, which has provided a lower percentage for Unit 1C. However, the difference in the estimated volume between the GHD dataset and the combined dataset was not significant suggesting a relatively low sensitivity.

Assessment of Unit 1C Thickness

Source	N	Average thickness for Unit 1A and 1B (m)	Average thickness for Unit 1C (m)	Percent of Unit 1C based on average thickness	No. Borehole Total Depth 5 m	No. Borehole Total Depth 6 m to 10 m	No. Borehole Total Depth > 10 m	Estimated Unit 1A and 1B volume (m^3)	Estimated Unit 1C volume (m^3)
GHD	38	4.73	0.135	2.81%	24	14	0	283,747	7,965
Worley Parsons	10	13.56	0.167	1.48%	0	0	10	283,747	4,212
Combined	48	6.46	0.141	2.54%	24	14	10	283,747	7,199

2 Volume of Material above Mean Low Water (MLW)

The volume of material above MLW will be that material that is most at risk of oxidation. The effects of the diurnal tides with respect to horizontal penetration into OHDSCA is unknown and the degree of partial saturation is also unknown. The calculation below has assumed all material above MLW will be partially saturated and hence be at risk of oxidation. This is considered a conservative approach.

The calculation is based on the following parameters:

- Mean Sean Level 0.9m CD
- Height of emplaced sediments 0.74m CD
- Mean Low Water is about 0.2m CD
- Height of material above MLW about 0.55m
- Area of OHSCDA about 10ha (based on Figure 3 of Dredge Plan (Hall 2019))
- Volume of material above MLW = 10ha x 0.55m = 55,000m^3 (about 82,000 tonnes assuming a density of 1.5t/m^3 – density based on Table 5.1 Sullivan 2018c)

3 Calculation of Seawater Buffering

Calculation inputs:

For the purposes of calculating the potential acidity load and the buffering effects of sea water, the following has been assumed:

- Area of OHSCDA 10 ha (based on Figure 3 of the Dredge and Excavation Plan).
- Emplaced sediments assumed oxidation rate - 100 tonnes H_2SO_4/year (over 10 ha) based on 10 tonnes H_2SO_4 per ha/year (Cook et al 2004)
- Buffering effects of sea water 1.73 millimoles/L (Thomson and Bonner 1931)
- Volume of water within Port Kembla 8439ML (https://www.environment.nsw.gov.au/Topics/Water/Estuaries/Estuaries-of-NSW/Port-Kembla)

Buffering calculation:

100 tonnes of H_2SO_4 equates to 32.69 tonnes of sulphur or 32,690,000 gms (molecular weight of S is 32.065 gms

Moles of S = 32,690,000 divided by 32.065 = 1,019,491 moles (1.019 x10^9 millimoles S)

Each mole of S produces 2 moles H+ = 2.039 x10^9 millimoles H+

Buffering capacity sea water is 1.73 millimoles/L (Thompson and Bonnar 1931)

Therefore, the volume of sea water required to neutralise 2.039 x 10^9 millimoles H+ = 2.039 x10^9 millimoles H+ divided by 1.73 = 1,178,603,072 L =1,178ML. This is approximately 14% of the total volume available in Port Kembla Harbour.

4. Calculation of Buffering Effects of Bund

Average ANC of bund material = 6.0% CaCO3 (refer Table 1)

Bund Material equivalent moles H+/tonne = 6.0 x 199.8 = 1,198.8 moles H+/tonne (conversion is per Sullivan et al 2018c Appendix E)

Moles H+ in 100 tonnes of H_2SO_4

(Molecular weight of H+ divided by molecular weight of acid) x 100 x 2 = (1.0078/98.079) x 100 x 2 = 2.056 tonnes H+ (2.056 X 10^6 gms H+)

Moles of H+ = 2.056 x 10^6 gms H+ divided by 1.0078 = 2.039 x 10^6 moles H+

Amount of tonnes of bund material required for neutralisation = 2.039 x 10^6 moles H+ divided by 1,198.8 moles H+/tonne = 1,700.85 tonnes

Amount of material in bund above MLW = 700 long x 10m wide by 0.55m high x 1.8 t/m^3 = 6,930 tonnes

Notes:

- Bund configuration based on Fig 6-3 and Section 6.2 of the Emplacement Cell Report (ref PKEM-20D-PLA-1010 Rev C - 10m wide crest height at 2.0m CD

- Density based on Table 5.1 Sullivan 2018c)

Attachment 2

<u>Addendum to ASSMP</u>

Management Procedures during Excavation and Dredging of Unit 1A, 1B and 1C will include the following:

Training and Responsibilities

The Contractor's Environmental Manager should appoint an appropriately trained person who is responsible for managing the ASS issues during the dredging activities. If required, a suitably qualified Environmental Consultant could be engaged to assist or train the Contractor in the identification of ASS.

This person should be familiar with:

- Council and other relevant statutory requirements;
- Recognition of dredged ASS sediments;
- Acid sulfate soil testing and treatment procedures;
- Onsite management of ASS materials, including implementing management procedures.

The classification of ASS materials during dredging / excavation of Unit 1A, 1B and 1C should be carried out by personnel trained in the identification of ASS. The classification will be based on visual classification and the field screening test. A flow chart (below) has been developed to aid in the identification and appropriate management of ASS encountered in Units 1A, 1B and 1C.

Visual Classification

The preliminary visual checking of potential ASS lenses and pockets with Units 1A and 1B will be based on material type, colour and consistency. The following classifications apply to the excavated and dredged sediments:

- Unit1A and 1B: SAND, brown, pale brown, yellow, orange, fine to coarse grained, shell fragments, fine to coarse gravel, silt bands and layers, clayey sand layers, trace iron stained sand, fine black sand layers (probable heavy mineral sands and non ASS), rounded to sub-rounded gravel, clay lenses and layers. Refer to Photo 1 below.
- Unit 1C: Clayey SAND, black, dark grey, grey, fine to coarse grained sand, medium to high plasticity clay, trace silt, shell fragments, gravel. Gravelly CLAY, black, dark grey, grey, low to medium plasticity, fine to coarse grained angular to sub-angular gravel, trace of fine to coarse grained sand. Refer to Photos 2 and 3 below.
- Unit 2: CLAY, grey, dark grey and green high plasticity, trace of fine coarse grained, trace of gravel, rounded cobbles, Silty SAND , dark grey, grey, brown, fine to coarse sand, trace of fine gravel, shell fragments. Refer to Photo 4 below.
- Residual soils (Unit 3) and weathered rock (Unit 4) are not classified as ASS. Residual soils and weathered rock are typically stiff to very stiff clays, dark brown mottled dark green-grey, pale brown and brown-orange.

Field Screening

A field screening test using hydrogen peroxide (H_2O_2) should be performed regularly on the dredged/excavated Unit 1A, 1B and Unit 1C sediments. The test will be used to assess the potential presence of ASS as per the flow chart (below). The field screening test will be undertaken based on Appendix I of the Acid Sulfate Soils Assessment Guidelines (Ahern et al, 1998a), or equivalent. Soils that record a pH of below 4, following oxidation with H_2O_2, will be managed as acid sulfate soils as shown in the flow chart (below).


Photo 1: Example of Unit 1A and 1B

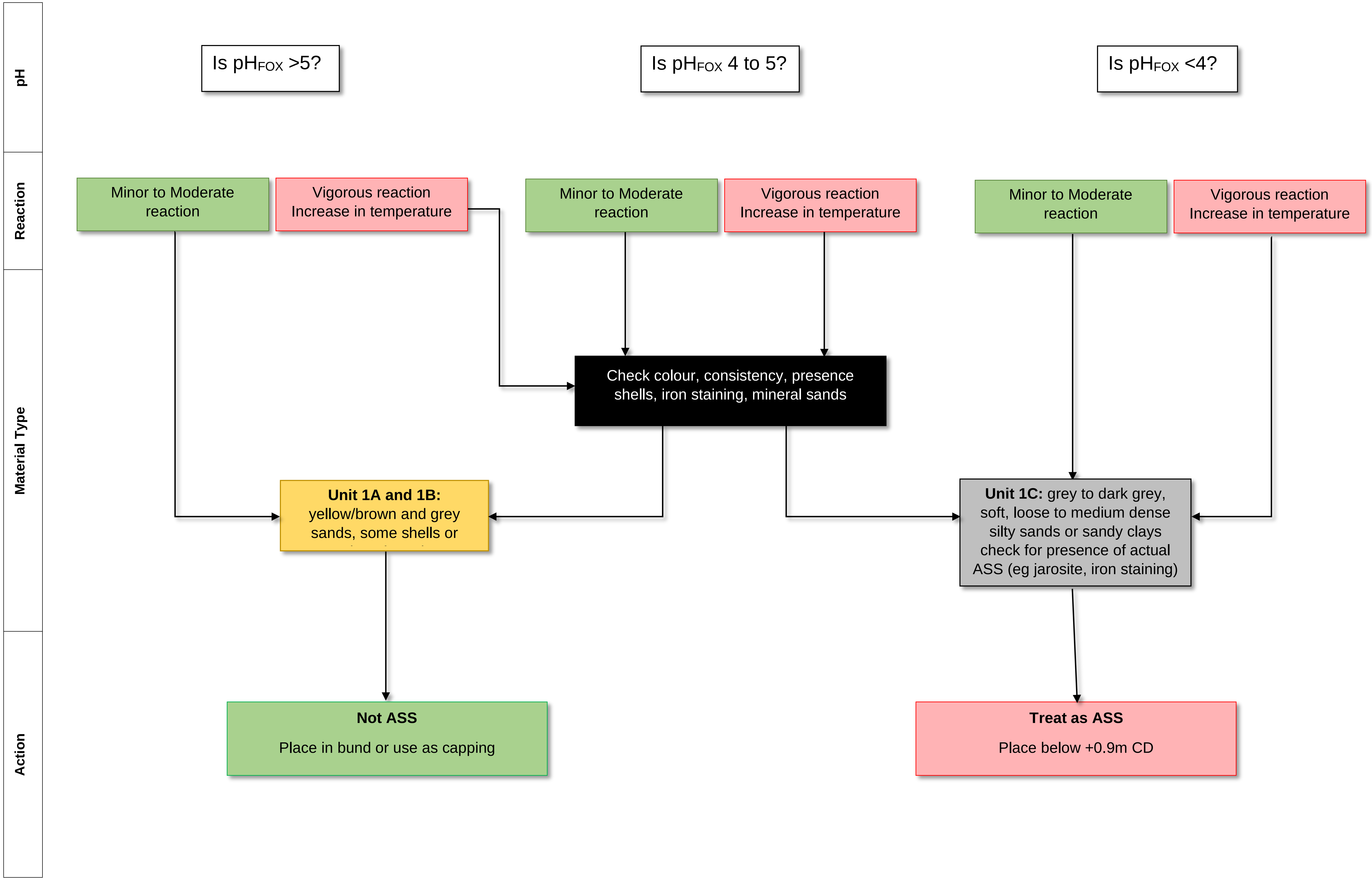

Photo 2: Example of Unit 1C

Photo 3: Example of Unit 1C occurring as a thin layer in Units 1A and 1B

Photo 4: Example of Unit 2 – estuarine

ASS DECISION MATRIX

Units 1A /1B and 1C based on field screening visual



Appendix B

Photographic Representation of Stratigraphic Units

APPENDIX B – PHOTOGRAPHIC REPRESENTATION OF STRATIGRAPHIC UNITS

Photo 1: Example of Unit 1A and 1B

Photo 2: Example of Unit 1C

Photo 3: Example of Unit 1C occurring as a thin layer in Units 1A and 1B

Photo 4: Example of Unit 2 – estuarine

Appendix C

Summary of Scr results

Table 15: Summary of Chromium Reducible Sulphur (Scr) results

Sample ID	Sample depth - base of sample (m bgs)	Surface elevation (m PKHD)	Sample elevation (base of sample - m PKHD)	Unit ID	pH $_{KCL}$	TAA (%)	Scr (%)	ANC % (CaCO3)	ANC % (%S)	Net Acidity (%)	Liming Rate (kg $CaCO_3$ per tonne)	pH-F (Field pH test)*	pH-FOX (Field pH Peroxide test)*	Reaction Ratings*	Change
GBH06 0.5-0.7	0.70	6.71	6.01	FILL	9.6	<0.02	0.008	9.4	3.0	<0.02	<1	9.4	8.7	4	0.7
GBH02 0.4-0.6	0.60	5.74	5.14	1B	12	<0.02	0.42	55	18	<0.02	<1	9.4	7.1	4	2.3
GBH12 1.7-2.0	2.00	6.28	4.28	1A	9	<0.02	0.02	1.4	0.44	<0.02	<1	8.9	6.9	4	2.0
GBH34 0.6-0.8	0.80	4.83	4.03	FILL	9.5	<0.02	0.011	3.3	1.1	<0.02	<1	9.7	9.3	4	0.4
GBH31 1.7-2.0	2.00	5.73	3.73	1A	9.5	<0.02	0.008	2.6	0.83	<0.02	<1	9.5	8.2	4	1.3
GBH09 2.2-2.4	2.40	5.94	3.54	1A	9.5	<0.02	<0.005	1.3	0.42	<0.02	<1	9.4	8.7	4	0.7
GBH11 2.1-2.3	2.30	5.84	3.54	1A	9.5	<0.02	0.009	1.6	0.50	<0.02	<1	9.6	7.5	4	2.1
GBH07 1.7-2.0	2.00	5.39	3.39	1A	9.5	<0.02	0.006	1.4	0.44	<0.02	<1	9.3	7.3	2	2.0
GBH03 2.3-2.5	2.50	5.84	3.34	1A	9.6	<0.02	0.007	1.8	0.58	<0.02	<1	8.4	8.5	4	-0.1
GBH08 2.2-2.4	2.40	5.70	3.30	1A	9.6	<0.02	<0.005	4.4	1.4	<0.02	<1	9.5	7.6	4	1.9
GBH38 2.7-3.0	3.00	6.30	3.30	1A	9.4	<0.02	0.011	6.4	2	<0.02	<1	9.3	7.7	4	1.6
GBH14 2.7-3.0	3.00	6.10	3.10	1A	9.6	<0.02	<0.005	4.4	1.4	<0.02	<1	9.3	7.5	2	1.8
GBH05 1.7-2.7	2.70	5.77	3.07	1A	9.4	<0.02	<0.005	3.0	0.97	<0.02	<1	9.5	8.2	4	1.3
GBH27 1.7-2.0	2.00	4.93	2.93	1A/1B	9.7	<0.02	<0.005	4.6	1.5	<0.02	<1	8.7	7.8	4	0.9
GBH26 1.8-2.0	2.00	4.88	2.88	1A	9.7	<0.02	0.013	5.1	1.7	<0.02	<1	9.1	7.4	4	1.7
GBH04 2.7-3.0	3.00	5.78	2.78	1A	8.1	<0.02	<0.005	0.54	0.17	<0.02	<1	8.8	7.5	4	1.3
GBH31 2.7-3.0	3.00	5.73	2.73	1A	9.7	<0.02	0.006	1.5	0.47	<0.02	<1	9.6	7.7	4	1.9
GBH06 3.7-4.0	4.00	6.71	2.71	1A	9.7	<0.02	<0.005	3.2	1.0	<0.02	<1	9.5	7.9	4	1.6
GBH01 2.7-3.0	3.00	5.69	2.69	1A	9.5	<0.02	0.007	1.3	0.41	<0.02	<1	12.0	11.0	4	1.0
GBH18 2.7-3.0	3.00	5.46	2.46	1A	9.8	<0.02	0.012	5.7	1.8	<0.02	<1	9.6	9.4	4	0.2
GBH28 2.3-2.5	2.50	4.92	2.42	1A	9.6	<0.02	0.007	3.8	1.2	<0.02	<1	9.1	7.1	4	2.0
GBH19 2.7-3.0	3.00	5.36	2.36	1A	9.8	<0.02	0.008	8.5	2.7	<0.02	<1	9.6	8.1	4	1.5
GBH37 2.4-2.6	2.60	4.95	2.35	1A	9.8	<0.02	<0.005	7.9	2.5	<0.02	<1	9.5	9.8	4	-0.3
GBH29 2.4-2.6	2.60	4.91	2.31	1A	9.7	<0.02	<0.005	7.7	2.5	<0.02	<1	9.6	7.3	4	2.3
GBH20 1.7-2.0	2.00	4.07	2.07	1A	9.8	<0.02	0.01	7.1	2.3	<0.02	<1	9.3	9.0	4	0.3
GBH25 3.5-3.7	3.70	5.68	1.98	1A	9.8	<0.02	0.013	6.4	2.0	<0.02	<1	9.5	10.0	4	-0.5
GBH13 2.7-3.0	3.00	4.94	1.94	1A	9.6	<0.02	<0.005	7.2	2.3	<0.02	<1	9.4	7.8	4	1.6
GBH30 3.8-4.0	4.00	5.90	1.90	1A	9.7	<0.02	<0.005	7.1	2.3	<0.02	<1	9.6	7.4	4	2.2
GBH15 3.7-4.0	4.00	5.89	1.89	1A	9.7	<0.02	<0.005	3.5	1.1	<0.02	<1	9.3	7.2	4	2.1
GBH26 2.8-3.0	3.00	4.88	1.88	1A	9.7	<0.02	0.011	3.9	1.2	<0.02	<1	9.3	7.5	4	1.8
GBH16 3.7-4.0	4.00	5.69	1.69	1A	9.8	<0.02	<0.005	7.4	2.4	<0.02	<1	9.7	7.9	4	1.8
GBH17 3.7-4.0	4.00	5.61	1.61	1A	9.8	<0.02	0.014	7.7	2.5	<0.02	<1	9.6	9.3	4	0.3
GBH39 4.5-4.7	4.70	6.25	1.55	1A/1B	9.7	<0.02	<0.005	6.4	2.0	<0.02	<1	8.7	7.3	4	1.4
GBH23 2.7-3.0	3.00	4.54	1.54	1A	9.8	<0.02	0.013	6.5	2.1	<0.02	<1	9.0	10.0	4	-1.0
GBH10 4.4-4.6	4.60	6.11	1.51	1A/1B	10	<0.02	0.049	8.5	2.7	<0.02	<1	10.0	8.7	4	1.3
GBH35 4.5-4.7	4.70	6.10	1.40	1A	9.7	<0.02	<0.005	7.5	2.4	<0.02	<1	9.6	8.2	4	1.4
GBH32 4.1-4.2	4.20	5.58	1.38	1A	9.8	<0.02	<0.005	7.8	2.5	<0.02	<1	9.4	10.0	4	-0.6
GBH19 3.7-4.0	4.00	5.36	1.36	1A	9.8	<0.02	0.008	11	3.6	<0.02	<1	9.5	8.2	4	1.3
GBH02 4.2-4.45	4.45	5.74	1.29	1B	8.4	<0.02	1.1	17	5.3	<0.02	<1	9.5	7.8	4	1.7
GBH33 3.8-4.0	4.00	4.93	0.93	1A	9.8	<0.02	<0.005	8.9	2.9	<0.02	<1	9.6	10.0	4	-0.4
GBH05 4.7-5.0	5.00	5.77	0.77	1A	9.7	<0.02	0.008	9.2	3.0	<0.02	<1	9.5	7.9	1	1.6

Summary

Unit ID
FILL
1A
1B
1A/1B
2

Elevation Range (m PKHD)

6 - 4.0 m
<4.0 - 1.5
<1.5 - -1.0
<-1.0 - -3.5
<-3.5 - -6.0
<-6 - -9

GBH02 4.8-5.0	5.00	5.74	0.74	1A	9.7	<0.02	<0.005	10	3.3	<0.02	<1	7.6	8.0	4	-0.4	
GBH21 3.7-4.0	4.00	4.65	0.65	1A	9.8	<0.02	0.011	9.9	3.2	<0.02	<1	9.4	8.4	4	1.0	
GBH18 4.7-5.0	5.00	5.46	0.46	1A	9.8	<0.02	0.009	8.9	2.9	<0.02	<1	9.6	7.7	4	1.9	
GBH07 4.7-5.0	5.00	5.39	0.39	1A	9.7	<0.02	<0.005	6.3	2.0	<0.02	<1	8.9	**2.8**	4	6.1	
GBH22 4.2-4.5	4.50	4.60	0.10	1A	9.7	<0.02	0.015	5.9	1.9	<0.02	<1	9.2	8.2	4	1.0	
GBH27 4.7-5.0	5.00	4.93	-0.07	1A	9.8	<0.02	<0.005	10	3.3	<0.02	<1	9.5	7.7	2	1.8	
GBH33 4.8-5.0	5.00	4.93	-0.07	1A	9.8	<0.02	<0.005	6.8	2.2	<0.02	<1	9.4	7.9	4	1.5	
GBH34 4.8-5.0	5.00	4.83	-0.17	1A	9.7	<0.02	<0.005	6.6	2.1	<0.02	<1	9.1	11.0	4	-1.9	
BH11 4.5-5.0	5.00	4.82	-0.18	1A	9.7	<0.02	<0.005	7.6	2.4	<0.02	<1	6.5	6.9	4	-0.4	
GBH24 4.7-4.9	4.90	4.56	-0.34	1B	9.6	<0.02	0.042	7.4	2.4	<0.02	<1	9.1	7.3	4	1.8	
GBH20 4.7-5.0	5.00	4.07	-0.93	1A	9.8	<0.02	0.014	14	4.4	<0.02	<1	9.3	9.1	4	0.2	
GBH13 5.7-6.0	6.00	4.94	-1.06	1A	9.7	<0.02	<0.005	8.0	2.6	<0.02	<1	9.2	7.3	4	1.9	This w
GBH06 7.7-8.0	8.00	6.71	-1.29	1A	9.8	<0.02	0.018	16	5	<0.02	<1	8.4	7.2	2	1.2	
GBH05 7.7-8.0	8.00	5.77	-2.23	1A	9.7	<0.02	0.009	15	4.8	<0.02	<1	9.5	9.6	4	-0.1	
GBH01 7.7-8.0	8.00	5.69	-2.31	2	8.4	<0.02	<0.005	0.5	0.16	<0.02	<1	8.3	6.3	4	2.0	
GBH06 9.7-10.0	10.00	6.71	-3.29	2	7.3	<0.02	<0.005	0.53	0.17	<0.02	<1	9.2	7.5	4	1.7	
GBH07 8.7-9.0	9.00	5.39	-3.61	1A	8.4	<0.02	0.33	5.9	1.9	<0.02	<1	8.0	**2.1**	4	5.9	
GBH16 9.7-10.0	10.00	5.69	-4.31	1A	9	<0.02	0.041	2.0	0.64	<0.02	<1	9.0	7.2	2	1.8	
GBH20 8.7-9.0	9.00	4.07	-4.93	1A	9.4	<0.02	0.017	7.9	2.5	<0.02	<1	8.6	7.3	2	1.3	
GBH27 9.7-10.0	10.00	4.93	-5.07	1A	7.9	<0.02	0.011	0.51	0.16	<0.02	<1	8.1	6.4	2	1.7	
GBH23 9.7-10.0	10.00	4.54	-5.46	1A	9.3	<0.02	0.066	6.7	2.1	<0.02	<1	8.6	8.1	4	0.5	
BH11 12.0-12.25	12.25	4.82	-7.43	2	6.9	<0.02	0.065	0.3	0.1	<0.02	<1	6.2	6.2	4	0.0	
BH09 15.15-15.25	15.25	5.99	-9.26	2	5.5	<0.02	0.6	n/a	n/a	0.6	28	7.9	**2.6**	4	5.3	
BH11 18.1-18.5	18.50	4.82	-13.68	2	6.5	<0.02	<0.005			<0.02	<1	9.8	8.2	4	1.6	
BH05 20.0-20.45	20.45	6.06	-14.39	2	7.2	<0.02	0.012	0.53	0.17	<0.02	<1	9.0	9.4	4	-0.4	
BH11 19.6-20.0	20.00	4.82	-15.18	2	6	<0.02	<0.005	n/a	n/a	<0.02	<1	8.6	7.1	1	1.5	
ACTION CRITERIA						**0.03**	**0.03**			**0.03**		**4.5**	**3.5**			
Table notes: exceeding concentrations highlighted in orange.																
GBH163_9.5-10	10	5.048	-4.95	1B								8.3	5.5	2	2.8	
GBH170_9.5_10	10	4.833	-5.17	1A/1B?								7.3	4.3	2	3.0	
GBH167_10.0_10.7	10.7	5.047	-5.65	1A?								8.0	5.3	2	2.7	
GBH171_11.-11.5	11.5	4.857	-6.64	1A/1B?								8.0	5.4	2	2.6	
GBH171_12.0_12.5	12.5	4.857	-7.64	3								8.2	5.6	2	2.6	
GBH164_12.0_12.5	12.5	4.289	-8.21									7.9	**2.1**	4	5.8	
GBH163_13.0_13.5	13.5	5.048	-8.45	2?								7.6	5.3	4	2.3	
GBH178_13.5_14	14	4.813	-9.19	1B								7.9	3.8	2	4.1	GBH178_14.0_14.5
GBH164_13.0_13.5	13.5	4.289	-9.21	1B								7.7	**2.1**	4	5.6	
GBH165_13.5_14	14	4.344	-9.66	2?								7.5	5.5	2	2.0	
GBH166_14.0_14.5	14.5	4.617	-9.88	1B								7.5	**2.7**	2	4.8	
GBH169_15.7_16	16	5.603	-10.40	1A?								8.3	**2.2**	4	6.1	QC10
QC10	16	5.603	-10.40	1A?								8.1	**2.0**	4	6.1	
GBH175_14.5_15	15	4.551	-10.45	1B								7.6	**2.3**	4	5.3	
GBH167_15.0_15.5	15.5	5.047	-10.45									8.6	**2.7**	4	5.9	
GBH164_14.5_15	15	4.289	-10.71	2								7.3	4.6	2	2.7	
GBH166_15.0_15.5	15.5	4.617	-10.88									8.6	7.6	4	1.0	
GBH175_15.0_15.5	15.5	4.551	-10.95									8.0	6.1	4	1.9	
GBH163_15.5_16	16	5.048	-10.95									7.9	7.4	4	0.5	
GBH168_15.0_15.5_788	15.5	4.505	-11.00	2												

GBH165_15.0_15.5	15.5	4.344	-11.16	2?	7.9	5.9	2	2.0	
GBH172_17.1_17.5	17.5	6.147	-11.35		8.0	**2.5**	4	5.5	QC7, QC7A
QC7	17.5	6.147	-11.35		8.2	**2.4**	4	5.8	
GBH169_16.5_17	17	5.603	-11.40	2	7.6	**2.0**	4	5.6	
GBH167_16.5_17	17	5.047	-11.95	2?	8.8	7.3	4	1.5	
GBH173_16.5_17	17	5.038	-11.96	2	8.5	**2.1**	4	6.4	
GBH163_17.0_17.5	17.5	5.048	-12.45	3?					
GBH168_16.5_17	17	4.505	-12.50						
GBH165_16.8_17	17	4.344	-12.66	3	8.1	7.6	4	0.5	
GBH178_17.0_17.5	17.5	4.813	-12.69		6.7	6.2	4	0.5	QC11, 1C11A
QC11	17.5	4.813	-12.69		7.6	7.2	4	0.4	
GBH164_16.5_17	17	4.289	-12.71	3?	7.2	5.9	2	1.3	
GBH166_17.0_17.5	17.5	4.617	-12.88	3?	7.7	5.9	2	1.8	
GBH169_18.0_18.5	18.5	5.603	-12.90	3	9.0	3.9	4	5.1	
GBH175_17.0_17.5	17.5	4.551	-12.95	3	8.2	4.4	2	3.8	
GBH172_19.0_19.5	19.5	6.147	-13.35		8.2	**2.2**	4	6.0	
GBH167_18.0_18.5	18.5	5.047	-13.45	3	8.0	6.3	4	1.7	
GBH173_18.0_18.5	18.5	5.038	-13.46	2	8.6	4.7	2	3.9	
GBH165_17.5_18	18	4.344	-13.66	3	8.0	5.7	2	2.3	
GBH169_19.0_19.5	19.5	5.603	-13.90	3	8.4	6.9	4	1.5	
GBH163_18.5_19	19	5.048	-13.95	3	7.9	7.4	4	0.5	
GBH172_20.0_20.15	20.15	6.147	-14.00	2	9.5	8.4	4	1.1	
GBH178_18.5_19	19	4.813	-14.19	3?	8.3	7.5	4	0.8	
GBH175_18.5_19	19	4.551	-14.45		7.4	6.5	1	0.9	
GBH169_20.0_20.5	20.5	5.603	-14.90	3	8.9	8.3	4	0.6	
GBH178_15.0_30.5	30.5	4.813	-25.69	2	7.8	5.4	2	2.4	

Unit ID tested	Exceedances				Avg Scr (%)	Avg ANC % (CaCO3)	Avg ANC % (% S)
	Scr (%)	Net Acidity (%)	pH-F (Field pH test)*	pH-FOX (Field pH Peroxide test)*			
2	0	0	0	0			
52	4	1	0	3			
3	3	0	0	0			
3	1	0	0	0			
7	1	0	0	0			
# tested, units							
4 (2 fill, 1x1B, 1x1A)	1	0	0	0	0.11	17.3	5.6
31 (all 1A but 3x1A/1B)	0	0	0	0	0.01	4.8	1.5
17 (15x1A, 2x1B)	2	0	0	1	0.15	9.1	2.9
5 (3x1A, 2xUnit 2)	0	0	0	0	0.01	8.0	2.5
5 (1A)	3	0	0	1	0.09	4.6	1.5
1 (Unit 2)	1	0	0	0	0.065	0.3	0.1
				Overall	0.07	7.3	2.4

as previously identified as estuarine but reassigned as Unit 1A / tidal sands during the ASSMP ghd.com

→ The Power of Commitment