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Report

East Arm Wharf Expansion Project

Tug Pen and Small Vessel Berths Dredging and Dredge Spoil Placement Management Plan - Revision 1

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Prepared for:
Darwin Port

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ABBREVIATIONS

Abbreviation	Description
AHD	Australian Height Datum
AIMS	Australian Institute of Marine Science
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agricultural Resource Management Council of Australia and New Zealand
ASS	Acid Sulfate Soils
BHD	Backhoe Dredge
BoM	Bureau of Meteorology
CD	Chart Datum
CSD	Cutter Suction Dredge
DDSPMP	Dredging and Dredge Spoil Placement Management Plan
DEWHA	(former) Commonwealth Department of the Environment, Water, Heritage and the Arts
DHAC	Darwin Harbour Advisory Committee
DLP	(former NTG) Department of Lands and Planning
DLPE	Department of Lands, Planning and Environment
DLRM	Department of Land Resource Management
DoE	Commonwealth Department of Environment
DoI	Department of Infrastructure
DPC	Darwin Port
EAG	Environmental Assessment Guideline
EAW	East Arm Wharf
EIS	Environmental Impact Statement
EMF/s	Environmental Management Framework/s
EMS	Environmental Management System
EMSP/s	Environmental Management System Procedure/s
EPA	Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation
HSE	Health Safety and Environment
HSEQ	Health Safety Environment and Quality
IMO	International Maritime Organization
KPI	Key Performance Indicator
LAT	Lowest Astronomical Tide
LDC	Land Development Corporation
MAGNT	Museums and Art Galleries of the Northern Territory
MARPOL	International Convention for the Prevention of Pollution from Ships
MBMP	Migratory Bird Monitoring Plan
MFO/s	Marine Fauna Observer/s
MSB	Marine Supply Base
MUBF	Multiuser Barge Facility

Abbreviation	Description
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measures
NRETAS	(former NTG) Department of Natural Resources, Environment, the Arts and Sport
NT	Northern Territory
NTG	Northern Territory Government
OH&S	Occupational Health and Safety
PASS	Potential acid sulphate soil
PWC	Power and Water Corporation
PWCNT	Parks and Wildlife Commission of the Northern Territory
QASSIT	Queensland Acid Sulfate Soil Investigation Team
RL	Reduced Level
SAP	Sampling and Analysis Plan
SEWPaC	(former) Commonwealth Department of Sustainability, Environment, Water, Population and Communities
SSC	Suspended Sediment Concentration
TAG	Technical Advisory Group
URS	URS Australia Pty Ltd
WA DEC	Western Australian Department of Environment and Conservation
WDL	Waste Discharge Licence
WQO/s	Water Quality Objective/s
WQPP	Water Quality Protection Plan

Units of Measurement

Abbreviation / Unit	Description
%	percent
%S	percent sulphur
>	greater than
<	less than
°C	degrees Celsius
kg	kilogram/s
kg/m^3	kilograms per cubic metre
km	kilometre/s
kn	knots
L/s	litres per second
m	metre/s
m^3	cubic metre/s
mg/L	milligrams per litre
µg/L	micrograms per litre
mS/cm	milliSiemens per centimetre
NTU	nephelometric turbidity units
t	tonne/s

1 INTRODUCTION

1.1 East Arm Wharf Expansion Project

The Northern Territory Government (NTG) has proposed an expansion of the East Arm Wharf (EAW) in Darwin Harbour to accommodate the requirements of prospective wharf users, including commercial users and the Department of Defence. The major features of the project (refer Figure 1-1) are as follows:

- Development of a Marine Supply Base (MSB), primarily to service the existing and developing oil and gas industries in the Timor Sea, Browse Basin and adjacent areas.
- Construction of a Multiuser Barge Facility (MUBF) including a barge ramp and hardstand area, berthing for barges and facilities for loading and unloading.
- Development of a berthing facility to accommodate tugs, customs boats and other smaller vessels hereon referred to as the 'tug pens'.

To address the requirements set out in Conditions 24 and 25 of the Commonwealth project approval (EPBC 2010/5304) issued by the Department of Environment[1] (DoE) under sections 130(1) and 133 of the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*, a Sampling and Analysis Plan (SAP) for the proposed tug pens dredging area was prepared by URS (2014a), approved by the DoE on 7 March 2014 and implemented by URS between 7 and 10 April 2014, with a Geochemical Investigation Report (URS 2014b) prepared and submitted to the DoE.

This Dredging and Dredge Spoil Placement Management Plan (DDSPMP) has been prepared for the dredging required for the tug pen location and addresses the requirements set out in Conditions 17 and 28 of the Commonwealth project approval (EPBC 2010/5304) under sections 130(1) and 133 of the EPBC Act.

1.2 Tug Pen and Small Vessel Berths Facility

Darwin Port proposes to conduct dredging, subject to receiving all approvals and licences, during the first quarter of 2015 to allow the construction of the tug pens at the western end of the northern side of the EAW groyne. The current design is of a smaller nature than that proposed in the Environmental Impact Statement (EIS), with design amendments undertaken in line with commercial requirements and with a view to minimising dredging. The smaller concept design requires an estimated volume of approximately 70,000 cubic metres (m^3) of sediment (including an allowance for approximately 3,000 m^3 of overdredging) to be dredged from the seabed. The current concept design is shown in Figure 1-2.

[1] Formerly Commonwealth Department of Sustainability, Environment, Water, Population and Communities

Figure 1-1 East Arm Wharf Expansion Project components

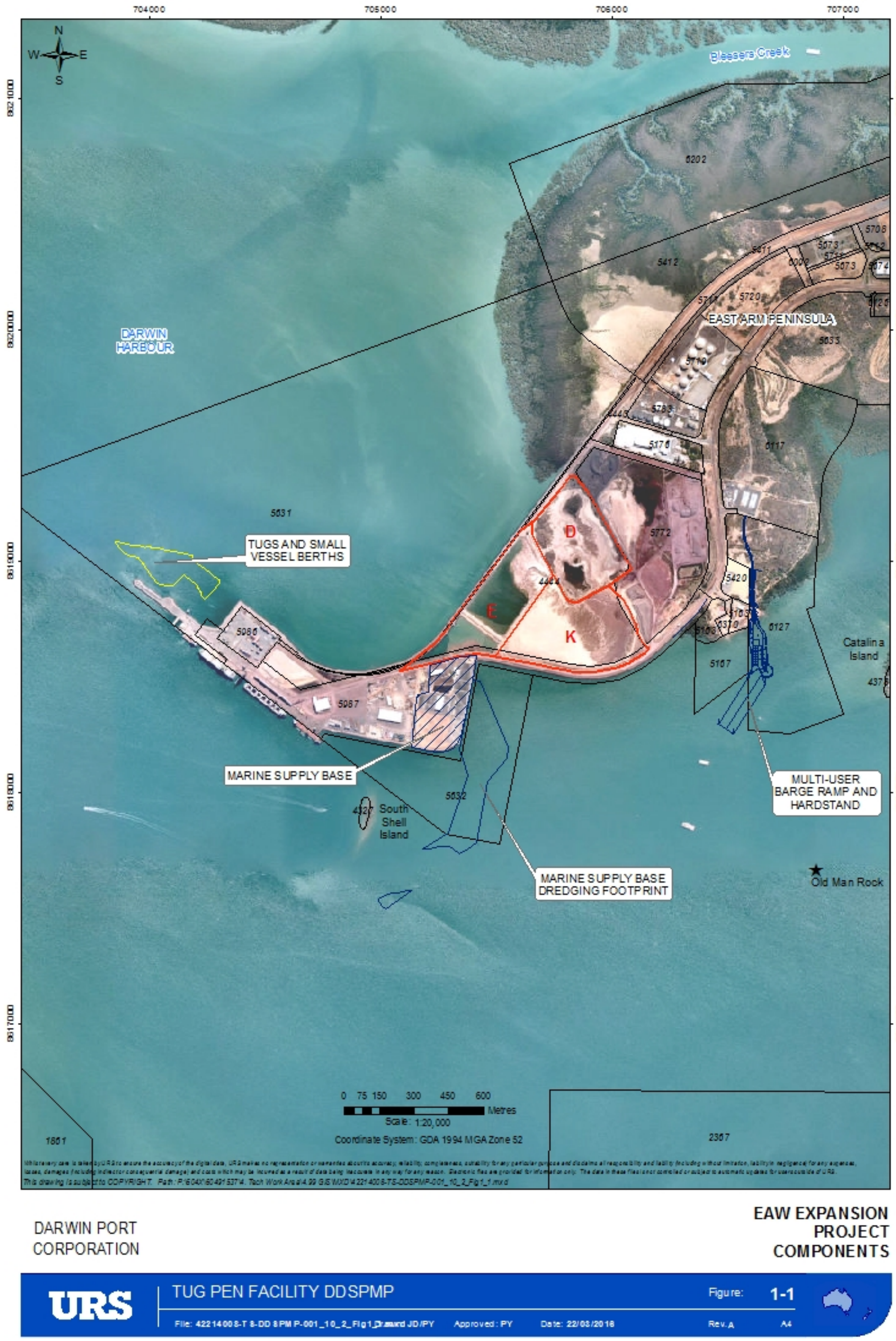
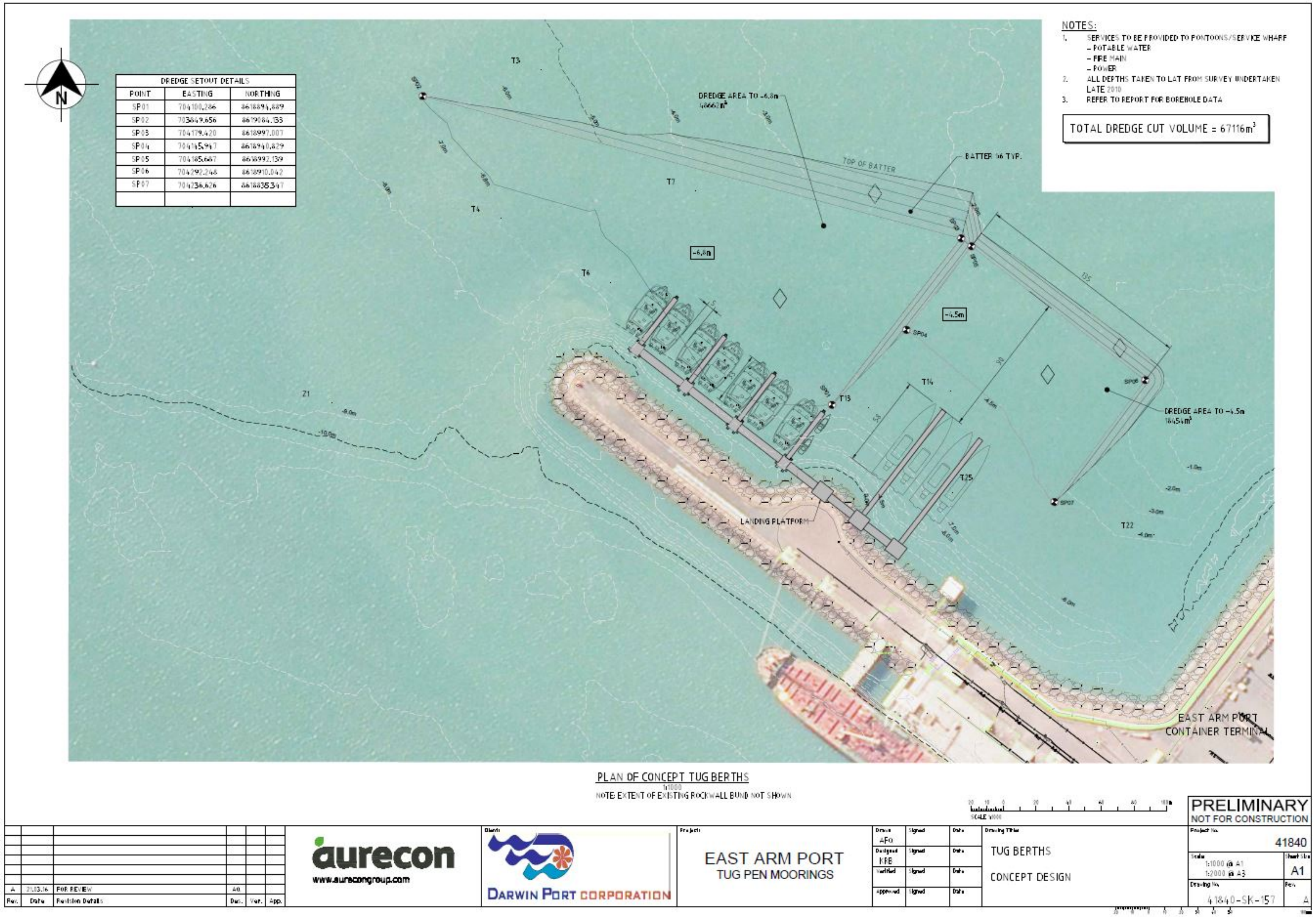


Figure 1-2 Tug Pen concept plan



1.3 Overview of proposed dredging and dredge spoil placement

Two options are being considered for the dredging methodology and required equipment:

- a small cutter suction dredge (CSD); or
- a backhoe to barge and slurry pump configuration.

A final decision on the dredging methodology will be made as part of commercial negotiations and selection of a suitable dredging contractor.

This plan has been formulated to consider the characteristics of both dredging methods with the intent that either one or a combination of both methods may be utilised for dredging the tug pens site.

The dredge footprint is located on the north western side of EAW as shown in Figure 1-3. Dredge spoil will be transported via a temporary pipeline to the disposal ponds. The final pipeline route will be determined by the dredging contractor in conjunction with DPC.

Table 1-1 Planned tug pens dredging campaign details

Feature	Estimated figures
Dredge depth	- 4.5 to - 6.8 m CD
Estimated dredge footprint	43,000 m^2
Estimated dredge volume*	70,000 m^3
Estimated 'soft' materials volume*	70,000 m^3

*Including overdredge

It is planned to pump dredge material directly into the existing East Arm Dredge Spoil Pond K and, potentially, some to Pond E (North), with the tailwater flowing through weir boxes from Pond K to Pond E (North) and into Pond E (South) where it returns to the receiving environment through a permeable section of the railway bund wall (see Figure 1-4).

Dredge spoil will enter the pond system in the north eastern corner of Pond K in the first instance. Machinery will be on site to stockpile coarser material on the western side of Pond K if required to further contain dredge spoil in Pond K. Dredge spoil will potentially be pumped into the northern end of Pond E (North) however this will only occur in the event that Pond K becomes full or complete submersion of dredge spoil is determined to be required due to the detection of potential acid sulfate soils (PASS). Tailwater may be routed through Pond D, however Pond D will not be used for direct sediment disposal. The dredging and reclamation methodology is discussed in detail in Section 2.

Figure 1-3 Tug Pen Dredging Zone

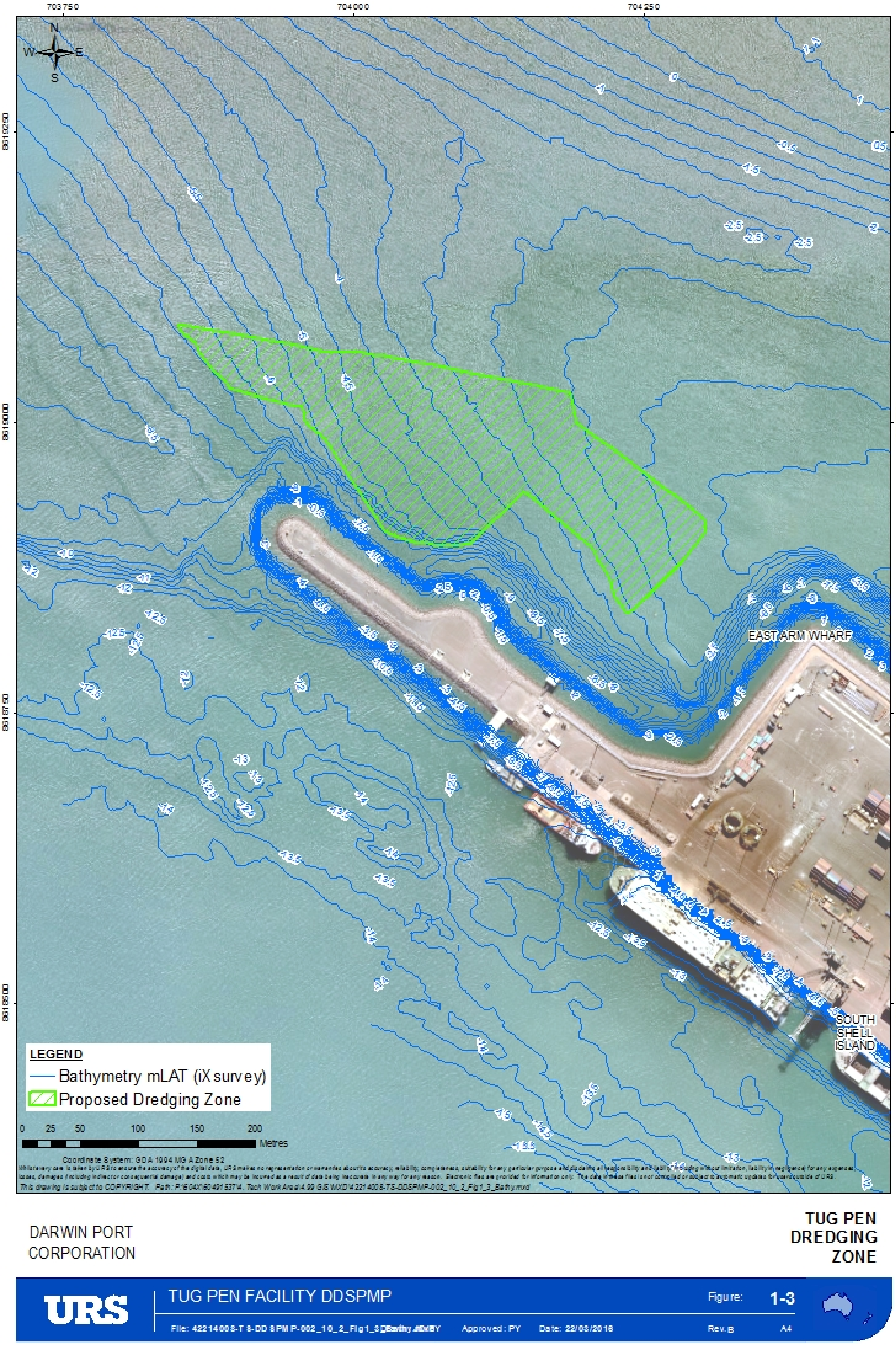
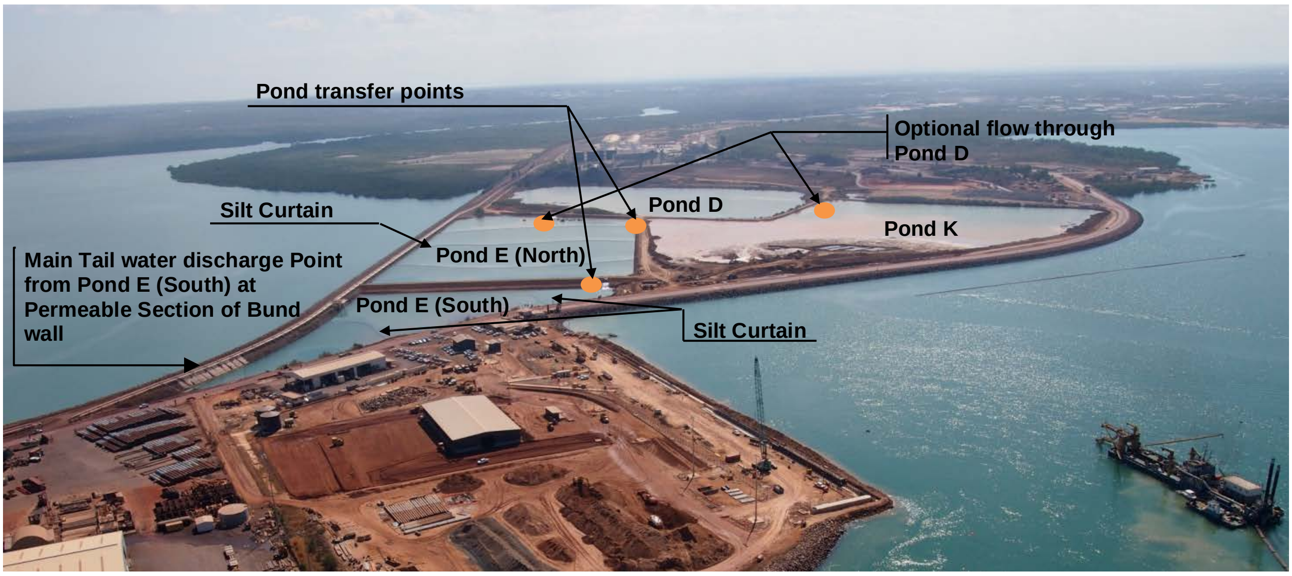


Figure 1-4 Aerial photographs showing dredge spoil placement configuration



1.4 Purpose of this plan

This document relates to the management and monitoring of the dredging operations and onshore disposal of the dredged material. The plan incorporates the requirements stipulated in approval conditions pertaining to the preparation of:

- a Dredging and Dredge Spoil Placement Management Plan (DDSPMP)
- a Water Quality Management Plan.

It also incorporates the commitment made by the former NTG Department of Lands and Planning (DLP 2011a) in their Draft EIS for the EAW Expansion Project to prepare an Acid Sulfate Soil (ASS) Management Plan. As the management and monitoring of dredging, dredge spoil placement, water quality and ASS are inextricably linked, it was deemed appropriate to combine the requirements of the three plans into a single plan.

This DDSPMP demonstrates that reasonable and practicable steps have been taken to manage the risks associated with, and the potential environmental impacts arising from, the dredging and spoil placement activities to be undertaken during the construction phase of the Tug Pens and Small Vessel Berths.

The DDSPMP details how the potential impacts of the dredging and spoil placement activities will be minimised by identifying and implementing appropriate management and monitoring controls. It describes the proposed management, monitoring, reporting, review and auditing requirements for the dredging and spoil placement activities in order to meet the conditions of the various environmental approvals.

The DDSPMP and supporting documentation has been prepared for submission to the East Arm Wharf Expansion Project Technical Advisory Group (TAG) for review and endorsement, and to the NT Environmental Protection Authority (EPA) and, via the DoE, to the Minister for Environment for approvals.

1.5 Proponent / primary Contractor

The Proponent of the East Arm Wharf Expansion Project is the NT Department of Lands, Planning and Environment [DLPE (formerly the DLP)], which is responsible for developing and providing strategic planning and growth frameworks, strategies and infrastructure plans required to develop the NT.

The Proponent is acting on behalf of the NTG. The primary contractor and any subcontractors for the project are yet to be appointed.

Proponent's address:
NT Department of Lands, Planning and Environment
GPO Box 2520
Darwin NT 0801
Attention: Mr Graeme Finch

1.6 Project approvals

The EAW Expansion Project was initially assessed through an EIS (DLP 2011a), with additional information and responses to stakeholder comments presented in an EIS Supplement (DLP 2011b). Complete details of the environmental assessment process are provided in these documents. The project was assessed jointly by the NTG under the *Environmental Assessment Act 1982* and the Commonwealth Government under the EPBC Act.

1.6.1 Northern Territory approval recommendations

The NTG approved the project under the *Environmental Assessment Act 1982* in December 2011. Twenty-two recommendations were listed within the Environmental Assessment Report (Department of Natural Resources, Environment, the Arts and Sport [NRETAS] 2011), which have been addressed by the provision of additional information by the Proponent, and commitments made in this DDSPMP. A copy of the NRETAS assessment report is available online at http://www.ntepa.nt.gov.au.

1.6.2 Commonwealth approval conditions

The Commonwealth Government awarded conditional approval under the EPBC Act on 5 March 2012 (Department of Sustainability, Environment, Water, Population and Communities [SEWPaC 2012a]), with a variation to the approval issued on 28 May 2012 (SEWPaC 2012b). Forty-nine ministerial conditions of approval were attached to the approval decision, all of which are legally binding to the Proponent. Four conditions (15, 17, 36 and 37) of the original approval were superseded in the variation issued 28 May 2012. A full copy of the Commonwealth approval decision is available online at http://www.environment.gov.au.

DoE will be consulted for approval if any changes or revisions to the DDSPMP or the proposed action occur, as required by Condition 5 (revision/change approvals). The approved DDSPMP is implemented in accordance with Condition 21. These approval conditions are also applicable to all other environmental management plans/strategies associated with the project.

1.6.3 Waste Discharge Licence

A Waste Discharge Licence (WDL) pursuant to Section 74 of the *NT Water Act* will be obtained by DPC (or the Contractor responsible for the tug pens dredging) prior to commencing work. The Contractor will comply with any conditions associated with the WDL. NT EPA will be consulted for approval if any changes or revisions to the DDSPMP occur.

1.6.4 Legal requirements and guidelines

This DDSPMP has been developed to meet Commonwealth EPBC approvals conditions (approval 2010/5304), NTG recommendations (Assessment Report 67 [NRETAS 2011]) and the conditions of WDL 187 (WDL 187 conditions refer to the previously completed MSB dredging and have been applied here in anticipation of conditions in the new WDL to be obtained by the DPC [or Contractor] prior to dredging at the tug pens site).

Other legislative requirements relevant to the dredging activities are presented in Table 1-2 (Commonwealth) and Table 1-3 (NT).

International conventions and guidelines relevant to the dredging activities are listed in Table 1-4.

A number of government strategy and guideline documents have been developed to provide advice to proponents in the development of environmental management and monitoring programs. In the development of this DDSPMP the documents listed in Table 1-5 and Table 1-6 have been taken into account.

In addition to Commonwealth and NT regulatory guidance, this DDSPMP takes account of the Environmental Assessment Guideline for Marine Dredging Proposals (EAG7) developed by the WA Environmental Protection Authority (EPA) under s16(k) of the *Environment Protection Act* (EPA 2011). The guideline aims to provide guidance for the clear and consistent presentation of predicted impacts of dredging and dredge-generated sediment on benthic habitats. Aspects of these guidelines have been adopted in combination with the Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA 2013).

Table 1-2 Commonwealth legislative requirements

Commonwealth	
Title	**Description**
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	The purposes of this Act are the preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginals in accordance with Aboriginal tradition.
Australian Ballast Water Management Requirements 2001	Requirements designed to reduce the risk of introducing harmful aquatic organisms into Australia's marine environment through ships' ballast water. Australian ballast water management requirements are consistent with International Maritime Organization (IMO) guidelines for minimising the translocation of harmful aquatic species in ships' ballast water.
Environment Protection and Biodiversity Conservation Act 1999	This Act provides a national framework for environmental and heritage protection. It focuses on protecting "matters of national environmental significance" including listed, protected species and marine species.
Hazardous Waste (Regulation of Exports and Imports) Act 1989	An Act to provide for the regulation of the export, import and transit of hazardous waste, and for related purposes.
Hazardous Waste (Regulation of Exports and Imports) Amendment Act 1996	An Act to amend the Hazardous Waste (Regulation of Exports and Imports) Act 1989, and for related purposes. The object of this Act is to regulate the export, import and transit of hazardous waste to ensure that exported, imported or transited waste is managed in an environmentally sound manner, so that society and the environment, both within and outside Australia, are protected from the harmful effects of the waste.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006	An Act relating to the protection of the sea from the effects of harmful anti-fouling systems. It includes application or use of harmful anti-fouling and the required certificates and anti-fouling declarations.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	This Act relates to the prevention of pollution (in any form) from ships.
Quarantine Act 1908 and Quarantine Regulations 2000	An Act relating to quarantine, including the quarantine and quarantine procedures of vessels, persons and goods.

Table 1-3 Northern Territory legislative requirements

Northern Territory Title	Description
Aboriginal Land Act 2010	This Act provides for access to: Aboriginal land, certain roads bordered by Aboriginal land and the seas adjacent to Aboriginal land.
Aboriginal Sacred Sites Act and Regulations 2011	An Act to effect a practical balance between the recognised need to preserve and enhance Aboriginal cultural tradition in relation to certain land in the NT and the aspirations of the Aboriginal and all other peoples of the NT for their economic, cultural and social advancement.
Crowns Land Act 2011	An Act responsible for managing Crown land and facilitating (development consented) land use for economic development.
Dangerous Goods Act 1998 and Amendment Act 2003 (Act No. 20, 2003)	An Act to provide for the safe storage, handling and transport of certain dangerous goods. The goods will be classified and need to be taken care of by specialised persons. This Act will be controlled by competent authorities.
Darwin Port Corporation Act 2005	An Act to provide for the establishment of the Darwin Port Corporation for the control and management of the Port of Darwin and for related purposes.
Environmental Protection (National Pollutant Inventory) Objective 2004	National Environment Protection Measures (NEPMs) are broad framework-setting statutory instruments defined in the *National Environment Protection Council (NEPC) Act 1994*. They outline agreed national objectives for protecting or managing particular aspects of the environment. A NEPM will become law in each participating jurisdiction once it is made by NEPC.
Environmental Offences and Penalties Act and Regulations 2011	This Act establishes penalties for certain offences under prescribed Acts (such as an environmental offence) and for related purposes.
Fisheries Act 1998	An Act to provide for the regulation, conservation and management of fisheries and fishery resources so as to maintain their sustainable utilisation, to regulate the sale and processing of fish and aquatic life, and for related purposes.
Heritage Act 2011	This Act establishes the Heritage Council and the NT Heritage Register. It sets the process by which places become heritage places, allows for interim protection of places and sets out the process for getting permission to do work to heritage places and allows for fines and imprisonment for offences against the Act.
Litter Act 2011	An Act relating to litter. It includes that no person shall leave, throw, deposit or abandon litter in, onto or from a public place or land elsewhere than into authorised receptacles.
Marine Act 2011 and Marine (Pilotage) Regulations 2001	This Act regulates shipping within the NT and provides for the application to the NT of the uniform shipping laws code and for related matters such as required qualifications and actions and other related purposes.
Marine Pollution Act 2004 and Marine Pollution Regulations 2010	An Act to protect the marine and coastal environment by minimising intentional and negligent discharges of pollutants (such as oil, garbage, sewage etc.) from ships into coastal waters and for related purposes.
Waste Management and Pollution Control Act 2011	This Act aims to protect, and where practicable, restore and enhance the quality of the NT environment; encourage ecologically sustainable development; and facilitate the implementation of NEPMs established by the National

Northern Territory	
Title	**Description**
	Environment Protection Council. It is designed to prevent contamination of the surrounding environment, including soil, air, and water, and imposes a general duty on conducting an activity or action that causes or is likely to cause pollution resulting in environmental harm, or that generates or is likely to generate waste.
Water Act 2011	This Act provides for the investigation, allocation, control, protection, management and administration of water resources in the NT. The Act prohibits waste to come in contact with water or water to be polluted unless under authorisation.

Table 1-4 International conventions and guidelines

International Conventions	
Title	**Description**
Guidelines for the Development of Garbage Management Plans for compliance with Regulation 9(2), Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL)	The use of three complementary techniques to manage garbage: source reduction, recycling and disposal. It must include the person in charge of carrying out the plan, procedures for garbage collection, and procedures for processing garbage, storing garbage and the disposing of garbage.
International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)	The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It covers the prevention of pollution by oil, chemicals, and harmful substances in packaged form, sewage and garbage.
International Convention for the Control and Management of Ships' Ballast Water and Sediments	The Convention aims to prevent the potentially devastating effects of the spread of harmful aquatic organisms carried by ships' ballast water from one region to another.
The Convention on the Conservation of Migratory Species of Wild Animals	Aims to conserve terrestrial, aquatic and avian migratory species throughout their range. It is an intergovernmental treaty, concluded under the aegis of the United Nations Environment Programme, concerned with the conservation of wildlife and habitats on a global scale.
International Convention for the Prevention of Pollution from Ships as modified by the Protocol of 1978 relating thereto and Annex V (Prevention of Pollution by Garbage from Ships) (IMO 1973)	This deals with different types of garbage and specifies the distances from land and the manner in which they may be disposed of. The requirements are much stricter in a number of "special areas" but perhaps the most important feature of the Annex is the complete ban imposed on the dumping into the sea of all forms of plastic.

Table 1-5 Commonwealth Government strategy and guideline documents

Commonwealth
National Assessment Guidelines for Dredging (Commonwealth of Australia 2009)
Guidelines for Fresh and Marine Water Quality - Australia and New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000
National Water Quality Management Strategy (Commonwealth of Australia 1992)
Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pest Incursions, April 2005

Table 1-6 Northern Territory strategy and guideline documents

Northern Territory
Draft Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (2013)
A Review of Environmental Monitoring of the Darwin Harbour Region and Recommendations for Integrated Monitoring (2005)
A Strategy for the Conservation of Marine Biodiversity in the Northern Territory of Australia, Parks and Wildlife Commission of the NT (PWCNT) (2000)
Declaration of Beneficial Uses and Objectives Darwin Harbour Region (June 2010)
Darwin Harbour Regional Management Strategic Framework 2009–2013 (Draft)
Darwin Harbour Water Quality Protection Plan (2014)
Darwin Port Corporation (DPC) Environmental Management System, Environment Policy and Occupational Health & Safety (OH&S) Policy 2002

1.7 Existing management frameworks in Darwin Harbour

The NTG developed the Darwin Harbour Water Quality Protection Plan (WQPP) (DLRM 2014) under the National Water Quality Management Strategy.

Phase 1 of the development of the WQPP was completed in 2009. The overall aim of the WQPP was to ensure that water quality objectives are maintained and that the community's values for waterways are protected. This included identifying key risks to water quality, development of interim water quality objectives (based on beneficial use declarations under the *Water Act*), improvements to monitoring activities and evaluation of pollutant loads (NRETAS 2010).

Phase 2 of the WQPP was released in February 2014 and aims to support good management and sustainable development by focussing on a range of management actions including monitoring, assessing and managing the impacts of sediment and nutrient (nitrogen, phosphorus) inputs to Darwin Harbour. It also highlights key considerations for future water quality protection (DLRM 2014).

The tug pen dredging activities fall within the Darwin Harbour Declaration of Beneficial Uses and Objectives of Surface Water. The declared beneficial uses are environment, cultural (aesthetic, recreational and cultural) and aquaculture (NRETAS 2010).

Performance against the water quality objectives described in the WQPP is assessed by DLRM on the basis of the annual mean value of the measured parameter. It is noted that the guidelines do not apply during high flow events associated with Wet Season conditions and that the water quality objectives are intended for use in "catchment management and land use planning activities". Hence the objectives could be considered as representing targets for long-term water quality rather than as limits to be adhered to during the dredging operations. However, they have been taken into account during the development of the environmental management frameworks detailed in Section 6. The environmental management frameworks have been developed in a manner that is consistent with the risk-based decision framework discussed above.

1.8 DDSPMP approval, review and availability

The Proponent is responsible for submitting the draft of this Plan to the TAG for review and comment, and the final revision submission to the NT EPA and the DoE for approval by the Minister. The Proponent is responsible for addressing all comments received and shall create and maintain a comment register for the purposes of tracking, managing and closing comments.

The approved DDSPMP will be included with the dredging program request for tender documentation and the appointed contractor expected to comply with the plan. Should circumstances require an amendment to the DDSPMP, this will be the responsibility of the appointed Contractor, with the Proponent required to resubmit the revision to the TAG, DoE and the NT EPA.

Given the short duration of the dredging program, no review of this plan is anticipated during the program. However, if deficiencies in the effectiveness of this DDSPMP, changes in environmental risks, changes in business conditions, processes for monitoring environmental performance, or any relevant emerging environmental issues currently not addressed are experienced, then a review of the relevant components of the DDSPMP will be undertaken. The Proponent would be responsible for resubmission of any revisions to the DoE and the NT EPA.

The approved plan will be publicly available on the East Arm Expansion EIS webpage at http://www.eastarmwharf-eis.nt.gov.au/home

2 DREDGING AND DREDGE SPOIL PLACEMENT

2.1 Introduction

These sections describe the dredging and spoil placement methodology that will be used by the dredging contractor during the tug pen dredging and the methodology described is the basis for this DDSPMP. The methodology presented provides for a number of possible scenarios for dredging and spoil placement. The Contractor will determine the most suitable dredge and spoil placement method to achieve the required environmental outcomes detailed in this plan.

There is no requirement for bottom dumping, rehandling or double handling of dredge material by the dredge and these practices will not be undertaken as part of this project.

Cyclonic and otherwise bad weather could necessitate the temporary cessation of the dredging activities. The Dredge Master will make ongoing assessments regarding weather conditions to determine if a cessation in dredging is required. If the Port goes into cyclone alert or shut down then the dredging contractor will comply with all directions from the Port Master.

The tug pen dredge works has an estimated total volume of 70,000 m^3 (including an allowance of approximately 3000 m^3 for overdredge). The sediment is proposed to be disposed of entirely onshore, with the dredge footprint and reclamation ponds displayed in Figure 1-3 and Figure 1-4.

2.2 Equipment

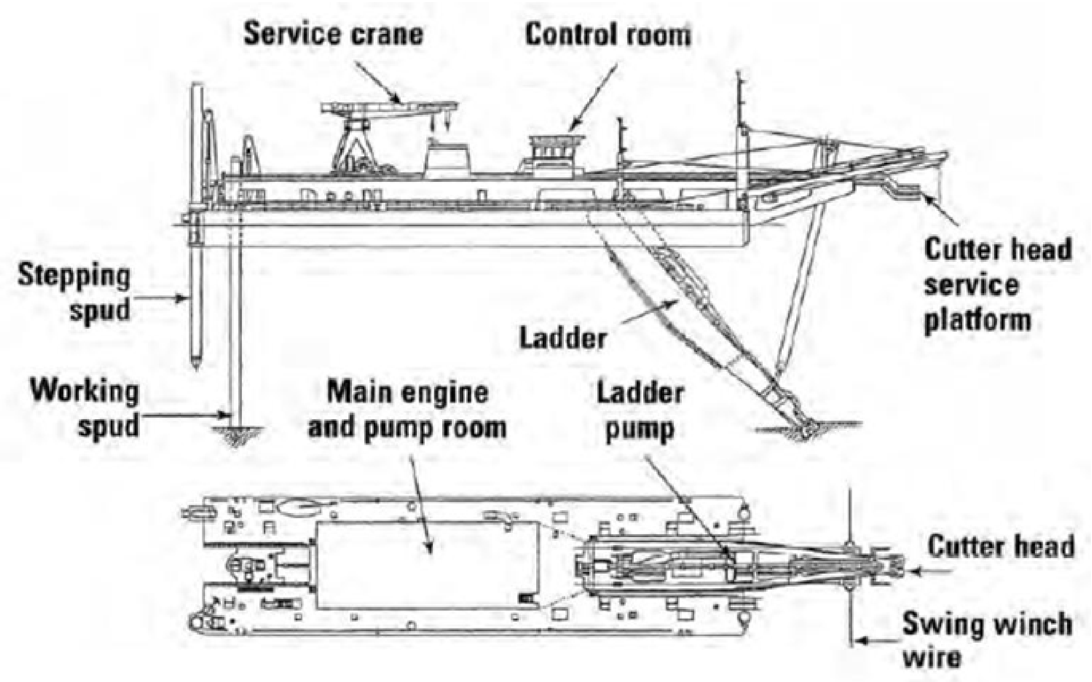
The location of the works within a tidal zone, limited available draught for vessels, and the direct hydraulic placement of the dredged material are determining factors for the selection of the preferred dredge methodology. The current seabed surface levels over the proposed dredging area range from -1.5 m Lowest Astronomical Tide (LAT) to -8.5 m LAT. The typical geotechnical profile of the material to be dredged consists of relatively homogeneous grey silt clay with minor sand content. During sediment sampling undertaken at the site sample recovery of between 2.6 and 6 m was achieved without encountering bed rock (URS 2014b).

While the dredging method has not been finalised, it is anticipated that dredging will be completed using a small cutter suction dredge (CSD) or a backhoe and slurry pump arrangement or a combination of these methods. Regardless of the dredge method employed, the dredging process will be adjusted to maintain the pond management process.

2.2.1 Cutter suction dredge

A typical CSD is shown in Figure 2-1. The CSD would dredge sediment from the seabed, transporting it to the onshore dredge spoil disposal ponds. A small CSD would be utilised to allow the entire dredge area to be dredged should that be the preferred method. Typical flow rates from a dredge of this size have been estimated at 500 L/s (equivalent to 1,800 m^3/hour). There are currently a number of small CSDs capable of undertaking work of this nature. To achieve the required pumping distances from the dredge footprint to the pond disposal site, a booster pump may be required to supplement the pumping capacity of the small CSD.

Figure 2-1 Typical cutter suction dredge



2.2.2 Dredging with backhoe and slurry pump

The use of a backhoe and slurry pump arrangement will also be considered as a potential dredge method. A backhoe would be placed on a work barge and manoeuvred around the dredge site, dredging sediment from the seabed and placing it into a slurry pump on the barge. There would be no overflow of water permitted from the barge into the surrounding waters. The slurry pump will then pump the dredge spoil through the pipeline to the dredge spoil disposal ponds.

2.3 Summary of work method

Dredging is anticipated to be undertaken during the first quarter of 2016. This will coincide with the Wet Season, however the final schedule will depend on the appointment of the dredging contractor and associated commercial negotiations.

Dredging will be undertaken up to 10 hours a day (during daylight hours) and continue daily until the required dredging is completed. The duration of dredging is expected to be approximately six weeks. Stoppages in dredging may occur for dredge maintenance or to assist in the control of the quality of the water exiting the settling ponds at the point of discharge into Darwin Harbour.

It is expected that tailwater flow rates into the pond system will be approximately 500 L/s (equivalent to 1,800 m^3/hour) at a water to sediment ratio of 9:1 (Patterson & Williams 2014). A sediment loss rate of 1% at the CSD cutter head could be expected and a dry bulk density of 857 kg/m^3 was suggested to be likely based on field studies undertaken by the Australian Institute of Marine Science (AIMS) (Patterson and Williams 2014).

The sediment loss from a backhoe would differ from that from a CSD cutter head, depending on the material being dredged. Dredging of fine sediments with a backhoe dredge (BHD) will likely result in greater sediment loss by a backhoe when compared to a CSD, while the opposite is likely when dredging consolidated sediments. In addition, sediment plumes from the backhoe would be discrete and intermittent 'pulses' of turbidity and suspended sediments rather than the constant leakage of sediment experienced during CSD operations. Very few measurements of resuspension of dredge material around backhoes have been made (HR Wallingford 2010) and as such it is difficult to provide a definitive figure for expected loss for dredging with a backhoe. HR Wallingford (2010) adopted a value of 3% in modelling for the INPEX Ichthys dredging campaign in Darwin Harbour; however it should be noted that this was for dredging undertaken in a deeper and exposed channel experiencing greater current flows than that proposed for this project which will be undertaken in a relatively shallow, sheltered location.

If a backhoe and slurry pump arrangement is used then the tailwater flow rate will be less and the water to sediment ratio considerably lower.

2.4 Dredge spoil placement area

Onshore disposal to existing decant ponds on the EAW (Figure 1-4) is a suitable option as it has been used for the disposal of material from capital dredging in East Arm and at the Darwin Waterfront, the disposal of maintenance dredge spoil and the recent MSB dredging campaign that was completed in January 2014. Offshore disposal is not part of the current development proposal.

Dredge spoil placement is discussed in detail in Section 2.5.3 - the dredged material will be pumped ashore through a temporary pipeline from the dredge area into the existing pond system, where it will be deposited in either Pond K or Pond E (North) (Figure 2-2). The pipeline route has not yet been determined and will be finalised by the dredging contractor in conjunction with DPC.

Transfer points from ponds K to E (North) and ponds E (North) to E (South) (refer to Figure 2-2) have reclamation boxes with an adjustable height weir. The weir boards are designed to be watertight to ensure sediment does not pass through, thus increasing the likelihood of a turbidity trigger event within Ponds K and E (North), but decreasing the likelihood of a turbidity trigger event in Pond E (South). The reclamation weir boxes and associated weir boards are the same as those approved and used for the MSB dredging. The transfer points into and out of Pond D are pipes.

Where dredge spoil will be deposited in Pond K the tailwater will flow around Pond K and into Pond E (North), through the weir box in the bund wall, through silt curtains in Pond E (North), through additional silt curtains in Pond E (South), then out of the permeable section of the railway bund wall (Figure 2-2).

While it will not be the primary tailwater flow path, some tailwater may be routed into Pond E (North) via Pond D after flowing through Pond K to increase the capacity and therefore residence time within the pond system. Tailwater will be transferred from Pond K into Pond D either using pipes embedded into the bund wall structures (reinstated as they were during the MSB dredging) or pumped through pipes laid over the top of the pond wall.

Figure 2-2 Placement of dredge spoil into EAW Ponds

During dredging works, regardless of the initial dredge spoil deposition location (i.e. Pond K or Pond E [North]), the tailwater will be returned to the environment through the permeable section of the railway bund wall located in the south-west corner of Pond E (South) (Figure 2-2).

2.5 Dredge spoil and tailwater management

The dredged material will be placed in the settlement ponds with tailwater stored for sufficient time to allow for settling of fine suspended sediments (residence time) prior to discharge of the tailwater back into Darwin Harbour. Water quality management and monitoring is discussed in detail in Section 6 and Section 7 of this plan.

The primary method of control over tailwater quality discharged from the pond system will be through the use of silt curtains, control of the dredging regime and through the management of weir boxes. The flow direction and flow rate of tailwater into the ponds will be controlled so that sufficient residence time is achieved to result in suspended sediment concentrations within allowable limits at the discharge point.

2.5.1 Settling ponds system and available volumes

Settlement ponds and internal ponds within the reclamation area are pre-existing ponds constructed during the previous development of East Arm Port and used during the recent MSB dredging.

Recent surveys of the ponds by Douglas Partners (2014) have shown:

- Pond K: Volume to Relative Level (RL) 6.5 m is 105,000 m^3 with available volume for dredge spoil to RL 6.0 m of 57,000 m^3.
- Pond E North: Volume to RL 5.0 m is 460,000 m^3 with an available volume for dredge spoil to RL 4.0 m of 374,000 m^3.

Based on the above, the pond system has a storage capacity of 431,000 m^3 for solids utilising only Ponds K and E North. It can be seen from these figures that sufficient capacity in excess of that required for the tug pens dredging is available in the current pond system. It may also be possible to stockpile some dredge spoil within the ponds to achieve greater available volume should it be required (as was done in the recent MSB dredging campaign). The capacity of Pond K will be used as a priority with the option to utilise Pond E (North) for dredge spoil placement should it be required.

2.5.2 Pond capacity management measures

As previously discussed, the project will dredge approximately 70,000 m^3 of material comprising predominantly silts and clay fines and, by applying the calculated conservative bulking factor of 3.5 - 5 (the generally expected range for such sediments), the dredging contractor requires pond capacity to store 245,000 – 350,000 m^3 of dredge spoil. Considering the pond volumes measured in recent surveys (refer to Section 2.5.1), ample capacity is available. The required residence times will be achieved through a number of measures to be implemented as required based on the results of water quality monitoring at the tailwater discharge point throughout dredging operations. The proposed management measures are:

- Controlling the flow of tailwater in to the ponds such that residence times are sufficient. Should it be required, dredging may be slowed or ceased to extend pond residence times.
- Adding or removing silt curtains to Pond E (North) or Pond E (South) to maximise efficiency of residence time in the pond.
- Stockpiling material in Pond K, with the final height to be confirmed by a geotechnical assessment to ensure stockpile and bund wall integrity is maintained.
- Management of weir boxes to increase residence time if required.
- Alternating tailwater flow through Pond D and Pond E (North) as required to allow additional residence time.

2.5.3 Pond fill sequence

Dredge spoil will be pumped from the dredge site into the south east corner of Pond K (and possibly the far northern section of Pond E [North]). Direct placement of spoil into Pond E (North) would only be considered in the event that Pond K reaches capacity and the chance of a large stormwater flow is low (i.e. during Dry Season) or in the event that PASS is detected, which will necessitate disposal of the material into a submerged environment. Should PASS be detected and discharge into Pond E (North) be required, the opening of the dredge spoil discharge pipe into Pond E (North) will be submerged to prevent PASS coming into contact with air.

As the ponds fill, the tailwater will make its way from Pond K into Pond E (North) or Pond D. Tailwater will then flow from Pond D (if used) into Pond E (North) then into Pond E (South) where it will eventually pass through a permeable section of the bund wall into Darwin Harbour. If dredge spoil is deposited directly into Pond E (North), residence time will be controlled by the weir and by reducing dredge pump flow rates. Tailwater may also be pumped from Pond E (North) into Pond K where it will flow back through Pond D into Pond E (North).

Pond D will not be used for direct placement of dredge spoil, but rather to extend the capacity and residence time of tailwater in the pond system. Minor sediment deposition will occur in Pond D.

To allow routing through Pond D, a link between Pond K and Pond D will be reinstated by either reinstalling pipes under the pond wall or by laying pipes over the pond wall into Pond D. Pre-existing links between Pond D and Pond E (North) will be used.

Silt curtains are already installed in ponds E (North) and E (South) and may be removed or reconfigured as required to optimise the pond performance and achievement of water quality requirements.

The pond flow sequence is shown in Figure 2-3.

2.5.4 Pond levels (water only)

The maximum water height in Pond K will be 6.0 m AHD or a minimum of 0.5 m freeboard (whichever is higher).

Pond E (North) will operate with a water level of 3.5 and 5.0 AHD and be controlled by a reclamation box with an adjustable weir.

The water level in Pond E (South) will be controlled to ensure at least 0.5 m freeboard at all times. During the tug pens dredging works, tailwater will pass through the permeable section of the railway bund (at the south-west corner of Pond E) at a rate which matches or exceeds the dredge output; hence the water level will in the pond will not vary significantly and is mainly influenced by tidal variation. As a backup there will be a pump discharge outlet located in the south-east corner of Pond E (South) where a pump system capable of pumping 600 L/s, if required, will return the tailwater to Pond K or Pond E (North).

The water height of Pond D will be regulated by the transfer pipes into Pond E (North), to ensure that the water level does not exceed 5.5 m AHD.

Each pond will operate with a minimum 0.5 m freeboard. While it is not anticipated to be required given the relatively low flow rates into the ponds, pumps may be used to supplement gravity flows to ensure transfer flows equivalent to the dredge output are maintained between ponds.

During dredging the daily water levels of each pond will be recorded and provided in the weekly reports. Where transfer pipes are fitted, the flow between ponds can be stopped by blocking the pipework between these ponds with steel plates and/or inserting rubber expanding plugs, with both options available on site.

Where a reclamation box is fitted the flow can be stopped by adding drop boards and raising the height of the weir. In both instances flow can be stopped within an hour as a corrective action if required (refer Table 6-2).

Figure 2-3 Water flow paths through EAW pond system

2.5.5 *Stormwater and landform*

Stormwater from the pond network and adjacent DPC land ultimately flows into Pond E (South) for return to the harbour via the permeable section of the railway bund wall (refer Figure 2-3). During dredging operations, particularly if dredging is undertaken over the Wet Season, consideration will be given to possible storm events and the Contractor will ensure that a flow path is always available for stormwater to find its way through the ponds, or allow a sufficient catchment to ensure the stormwater can be retained for future release.

Stormwater from the Pond K road bund and a catchment area near the gatehouse, estimated to be 20,000 m^2, is now diverted into a new stormwater channel in place along the boundary between Pond K and the former Pond C area, instead of flowing into Pond K. Stormwater from the highpoint on the road to the south of Pond K now flows along a stormwater channel and through a culvert into Pond E (North).

The runoff from DPC land to the north of the ponds passes through both Pond D and into Pond E (North). Importantly, stormwater does not flow into Pond K allowing greater control over water exiting from this primary disposal pond.

With Pond E divided into Pond E (North) and Pond E (South), the Contractor has the option of placing dredge spoil directly into Pond K or Pond E (North), although dredge spoil deposition will be limited to Pond K during the Wet Season to allow stormwater to flow through Ponds D and E for settlement and discharge to the environment via the permeable section of the railway bund.

Pond E (North) will be filled with solids to a level which will allow sufficient capacity for stormwater and tailwater management.

The pond network has the ongoing function of stormwater management beyond the duration of this dredging project and will be maintained during and after the completion of this project, therefore the pipe connections between ponds will be retained for ongoing stormwater management. When the dredging is complete a surface survey will be completed and a surface profile developed to minimise the risk of ponding against the access road causeway or in areas not forming part of the stormwater system, and the final landform will be effective in directing surface water through Pond E (North) before entering into Pond E (South), then returning to the receiving environment through the permeable portion of the railway bund wall.

3 ENVIRONMENTAL PROJECT MANAGEMENT AND RESOURCING

This project will be undertaken in accordance with the DPC Environment Policy (Figure 3-1) and management systems. The DPC Environmental Policy requires that the DPC develops and maintains an Environmental Management System (EMS), provides sufficient resources to achieve its environmental targets and seeks to prevent pollution from its activities.

3.1 Environmental Management System and Procedures

The DPC EMS is based on the requirements of ISO14001:2004 (International Standard for Environmental Management Systems) and provides a framework for the achievement of continual environmental improvement. The EMS is underpinned by 12 procedures (EMSPs) that explain the operation of the EMS.

The DPC EMS structure is shown in Figure 3-2, which outlines the relationship between the policy, procedures, environmental management plans, and other related documents.

The DPC EMS and procedures will guide the dredging of the tug pens site. On appointment, the Contractor will develop any additional project specific detailed plans required as bridging documents to the DPC EMS and procedures. These plans will be approved by the DPC before dredging commences.

3.2 Key roles and responsibilities

Key roles and responsibilities will be identified by the Contractor on appointment and a project specific organisational chart will be developed and maintained by the Contractor.

Site management responsibilities will be defined and documented by the Contractor before dredging commences including reporting and communication pathways between Contractor and DPC personnel.

Key roles to be identified include (but are not limited to):

- Project Manager
- Health Safety Environment and Quality (HSEQ) Advisor
- Supervisors / engineers
- Employees and subcontractors

3.2.1 Technical Advisory Group

The NTG has established an independent TAG to provide advice on management of dredging and disposal works for the EAW development project. The TAG is responsible for providing independent scientific and environmental review of the DDSPMP as part of the EPBC Act approval conditions for the EAW expansion project. The TAG is required to review any plans or proposed amendments prior to their submission to the DoE for approval.

Figure 3-1 Darwin Port Environment Policy

DARWIN PORT CORPORATION

ENVIRONMENTAL POLICY STATEMENT

The Darwin Port Corporation manages the Port of Darwin. The Darwin Port Corporation recognises the environmental, social and economic importance of operating in an **environmentally sustainable** and **responsible manner, ensuring a high level of environmental performance** and is **committed to achieving this** through **continual improvement** of its **environmental management system**.

To achieve environmental performance consistent with this Policy, the Darwin Port Corporation will:

- Develop and maintain an environmental management system, consistent with the Corporation's activities, services and environmental impacts, that includes planning, setting objectives and targets, implementation and operation, monitoring performance, review and continuous improvement.
- Provide sufficient resources and training to achieve the targets defined in its environmental management system.
- Implement risk management techniques to assess impacts of the Corporation's activities and to introduce appropriate mitigation measures.
- Comply with all applicable environmental laws, regulations, policies and standards which relate to its activities and services in a transparent manner.
- Seek to prevent pollution resulting from port activities and services.
- Communicate to employees and stakeholders this policy and the Corporation's progress in meeting the objectives and targets defined in its environmental management system.
- Continually improve its environmental management and environmental performance.

The Chief Executive Officer and the Port Management Group are responsible for the effective implementation of this policy and all of the Darwin Port Corporation's employees, contractors and those otherwise engaged by the Corporation are required to comply with this Environmental Policy.

This policy will be reviewed annually to ensure it is consistent with stakeholder expectations and reflects the nature and impact of port activities and services.

Publicly available from: www.darwinport.nt.gov.au

Terry O'Connor
Chief Executive Officer

Melissa Reiter
General Manager Corporate Services

Anne Coulter
Chief Financial Officer

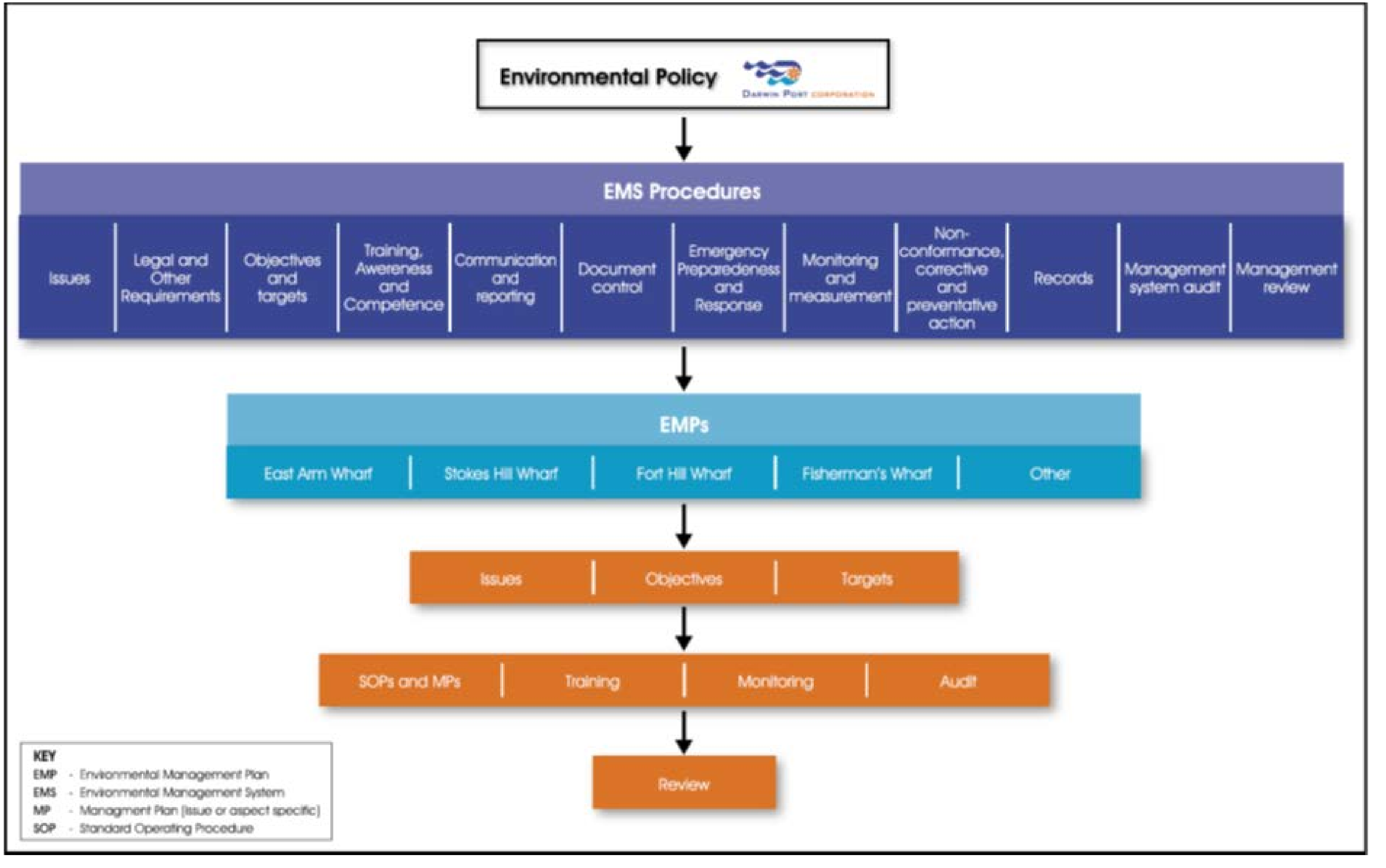
Peter Raines
General Manager Facilities

Ian Niblock
General Manager Operations

Peter Dummett
General Manager Port Development

Tony O'Malley
Harbourmaster

Figure 3-2 Darwin Port Environmental Management System Schematic



3.3 Inductions and training requirements

Inductions and training requirements will be determined by DPC and the Contractor on appointment and will be in accordance with DPC and Contractor's policies and procedures. All relevant inductions will be completed by all personnel before they begin work on the project. A training and inductions register will be maintained by the Contractor.

3.3.1 Environmental inductions

The DPC Environment Policy commits to providing sufficient resources and training to achieve the targets defined in its environmental management system. DPC will fulfil this commitment by appointing a contractor with complementary environment policies and provision of advice to the contractor on required environmental inductions and information.

Environmental inductions may include but not be limited to the following environmental topics:

- overview of key environmental issues and personnel responsibilities
- promoting awareness of significant environmental issues and personnel responsibilities
- reporting of environmental incidents - which will include how an event is reported and to whom the event is reported (all incidents are to be reported, including near misses)
- emergency procedures - which will cover the procedure for an emergency and for evacuation of the site in the event of a catastrophic situation arising
- Contingency Plans - e.g. for chemical spills or in the event that an unidentified Aboriginal heritage item is uncovered during the works.

3.3.2 Environmental awareness

A schedule of toolbox meetings will be developed by the Contractor and DPC and will be mainly aimed at operational staff. All Contractor and subcontractor personnel (if any) will be required to attend. Toolbox meetings will focus on environmental and safety items relevant for the project during that time, and are used as the main tool to further increase awareness of significant environmental and safety issues, and to communicate the relevant items contained in the Environmental and Safety Management Plans.

Typical items discussed in these toolbox meetings include environmental items such as new procedures or reinforcement of existing procedures relating to erosion control, handling of hazardous chemicals, weeds, clearing boundaries, management of waste/ recycling, biting insect problems, need to report all incidents and hazard/ near misses, etc.

3.3.3 Training

Only qualified and experienced personnel will be engaged on the project. All personnel will have appropriate qualifications and experience for their role on the project.

3.4 Environmental documents and records management

The Contractor appointed will have in place or will develop before the start of dredging, a document management system that fulfils requirements to operate under the DPC EMS.

Project records, including subcontractor project records, will be maintained to provide evidence of conformity to DPC requirements and commitments in this DDSPMP.

Such records include, but are not limited to:

- correspondence to/from the DPC and interested parties
- permits, licenses and approvals
- induction training records
- inspection and test documentation (including calibration)
- non-conformance and corrective action / complaints
- environmental incidents
- audits and inspections
- monitoring records
- delivery / waste dockets.

3.5 Performance management

Performance management includes activities to ensure that goals are consistently being achieved in an effective and efficient manner. A key component of the environmental management process is the development and implementation of specific measures to ensure that the environmental risks arising from the dredging and dredge spoil disposal activities are minimised. The success of these objectives is measured with key performance indicators (KPIs) defined for environmental management.

3.5.1 Environmental objectives

The environmental objectives of dredge operations management are to:

- Limit impacts of dredging and dredge spoil management operations on marine life and water quality.
- Ensure that protected marine species, including dolphins, dugongs, turtles and sawfish are not significantly adversely affected by dredging activities.
- Reduce the potential impacts from noise generated by dredging equipment.
- Limit sediment (turbid plume) mobilisation to an extent consistent with protecting the viability of specified communities.
- Ensure migratory bird species that use the dredge spoil deposition ponds are not directly adversely affected by dredge activities.
- Ensure that dredging and dredge spoil placement are undertaken in accordance with regulatory approvals, licenses, permits or authorisations.

3.5.2 *Performance criteria*

The DDSPMP is the key reference document which identifies actions and commitments to be followed by the Contractor and subcontractor personnel throughout dredging operations. The broad performance criteria of the DDSPMP are as follows:

- Compliance with the DDSPMP by all project personnel and activities.
- Adherence to discharge water quality parameters as identified in the Water Quality Monitoring Plan (Section 7.2 of this plan).
- No net adverse impacts on corals, mangroves, dolphins, dugongs, turtles, sawfish or migratory birds.
- No injuries to protected marine species.
- No complaints received in relation to noise, vibration and no impacts on protected species from these sources.
- Response to all registered complaints and completion of Complaint Record and / or Incident Report; appropriate corrective actions taken within three working days.

Where performance criteria are not met, this will form a trigger for review of the Plan, in addition to initiating corrective actions specific to the scenario.

3.5.3 *Environmental management KPIs*

In the environmental management frameworks detailed in Section 6 of this plan, specific objectives and targets are set for each significant environmental aspect. KPIs related to the objectives and targets for each of the environmental management frameworks can be found in Section 6.

General objectives and targets are:

- all personnel working on site have undergone an environmental induction
- internal audit score of 100% compliance with the DDSPMP
- client conducted audit score of 100% for compliance with the DDSPMP
- DoE conducted audit score of 100% for compliance with the DDSPMP
- no activity in breach of the provisions of any environmental legislation
- 100% investigation and reporting of any environmental incident at the site
- 100% compliance required for management measures relating to dredging and dredge spoil management.

3.5.4 *Environmental incident reporting*

All Contractor and subcontractor site personnel will be required to report all environmental incidents immediately to the appropriate supervisor in accordance with their incident reporting procedures. The Contractor engaged will have (or will develop prior to the start of dredging) an Incident Reporting and Investigation Procedure.

Incidents shall be tracked through to close out using an incident tracking system or register. Complaints will be investigated by the Project Manager and action taken to enable satisfactory closeout. Any incidents that have caused environmental harm or that have the potential to cause environmental harm will also be reported to the DPC representative and to NT EPA Pollution Hotline (1800-064-567) within 24 hours. When in any doubt as to the seriousness of the event, the Contractor will notify the authorities, in liaison with the DPC. The DPC will be notified of any notices received from authorities.

3.6 Management review

3.6.1 Inspections / monitoring

Daily visual monitoring will be conducted by site supervisors. Any corrective actions resulting from inspections will be entered onto a 'Non-conformance and Corrective Action Register' and the progress tracked for completion.

3.6.2 Internal audits

Given the short duration of dredging expected, an internal audit of this DDSPMP will be undertaken prior to commencement of dredging to assess the effectiveness of the Plan in the field and identify any opportunities for improvement.

3.6.3 External audits

External audits can be conducted by DPC or third parties, such as other government departments. The NTG may conduct an audit at any time when they believe there is an issue in relation to environmental compliance. DoE can also conduct or direct an external audit. The Project Manager will assist with any external audit.

Results from any external audits will be reviewed by the Project Manager, with any necessary corrective actions assigned to project personnel to ensure appropriate and timely closeout. Any corrective actions will be entered into a project corrective action register and the progress tracked for completion.

3.6.4 Project Corrective Action Register

Any environmental non-conformance (e.g. incidents, audit-related non-conformance, complaints, government notices, etc.) will be recorded in a project corrective actions register or similar to be developed by the Contractor. The corrective actions register will detail the non-conformance, allocates corrective action required, responsible persons, timeframes by which the action is to be completed, and the actual completion date. Each non-conformance shall be reviewed and it will be established if there are any actions available to reduce the severity or likelihood of re-occurrence.

3.6.5 Continuous improvement

The Contractor will have in place mechanisms described to review performance and to identify opportunities for improvement. Records will be kept and reporting will be done according to contractor procedures for managing documentation. Observations will be detailed in project reporting to DPC.

Mechanisms may include but will not be limited to:

- prestart meetings
- toolbox meetings
- progress reports.

4 EXISTING ENVIRONMENT AND RELEVANT STUDIES

4.1 Background

The marine environment within the project area is described in detail in the Draft EIS and EIS Supplement (DLP 2011a, b). This section of the DDSPMP provides a brief overview of those components of the existing environment that are pertinent to the consideration of impacts from dredging and spoil placement during the construction of the tug pens. It also provides information on studies that have been undertaken subsequent to the primary approvals process. This information provides the context for determining the management strategies detailed in Section 6 and the monitoring programs detailed in Section 7.

The Darwin Harbour region encompasses 2,417 km² and includes the catchments of the rivers and streams that flow into the harbour, including the Howard River, Elizabeth River and Blackmore River, as well as the large estuarine/marine water body that is Darwin Harbour. Within the harbour, shores are characterised by extensive intertidal mud flats and mangroves. Corals exist in several areas within the harbour.

The tug pens site is located in the vicinity of the existing East Arm Wharf, within Darwin Harbour (Figure 1-1).

4.2 Existing physical environment

4.2.1 Meteorological conditions

Darwin Harbour lies in the monsoonal (wet–dry) tropics of northern Australia and experiences two distinct seasons; a hot Wet Season from November to March (when winds are predominantly westerly) and a warm Dry Season from May to September (when winds vary from south-easterly through to northerly). The months of April and October are transitional. Maximum temperatures are defined as hot all year round, but November is the hottest month with a range of 25 °C minimum to 33 °C maximum, while June and July normally experience the lowest average daily temperatures with a range of 19 °C minimum to 30 °C maximum (Bureau of Meteorology [BoM] 2013).

The mean annual rainfall for Darwin is 1733 mm, with rain falling on an average of 113 days, mainly from November to March. A range of monthly rainfall averages received at Darwin International Airport (highest, mean and lowest monthly rainfall) is provided in Table 4-1 (BoM 2014). Daily mean evaporation ranges from 6 mm in February to 8 mm in October. The mean annual evaporation rate is 2482 mm (BoM 2012).

Table 4-1 Average monthly rainfall for Darwin (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug*	Sep*	Oct*	Nov*	Dec*
Mean	426	375	319	102	21	2	1	5	16	71	142	251
Max	940	1110	1014	396	299	51	27	84	130	339	371	665
Min	136	103	88	1	0	0	0	0	0	0	17	19

* Averages to 2013

Cyclone activity occurs intermittently in the Darwin region, mainly between November and April, with cyclones typically causing the most damage within a distance of 50 km from the coast. Aside from the impacts of strong winds, storm surges can be of concern to vessels and coastal developments surrounding Darwin Harbour. Storm surges (generally 2–5 m higher than normal tide levels), result from strong onshore winds and reduced atmospheric pressure (BoM 2012), and can cause flooding and damage through raised tidal levels and increased wave heights. The height of a storm surge is influenced by many factors, including the intensity and speed of winds within the associated cyclone, the angle at which the cyclone crosses the coast and the bathymetry of the affected area.

4.2.2 Coastal geomorphology and bathymetry

Darwin Harbour is a large ria system, or drowned river valley, formed by post-glacial marine flooding of a dissected plateau. The harbour, which has a surface area of some 500 km^2, was formed by rising sea levels about 6000–8000 years ago. Since the formation of the harbour, surface erosion from the adjoining terrestrial environment has carried substantial quantities of sediment into the harbour. This sediment now forms much of the intertidal flats that which overlie bedrock around the harbour margins. The Elizabeth River flows into the East Arm of the harbour, within which lies the project area.

The harbour extends for more than 30 km along a north-west to south-east axis. The main channel of the harbour is around 15-25 m chart datum (CD) deep, with a maximum depth of some 36 m. The channel favours the eastern side of the harbour and continues into East Arm, at water depths of more than 10 m CD. The bathymetry in this area has been already previously modified by dredging for the development of the East Arm Wharf.

In 2010, iXSurvey Pty Ltd completed a hydrographic survey in the vicinity of East Arm. Figure 1-1 shows that the bathymetry falls from approximately -1.5 m LAT at the north-east corner of the area to be dredged to a depth of approximately -6 m LAT at the north-western corner. A deeper channel between -6 to -9 m LAT follows the existing rock wall on the southern side of the area to be dredged.

4.2.3 Marine sediments

The sediment profile for the East Arm of Darwin Harbour consists of Quaternary age intertidal marine alluvium comprising mud, silt, sand and coral remnants, underlain by the Proterozoic metasediments of the Burrell Creek Formation, consisting of meta-siltstone, meta-sandstone and phyllite. The rocks strike close to north-south and are steeply dipping either to the east or west. Quartz veins are widespread within the Burrell Creek Formation.

Approximately 80% of the Darwin Harbour region's seafloor is estimated to be covered with soft surfaces consisting of mud and fine sand. Soft surfaces containing varying amounts of gravel and sand are found in the main channels around reefs, on beaches and on spits and shoals near the mouth of the harbour (Fortune 2006).

In a geotechnical investigation of the greater EAW area, including the tug pens dredge footprint and surrounds, Aurecon (2011) reported predominantly fine grained deposits were detected with granular content of less than 40%. Gravel was found in only one sample. In general, the alluvial material in the tug pens area can be described as silty clay with trace sand. The majority of Atterberg limits indicate that the sediment is clay of high plasticity. The maximum depth of these marine alluvial sediments ranged from -8.47 to -10.11 m CD across the dredge footprint. This was supported by the findings of the geochemical assessment of the sediments within the tug pens dredging footprint (URS 2014) in which PSD analysis reported silty clay as the primary component in all samples, with sand present generally in deeper samples (>0.5 m depth). Gravel was reported close to, or below, 1% in all samples; however gravel may be misrepresented through the presence of shell or coral fragments.

The Tug Pen and Small Vessel Berths Sediment Geochemical Investigation report (URS 2014) contains a summary of the potential contaminant inputs to the dredging area. Data obtained from this investigation are provided in Appendix A for context.

Land uses in the Darwin Harbour catchment represent potential sources of contaminants that may accumulate in the barge facility footprint. In the mid-1990s, the mean annual contaminant loads contributed to the harbour from the Hudson Creek catchment (upstream of the barge facility development) were calculated by Padovan (2001) to be 15 t of nitrogen, 3 t of phosphorus, 40 kg of arsenic, 6 kg of cadmium, 220 kg of chromium, 189 kg of copper, 327 g of lead, 43 kg of nickel and 1860 kg of zinc. Management and monitoring of acid generation and contaminants within the reclamation area are described in Sections 6 and 7 of this DDSPMP.

4.2.4 Metocean conditions

Darwin Harbour has semidiurnal macro-tides (two highs and two lows per day) with a strong diurnal inequality. The highest astronomical tide is 8 m CD. The mean spring tidal range is 5.5 m and the mean neap tidal range is 1.9 m, with a maximum range of 7.8 m. It is a well-mixed system with large volumes of water moving within the harbour with tidal fluctuations. Tidal movement plays an important role in re-suspending material from the harbour floor into the water column.

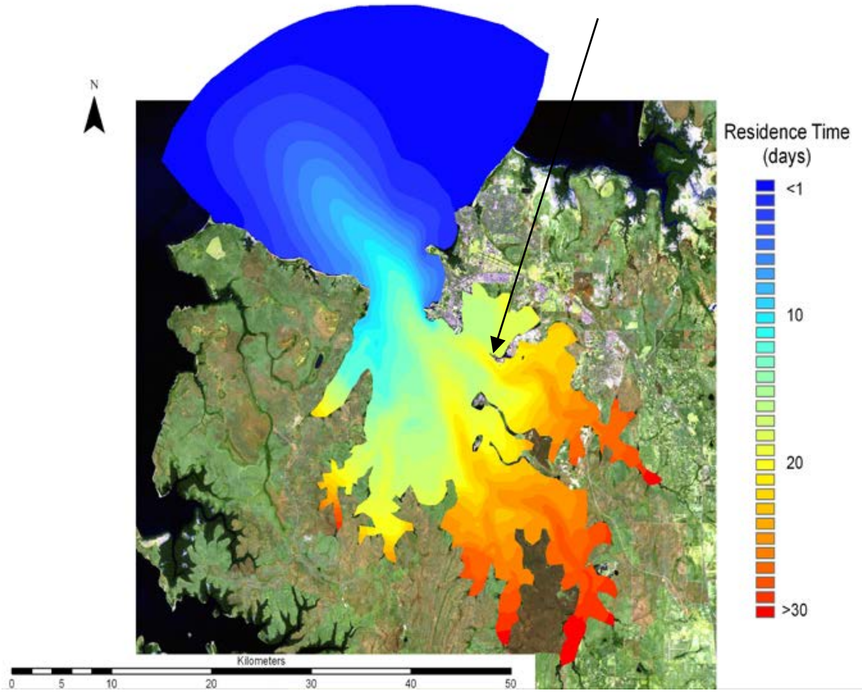
Williams, Wolanski and Spagnol (2006) investigated the link between hydrodynamics, sediment and nutrient dynamics in the harbour to assist in the management of infrastructure developments. Near headlands and embayments, a complex circulation occurs that includes jets, eddies, separation points and stagnation zones. These currents are different at flood and ebb tides, and the asymmetric dispersion of particles results in trapping at headlands and embayments. Sediment is delivered to the upper arms by runoff. Despite being macrotidal the harbour was found to be poorly flushed, with much of the riverine fine sediment remaining trapped in mud flats and mangroves with little escaping to the sea. The residence time of pollutants in the upper reaches of the harbour was found to be in the order of 20 days (Williams, Wolanski & Spagnol 2006).

The tug pens site is located in an area where the Dry Season flushing is estimated to be around 20 days (Figure 4-1), hence it is defined as being in the Upper Estuary Zone.

4.2.5 Marine water quality

Water quality in Darwin Harbour is described as generally high, although naturally turbid most of the time (DLP 2011a). Water quality parameters vary greatly with the tide (spring versus neap), location of sampling point (inner versus outer harbour), and with the season (Wet Season versus Dry Season).

Figure 4-1 Dry Season flushing zones in Darwin Harbour



During the Dry Season the salinity is quite uniform and the estuary well mixed. This contrasts with Wet Season conditions where the saline water of the harbour is met in the upper estuary by a buoyant plume of freshwater (from the catchment). A strong salinity gradient can persist during and after rainfall events in the upper reaches of the estuary and the tidal creeks. The Wet Season effects on harbour water quality (through high surface runoff from the land) can last until April or May, depending on the amount and duration of rainfall.

Duggan (2006) conducted research on the water quality of Darwin Harbour from 2002 to 2004. Seasonal aspects, rather than spatial or tidal aspects, were found to be the most important determinant of water quality, with rainfall considered to have the greatest impact on water quality (increasing nutrients, suspended solids and chlorophyll a).

There is no evidence of widespread water or sediment pollution in the harbour, although some localised pollution has been identified in the past (e.g. Padovan 2003; Water Monitoring Branch 2005; Drewry 2011). Anthropogenic influences to harbour water quality include the East Arm Wharf port operations, historic industrial activities at Darwin Waterfront, Sadgroves Creek and wastewater outfalls (URS 2004), however there is no evidence of hydrocarbon or pesticide pollution in the harbour (Darwin Harbour Advisory Committee [DHAC] 2007).

4.2.6 Water quality baseline data

Between 2008 and 2011, a number of water quality investigations were undertaken by URS on behalf of INPEX Browse, Ltd (INPEX) to characterise the existing conditions in East Arm (URS 2009, 2011). Table 4-2 presents summary statistics for Dry and Wet Season water quality, as recorded at a site off the southern tip of South Shell Island (URS 2011a).

These data were collected every 15 minutes over a year-long program. Data were grouped and averaged based on tidal cycle and seasonal variation, allowing seasonal means, medians and percentiles to be calculated. This gives a robust body of data to compare background levels of turbidity with potential increases associated with various natural and artificial turbidity-generating events in the harbour.

Water quality data from South Shell Island are relevant to the present project as this location is the nearest significant receptor (coral communities) to the dredging location, although modelling does not indicate an impact at this site (refer to Section 5).

Table 4-2 Summary of water quality parameters at South Shell Island (URS 2011a)

	Dry Season			Wet Season		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Temperature (°C)	28.1	25.3	32.1	30.4	28.1	32.0
Conductivity (mS/cm)	48.7	40.2	52.9	46.2	36.7	49.8
Depth (m)	6.3	2.4	11.0	6.7	2.5	11.3
pH	8.0	7.7	8.5	8.0	7.6	8.2
DO (%)	93.5	73.4	121.1	88.5	67.3	106.4
Turbidity (NTU)	4.4	0.1	46.4	8.3	0.2	68.0
Suspended sediment concentration (SSC) (mg/L)*	10.8	7.1	46.4	14.1	7.2	64.7

* Calculated from NTU using relationship in URS (2011a): SSC = 0.848 * NTU + 7.0477

4.3 Environmental receptors

4.3.1 Marine habitats and filter feeder communities

A comprehensive survey of the marine habitats around South Shell Island was undertaken in May 2012 by Geo Oceans Pty Ltd (Geo Oceans 2012). A habitat map (Figure 4-2) was produced from interpolated substrate and biological community data collected on the survey. The map also incorporated data from previous habitat mapping in the area (Geo Oceans 2011), along with digital imagery and acoustic survey data (including that of iXSurvey [2010]). It should be noted that “no epibenthos” refers to areas in which the cover of epibenthic macrobiota (e.g. corals, filter-feeders, macroalgae) was less than 10%.

Further knowledge of the benthic communities in and surrounding the project area is provided by the benthic community modelling undertaken by DLRM in 2015 (DLRM, 2015). This modelling described the benthic communities in and neighbouring the tug pens dredge area (Figure 4-3). The modelling considered a range of spatial data sets describing the physical environment and available biological data using a GIS based spatial model to predict the likely benthic communities for the area mapped. The data layers used in the modelling included:

- Darwin Harbour bathymetry
- Darwin Harbour seascapes
- Darwin Harbour % mud, sand and gravel
- Darwin Harbour intertidal layer

- Darwin Harbour flora and fauna point data collated from various surveys

It can be seen in Figure 4-3 that the area of the tug pens dredge footprint and adjacent to the settlement pond discharge point are mapped as being bare sediment with no flora, macroalgae, seagrass or infauna present.

Patterson and Williams (2014) completed a number of side scan sonar transects and sediment grab samples within and surrounding the area to be dredged (approximated by area A in Figure 4-2) to inform the sediment transport modelling component of this Plan (Section 5). Their observations, while not made for the purpose of validating the benthic community modelling, generally provide agreement with the modelled benthic community data to the north of East Arm Wharf. The seabed scans revealed a 'flat, homogeneous bed surface with little irregularities between each transect and from one end of a transect to the other. This was verified by grab sample results'.

Filter feeder communities primarily occur on intertidal or subtidal hard substrates and can be the dominant component of the benthic community in areas where a soft sediment veneer overlies hard substrate. While no filter feeder communities have been mapped in the tug pens dredge footprint, adjacent to the area to be dredged on the north side of East Arm Wharf or adjacent to the settlement pond discharge point, small patches of filter feeder communities have been mapped on the southern side of East Arm. These communities are widely dispersed throughout Darwin Harbour in comparable sub-tidal environments (Geo Oceans 2011, 2012; Smit, Penny & Griffiths 2012).

Figure 4-2 Benthic habitats, East Arm adjacent to the tug pens site (Geo Oceans 2012)

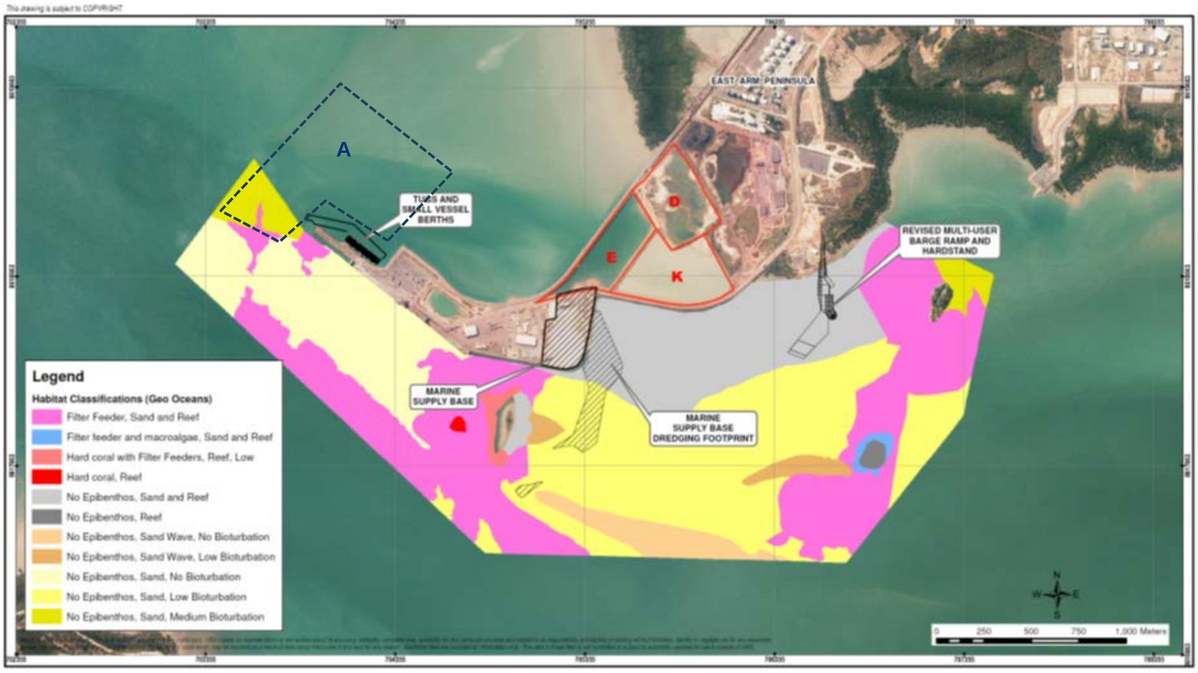
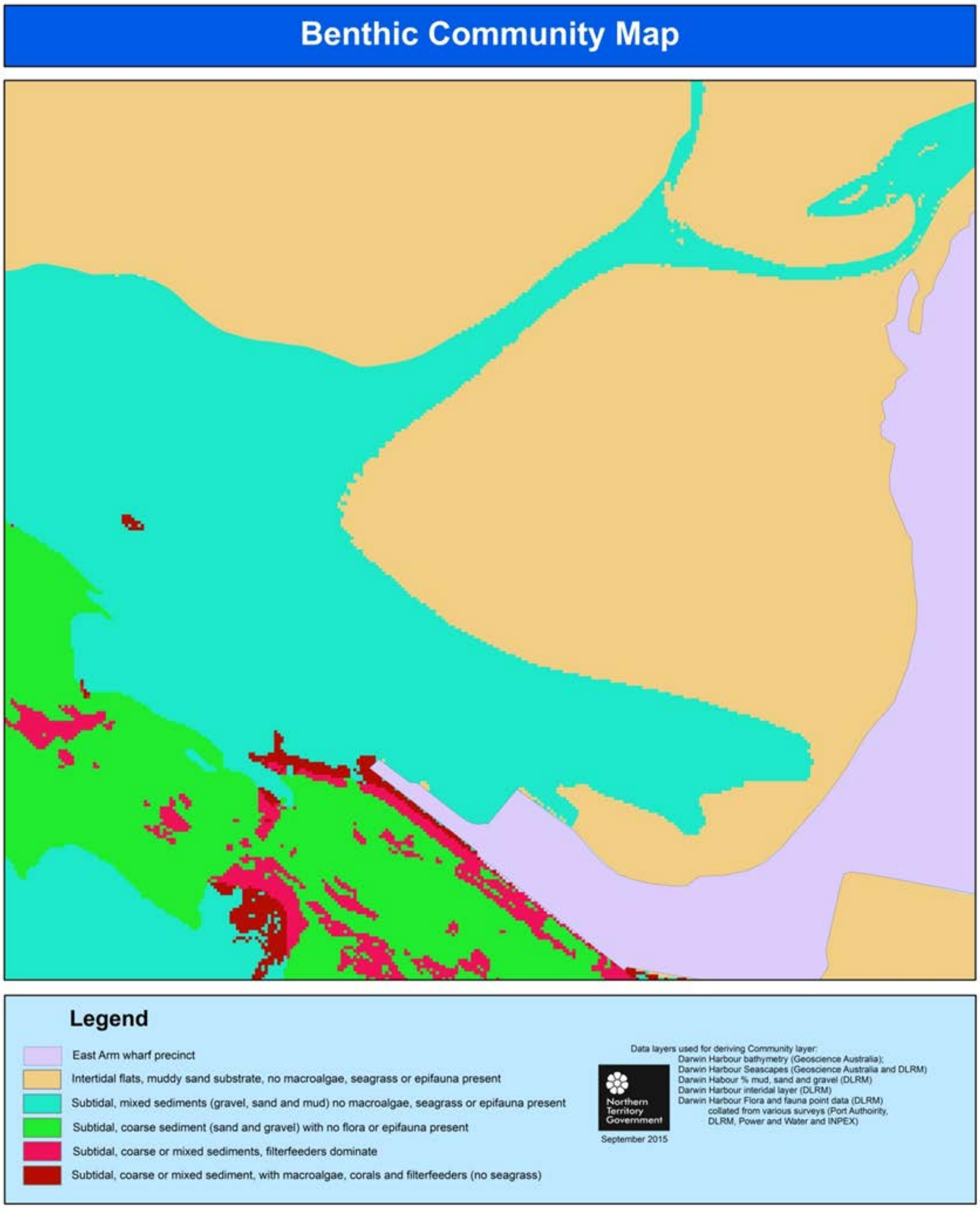


Figure 4-3 Modelled benthic communities (DLRM, 2015)



4.3.2 Hard coral communities

Hard coral communities occur in Darwin Harbour where the substrate is rocky in the lower intertidal and shallow subtidal zones and where hydrodynamic conditions permit. Hard corals are dominant within some of the benthic communities around South Shell Island (Figure 4-2), mainly on the western side of the island. Other well-known hard coral communities in Darwin Harbour include:

- Off the north-east shore of Wickham Point, within 4 km of the proposed tug pens dredging works.

- Weed Reef, Plater Rock and Kurumba Shoal, on the western side of the harbour, and Dudley Point at the northern end of Fannie Bay, all more than approximately 10 km from the tug pens.
- Channel Island coral community in Middle Arm, on the intertidal platform between Channel Island and the mainland. This is listed on the Register of the National Estate and is a declared Heritage Place under the NT H*eritage Conservation Act 1991*. It is some 15 km (by sea) from the tug pens.

All of these communities are sufficiently remote from the tug pens that the proposed dredging works pose no credible risk of impact to them. Sediment plume modelling (Section 5) predicts that the South Shell Island coral community is also sufficiently distant from the proposed dredging works to be at no risk of impact.

4.3.3 Protected marine species

4.3.3.1 Cetaceans

Three species of coastal dolphin inhabit the Darwin Harbour region: the Australian humpback (*Sousa sahulensis*; formerly known as the Indo-Pacific humpback [refer to Jefferson et al (2014) for taxonomic results]), Indo-Pacific bottlenose (*Tursiops aduncus*) and Australian snubfin (*Orcaella heinsohni*) dolphins. All three species are listed as Marine and Migratory species and are therefore Matters of National Environmental Significance under the EPBC Act.

Brooks & Pollock (2014) undertook the most extensive and recent study of the abundance, movements and habitat use of coastal dolphins in the Darwin region (Darwin Harbour, Bynoe Harbour and Shoal Bay) between 2011 and 2014, a program initiated as part of the environmental approvals for the Ichthys LNG project. Their study revealed that together, these three species are more commonly observed in Shoal Bay, while in Darwin Harbour, dolphins are more commonly seen in East Arm and West Arm than other parts of Darwin Harbour.

Brooks & Pollock (2014) analysed the results of the first six primary samples from dolphin surveys undertaken between October 2011 and March 2014 concluding:

- Australian humpback dolphins were the most abundant at all three sites monitored with the number estimated across the six surveys in Darwin Harbour remaining relatively consistent at between 37 and 49 individuals.
- Bottlenose dolphin numbers in Darwin Harbour were more abundant than at Bynoe Harbour and Shoal Bay with numbers varying between 13 and 30 across the surveys. Temporary emigration between sites is thought to account for higher variation in numbers of bottlenose dolphins.
- Snubfin dolphins were the least observed species in the Darwin Harbour region with highly irregular numbers observed between surveys. Only one snubfin dolphin was detected in the vicinity of Darwin Harbour East Arm during the surveys.
- While significant change in detection rates in East Arm were evident through this study, these differences occurred prior to any construction activity associated with the Ichthys project. Significant changes were also observed at Bynoe Harbour, a site distant from any potential construction impact.

4.3.3.2 *Dugongs*

Dugongs are known to occur in Darwin Harbour waters, although in relatively low numbers. Dugongs have been recorded in higher densities at Gunn Point and the Vernon Islands, some 30–50 km to the north-east of the mouth of the harbour. Dugongs have also been observed in relatively high numbers at Bare Sand Island and Dundee Beach in Fog Bay, 60 km south-west of Darwin Harbour, and are known to travel long distances (Whiting 2008).

Cardno (2014) compared the results of baseline surveys with four surveys undertaken throughout the dredging phases of the Turtle and Dugong Monitoring Program associated with the INPEX Ichthys project. This study revealed that dugongs were observed in varying numbers between surveys however no trends (including seasonal trends) were evident. There was a higher number of dugong observed in shallower waters (6 – 10 m), generally in foraging areas where seagrass was present. It was concluded that variation in dugong numbers observed at each site between surveys was most likely to be a result of short term movement to visit optimum foraging areas of seagrass.

During baseline surveys (June to October 2012) most sightings in Darwin Harbour were around Weed Reef, West Arm and near Bladin Point, as well as in the shallow regions of Shoal Bay. During later baseline surveys, most dugong sightings were around outer Darwin Harbour, with aggregations around mapped seagrass near Casuarina Beach.

During the first of the Dredging Phase surveys (May 2013), dugongs were predominantly sighted in outer Darwin Harbour, with only one dugong sighted near Weed Reef and another in the shallow areas in West Arm. During the Dredging Phase surveys in July/August and October 2013, no dugongs were sighted in the inner Darwin Harbour, while during the end of dredging survey (May 2014) three dugongs were sighted near Weed Reef.

During the two surveys undertaken in October 2013, sightings were concentrated around Casuarina Beach and were associated with areas of seagrass (*Halodule* sp.). Lower numbers were observed in this area in wet season surveys and it was considered that the reduced seagrass coverage in this season was likely to have been a contributing factor (Cardno 2014).

In general, it is considered that dugongs could occur anywhere in the harbour that could support seagrasses or algae. The closest benthic community to the tug pens that was found by Geo Oceans (2012a) to support a notable amount of macroalgae was on the mixed sand and rocky reef habitat around Old Man Rock, some 3 km to the east of the tug pens (Figure 4-2). Substantially greater areas of potential foraging habitat for dugong exist elsewhere in the harbour (INPEX 2011b).

4.3.3.3 *Turtles*

Six species of marine turtles are known to occur in NT waters. Of these, four (the green, hawksbill, olive ridley and flatback turtles) are considered to occur in the Darwin Harbour region regularly, while the olive ridley and loggerhead turtles are suspected to be infrequent users (Cardno 2014). The leatherback turtle is considered to be an oceanic species and is unlikely to occur in Darwin Harbour (Whiting 2003).

Turtles recorded during surveys associated with the Ichthys Turtle and Dugong Monitoring Program (Cardno 2014) showed a general trend of decreasing numbers with depth (62% observed in water 0 – 5 m deep) with the majority of turtles observed in the Darwin Harbour region over sand, gravel or reef habitats. There were only a few turtles sighted in association with mangroves and mud habitats (0.5% and 3%, respectively), which are those habitats that occur in the vicinity of the tug pens dredging area.

The shoreline throughout Darwin Harbour, and particularly in East Arm, consists largely of mangrove forests and mudflats and does not provide suitable nesting habitat for any species of turtle. The nearest nesting beach (used by the flatback turtle) is located in the Casuarina Coastal Reserve near Lee Point on the north-eastern shore of the harbour. Turtles visiting the harbour are more likely to be foraging for food. Flatback and hawksbill turtles forage on the filter-feeder communities which are extensive in the harbour. The hawksbill turtle also forages on seagrass and macroalgal communities in addition to filter-feeders. Green turtles forage amongst seagrass and macroalgal communities (INPEX 2011a).

4.3.3.4 Sawfish

The EPBC protected matters database indicates that dwarf sawfish (*Pristis clavata*), largetooth sawfish (*Pristis pristis*) and green sawfish (*Pristis zijsron*) may potentially inhabit Darwin Harbour. The three species of sawfish are widely distributed throughout Australian tropical waters and are thought to be uncommon within the harbour.

No records have been found of sightings of the largetooth sawfish within the harbour. Two green sawfish have been recorded in Buffalo Creek, which discharges into Shoal Bay, outside of the main harbour (Parks and Wildlife Commission 2006) while the Atlas of Living Australia (biocache.ala.org.au) contains only two records of the dwarf sawfish in the Darwin Harbour region:

- Buffalo Creek, (Museums and Art Galleries of the Northern Territory [MAGNT] record);
- an Australian Museum record with an imprecise location, possibly from Rapid Creek which is in the middle harbour approximately 10 km to the north of the tug pens.

These are both tidal creeks, quite a different environmental setting from the area to be dredged for the tug pens.

4.3.4 Migratory bird species

Migratory bird species recorded around East Arm Port area have been predominantly within the mangroves, the saline wetlands and beside the water in the dredge spoil ponds. Although historical counts suggest that migratory shorebird numbers within Darwin Harbour are modest (Chatto [2003] survey Block 4), the East Arm Port does seasonally support nationally significant numbers of some migratory shorebirds (Table 4-3).

Shorebird monitoring has been continued at EAW and the dredge sediment disposal ponds since November 2009. In accordance with EPBC Approval EPBC 2010/5304, the Migratory Bird Monitoring Plan (MBMP) was developed and approved in 2013.

The criteria for determining the importance of habitat for migratory shorebirds in Australia (EPBC Act policy statement 3.21) rates a site as nationally important habitat if:

- the site is identified as internationally important under Ramsar: or
- the site supports:
  - at least 0.1% of the fly away population of a single migratory shorebird species; or
  - at least 2000 migratory birds; or
  - at least 15 shorebird species.

The East Arm Port area meets the criteria for supporting nationally important migratory shorebird habitat in that:

- five migratory shorebird species (lesser sand plover, greater sand plover, far eastern curlew, terek sandpiper and sharp-tailed sandpiper) have been recorded within the East Arm Port area at numbers greater than 0.1% of the fly away population by Chatto (2003) (see Table 4-3)
- six migratory shorebird species (whimbrel, far eastern curlew, common greenshank, sharp-tailed sandpiper, lesser sand plover and greater sand plover) have been recorded within Pond D at numbers greater than 0.1% of the fly away population by Lilleyman et al (2013) (see Table 4-4)
- at least 2000 migratory birds have been recorded
- twenty-two migratory shorebird species have been recorded within the study area (EMS 2011).

Table 4-3 Migratory shorebirds recorded in numbers greater than thresholds for nationally significant habitat in Darwin Harbour prior to start of the EAW development project (Survey Block 4. Chatto, 2003)

Species	Recorded Numbers Darwin Harbour Survey Block 4
Lesser sand plover	1800 (6% Figure 104)
Greater sand plover	3410 (11% Figure 106)
Far eastern curlew	200 (4% Figure 64)
Terek sandpiper	1099 (7% Figure 74)
Sharp-tailed sandpiper	370 (2% Figure 92)

Table 4-4 Migratory shorebirds counted in Pond D (where numbers exceeded EPBC threshold for nationally significant habitat) between 2010 and 2015 as part of East Arm Wharf monitoring (Lilleyman et al 2015)

Shorebird	Counts[2]	Maximum count[3]	No. Counts > EPBC threshold	Threshold (DEWHA 2009)
Whimbrel	94	289	17	55
Far eastern curlew	101	235	39	38
Common greenshank	186	112	4	100
Terek Sandpiper	45	142	9	50
Grey-tailed Tattler	52	218	14	40
Red Knot	14	253	1	220
Sharp-tailed sandpiper	98	200	1	180
Pacific golden plover	37	145	2	100
Lesser sand plover	74	300	4	140
Greater sand plover	91	483	23	100

Nationally significant numbers of some migratory birds listed under the EPBC Act roost on the dredge spoil ponds at East Arm Wharf. Numbers of waterbirds counted varied from 50 to 1333 (EMS 2011). This variation is likely to reflect variation in both time of the year and tidal heights at the time of the survey, given the macrotidal nature of Darwin Harbour and thus the variability in the number and quality of natural roosting sites that might be available. This suggests that alternative roosting sites are both available and currently being used by migratory birds when they are not present at the East Arm Port. However, at the highest tides, EAW appears to be a favoured roost, presumably because rates of disturbance and perceived vulnerability to predators are lower than at other sites. This may be important for migratory species at times when they are fattening up before migration.

[2] Number of counts that species were present
[3] Maximum number of species present in one count

5 SEDIMENT TRANSPORT MODELLING AND IMPACT ASSESSMENT

5.1 Synthesis of assessment approach

DPC commissioned AIMS to undertake sediment transport modelling to assess the impact of dredging of the tug pens on the local water quality and potential sedimentation impacts in the local area. The assessment of potential environmental impacts from the dredging works at the tug pens was informed by:

- two-dimensional hydrodynamic models that incorporated water levels, currents and waves
- sediment transport models that determined suspended sediment dispersion and sediment accumulation
- GIS analyses to quantify and depict potential impacts on habitats on the basis of tolerance limits.

5.2 Hydrodynamic model

The hydrodynamic model used by AIMS (2014) was the ‘Darwin Harbour community model’. This model was developed for the original EAW development and, over a period of 16 years, was applied to many of the dredging campaigns within Darwin Harbour. Over the past five years the model has been further refined and developed by AIMS to assist in understanding the general movement of cohesive and non-cohesive sediments and nutrients in the harbour. It has formed the foundation for the NTG’s WQPP for the harbour (refer Section 1.7).

Boundary conditions for the model were taken from observations recorded at Buoy 5 at the entrance to Darwin Harbour. Buoy 5 is a DPC channel marker that is equipped with instrumentation to measure wind speed and direction; tidal depth, current and direction; and waves. This model was applied to the dredging and tailwater management method proposed for the dredging works (as described in Section 2).

5.3 Sediment transport model

AIMS undertook sediment transport modelling to predict the dispersion of sediment plumes over the predicted duration of the dredging program (840 hours) and the sediment accumulation after a period of one month.

The model used in the AIMS April 2014 Lands Development Corporation (LDC) report, updated with recent bathymetry since the dredging of the MSB, was used to carry out dredge modelling for the proposed tug berths (Patterson & Williams 2014).

5.3.1 Modelling use of cutter suction dredge

The assumptions incorporated into the AIMS model were made in consultation with DPC and represent a likely scenario based on the use of a small CSD.

The major assumptions made included:

- dredge volume of 70,000 m^3 at a dredge rate of 2,000 m^3/hr (200 m^3 of solids), which is slightly conservative, given the expected dredge rate of approximately 1,800 m^3
- water to sediment ratio of 9:1
- 1% leakage for CSD and 3% for BHD
- dry bulk density of 857 kg/m^3 (based on field observations [Patterson & Williams 2014])
- 840 hours dredging duration (dredge operating 10 hours per day)
- discharge of water from the settlement ponds through the permeable bund wall at a rate of 1 m^3 per second for 10 hours per day with a SSC of 54 mg/L.

5.3.2 Modelling use of a backhoe dredge

Additional modelling was undertaken to provide a conservative prediction of the sediment plume that could be expected should a BHD be utilised. This scenario was modelled using the same assumptions as above for a CSD with a 300% increase in the loss rate or disturbance rate at the point of dredging to allow for uncertainty in the loss rate.

If a backhoe and slurry pump are used then sediment plume patterns from the backhoe would be discrete 'pulses' of turbidity and suspended sediments rather than the steady streams arising from a CSD head. The plume generated by a BHD is dependent on the bucket size and type, material characteristics, speed of the dredge operation, depth of water and current strength in the area being dredged.

While loss rates and resulting plume patterns at the dredge site may differ depending on the dredging method employed (CSD or BHD), it is reasonable to conclude, given the proposed dredge depth and sheltered location, that the short duration of dredging and relatively small quantity of spoil to be removed from the site will result in little difference in dredge plume.

5.3.3 Modelling results

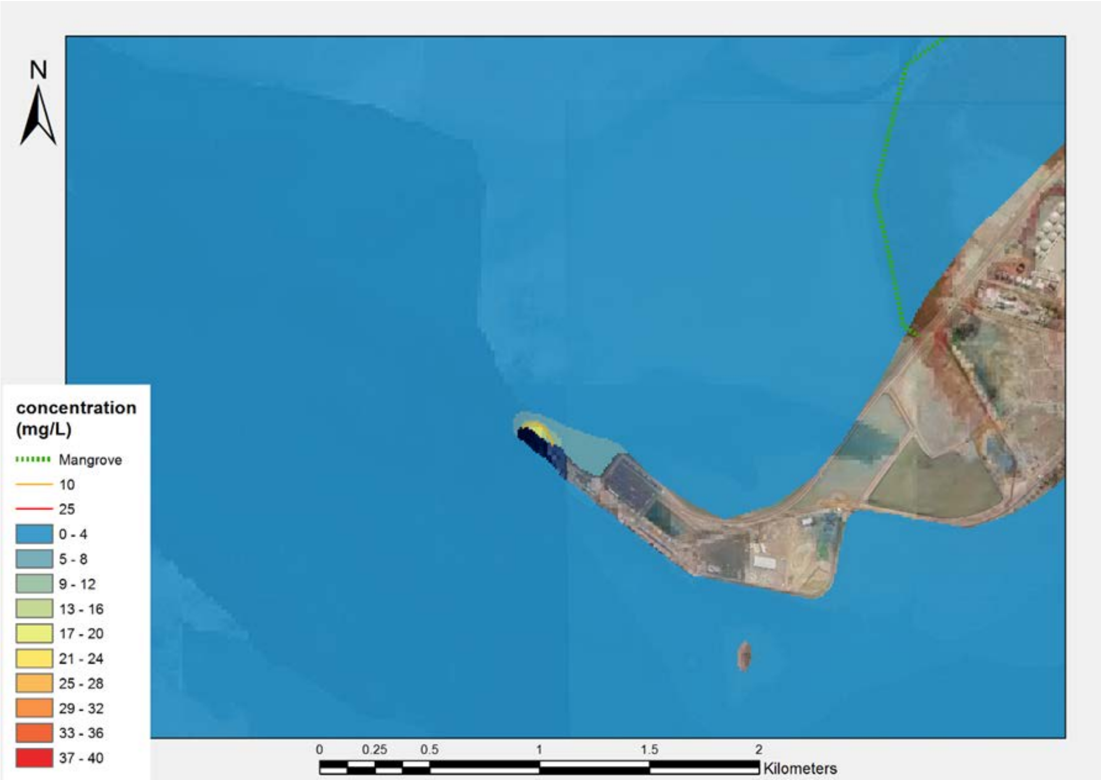
The sediment transport modelling has incorporated a number of factors to increase the conservative nature of SSC predictions including:

- modelling of 10 hours of continuous dredging per day when dredging will likely be interrupted by operational requirements, allowing plumes to disperse.
- a discharge duration of 30 days post dredging has been modelled for sediment deposition. The duration of discharge will likely be considerably less than this.

The dredge plume was modelled for a period of 840 hours representing the expected duration of dredging based on the dredge rate and volume to be dredged. Model outputs are presented as:

- 90th percentile plot of modelled suspended sediment concentration (mg/L) (Figure 5-1)
- 95th percentile plot of modelled suspended sediment concentration (mg/L) (Figure 5-2)
- Time series chart of sediment concentration (mg/L) (Figure 5-3)
- Sediment accumulation after one month (Figure 5-4).

Figure 5-1 90th percentile modelled suspended sediment concentration (mg/L) for a CSD (top) and BHD (bottom)



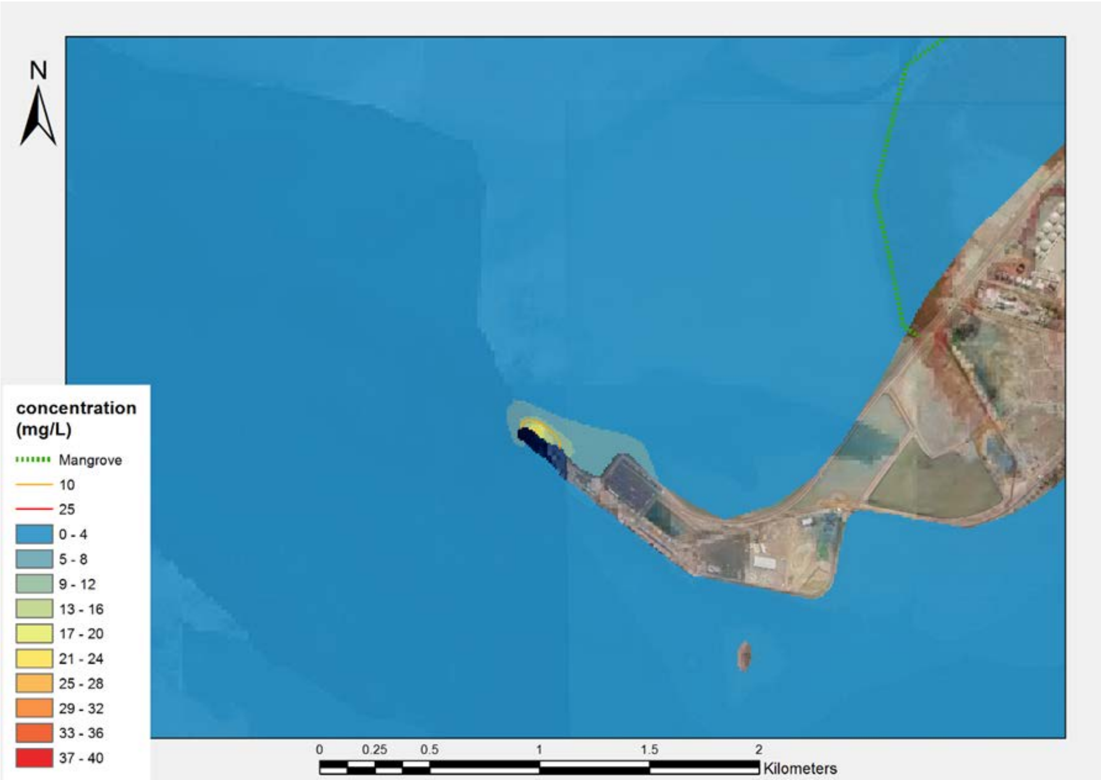


Figure 5-2 95th percentile modelled suspended sediment concentration (mg/L) for a CSD (top) and BHD (bottom)

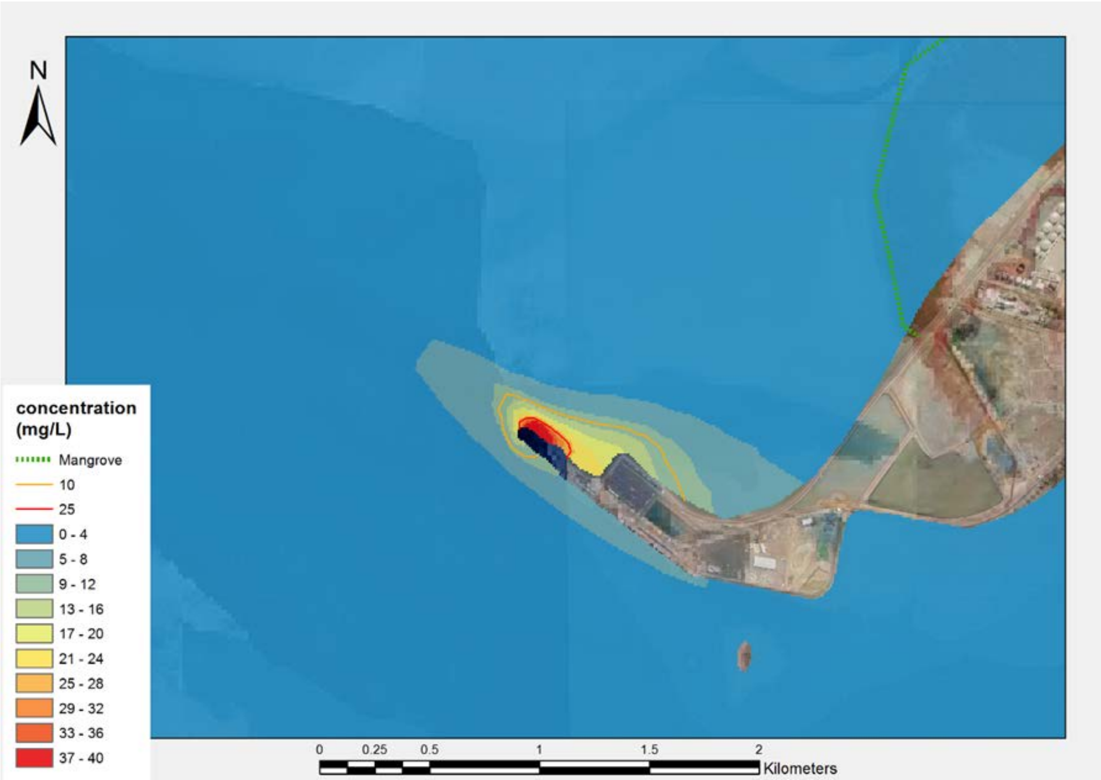
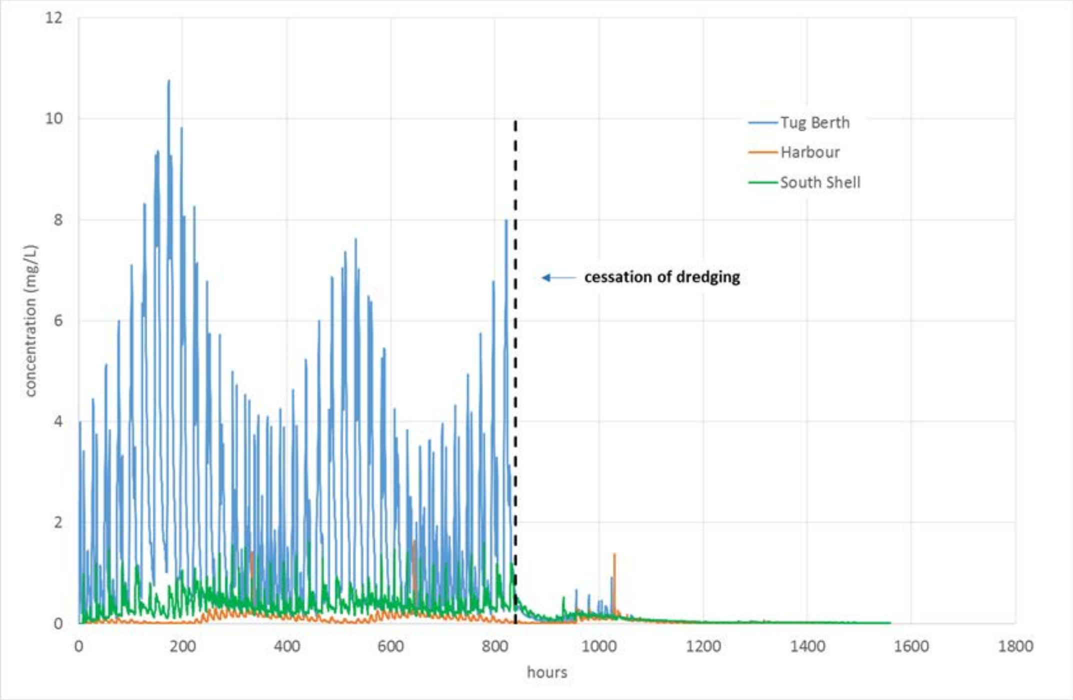


Figure 5-3 Time series of sediment concentration (mg/L) for the Tug Pens area (blue), midway between East Arm Wharf and Darwin city (orange) and South Shell Island (green) for CSD (top) and BHD (Bottom)



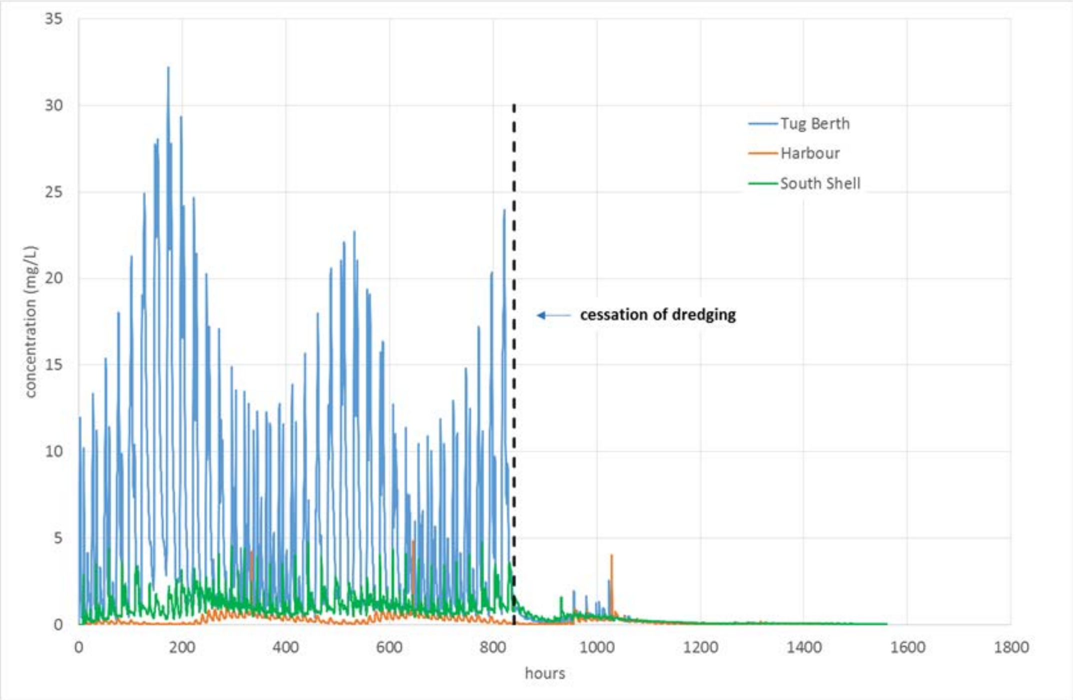
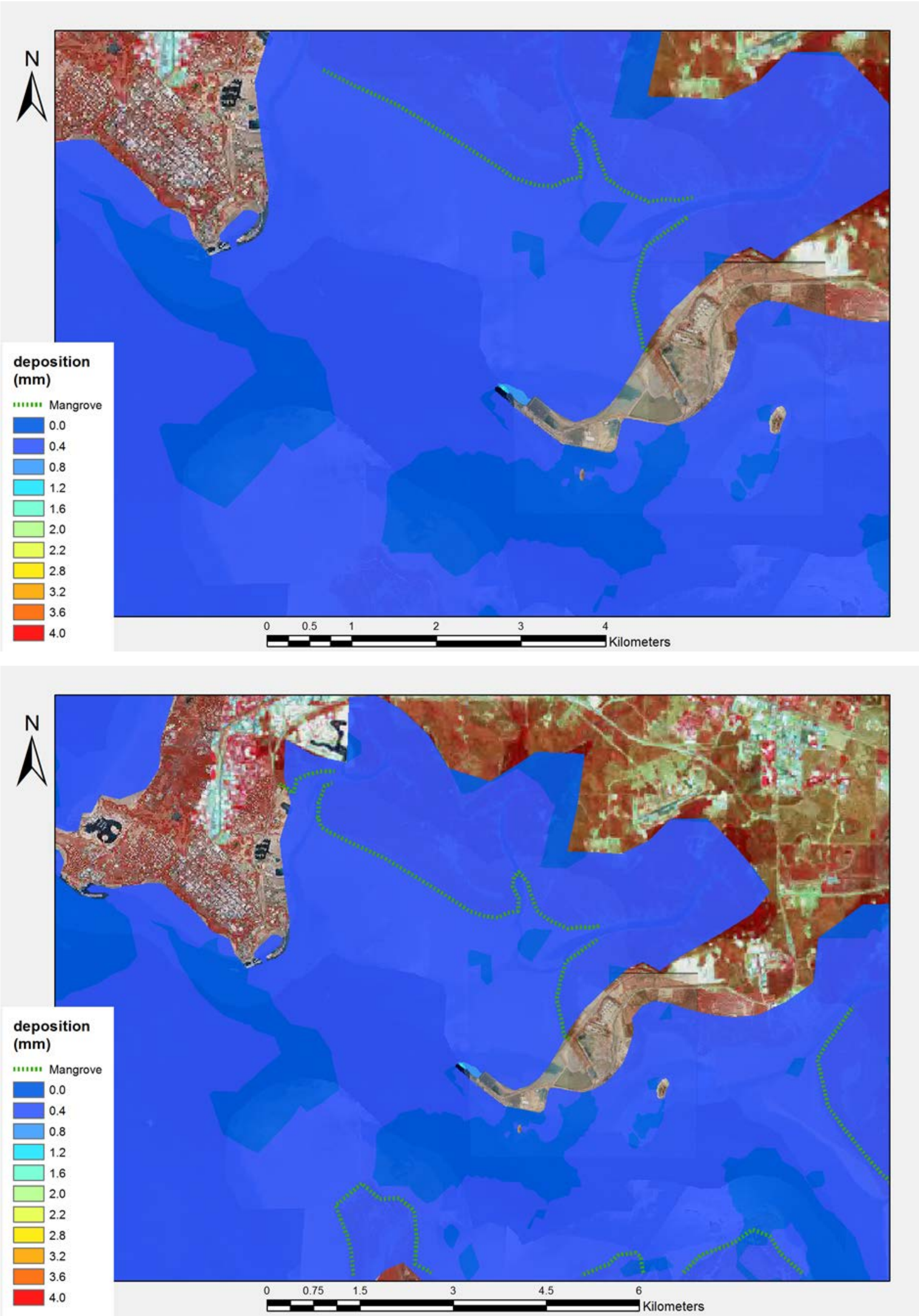


Figure 5-4 Modelled sediment accumulation after one month for a CSD (top) and BHD (bottom)



5.4 Tolerance limits for biological communities

Tolerance limits used for the MSB dredging will be adopted for this project.

Given that the schedule for dredging has not yet been defined, the tolerance limits applicable to the dredging will be dependent on whether dredging takes place in the Wet or Dry Season.

Tolerance limits were calculated from the appropriate (Dry or Wet Season) subset of a one-year baseline dataset of water quality (URS 2011a), on the presumption that biological communities in East Arm are adapted to local conditions but will be stressed if exposed to conditions that regularly exceed the 95th percentile of normally prevailing background concentrations (calculated from URS 2011a).

As the sediment transport model calculates excess (above background) SSC caused by the dredging and tailwater disposal, the median of the background concentrations was subtracted from the 95th percentile of the background concentrations to provide a comparable tolerance limit. This yielded a tolerance limit for Dry Season dredging of 10 mg/L and a Wet Season SSC tolerance limit of 25 mg/L.

Tolerance limits for sediment deposition on mangroves were derived by INPEX (2010, 2011a) from a review of the outcomes of habitat-specific dose-response experiments and field observations reported in the scientific literature. These tolerance limits were adopted for the MSB dredging program and will also be applied to the tug pens dredging program – i.e. 50 mm accretion may lead to reduced health or mortality; above 100 mm accretion mortality of trees was considered “likely”. For corals and filter-feeder communities, INPEX (2011a) contended that a meaningful sedimentation threshold could not be derived from the literature due to factors such as wide variations in tolerances between species, and between morphologies within species.

5.5 Zones of Impact and Influence

For the assessment of potential dredging-related impacts upon benthic communities, definitions of Zones of Impact and Influence consistent with the EPA (2011) EAG7 (introduced in Section 1.6.4) were adopted:

- **Zone of High Impact:** this zone constitutes the direct footprint of the dredged area and a 20 m wide annulus around the footprints to account for smothering from coarse sediments liberated from the cutter head during dredging. Impacts in these areas are predicted to be severe and often irreversible.
- **Zone of Moderate Impact:** within this zone, damage to benthic habitats and mortality of benthic biota may occur, primarily as a result of the indirect impacts from increased turbidity and sedimentation that may occur at times over areas within the zone. Impacts within this zone are predicted to occur, but the disturbed areas may recover (after completion of the dredging and disposal operations). It is expected that there will be no long-term modification of the benthic habitats in this zone. The outer edge of the Zone of Moderate Impact is delineated by the 90th percentile contour plot for SSC, as defined by dredge plume modelling. This delineates the areas where, for 90% of the time, the predicted SSC is below the calculated tolerance for benthic communities (dredging-related SSC of 10 mg/L for East Arm communities during the Dry Season, 25 mg/L during the Wet Season, refer Section 5.4). The 10% of time during which the SSC threshold is

predicted to be met or exceeded is likely to represent periods of mid-flow tidal states (particularly during spring tides) and any one exceedance event is not likely to exceed two hours.

- **Zone of Influence:** this zone includes the areas in which, at some time during the dredging works, benthic communities may experience (detectable) changes in sediment-related environmental quality outside the natural ranges that are normally expected. However, the intensity, duration and frequency of these changes is such that any damage to benthic habitats is likely to be reversible, and no mortality of benthic biota is expected to occur. The outer boundary of this zone is delineated by the 95th percentile contour plot for SSC, as defined by dredge plume modelling. This reflects the area where, for 95% of the time, excess SSC from the dredging will be below the calculated tolerance for benthic communities (10 mg/L in the Dry Season, 25 mg/L in the Wet Season, refer Section 5.4).

It can be seen from Figure 5-1 and Figure 5-2 that the 10 mg/L and 25 mg/L SSC concentrations will be reached at both the 90th and 95th percentile levels when dredging with a CSD is modelled. However, when SSC is modelled for a CSD under wet season conditions, the 25 mg/L SSC is not expected to be reached at either the 90th or 95th percentile level, so the Zone of Moderate Impact and Zone of Influence will lie within the Zone of High Impact. These contours translate to Zones of Impact and Influence described in Table 5-1 and shown in Figure 5-5 (wet season) and Figure 5-6 (dry season).

Table 5-1 Zones of Impact based on sediment transport model results for wet season and dry season application to CSD and BHD utilisation

Zone	CSD		BHD	
	Wet season	Dry Season	Wet season	Dry Season
Zone of Moderate Impact	N/A	80 m	101 m	560 m
Zone of Influence	N/A	110 m	167 m	725 m

Based on the combined modelling of SSC resulting from dredging and water discharged from the settlement ponds, the SSC surrounding the settlement pond discharge point is not expected to exceed approximately 8 mg/L, therefore no Zones of Moderate Impact and Influence are identifiable at the tailwater discharge point at the permeable section of the railway bund wall (Figure 5-1 and Figure 5-2).

Figure 5-5 Wet season Zones of Impact and Influence

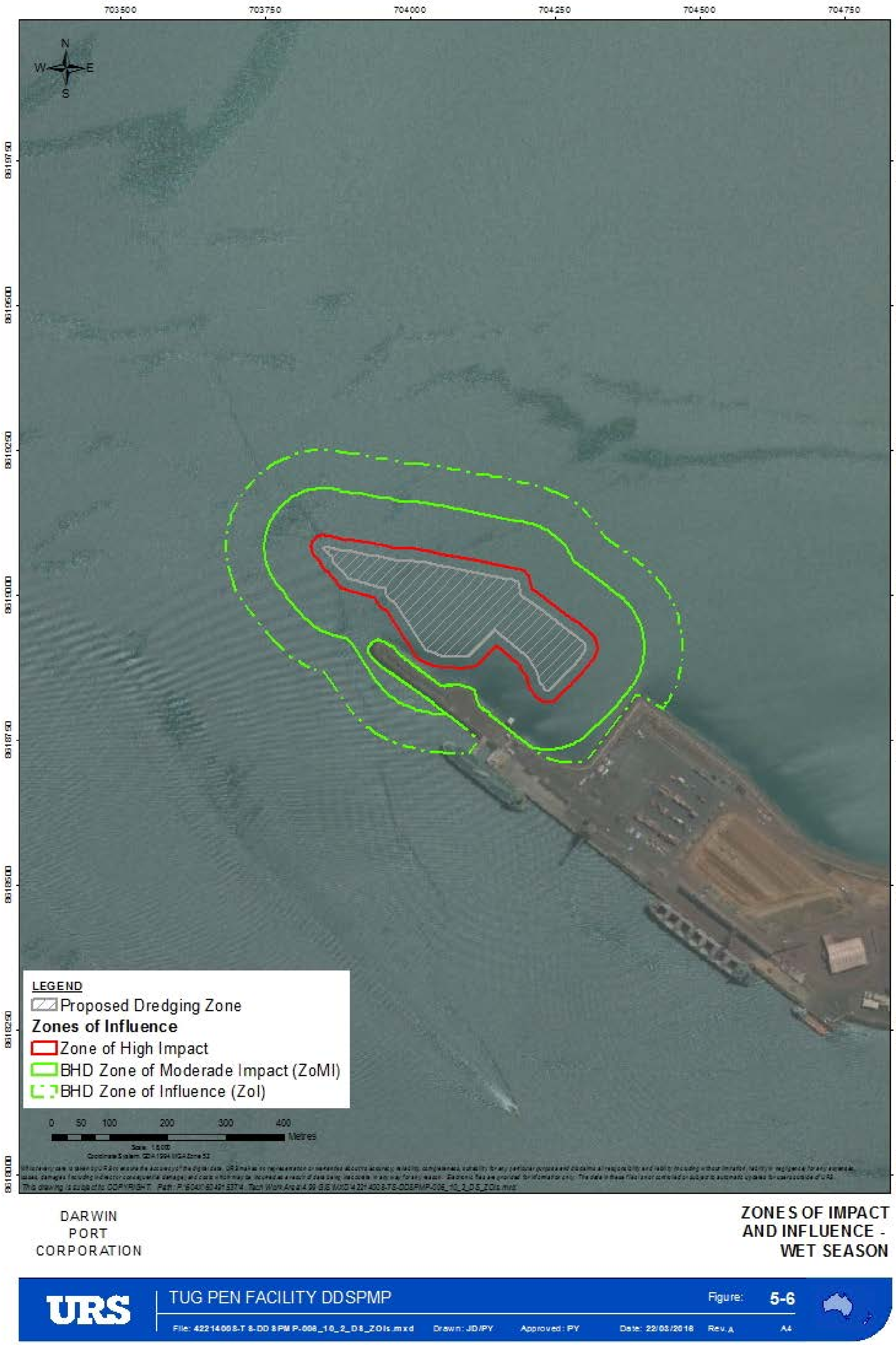
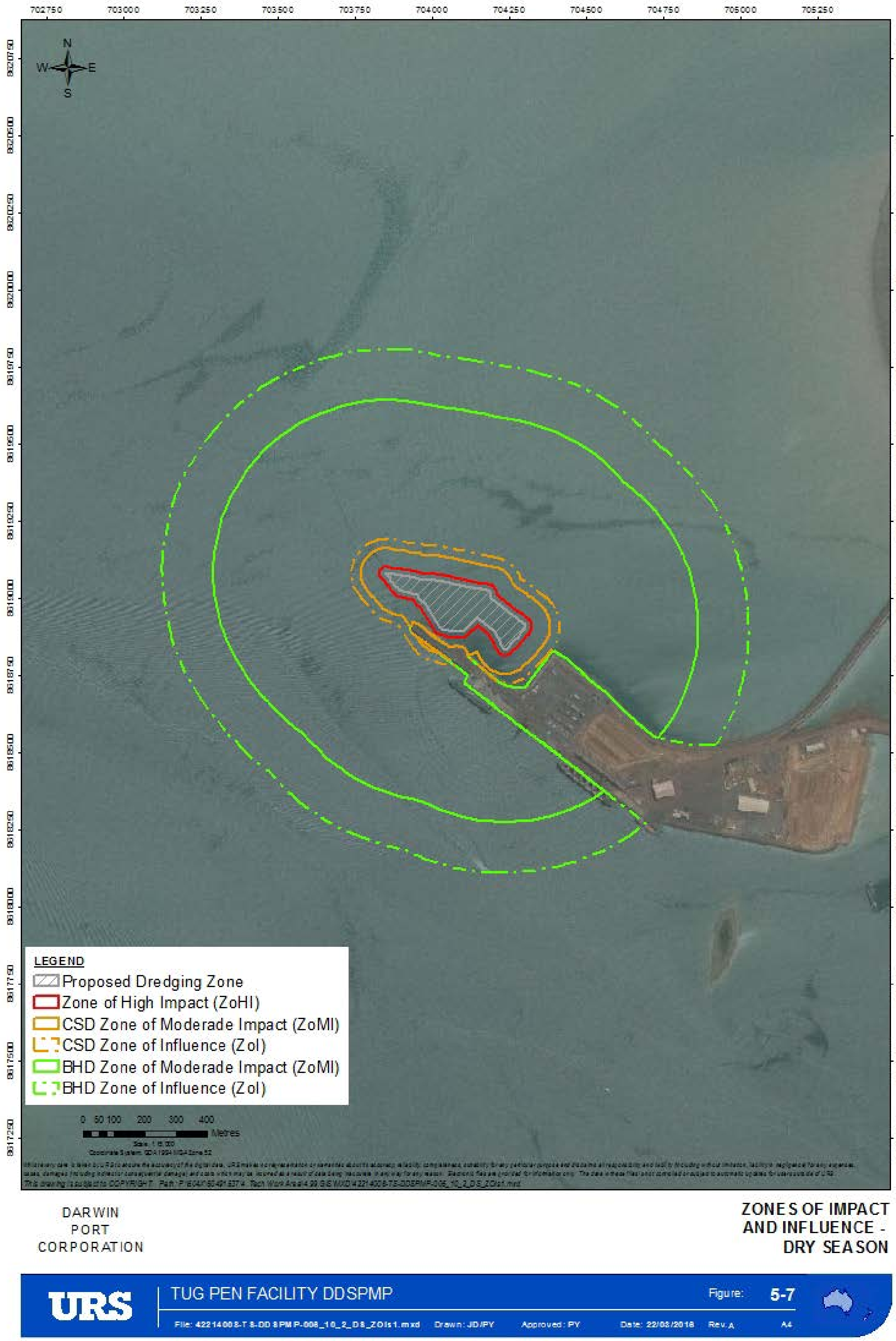


Figure 5-6 Dry season Zones of Impact and Influence



5.6 Conclusions

5.6.1 Suspended sediments

The modelling indicates that suspended sediments are not predicted to extend beyond the dredging area at concentrations that could result in long term detectable changes to environmental quality.

Recovery of water quality to background SSC on cessation of dredging is expected to be rapid (Figure 5-3) and although dredging has been modelled as continuous for ten hours per day, it will likely be punctuated by short periods of down time (for crew changes, maintenance, dredge vessel repositioning and cutter head repositioning etc.) Modelling showed the predicted dredge plume 30 minutes after dredging stops quickly dissipated to below 1 mg/L above background concentrations if a CSD were in use, and to less than 2 mg/L above background concentrations if a BHD were in use, both of which are well below levels that could potentially lead to environmental impact.

Suspended sediments may potentially impact a small area of benthic habitat up to the limits of the Zone of Influence included in Table 5-1 and shown in Figure 5-5 and Figure 5-6. Benthic habitat modelling undertaken by DLRM (DLRM, 2015), as presented in Section 4.3.1, suggests that this area is typically bare soft sediment seabed to the north of East Arm wharf with potential small areas of filter feeder and coral present on the south side of the wharf. The bare silt sediment habitats would typically be expected to support benthic invertebrates living on and in the surface sediments. The suspended sediments could impact upon these organisms through clogging of feeding or respiratory structures, though any impacted areas would be expected to be recolonised by similar fauna once dredging has ceased.

Impacts are predicted to be of a temporary nature and it is expected that there will be no long-term modification of the benthic habitats as described for the Zones of Moderate Impact and Influence provided in section 5.5.

It should also be noted that no exceedance of suspended sediment limits set during the recent MSB dredging were observed at the outflow point from the pond system.

It is concluded that suspended sediment effects on the receiving environment need not be considered further in this plan. It is considered that monitoring and management of suspended sediment levels within the area immediately adjacent to the dredge location and pipelines (within 150 m) and within the pond system will provide an appropriate level of mitigation against the risk of impacts upon the receiving environment.

5.6.2 Sedimentation

Hydrodynamic modelling has predicted weak currents in the vicinity of the tug pens and tailwater discharge point and a corresponding low dispersion of sediment. Figure 5-4 shows that the accumulation of dredging-derived sediment one month after the completion of dredging to be very low with 1.3 mm of sediment modelled to settle back in the dredge area while deposition on intertidal mud flats adjacent to the settlement pond discharge point was predicted to be less than 0.1 mm.

Sediment accumulation one month after completion of dredging is not predicted to exceed 50 mm (the tolerance limit referred to in the section 5.4) in any of the mangrove communities that are potentially reached by the turbid plumes generated by the dredging and tailwater disposal. Hence sediment accumulation is not expected to impact on mangrove communities in areas such as Blessers Creek and Charles Darwin National Park. It would be reasonably expected that wet season wave activity under normal conditions would have a greater impact in these areas than sedimentation associated with the dredging and tailwater discharge (D Williams, AIMS, pers. comm. 2015).

Although it has not been possible to derive reliable sedimentation thresholds for coral and filter-feeder communities, it is noted that, as shown in Figure 5-4, there is no net sedimentation of >5 mm predicted to occur within the coral and filter-feeder communities in East Arm (refer Figure 4-2).

If the rate of sediment deposition adjacent to the settlement pond discharge point is sufficiently high, then some of the benthic fauna may be smothered. However, modelling suggests that sediment deposition in this area will be below background levels 30 days after the completion of the dredging program. Given this, it is expected that, if there is any impact to benthic fauna, any impacted areas would be recolonised by similar fauna once tailwater discharge has ceased.

It is concluded that potential sedimentation effects need not be given further detailed consideration in this Plan and that monitoring and management of suspended sediment levels within the pond system will provide an appropriate level of mitigation against the risk of impacts upon the receiving environment.

5.6.3 Prior dredging experience

Monitoring during the recent MSB dredging provides a relevant comparison with which to compare likely suspended sediment and siltation resulting from dredging at the tug pens site.

With no exceedances occurring in the natural environment at the outflow point of the pond system, it can be seen that the settling ponds are capable, with effective management, of maintaining tailwater outflow to the environment within the set limits for longer dredge programs utilising dredging equipment providing significantly higher flow rates into the ponds. Based on this experience it is expected that the use of the ponds as described in this plan will result in outflow to the environment at acceptable suspended sediment concentrations.

6 ENVIRONMENTAL MANAGEMENT

6.1 Introduction

This section describes the Environmental Management Frameworks (EMFs) that have been developed for the key risks associated with the dredging works, as identified through the environmental risk assessment process (DLP 2010, 2011). The EMFs are instrumental to effectively manage and mitigate environmental risks to sensitive receptors identified in Section 4.

EMFs have been developed for the following aspects:

- water quality – dredge spoil placement ponds
- water quality – Darwin Harbour
- protected marine species – physical interaction
- protected marine species – underwater noise
- migratory birds.

Each EMF states the relevant project commitments made and objectives to be met, and contains specific, measurable targets to achieve the objectives. It also summarises the management actions required to meet these targets, the relevant KPIs and the monitoring activities to be employed to measure success in meeting the requirements and identify the need for corrective actions.

It should be noted that:

- management actions are routine tasks that will be undertaken to meet the objectives of each EMF
- corrective actions are those tasks that are possible to be undertaken if monitoring indicates that trigger levels have been exceeded.

Where trigger levels are proposed, it should be noted that these are triggers for further investigation and are set well below levels at which significant adverse ecological effects could be anticipated. Monitoring is described in greater detail in Section 7. Each EMF also indicates the relevant reporting requirements (detailed further in Section 8) and the responsibilities of project personnel.

6.2 Water quality – dredge spoil placement ponds

6.2.1 Potential impacts

Potential impacts upon the water quality within the dredge spoil placement ponds (reduced pH) may occur as a result of generation of acid if dredged sediments that contain PASS are exposed to air within the ponds for extended periods. Synergistic impacts may arise if the more acidic water leaches metals (arsenic in particular) from the dredged sediments, or from the existing sediments in the ponds.

If acidic water is pumped from the ponds into East Arm, then impacts around the discharge location could include:

- injury to, or mortality of, protected marine species, fish, crustaceans, mangroves, etc.
- reduction of bicarbonates in the receiving water, potentially resulting in deformities in shellfish development.
- release of contaminants from sediment in the receiving environment.
- corrosion of metals and weakening of concrete structures, potentially impacting on infrastructure and/or engineering works.

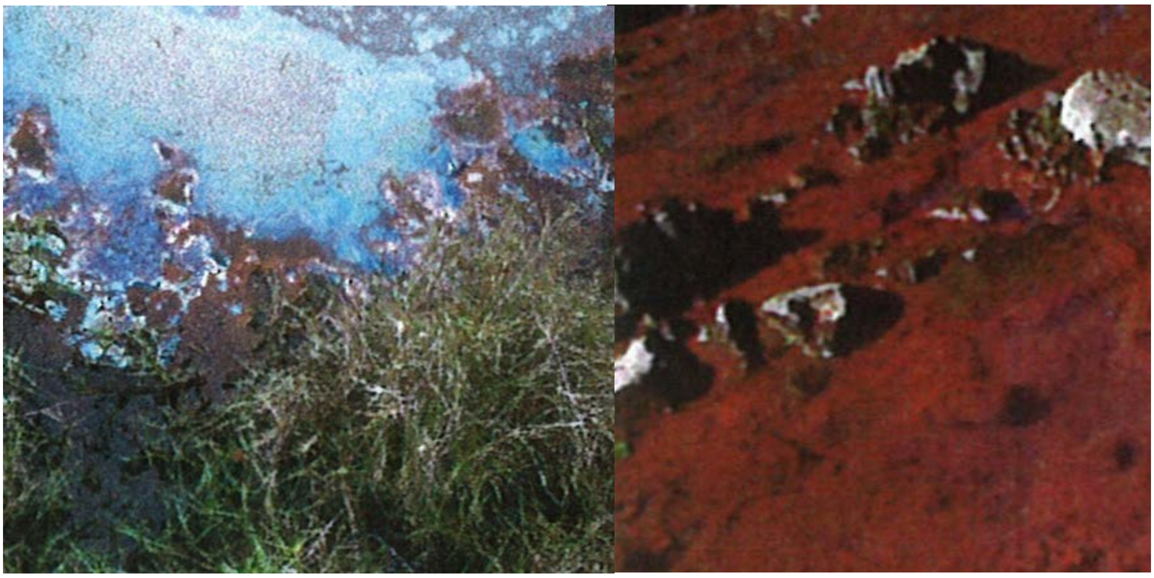
Potential impacts upon the receiving environment from the discharge of tailwater with elevated concentrations of suspended sediments are addressed in Section 5.6.

6.2.2 Potential indications of impact

Some indicators for the presence of acid leachate arising from oxidation of PASS (Figure 6-1) are:

- green-blue water, sometimes cloudy but sometimes extremely clear due to the presence of metals that have leached from the soils (aluminium)
- rust coloured stains on soils, and rust coloured slime on water (due to iron oxidising bacteria)
- yellow patches on soils as they dry out ("jarosite").

Figure 6-1 Potential indicators of acid leachate



6.2.3 Water quality criteria for disposal of tailwater

The key water quality guidelines that are relevant to the MSB development are the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (hereafter 'ANZECC Guidelines', ANZECC & ARMCANZ 2000) and the Water Quality Objectives (WQOs) for the Darwin Harbour Region 2010 (hereafter 'Darwin Harbour Region WQOs' [Fortune & Maly 2009; NRETAS 2010]). The Darwin Harbour Region Report Cards (e.g. Drewry et al. 2011; Aquatic Health Unit 2013) are also relevant as they contain data from ongoing NTG water quality monitoring in Darwin Harbour.

The National Water Quality Management Strategy recommends that “the guidelines for each indicator should be based on locally derived data to reflect local (ambient) conditions. Where derivation of guidelines based on local monitoring is not possible, it is recommended that the national ANZECC Guidelines are used instead (for tropical Australia)”. Therefore, the most applicable guidelines for this project are Darwin Harbour Region WQOs, and in the absence of guidelines for certain parameters, reference will be made to the national ANZECC Guidelines.

The Darwin Harbour Region WQO reports (Fortune & Maly 2009; NRETAS 2010) state that in the case of Darwin Harbour the most stringent water quality criterion is the environmental beneficial use category. This is because the intent of environmental beneficial use is to maintain the health of aquatic ecosystems, and a water body that meets an environmental beneficial use will in almost all circumstances also meet the requirements for all other beneficial uses. Human health related guidelines are also provided to protect recreational and cultural values in the region.

NRETAS (2010) has adopted the ANZECC Guidelines approach for physico-chemical indicators for slightly to moderately disturbed systems. The ANZECC guidelines have defined acceptable effect sizes for each level of protection for different indicator types (Table 6-1).

Table 6-1 ANZECC Guidelines default effect size for varying levels of protection

Indicator Class	Effect Size or Departure from Reference		
	High Conservation Value Systems	Slightly to Moderately Disturbed Systems	Highly Disturbed Systems
Toxicants in water	No change to natural values	95% of species protected	80-90% spp. protected
Toxicants in sediments	No change to natural values	>90% individuals protected	
Physico-chemical*	No change to natural values	Median lies within $20^{th}/80^{th}$ percentile of reference range*	Locally determined ($10^{th}/90^{th}$ percentile of range)
Biological	No change to natural values	Median lies within $20^{th}/80^{th}$ percentile of reference range	Locally determined ($10^{th}/90^{th}$ percentile of range)

*Applicable to the approach taken with WQOs for the Darwin Harbour region

NRETAS (2010) states that the Darwin Harbour Region WQOs can be used as a tool for monitoring water quality and supporting decision making on the management of activities affecting coastal marine waters in the Darwin Harbour catchment. They apply to ambient waters (i.e. the receiving waters) and should not be regarded as individual discharge criteria. The values include protection of aquatic ecosystems and recreational activities associated with the use of marine waters such as swimming, boating and fishing. Where the values are not being met, planning and management of these areas should move towards achieving the objectives over time.

The Darwin Harbour Region WQOs and the ANZECC Guidelines can be used to provide guidance to those undertaking water quality monitoring programs by providing key water quality indicators that can be monitored over time. Measured water quality can be compared with the criteria to determine whether management goals are being achieved or where management action is required.

The ANZECC Guidelines and Darwin Harbour Region WQOs apply to the receiving environment, rather than to the tailwater. However, if the tailwater meets the following criteria then it will be considered suitable for continued disposal:

- The daily mean pH of the three water samples collected during monitoring at the discharge point from Pond E (South) (see Section 7.3.2) is greater than 6.0 and less than 8.5. This will meet the criterion for an Upper Estuary setting, as presented in the Darwin Harbour Region Water Quality Objectives.
- For toxicants [4] (including arsenic) the Darwin Harbour Region WQOs defer to the ANZECC Guidelines. Hence concentrations of toxicants will be compared against the ANZECC Guidelines for slightly to moderately disturbed ecosystems (i.e. for 95% species protection) (ANZECC & ARMCANZ 2000, Table 3.4.2). For some toxicants (including arsenic) the ANZECC Guidelines have no criteria levels for marine waters as there are considered to be insufficient data to derive reliable trigger values. In these instances it is proposed to adopt the criteria levels for fresh water. The list of metallic toxicants to be tested (presented in Section 7.3.3) is based on the potential presence and toxicity of these metals in Darwin Harbour. It is noted that none of these metals (with the exception of arsenic) were found at concentrations exceeding the ANZECC Guidelines during testing for this project.
- The target SSC for the tailwater will be 100 mg/L (140 NTU). As SSC cannot be monitored directly in the environment therefore turbidity (in NTU) is used as a surrogate measure. A mathematical relationship between NTU and SSC has been derived from water samples collected within the pond system and analysed for both SSC and turbidity as part of the MSB dredging monitoring program. The project specific SSC / NTU relationship reported in the annual monitoring report for the Darwin Marine Supply Base Dredging and Dredge Spoil Placement Activities (DoI 2014) is 100 mg/L = 140 NTU. This relationship will be applied during interpretation of water quality monitoring undertaken during the tug pens dredging.

Measures to reduce the acidity of the pond system (refer to Section 6.2.4) if pH is below 6 or contaminant concentrations exceed ANZECC guidelines, and to improve settlement rates if SSC exceeds the target value at the monitoring point inside Pond E (South), will be implemented and confirmed as successful by monitoring before recommencing discharge.

6.2.4 Management of water quality

6.2.4.1 Management of PASS

- The dredging contractor will disturb only the minimum footprint necessary for dredging the tug pens footprint. Contingency PASS management options that will be applied include:Use of Pond E (North) for placement of PASS dredge spoil through a submerged dredge discharge pipe at the far northern end of the pond.

4 The ANZECC Guidelines define a toxicant as a chemical capable of producing an adverse response (effect) in a biological system at concentrations that might be encountered in the environment, seriously injuring structure or function or producing death. Examples include pesticides and heavy metals.

- Neutralisation of PASS using lime (refer to detailed description below).
- Strategic reburial (without prior lime treatment). Reburial within the ponds at East Arm is likely to be the most suitable management option, at depth and covered with non-PASS materials.

In the first instance, should PASS sediments be detected, dredge spoil placement into the ponds will shift to the northern end of Pond E (North) which has a permanent water level as opposed to Pond K which will dry out after completion of dredging, exposing PASS to the atmosphere and potentially allowing oxidation and acidification.

Alternatively, PASS sediments will be dredged into the lower portion of the pond K and sediments that are not PASS can then be deposited on top, allowing for strategic burial of the underlying PASS materials within the ponds. Depending on the %S levels, additional treatment may be necessary; in liaison with the DPC, NT EPA and DoE, actions such as lime treatment, covering with clean soils or water, etc., may be necessary.

6.2.4.2 Neutralisation of PASS

The preference for the treatment of PASS is to avoid contact with the atmosphere and the potential acidification of sediments. To achieve this, PASS would remain buried or submerged at all times through the strategic placement of dredge spoil into ponds where the PASS will remain submerged or can be strategically buried beneath non-PASS material already in the pond system.

If this is not practical or is not successful, physically incorporating neutralising alkaline materials such as lime into the soil is a common technique used in managing PASS. It is important that sufficient lime is used to ensure that existing soil acidity and all potential acidity that can be generated is neutralised over time. Lime treatment is an option whereby the soils can be reused as clean fill (noting that the soils are often unsuitable for geotechnical reasons).

The laboratory analysis of the oxidisable sulphur in each soil sample is used to calculate the amount of acid that can be generated if the sulphides are completely oxidised or totally exposed to the air. The results are generally given by the laboratory in %S.

The analytical results from the laboratory chromium reducible sulphur test provide a liming rate (kg lime/tonne of soil). These rates can also be estimated using Table 3 in the Queensland Acid Sulfate Soils Investigation Team guidelines (QASSIT 2008). These include a safety factor of 1.5. An approximate weight can be obtained from volume by multiplying volume (m^3) by bulk density (t/m^3).

It is important to mix adequate neutralising material so that all acid that can be produced is neutralised and to bring the pH of the soil to 5.5 as a minimum. Suggested neutralising agents for the treatment of ASS should be slightly alkaline with low solubility (pH 7–9). Fine aglime ($CaCO_3$) is the preferred neutralising agent for treating ASS, using the purest form available.

The guidelines recommend constructing a treatment pad, including a compacted clay layer, leachate collection system and containment with bunding.

Where excavation and mechanical mixing are not feasible, a more soluble material such as hydrated lime $Ca(OH)_2$ or sodium bicarbonate $NaHCO_3$ can be used.

Soil that has been treated using a neutralising agent such as lime should follow the following performance criteria:

- an excess of the neutralising agent (lime) should be used to allow for potential acidity of the soil
- post neutralisation of the soil, the pH is to be 5.5 or greater
- the excess lime should remain in the soil until all acid generation reactions are complete.

Validation samples will be collected of the mixed material, at a rate of to be determined. This will determine if the criteria have been met. Soil that has not met the above criteria must be retreated until it meets the performance criteria. Normal turnaround time for samples is two weeks. If needed, additional lime can be mixed in at any time after the sample results have been received.

6.2.4.3 Water quality management (ponds)

The tailwater will be managed within the settling ponds such that the quality of the water discharging through the railway bund wall is within the guideline criteria discussed in Section 6.2.3. If trigger levels are exceeded within any of the ponds then this will be reported to DPC within 24 hours of the exceedance occurring. Should the exceedance occur at either of the two critical monitoring locations – Pond E (South) or in Pond E (North) at the weir into Pond E (South), the contractor shall notify DPC and the NT EPA (on behalf of DPC).

Exceedances occurring in Pond E (North) at the weir into Pond E (South) or in Pond E (South) shall trigger management actions requiring the cessation of flow from Pond E (North) into Pond E (South). Monitoring results approaching or exceeding the trigger levels at all other monitoring locations shall be used as an early indication that pre-emptive management actions should be considered to prevent an exceedance in Pond E (North) prior to the weir into Pond E (South) or within Pond E (South). Where an exceedance requires the closing of the weir into Pond E (South), Pond E (South) shall remain isolated from the tailwater management system until corrective actions (see Table 6-2) can be implemented to preserve the quality of the receiving waters. It will remain isolated until such time that it can be demonstrated that the pond can be reinstated into the tailwater management system without causing the water quality in Pond E (South) to exceed trigger levels.

The frequency of monitoring within the ponds (refer Section 7.2) limits the risk of trigger level exceedances within Pond E (South) arising from tailwater effects. Trends identified within the preceding ponds will enable corrective actions to be implemented before exceedances occur within Pond E (South). In this manner Pond E (South) is effectively considered to be the ‘receiving environment’, with the railway bund wall providing an additional buffer against impacts upon the environment of Frances Bay and Darwin Harbour.

Table 6-2 Water quality EMF - dredge spoil placement ponds

Water Quality Management Framework - dredge spoil placement ponds	
Element	Maintenance of water quality within dredge spoil placement ponds.
Commitments	EPBC 2010/5304 conditions 27 and 28 Conditions likely on WDL to be obtained by contractor.
Objectives	– No increase in acidity within pond waters to the extent that the tailwater is unacceptable for discharge due to low pH or elevated toxicant concentrations. – No adverse impacts upon migratory birds utilising the ponds. – To protect receiving waters from dredging-related impacts.
Target	1. No occasions when tailwater pH is outside the guideline range (6.0-8.5) at the point of discharge to the marine environment, as a result of acid leachate generation. 2. No exceedances of ANZECC & ARMCANZ (2000) water quality criteria for arsenic or other bioavailable toxicants at the point of discharge to the marine environment (refer to Section 7.2). 3. 100% of tailwater ready for discharge has SSC less than 100 mg/L (measured as turbidity, refer Section 6.2.3 and Table 7-1). 4. Pond D tailwater level must not exceed 5.5 m AHD. 5. No occasions when tailwater discharging from Pond E (South): a. Contains floating oil or grease or petroleum hydrocarbon sheen or scum, or litter or other objectionable matter. b. Causes or generates odours which would adversely affect the use of surrounding waters. c. Causes algal blooms. d. Causes visible change in the behaviour of, or mortality of, fish or other aquatic organisms. e. Causes adverse impacts on plants.
Key Performance Indicator(s)	– Number of instances when pH or bioavailable toxicant concentrations are outside of acceptable guidelines (pH <6.0 or >8.5; bioavailable toxicant concentrations >ANZECC Guidelines) at the point of discharge to the marine environment. – Number of instances when SSC in Pond E (South) is >100 mg/L (measured as turbidity, refer Section 6.2.3 and Table 7-1). – Number of instances when target criteria 5 (a)-(e) are not met.
Management	– Ensure that all site personnel are aware of potential issues with PASS (via induction and toolbox meetings). – The dredged sediments are pumped via pipeline into the ponds, and the sludge is allowed to settle within the ponds. PASS sediments will not be stockpiled or transported to where they may be exposed to the atmosphere. – Placement of dredged PASS into Pond E (North) through a submerged dredge discharge pipe to avoid exposure to the atmosphere and subsequent oxidisation – Placement of dredged PASS material in a designated area, at a deeper level within the dredge spoil disposed in Pond K than the subsequent layers, preventing oxidisation of PASS material. – Ensure direct discharge of dredge spoil into Pond E (North) only takes place when the risk of large stormwater events is low i.e. in the Dry Season. – Pond K maintained with a minimum freeboard of 0.5 m to ensure sufficient water to facilitate settlement of suspended sediments and to minimise mobilising existing sediments. – Dredge spoil will be directly deposited only into Pond K or Pond E (North).
Monitoring (Section 7.2	– Water quality monitoring within ponds – pH, toxicants, NTU as detailed in Section 7.2. – Visual monitoring of target criteria 5 (a)-(e) outside the permeable section of railway bund (during the water quality monitoring events indicated in Section 7.2).
Reporting (**Section 8**)	– Weekly reporting of data to DPC. – Monitoring report to NT EPA at conclusion of dredging. – Trigger level exceedances at any monitoring location will be reported to DPC, within 24 hours of the exceedance occurring. DPC will also notify the TAG. – Trigger level exceedances in Pond E (South) or Pond E (North) at the weir into Pond E (South) will be reported by the Contractor direct to DoE and NT EPA

Water Quality Management Framework - dredge spoil placement ponds	
	within 24 hours of the exceedance occurring. A report on corrective actions implemented to address the cause of the exceedance will be provided within five business days of the notification.
Corrective Action(s)	– If pH falls below 6.0 or exceeds 8.5 or toxicant concentrations exceed ANZECC Guidelines in Pond E (South) or Pond E (North) at the weir into Pond E (South) then tailwater flows out of Pond E (North) will be blocked at the transfer weir within one hour of detection (refer to Section 2.5.4). – If SSC exceeds 100 mg/L in Pond E (South) at the railway bund wall then tailwater flows out of Pond E (North) will be blocked at the transfer weir until SSC levels at the transfer point between Pond E (North) and Pond E (South) have fallen below 100 mg/L. – If deemed by the Contractor to be potentially effective in returning the pH of the water in any of the ponds to above 6.0, lime may be applied to discrete areas within the ponds. Lime may also be applied to pond sediments that are exposed to air if it is apparent they are a source of acidification of the water. Water will be recirculated until the pH at the point of discharge into the next pond is >6.0 (but below 8.5). – If pH is >8.5 in Pond E (north), then the water will not be discharged into Pond E (South) until such time as the pH decreases to below 8.5 (but not below 6.0). The elevated pH will add to the buffering capacity of the pond system to neutralise acid that may be generated from the exposure to air of ASS. – If toxicant concentrations exceed ANZECC Guidelines in Pond E (North) at the weir into Pond E (South) then tailwater flows out of Pond E (North) will be blocked at the transfer weir within one hour of detection. The water may be diluted using water with lower toxicant concentrations (either from within the pond system or from within the dredging footprint) until toxicant concentrations are returned to below ANZECC Guideline levels.
Term	For the duration of tailwater disposal.
Responsibility	– Dredging Contractor to ensure documents are compliant with the DDSPMP. – Dredging Contractor project manager to ensure monitoring program and water quality management measures are implemented. – Dredging Contractor is required to take direction from the Project Manager.

6.3 Water Quality – dredge footprint and Darwin Harbour

6.3.1 Potential impacts

Dredging with a CSD or BHD will generate plumes of turbid water containing elevated levels of suspended solids that will be dispersed by tidal activity. The plumes of suspended sediment could impact upon marine organisms through clogging of feeding or respiratory structures or through reduction in light penetration through the water column. As the suspended sediments settle, this could lead to smothering of benthic communities. Modelling undertaken for the project indicates that the plumes from both dredge operation and discharge from the treatment ponds is expected to impact on only a very localised area. Turbid plumes are not expected to reach the nearest sensitive environmental receptor of coral communities at South Shell Island.

Whilst the water quality trigger level for SSC exceeds the exposure limits for benthic communities at South Shell Island (the nearest sensitive receptor), the trigger level of 100 mg/L / 140 NTU has been set for the area surrounding the dredge as a conservative limit considering the distance to South Shell Island and likely dispersion / dilution that will occur between the dredge site and South Shell Island. Modelling suggest that turbid plumes will not emanate far enough to impact benthic communities at South Shell Island and the management regime in this section is considered a conservative precautionary measure to monitor and manage any potential risk.

6.3.2 Management Measures

Modelling of the turbid plumes expected from the dredging indicates that sensitive receptors at South Shell Island will not be impacted upon. However, as a precautionary action, visual monitoring at a distance of 150 m from the dredge footprint boundary will be undertaken while dredging is underway and turbidity monitoring will be implemented should the turbid plume be observed at a distance greater than 150 m from the dredge footprint boundary (as described in section 7.2.3).

The management measures to be implemented by the dredging contractor are outlined in Table 6-3.

On detection of an exceedance of 140 NTU (mean turbidity through the water column as described in section 7.2) at a distance of 150 m from the dredge footprint boundary, contractor will implement appropriate management measures from Table 6-3 within one hour and will continue to apply management measures until the water turbidity drops below the 140 NTU trigger level at a distance of 150 m from the dredge footprint boundary.

The dredging contractor will retain the ability to implement the measures (or combination of measures) deemed most appropriate to reduce turbidity based on the prevailing environmental conditions at the time of exceedance (e.g. tide phase, wind strength and direction).

The dredging contractor will record which management measures are implemented and the time of implementation. The dredging contractor will resample turbidity of the plume at least every two hours and continue to implement management measures until the turbidity falls back below the trigger level.

If the exceedance persists for a duration of eight hours, dredging will be suspended until the plume falls back below 140 NTU within 150 m of the dredge footprint boundary.

Table 6-3 Management measurements for response to turbidity trigger level exceedances

CSD	BHD
– Reduce cutter head speed – Alter dredging direction – Change step size of the dredger – Adjust swing speed – Increase pump rate – Relocate dredge to a more sheltered position – Suspend dredging	– Reduce bucket lift speed – Increase time between ‘grabs’ – Relocate dredge to a more sheltered position – Suspend dredging

Table 6-4 Water quality EMF - Darwin harbour

Water Quality Management Framework – Darwin Harbour	
Element	Maintenance of water quality within Darwin Harbour.
Commitments	EPBC 2010/5304 condition 28 Conditions likely on WDL to be obtained by contractor.
Objectives	– To minimise impacts upon the hard coral and filter feeder communities at South Shell Island from dredge generated turbidity.
Target	– No dredging related impacts exposing sensitive receptors at South Shell Island to turbidity above exposure limits. – No occasions when turbidity exceeds 140 NTU beyond 150 m from the dredge or pipelines.
Key Performance Indicator(s)	– Number of instances when SSC measured at a distance of 150 m from the dredge is > 140 NTU and dredge management measures are implemented.
Management	– Continuous visual monitoring if the sediment plume. – Monitoring of surface turbidity at a distance of 150 m from the dredge footprint boundary once plume exceeds that distance. – Implementation of measures in Table 6-3 once turbidity exceeds 140 NTU at a distance of 150 m from the dredge footprint boundary.
Monitoring (**Section 7.2**)	– Visual monitoring of the dredge plume to identify when it exceeds the 150 m buffer and monitoring must commence – Mean water column turbidity monitoring based on visual observations of the plume as detailed in Section 7.2. –
Reporting (**Section 8**)	– Weekly reporting of data to DPC. – Monitoring report to NT EPA at conclusion of dredging. – Trigger level exceedances at any monitoring location will be reported to DPC, within 24 hours of the exceedance occurring. DPC will also notify the TAG.
Corrective Action(s)	– Measures identified in Table 6-3 will be implemented in response to any trigger exceedance (Surface turbidity > 140 NTU at distances greater than 150 m from the dredge footprint boundary). – Management measures will be implemented until the turbidity at a distance of 150 m from the dredge footprint boundary falls back below 140 NTU
Term	For the duration of dredging.
Responsibility	– Dredging Contractor to ensure documents are compliant with the DDSPMP. – Dredging Contractor project manager to ensure monitoring program and water quality management measures are implemented. – Dredging Contractor is required to take direction from the Project Manager.

6.4 Protected marine species – physical interaction

The main risk of physical interaction with protected marine species will be in relation to the movement of dredge support vessels (e.g. crew transfer vessel, tender vessel). The risk of direct impact to protected marine species from the operating dredge is considered to be very low. As the dredge will be stationary during most of the works, with the most mobile part of the equipment (the cutter head when a CSD is being used) generating noise and vibration which is likely to discourage any species that may be present from approaching sufficiently close to the dredge for them to be exposed to the risk of impact. When moving between or within the dredging footprint, the dredge will transit at low speeds (<5 kn) and only over small distances (tens of metres).

It should be noted that physical interactions between dredging vessels and marine species are a higher risk when mobile dredges such as Trailer Suction Hopper Dredges are used and when dredged material is disposed offshore. Neither of these scenarios is applicable to the tug pens dredging.

Nevertheless there will be monitoring (refer Section 7.4) and management measures implemented to reduce the risk of physical interaction with protected marine species, as described in the following EMF and depicted in Figure 6-3. These measures will apply to the operation of the dredge and also to any other vessels engaged in the works (e.g. crew transfer vessels). These will be facilitated with the use of spotlights/vessel searchlights to increase visibility for Marine Fauna Observers (MFOs).

Table 6-5 Protected marine species EMF - physical interaction

Protected Marine Species Management Framework – physical interaction	
Element	Vessel interaction with protected marine species.
Commitment	EPBC 2010/5304 condition 17(e).
Objective	Minimise the risk of injury to, or mortality of, protected marine species. Develop and maintain awareness of the need to protect marine species.
Target	– No incidents of vessel interaction with protected marine species. – All dredging personnel to complete an HSE induction, including protected marine species awareness and management requirements. – All vessel masters competent in protected marine species interaction procedures. – At all times that the dredge is operational, at least one crew member is a trained MFO.
Key Performance Indicator(s)	– Number of audits and incident reports. – Number of reported sightings of live, injured or dead marine fauna. – Number of personnel completing an HSE site induction. – Availability of MFO trained dredge operator
Management	– Training of Vessel Masters in interaction procedures and specified crew as MFOs. – A trained Marine Fauna Observer must be on duty, above deck with good visibility, during all dredging operations. – On each occasion that the dredge has been non-operational for a period exceeding 30 minutes, a visual assessment shall be undertaken of the 150 m radius Observation Zone by the MFO for a period of 10 minutes. Dredging will not recommence until no protected marine species have been sighted within the 150 m radius Observation Zone for a period of 10 minutes. – The assessment of the Observation Zone will be made from an elevated position on the dredge, where a clear line of sight is achievable to the edge of the zone. – The MFO shall not be engaged in any other activities during the 10 minute assessment period. – The MFO will maintain ongoing visual scanning of the Observation Zone for protected marine fauna and, every 30 minutes, will dedicate a period of five minutes for observation (from an elevated position) for protected marine fauna. – Dredging will be undertaken during daylight hours only. – Respond in accordance with vessel interaction procedures if protected marine species are sighted within the Observation Zone. Cease dredging if turtles, dugongs or dolphins enter within 50 m of the cutter head or backhoe, or dolphins with calves enter within 150 m of the cutter head or backhoe. – When a CSD is in operation rotation of the dredge cutter head will only start when it is positioned near the seafloor, and rotation will be stopped before the cutter is raised through the water column. – Vessels to adhere to DPC speed restrictions. – Follow DoE guidelines (Figure 6-2). – Do not approach, circle or wait in front of wildlife for the purposes of casual viewing. – Maintain watch for stranded, injured or dead marine fauna and contact the

Protected Marine Species Management Framework – physical interaction	
	Department of Land Resource Management (DLRM) Marine Wildwatch (1800-453-941) for retrieval, treatment or post-mortem.
Monitoring (Section 7.4)	Regular monitoring for the presence of stranded, injured or dead marine fauna Marine fauna observations (refer to management section)
Reporting (Section 8)	– Daily submission of marine fauna observations sheets (Figure 7-2). – Weekly summary reporting of number of sightings, incidents and corrective actions. – Monitoring report to NT EPA at conclusion of dredging. – Any vessel interaction incidents and protected species injury or mortality will be reported to DPC, and to NT EPA and DoE, within 24 hours of the incident occurring. DPC will also notify the TAG.
Corrective Action(s)	– In the event that an incident or near miss occurs between vessels and protected marine species, the incident will be investigated and discussed to further improve awareness to reduce risk of collision. – For mobile vessels, a 5 kn vessel speed limit will be applied in areas where frequent sightings (an average of >1 per day in any one week) are made of protected marine species. – If protected marine species approach within the Caution Zone (Figure 6-2), vessels that are under way will proceed at a “no wash” speed.
Term	For the duration of dredging activities.
Responsibility	– Dredging Contractor to ensure their documents are compliant with the DDSPMP – Dredging Contractor implements protected marine species management and monitoring program – Contractor Project Manager to liaise with DLRM on response to stranded, injured or dead marine fauna and potential recovery, treatment or post-mortem

Figure 6-2 DoE guidelines on approach distances for dolphins

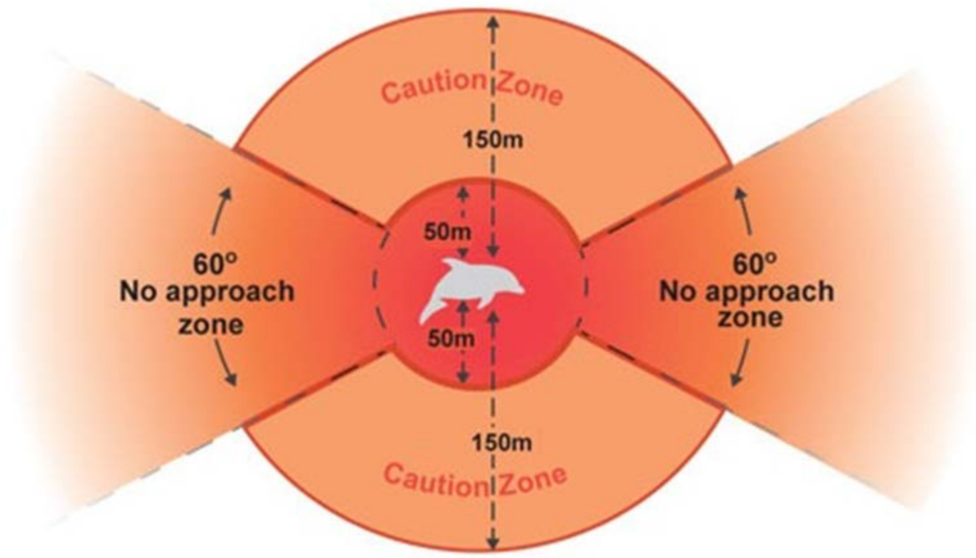
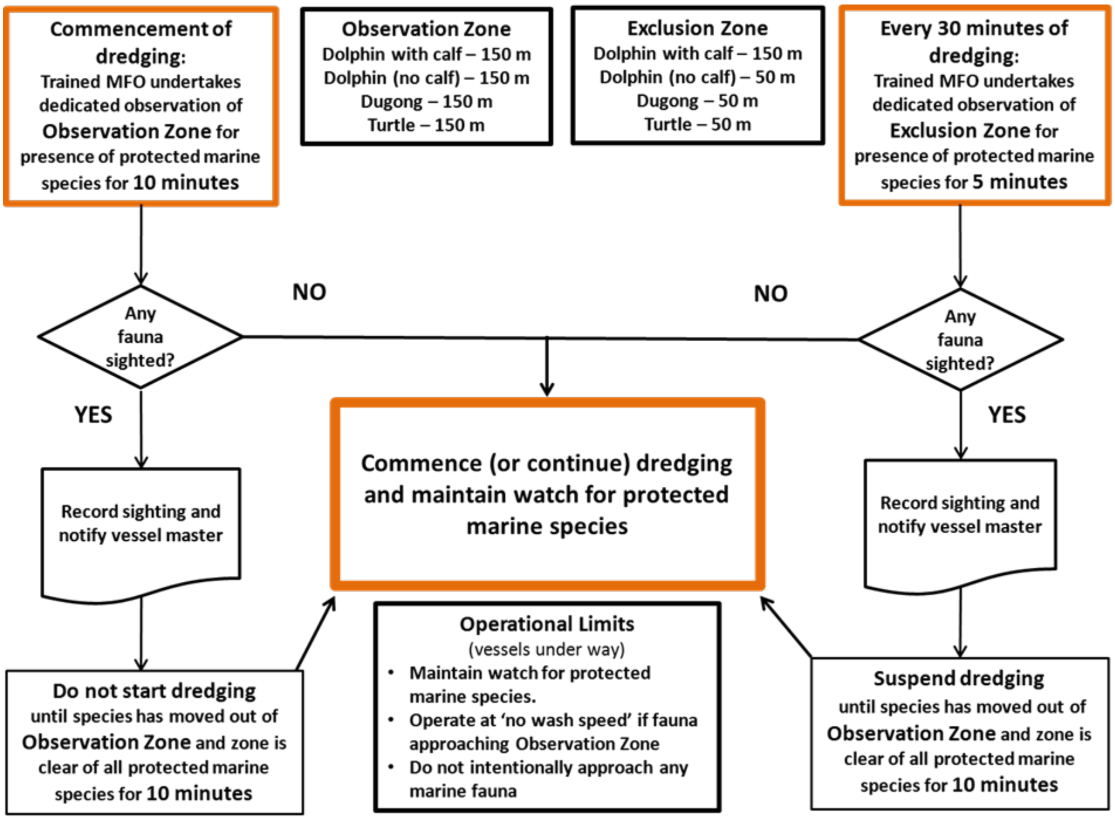


Figure 6-3 Vessel interaction management flowchart



6.5 Protected marine species – underwater noise

Dredging for construction of the tug pens will create additional underwater noise in various forms and intensity above current ambient levels in Darwin Harbour. The level of underwater noise attributable to dredging activities that is above existing background noise levels in the area is highly dependent on a number of factors, which are described below.

DLP (2011a) suggests that expected noise from a CSD could reasonably be expected to be below 1000 Hz (1 KHz) and is typically between 100 – 200 Hz. Dredging of hard substrates typically results in higher underwater noise levels than when dredging soft sediments such as those to be dredged for this project. At these frequencies, dolphins and dugongs are unlikely to be significantly disturbed as this noise generally falls outside the auditory sensitivity range of these animals.

Scattering and absorption of sound in the marine environment is a complex function of a number of parameters including:

- surface scattering from wind-generated surface roughness
- bubbles present near the surface as a result of recent wave action
- suspended silts and other particles (turbidity)
- density of sound absorbing phytoplankton and other marine organism tissues (including fish bladders)
- seabed topography, sediment type and thickness (seabed absorption is typically 1000 or more times that of seawater, and can be 100% depending on the frequencies of interest)

- scattering and leakage at boundaries between water masses with different temperature, salinity and/or turbidity properties
- intervening landmasses, including reefs, shoals and mudflats.

Coastal dolphins use sound for navigation, feeding and avoiding predators (through echo location) and also for communication (through narrow band frequency modulated sound). The ability of dolphins to communicate, navigate and echo locate can be compromised by sound generated by human activity though dredging noise is not expected to occur in the higher frequencies used by dolphins for these purposes (with most noise expected to be below 1 kHz). While the ocean is naturally noisy, marine mammals are well adapted to natural levels of ambient noise. However, anthropogenic noise can cause masking (i.e. the blocking of the perception stimulus due to the presence of another stimulus in the same range) to occur (Jensen et al. 2009). Dolphins may be temporarily displaced from the vicinity of the tug pens site by the increase in noise levels. Alternatively the dolphins may adapt (dolphins are known to frequent busy harbours such as Singapore) or may tolerate the increased noise to feed on fish attracted to the operating dredge in search of food. Indo-pacific bottlenose dolphins have an audio –sensitivity threshold between approximately10 – 100 kHz and a threshold of hearing of 130 dB at 100 Hz and 95 dB at 1 kHz (Johnson 1967). Given the previously discussed peak expected noise from dredging of 160 – 180 dB at 100 Hz, much of the sound generated by dredging is below the hearing threshold of the Indo-pacific bottlenose dolphin.

Turtle auditory morphology is adapted for hearing in water. They hear largely in the low frequency range (<1000 Hz), though the bandwidth and peak sensitivity varies between species. The use of sound by turtles is little understood. Experimentally, turtles have initially shown avoidance behaviour, then eventually habituating to the noise (Moein Bartol & Musick 2003). However, given the short duration of dredging for this project (two weeks), it is unlikely that turtles will habituate to the noise and will avoid the area if noise intensities are too great. Observation of dredge activities around Australia is that turtles largely avoid coming in close proximity to the dredge. In part this is attributed to the sound of the dredge.

While little information is available on the auditory systems of dugongs and little research has been undertaken to investigate the sensitivity of dugongs to noise, dugong vocalisations are composed of barks at 0.5 to 2.2 kHz and higher frequency clicks and chirps at 3 to 18 kHz and their sensitive range of audibility is between 1 to 18 kHz (Anderson & Barclay 1995). It is estimated that the threshold audibility is similar to that of the manatee which is 105 dB at 500 Hz and 80 dB at 1 kHz. This suggests that the majority of dredge derived noise (typically between 100 to 200 Hz) would be undetectable to dugongs (DLP 2011a). There are only anecdotal reports of dugongs avoiding areas with high boat traffic.

Monitoring of protected marine species is described in Section 7.4. Management measures implemented to reduce the risk of disturbance of protected marine species by underwater noise generated by the dredging works are listed in the following EMF.

Table 6-6 Protected marine species EMF - underwater noise

Protected Marine Species Management Framework – underwater noise	
Element	Impact of underwater noise on protected marine species.
Commitments	EPBC 2010/5304 condition 17(e)
Objectives	– Minimise the risk of disturbance to protected marine species from underwater noise. – Establish and maintain awareness of the importance of protecting marine species.
Target	– No disturbance to protected marine species as a result of noise generated during dredging activities. – All dredging personnel to complete an HSE induction addressing protected marine species interaction and protection. – At all times that dredge is operational, at least one crew member is a trained MFO.
Key Performance Indicator(s)	– Number of audits and incident reports. – Number of reported sightings of live, injured or dead protected marine species. – Number of personnel completing an HSE site induction. – Availability of MFO trained dredge operator.
Management	– Ensure that all equipment is maintained in good operating condition (balancing, greasing, etc.) and have proper noise control systems in place. – Ensure all noise minimisation measures such as mufflers, special enclosures and sound-insulation mounts are fitted and working. – Ensure revolving equipment such as propellers and drive shafts are balanced to reduce vibration. – Minimise the noise generation of equipment (thrusters and auxiliary plant) by switching them off when not used (i.e. avoid running on standby mode).
Monitoring (Section 7.4)	– Marine fauna observations. – Regular monitoring for stranded, injured or dead marine fauna.
Reporting (Section 8)	– Daily submission of marine fauna observations sheets (Figure 7-2). – Weekly summary reporting to DPC of number of sightings of protected marine species. – Monitoring report to NT EPA at the conclusion of dredging. – Any suspected noise related incidents will be reported by the Contractor to DPC, and to DoE (on behalf of DPC), within 24 hours of the incident occurring. DPC will also notify the TAG. Incidents will also be reported by Contractor direct to NT EPA within 24 hours of the incident occurring. – Any corrective actions implemented in response to suspected noise related incidents will be detailed in the weekly report to DPC. This report will also be provided to NT EPA. DPC will provide this report to the TAG and DoE.
Corrective Action(s)	In the event that noise-related impact is suspected, the incident will be investigated to confirm a noise-related impact has occurred and identify the most appropriate action(s) to reduce the impact. This may include one or more of the following: noise reduction measures; soft-start start-up procedures; restriction on vessel movements/activities; increase the radius of the Observation Zone to 200 m.
Term	For the duration of dredging activities.
Responsibility	– Dredging Contractor to ensure their documents are compliant with the DDSPMP. – Dredging Contractor to implement noise management aboard vessels.

6.6 Migratory birds

6.6.1 Pond system characteristics

The filling of the dredge spoil placement ponds will reduce the pond area at EAW. Most of the bird observations during the bird surveys conducted by EMS (2011) were at Pond D (2169 individuals observed out of 3722 observed at 14 sites in total).

Pond D will not be used for direct placement of dredge spoil during dredging of the tug pens site with Pond K and Pond E (North) being the only ponds used for direct placement. However, Pond D may be used for routing tailwater between Pond K and Pond E (North) should it be required. For this reason, migratory birds are considered in this plan to provide for the possible use of Pond D.

Pond D is subject to minimal disturbance from surrounding industrial activities associated with Port operations at EAW, such as bulk mineral stockpiling and rail operations. This pond fills to capacity during the Wet Season as a result of storm water inundation and dries out completely by the end of the Dry Season. When dry the site is unattractive for roosting shorebirds. Ongoing settlement of the dredge spoil previously placed in Pond D is contributing to a gradual lowering of the surface profile of the pond. This may extend the period in the year when the pond is suitable for shorebirds.

It is anticipated that the birds that previously roosted on the banks of Pond K now use Pond D and Pond E, or roost at the natural habitat types within Darwin Harbour that they used before EAW was constructed, and continue to use under many tidal and seasonal conditions.

The most likely reasons Pond D is chosen by migratory shorebirds for roosting is that it:

- is in close proximity to the coast
- is fenced from disturbance
- is sufficiently open so that aerial predators are readily detected
- contains shallow water, allowing thermoregulation through the legs while roosting.

During the Wet Season Pond D will operate as it normally would during any other Wet Season, and storm water will flow though into Pond E. If tailwater is passed through Pond D, the water heights will be maintained to be no higher than during periodic storm events that occur each year.

The regular wetting and drying of the edge of this pond will keep it free of vegetation and thus retain its attractiveness to roosting shorebirds.

The regular counts of EAW also show that Pond E is used for roosting by internationally significant numbers of shorebirds. For the last two years the birds have roosted on the edge of the fresh dredge material that has flowed in from Pond K. Pond E provides high quality roosting habitat because water is always available in which the shorebirds can stand to cool down. It also has all the other benefits of Pond D in terms of lack of disturbance, availability at all tides and high visibility of potential predators. The tidal flux and the ongoing deposition of dredge spoil ensures that no vegetation grows along the edge, thus ensuring there is no cover for potential predators, which are also likely to be discouraged by the soft nature of the freshly deposited spoil. Pond E has a proven record of supporting roosting shorebirds during the dredging process so it is not anticipated that continued placement of the dredge spoil into Pond E will have a detrimental effect on this behaviour. Unlike with Pond K, there are no plans to fill Pond E during the current dredging campaign as it must continue to have a role in storm water containment.

6.6.2 Triggers for corrective actions

6.6.2.1 Pond water height

If Pond D is used, water height will be maintained as per previous Wet Seasons (refer Section 7.5.2.1). This is the only time that there may be an impact on migratory birds.

6.6.2.2 Migratory Birds

To comply with EPBC approval Condition 15, monitoring of migratory birds (as described in Section 7.5) will be implemented. Two triggers will be adopted for management actions with reference to migratory birds during dredging and shall apply if Pond D is open to tailwater flow from Pond K.

The first action (to analyse causation and to implement targeted management responses) will be taken should the total number of shorebirds counted fall by greater than 50% from one week to the next. The figure of 50% is adopted because these counts cannot be compared with baseline surveys and are being used only to attempt to detect sudden changes in pond suitability during dredging.

Action will also be taken should the maximum number of shorebirds counted during the month fall below 60% of maximum baseline numbers (from MSB dredging data) in total for that month, or for any of the four species which have been recorded at Pond D in nationally significant numbers, or have fewer than 60% of the number of species recorded during baseline surveys. The figure of 60% is adopted as being a threshold that allows for the high levels of daily and seasonal variation expected and the megatidal environment of Darwin Harbour, while still demonstrating that the site retains its value to migratory shorebirds.

6.6.3 Response to trigger exceedances

If any of the triggers described in Section 6.6.2 are exceeded, the Contractor will notify the DoE, NT EPA and DPC within 24 hours of the exceedance being determined and will provide all monitoring data relevant to the pond systems to the TAG for consideration within three business days of the relevant count. The TAG will investigate in conjunction with the Contractor to determine whether changes detected are attributable to dredging and pond management activities (e.g. water levels too high, water quality, direct disturbance) or whether changes are more likely to be caused by extrinsic factors (e.g. tides, on-migration, local rainfall, wind etc.). The changes will be compared to any counts under the auspices of the Australian Wader Studies Group at other sites in the Darwin region and elsewhere in Australia to determine if they are part of a larger trend. A review of the conditions at the site will also be undertaken to determine if any local habitat variables have altered, particularly whether water has been available, whether the potential roost sites have become excessively vegetated or any other matters that might have discouraged birds from roosting at the site.

Where the variation is considered by the TAG to be site specific, a more detailed investigation of all of the pond monitoring and environmental data will be undertaken. If the cause can be identified as relating to pond management or dredge spoil placement and handling practices, the TAG will propose corrective actions. The TAG will ensure that analysis and consideration of relevant contributing factors is undertaken within a period of 15 business days of its receipt of initial trigger exceedance data from the Contractor.

Management measures to be implemented to reduce the risk of adverse impacts upon migratory birds are listed in the following EMF (Table 6-7). If required due to trigger exceedances, corrective actions will be implemented.

Table 6-7 Migratory birds EMF

Migratory Birds Management Framework	
Element	Impact of spoil placement on protected migratory birds.
Commitments	EPBC 2010/5304 condition 17(e)
Objectives	– Minimise the risk of adverse impacts upon migratory birds from the operation of the dredge spoil placement ponds. – Establish and maintain awareness of the importance of protecting migratory birds and their habitat.
Targets	– Maintenance of Pond D at normal Wet Season water level (5.5 m AHD) from 1 November to 30 April if in use at this time. – During dredging, total number of shorebirds counted during monitoring does not fall by >50% between weeks. – Maximum number of shorebirds counted during any month does not fall below 60% of the maximum total baseline numbers for that month. – Maximum number of shorebirds counted during any month does not fall below 60% for any of the four species that have been recorded at Pond D in nationally significant numbers. – The number of shorebird species present during any month does not fall below 60% of the number of species recorded during baseline surveys. – All personnel engaged in the operation of the pond system to complete an HSE induction, including migratory bird awareness and management requirements.
Key Performance Indicators	– Number of audits and incident reports. – Water height in Pond D (if in use). – Number of migratory birds utilising the pond system as habitat. – Number of personnel completing an HSE site induction.
Management	– Protect the high tide roost site in Pond D if it is used. – Control activities or facilities that might cause additional disturbance to feeding and roosting birds (e.g. excessive noise, additional nocturnal lighting). – Continue restricted access to the public and animals (dogs) to Pond D. – Implementation of the approved EAW Migratory Shorebird Management Plan to compensate for residual detriment of Project activities on migratory bird species. – If used, ensure the water level in Pond D does not exceed the normal Wet Season level (5.5 m AHD) for the period between 1 November and 30 April inclusive.
Monitoring (Section 7.5)	– Monitor shorebirds at East Arm Wharf in accord with DoE recommendation. – If in use for tailwater management, Pond D will be monitored to measure changes in water depth with reference to the potential to explain migratory bird habitat impacts. – An adapted monitoring approach will be considered in consultation with the TAG (approved and directed by DoE) if significant decline in bird use is observed. – Ongoing Migratory Bird monitoring for five years post-dredging undertaken to satisfy EPBC approval condition 17(f).

Migratory Birds Management Framework	
Reporting (Section 8)	– Monitoring report to NT EPA at conclusion of dredging. – In the event of an exceedance of a bird abundance trigger (Section 6.6.2), DoE, DPC and NT EPA will be notified within 24 hours. All relevant pond monitoring data will be provided to the TAG within three business days of the relevant count. A report on corrective actions implemented to address the cause of the exceedance will be submitted by the Contractor to DoE, DPC and NT EPA within five business days of the notification. – Any mortality of protected migratory birds from dredge spoil placement activities will be reported to DPC, NT EPA and DoE within 24 hours of the mortality occurring. DPC will also notify the TAG.
Corrective Action	Removing Pond D from the pond system used for settling or reducing the water level in Pond D if it is in use.
Term	For the duration of dredging activities, continuing into operations phase.
Responsibility	– Dredging Contractor to ensure their documents are compliant with the DDSPMP. – Dredging Contractor is to implement monitoring program and water quality management measures.

7 ENVIRONMENTAL MONITORING

7.1 Overview

The environmental monitoring program to be implemented as a part of this DDSPMP comprises the following:

- monitoring of water quality surrounding the dredge and pipelines transporting spoil to the pond system for disposal (Section 7.2)
- monitoring of water quality within the dredge spoil placement ponds (Section 7.3)
- monitoring for presence of protected marine species in the vicinity of the tug pens dredging works (Section 7.4)
- monitoring of migratory birds in Pond D (if used during Dry Season) (Section 7.5)

Key aspects of each of the monitoring programs are summarised in Section 7.6.

7.2 Darwin Harbour surrounding dredge and dredge pipelines – water quality

7.2.1 Objectives

The objectives of monitoring water quality in the vicinity of the dredge and dredge spoil pipelines are to:

- Determine if the detectable plume is exceeding the expected range (150 m) and intensity (140 NTU) surrounding the dredge footprint boundary during dredging.
- Detect exceedances in the allowable suspended sediment levels of 100 mg/L (measured as turbidity, 140 NTU) at a distance of 150 m from the dredge footprint boundary or pipelines.
- Provide a trigger for dredge management measures to be implemented to control the plume surrounding the dredge and pipelines.

7.2.2 Monitoring locations

Monitoring locations will be dependent on the plume extent and location but will include measurements at a distance of 150 m from the dredge footprint boundary or pipelines where the plume extends beyond this distance.

7.2.3 Methodology

A visual survey of the area surrounding the dredge and associated pipelines will be undertaken on a regular basis to determine the extent of the dredge plume. Should the visual survey determine that the plume may extend beyond 150 m from the dredge footprint boundary or pipelines, a small vessel or dredge tender will be used to inspect the distance from the dredge footprint boundary to the edge of the plume using a GPS. The GPS will be used to locate and record a point 150 m from the dredge footprint boundary at which point a turbidity measurement will be taken using a hand held water quality probe to measure the mean turbidity through the water column against the allowable limit of 140 NTU. Procedures detailing instrument calibration, sample collection and processing methods will be developed by the Contractor and will include the use of a hand deployed multiparameter probe to collect NTU readings at set intervals (e.g. every 2 seconds) through the water column. The mean of the turbidity values at each interval through the water column will be used for the comparison to the trigger value.

7.2.4 *Data Analysis*

NTU levels measured in the field as required shall be assessed against the turbidity trigger level of 100 mg/L using the project specific SSC / NTU relationship of 100 mg/L = 140 NTU.

7.2.5 *Outcomes*

Based on the surface SSC determined at a distance of 150 m from the dredge footprint boundary or pipelines, dredge management procedures will be initiated to reduce the surface SSC to below 100 mg/L at distances greater than 150 m from the dredge footprint boundary. This may include management measures identified in Table 6-3. These management measures shall remain in place until the surface SSC of the dredge plume waters greater than 150 m from the dredge or pipelines falls below 100 mg/L (measured as turbidity, 140 NTU).

Should the mean turbidity through the water column exceed 140 NTU at any point outside a distance of 150 m from the dredge footprint boundary, the management responses identified in Table 6-3 will be implemented until the surface water turbidity levels fall back below 140 NTU at a distance of 150 m from the dredge.

7.3 Dredge spoil placement ponds – water quality

7.3.1 *Objectives*

The objectives of monitoring water quality within the dredge spoil placement ponds are to:

- detect trends in tailwater pH that may indicate the generation of acid from dredged PASS material pumped into the ponds
- detect trends in toxicant concentrations within the ponds that may indicate the mobilisation of toxicants from the dredged sediments, or from material placed in the ponds during past dredging programs (EAW development, Darwin City Waterfront, etc.)
- confirm the physico-chemical properties (pH, toxicants and SSC) of the tailwater are suitable for discharge from the ponds to the harbour waters.

7.3.2 *Monitoring locations*

The water quality monitoring locations are shown in Figure 7-1.

The pH, turbidity and toxicant concentrations of the tailwater will be monitored at any pond discharge point where dredge tailwater is flowing and within Pond E (South).

In the event that stormwater enters Ponds D or E from existing reclamation areas or ponds within East Arm Port at times when dredge tailwater is in these ponds, then pH and toxicants will be monitored weekly by DPC at the point of stormwater entry to the ponds. Pond D will only be monitored if it is being used for tailwater management. This will inform the assessment of potential causes of any changes in pH and toxicant concentrations that may become evident in Ponds D or E. It is noted that there are no controls on entry of stormwater into dredge spoil ponds D and E.

Figure 7-1 Water quality monitoring locations

7.3.3 Methodology

Over the course of discharge of tailwater from the pond system:

- tailwater pH will be monitored by extracting water samples daily from each monitoring location and testing the water with a hand-held pH meter
- turbidity will be monitored at each location using a hand-held probe
- one water sample per week to be collected from each of the monitoring locations and sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis of toxicant concentrations (including arsenic). Prior to analysis, the samples will be filtered to remove particles >45 µm in diameter; reducing the potential for sediment-bound toxicants to be included in the analyses.

Procedures detailing instrument calibration, sample collection and processing methods will be developed by the Contractor.

Based on potential toxicity and presence within Darwin Harbour sediments, the metallic toxicants to be monitored through collection of water samples are displayed below. The toxicant trigger levels are set at the 95% level of protection (% of species) within the ANZECC Guidelines. Where marine water quality triggers are not available due to insufficient data, freshwater trigger levels applicable to slightly–moderately disturbed systems are adopted.

Arsenic (AsIII)	24 µg/l (freshwater)
Arsenic (AsV)	13 µg/l (freshwater)

Cadmium	5.5 µg/l	
Chromium (CrIII)	27.4 µg/l	
Chromium (CrVI)	4.4 µg/l	
Copper	1.3 µg/l	
Lead	4.4 µg/l	
Mercury (inorganic)	0.4 µg/l	
Nickel	70 µg/l	
Selenium (total)	5 µg/l	(freshwater)
Zinc	15 µg/l	

Speciated toxicants (arsenic and chromium) will be analysed for total values, and if any total exceeds the trigger level of one of the species, then the samples will be reanalysed for the individual species.

7.3.4 Data analysis

pH, turbidity and metals (toxicants) are to be plotted and considered for trends. Any trends towards allowable limits will be used as an early warning mechanism and dredging operations reconsidered to avoid exceedance of water quality limits.

7.3.5 Outcomes

The data outputs from the monitoring enable ongoing assessments to be made of the need to implement further tailwater (or stormwater) management measures to maintain water quality parameters within the pond system below trigger levels and to render the water suitable for disposal from Pond E (South) (see Section 6.2.4).

7.4 Protected marine species

At all times that the dredge is operational, the crew will include at least one member that is trained (by a training provider whose capability is recognised by the TAG) as an MFO. As described in Table 7-1, the MFO will be responsible for undertaking visual assessments (for protected marine species) of the 150 m radius Observation Zone around the dredge. The assessment of the Observation Zone will be made from an elevated position on the dredge, where a clear line of sight is achievable to the edge of the zone. The MFO will not be engaged in any other activities during the dedicated assessment periods.

During dredging, at 30 minute intervals the designated MFO will check the Observation Zone for a period of five minutes. If any protected marine species are present within the zone, the sighting will be recorded (including details of the time and results of observation) and the management measures described in Section 6.3 will be implemented.

The Dredging Contractor will provide awareness training to selected crew members to inform them about the protected marine species which may occur within Darwin Harbour; to provide a description of the record form to be used for recording protected marine species sightings; and to explain how to apply appropriate avoidance mitigation measures to minimise potential impacts or collisions with marine fauna. The purpose of the training is to raise awareness; to encourage recording and reporting of protected marine species sightings, and to emphasise the requirement to report stranded, injured or dead marine species regardless of what caused the injuries or deaths.

The Dredging Contractor will undertake observations for protected marine species and will report all positive sightings by the MFO to the Project Manager who ensures sightings are logged and information is provided to DPC. All sightings of protected marine species are recorded by the MFO on marine fauna observation forms similar to that presented in Figure 7-2 which will be available on all Project vessels. These records are then logged into the project marine fauna sighting register.

The Contractor will be responsible for reporting sightings of any EPBC-listed marine fauna to the relevant authorities within 24 hours. This includes the requirement under EPBC condition 17(g) to report to the relevant Minister, within one business day, where there is injury or mortality to a listed threatened or migratory species that may be attributable to the dredging activity. The report will include details of the individual species observed, the frequency, location and timing of observations, and photos (if available). The objective of these reports is to identify potential interaction areas which will be incorporated by the Dredging Contractor into pre-starts, toolboxes, marine fauna awareness training, or other general awareness sessions as required.

Figure 7-2 Marine fauna observations form

Name :

Employer :

Date :

Day or Night Shift :

Time	Reported Observations & Actions							Initial
	Species[1]	No.	Calves (Y/N)	Distance (m)	Mitigation response[2]	Beaufort state	Comment	

[1] Record the species as accurately as you can. If unsure, use the general terms "dolphin", "turtle", "sawfish", etc.
[2] If no mitigation response is required, you should still record this.
Take photos if possible.

7.5 Migratory birds

7.5.1 Recent monitoring

Surveys of migratory birds utilising Pond D have been undertaken since November 2009 as part of the EAW Expansion Project.

The Migratory Shorebirds Management Plan (MBMP) has been developed and implemented in accordance with DoE Approval EPBC 2010/5304 condition 36. Weekly surveys were completed between May to December 2013 during the MSB dredging program with results reported in the Annual Monitoring Report for Dredging Activities (DoI, 2014).

Three Migratory Shorebirds Reports have been written since the MBMP was approved (Lilleyman et al 2013, Lilleyman et al 2014, Lilleyman et al 2015).

Since 2014, in addition to regular surveying of Pond D, a trapping and tagging program has been undertaken with VHF tracking devices applied to shorebirds (Lilleyman et al 2014).

The MBMP and above-mentioned reports are available on the EAW EIS webpage at http://www.eastarmwharf-eis.nt.gov.au/home

7.5.2 Planned monitoring

7.5.2.1 Pond water height

If Pond D receives tailwater, then pond water height measurements will be taken daily throughout dredging, and used to reference current pond height against natural high water levels.

7.5.2.2 Migratory bird monitoring

Ongoing migratory bird counts will be undertaken throughout the dredging of the tug pens site in accordance with the MBMP. This monitoring will include counting and tracking of migratory birds utilising Pond D and will include at least two summer surveys for a period of five years after cessation of dredge spoil placement as per section 2.2.1 of the MBMP.

As part of the MBMP, survey results will be analysed to compare the total numbers, numbers of species and numbers of four species (i.e. those previously identified to have used Pond D for roosting in numbers exceeding the threshold for national significance) with the mean value in baseline surveys, allowing for the month of survey.

The contractor will be required to arrange weekly surveys for the duration of the tug pens dredging program, due to the expected short timeframe of the program.

7.6 Summary of monitoring programs

Key aspects of each of the monitoring programs are summarised in Table 7-1.

Table 7-1 Summary of environmental monitoring programs

Locations	Parameter	Methods	Frequency	Triggers	EMF
DREDGE PLUME 150 m FROM DREDGE OR PIPELINES					
Section 7.2 Water column where the dredge plume extends beyond 150 m from the dredge or pipelines	Turbidity	Visual Hand-held probe	As required by visual monitoring	SSC>100 mg/L (measured as turbidity, 140 NTU) 150 m from the dredge or pipelines. Continue to monitor and implement management actions to reduce SSC levels below 100 mg/L (140 NTU) at a distance of 150 m from the dredge footprint boundary or pipelines. Relevant monitoring locations: within the dredge plume at a point 150 m away from the dredge footprint boundary or pipelines	Water Quality Management - Darwin Harbour
DREDGE SPOIL PLACEMENT PONDS (Corresponding relevant monitoring locations from Figure 7-1 are shown as ⊗ in the text)					
Section 7.3 At all pond outlets where tailwater is flowing. *If required:* Stormwater from existing Port land.	pH	Hand-held probe	Daily from the commencement of dredging until the cessation of tailwater discharge	pH<6.0 or pH>8.5 Continue to monitor and consider pre-emptive management actions to prevent exceedance in Pond E (North) at the weir into Pond E (South) or in Pond E (South) if either trigger exceeded (Section 6.2.3) Relevant monitoring locations: ③ ④ ⑤ ⑥ ⑦.	Water Quality Management - Dredge Spoil Placement Ponds
	Toxicants	Laboratory	Sample collected once per week from the commencement of dredging	Exceedance of any ANZECC Guidelines trigger levels (Section 6.2.3; trigger levels detailed in Section 7.3.3). Continue to monitor and consider pre-emptive management actions to prevent exceedance in Pond E (North) at the weir into Pond E (South) or in Pond E (South). Relevant monitoring locations: ③ ④ ⑤ ⑥ ⑦	
	Turbidity	Hand-held probe	Daily from the commencement of	Use project specific SSC/NTU relationship	

Locations	Parameter	Methods	Frequency	Triggers	EMF
	(NTU)		dredging until the cessation of tailwater discharge	(Section 6.2.3) 100 mg/L SSC = 140 NTU Continue to monitor and consider pre-emptive management actions to prevent exceedance in Pond E (North) at the weir into Pond E (South) or in Pond E (South) if trigger exceeded. Relevant monitoring locations: ③ ④ ⑤ ⑥ ⑦	
Section 7.3 Pond E (North) at the weir prior to flow into Pond E (South) and in Pond E (South) prior to discharge through the railway bund wall.	pH	Hand-held probe	Daily from the commencement of dredging until the cessation of tailwater discharge	pH<6.0 or pH>8.5 Discharge from Pond E (North) into Pond E (South) discontinued if either trigger exceeded (Section 6.2.3). Relevant monitoring location: ① ②	Water Quality Management - Dredge Spoil Placement Ponds
	Toxicants	Laboratory	Once per week from the commencement of dredging until the cessation of tailwater discharge	Exceedance of any ANZECC Guidelines trigger levels (Section 6.2.3; trigger levels detailed in Section 7.3.3). Discharge from Pond E (North) into Pond E (South) discontinued. Relevant monitoring locations: ① ②	
	Turbidity (NTU)	Hand-held probe	Daily from the commencement of dredging until the cessation of tailwater discharge.	Use project specific SSC/NTU relationship (Section 6.2.3) 100 mg/L SSC = 140 NTU. Discharge from Pond E (North) into Pond E (South) discontinued if trigger exceeded. Relevant monitoring locations: ① ②	
Section 7.5 All ponds	Pond water level	Water height marker in pond	Daily, commencing at start of tailwater flow through the relevant pond.	Pond D water level above 5.5 m AHD (from 1 November to 30 April only). All other ponds – water height at least 0.5 m below bund height. Discontinue tailwater flow into the pond and open outlet points to lower water level.	Migratory Birds Management Plan
Section 7.5 Pond D	Migratory birds: species presence, abundance,	Observation by trained observer	Weekly survey program during dredging. In accordance with ongoing monitoring outlined in the EAW MBMP.	Fall in numbers >50% between weekly counts. 60% below monthly maximum levels for total numbers, number of four key species, total number of species	

Locations	Parameter	Methods	Frequency	Triggers	EMF
	mortality			(See Section 7.5.2.2 for details)	
TUG PENS DREDGING AREA					
Section 7.4 Observation Zone and Exclusion Zone around dredge	Protected Marine Species - presence	Observation by trained observers (MFOs)	1. On each occasion that the dredge has been non-operational for a period exceeding 30 minutes, a visual assessment will be undertaken of the 150 m radius Observation Zone by the MFO, for a period of 10 minutes prior to the recommencement of dredging. 2. Every 30 minutes, the Observation Zone will be assessed by the MFO for a period of five minutes.	Trigger – entry of protected marine species into the Exclusion Zone: • 150 m for dolphin with calf • 50 m for all other protected marine species, including dolphin without calf. 1. Dredging shall not commence until no protected marine species have been sighted within the Observation Zone for a period of 10 minutes. 2. If protected marine species enter into the Exclusion Zone, then dredging will cease until such time as there have been no protected marine species sighted within the Observation Zone for a period of 10 minutes. (Section 6.3)	Protected Marine Species Management – physical interaction and underwater noise

8 REPORTING

8.1 Routine reporting

8.1.1 Daily reporting

Brief daily reports will be provided by the Contractor to DPC and will include:

- a summary of the dredging completed on that day and status of dredging operations
- information relating to any exceedances detected through monitoring
- proposed schedule for dealing with exceedances reported and next steps to be followed
- records of sightings of protected marine species (Section 7.4)
- dredge daily logs showing work area and availability.

8.1.2 Weekly monitoring report

Each week during the dredging and tailwater discharge activities, a weekly summary report of monitoring data will be submitted by the Contractor to DPC for dissemination to the TAG and to other stakeholders that may be designated by the TAG. The report will include:

- turbidity (NTU) data at a distance of 150 m from the dredge footprint boundary where visual monitoring identifies an exceedance (Section 7.2)
- details of management measures implemented and time of implementation in response to an exceedance in turbidity trigger surrounding the dredge
- pH and turbidity (NTU) data within the dredge spoil placement ponds, from the commencement of dredging and spoil placement (Section 7.3)
- toxicants data for pond waters, once available from the laboratory (Section 7.3)
- comments on any apparent trends in the data, both over time and between ponds (Section 7.3.4)
- summary of daily data reports (Section 8.1.1)
- discussion of any trigger level exceedances (Section 8.2)
- corrective actions taken to address exceedances (Section 6)
- summary of observation data for migratory birds (numbers and species) (Section 7.5)
- details of any injuries to, or mortalities of, turtles, dugongs, dolphins or migratory birds as a result of dredging activities or pond water management (Section 8.3)
- a summary of environmentally significant equipment failures or events and an outline of corrective actions taken, or proposed, to reduce environmental harm arising therefrom (Section 8.3).

8.1.3 Dredge operation records and reporting

The Dredging Contractor will maintain daily records of areas dredged, the volumes of material removed and dredge availability. These records will be provided to TAG weekly, and the findings from hydrographic surveys confirming dredge volumes and locations will be included in the Contractor report to the DPC fortnightly and on completion of the dredging (see Section 8.1.4). Copies of the daily environmental inspection checklists and other relevant environmental records will be provided by the Dredging Contractor to DPC for circulation as appropriate. All records will be provided in a format that allows auditing by relevant environmental regulators if required.

8.1.4 End of dredge phase reporting

Within one month of the conclusion of dredging, Contractor will submit a monitoring report to the TAG, DoE, DPC and NT EPA which includes the outcomes of all monitoring activities, exceedances, management actions and any relevant trend analysis and interpretation of analytical data collected in accordance with environmental conditions.

8.1.5 Compliance reporting

The NTG, as the holder of the EPBC approval, will report to the Commonwealth Government on a yearly basis (by 30 March of each year after the commencement of the Action). The Contractor will provide information to the NTG as required to facilitate this reporting requirement, including:

- summaries of all monitoring program outcomes
- summaries of any monitoring exceedances
- details of corrective actions implemented to dredging and tailwater discharge methods in response to monitoring exceedances.

A WDL will be required for the dredging works. DPC (or Contractor, on award of the contract) will be required to acquire a WDL for the dredging to be completed. As licensee under the WDL, DPC [or Contractor] will submit to NT EPA any reports, data and/or information required by the license. These reports, data and / or information will be submitted in accordance with any timeframes required by the license.

During dredging, the WDL holder will notify NT EPA of any non-compliance with the WDL, as required by that licence.

8.2 Exceedance notification and reporting

The following notifications of exceedances will be made to the Proponent, TAG, DPC and DoE, within 24 hours of the exceedances occurring:

- Within the dredge spoil placement ponds in Pond E (North) at the weir into Pond E (South) or in Pond E (South), exceedance of:
  - pH, toxicant or SSC (measured as NTU) trigger levels (as per Section 6.2.3)
- Triggers for reduction in numbers of migratory birds (as per Section 6.6.2.2).

Where exceedances occur at other monitoring locations, the Contractor will notify the Proponent and DPC within 24 hours of the exceedance occurring.

Exceedances will also be reported to NT EPA in accordance with Conditions of the WDL and as and when required under the *Waste Management and Pollution Control Act* and the *Water Act*.

For each exceedance at Pond E (North) at the weir into Pond E (South) or in Pond E (South), the Contractor will provide NT EPA with a report on the corrective actions implemented to address the cause of the exceedance. This report will be submitted in accordance with the required timeframe stipulated in the WDL.

8.3 Environmental incident notification and reporting

In the event of the following environmental incidents, the Contractor will notify DoE and DPC within 24 hours of the incident occurring (DPC will in turn notify the TAG):

- vessel interaction with protected marine species, including details of injury to, or mortality of, individuals in accordance with EPBC approval Condition 17(g) (Section 6.3)
- suspected disturbance of protected marine species related to noise generated by tug pen dredging activities (Section 6.5)
- mortality of protected migratory birds in dredge spoil placement ponds (Section 6.6).

Other environmental incidents (spills, etc.) will also be recorded and reported in environment monitoring reports and to DPC. If the incident is a notifiable incident under the Waste Management and Pollution Control Act, then NT EPA will also be notified within 24 hours.

All incidents will be investigated and recorded on a Contractor 'Incident Report Form', 'Environmental Incident Details Form' or similar in accordance with Contractor's accident investigation and reporting procedures. Preventative and corrective actions will be established and these will be recorded on the Contractors 'Non-conformance and Corrective Action Register', and the progress tracked for completion.

8.4 Complaints reporting

In the event of a complaint received as a result of dredging activities, they will be entered and tracked using Contractors incident management system. Details to be recorded include:

- date, time and method of complaints
- description of complaint
- complainant details
- cause, action and proposed action, including allocation of a person to action the complaint and an action date
- follow-up and close-out.

Corrective action in response to valid complaints is to occur within 48 hours following receipt of the complaint. Records will be made available to the DPC and authorities upon request, taking into account any privacy issues of the complainant as appropriate.

8.5 Reporting and notification summary

The Proponent will report as required to the Commonwealth Government under the EPBC approval. The Proponent will publish the results on the following web site, in accordance with EPBC Condition 17(h):

Website www.eastarmwharf-eis.nt.gov.au

Reporting and notifications will be sent to the following stakeholders as per the requirements detailed within Section 6 of this DDSPMP.

Proponent Graeme.Finch@nt.gov.au

NT EPA environmentops@nt.gov.au

DoE post.approvals@environment.gov.au

The reporting and notification requirements for the Project are summarised in Table 8-1.

Table 8-1 Reporting and notification summary

Reporting Type	Time	Reporting to	Content/Comments
Routine reporting			
Start up	14 days 1 month (from commencement)	Proponent, DoE Websites	Notice of dredging commencement as per EPBC approval Condition 1 Post DDSPMP on Proponent website as per EPBC approval Condition 8 and as per WDL Conditions to be determined.
Protected marine species sightings (Section 7.4)	24 hours (from sighting)	Proponent	Marine Fauna Observations sheet (Figure 7-2)
Weekly monitoring reports (Section 8.1.2)	Weekly	Proponent, TAG	Water quality data from monitoring within the dredge spoil placement ponds and at the perimeter of the dredging footprint and seaward of the permeable section of the railway bund wall. Protected marine species sightings (summary from daily observations sheets).
End of dredging reports (Section 8.1.4)	Within one month of conclusion of dredging	Proponent, TAG, DoE, NT EPA	Monitoring report as per any relevant WDL conditions to be determined.
Yearly compliance and monitoring reports (Section 8.1.5)	30 March 2015	Proponent, DoE, Website	Compliance report as per EPBC approval Condition 3. All monitoring as per EPBC approval Condition 17(h).
	TBC on receipt of WDL	NT EPA	Audit and compliance report as per relevant WDL conditions to be determined.
Exceedance reporting			
Water quality exceedance – initial notification (Section 8.2)	24 hours (from occurrence)	Proponent, TAG, NT EPA, DoE	Location and value of exceedance.
Water quality exceedance – corrective actions (Section 8.2)	Five business days (from notification)	NT EPA	As per relevant WDL conditions to be determined

Reporting Type	Time	Reporting to	Content/Comments
Migratory bird monitoring – initial notification (Section 8.2)	24 hours (from occurrence)	Proponent, TAG, NT EPA, DoE	Nature of exceedance.
Migratory bird monitoring – pond monitoring data summary (Section 8.2)	Three business days (from trigger exceedance)	Proponent, TAG, DoE	Daily numbers and species of migratory birds sighted in pond network (Section 7.5.2.2)
Migratory bird monitoring - corrective actions (Section 8.2)	Five business days (from notification)	NT EPA	As per relevant WDL conditions to be determined
Environmental incident reporting			
Injury to, mortality of, or disturbance of, a protected species (Section 8.3)	24 hours (from occurrence)	Proponent, TAG, NT EPA, DoE	Time, location and photos.
Other environmental incidents (Section 8.3)	24 hours (from occurrence)	NT EPA	Report generated from Contractor incident management system
Complaints reporting			
Complaints (Section 8.4)	48 hours (from occurrence)	Proponent	Report generated from incident management system
Ongoing monitoring reporting			
Migratory bird monitoring (Section 7.5.2.2)	Ongoing	DoE	Ongoing survey with reporting identified in the MBMP developed in accordance with EPBC approval Conditions 17(f) and 36.
TAG advice reporting			
TAG advice relating to EPBC approval Condition 13(a)	1 week	DoE	A copy of all advice and recommendations made by the TAG and an explanation of how this advice and recommendations will be implemented or an explanation of why the person taking the action does not propose to implement certain recommendations
TAG advice relating to EPBC approval Condition 13(b)	48 hours	DoE	

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10 LIMITATIONS

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Darwin Port Operations (DPO) and only those third parties who have been authorised in writing by URS to rely on this Report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this Report.

It is prepared in accordance with the scope of work and for the purpose outlined in the Contract numbered D10-0252 (CD2028/11) Amendment No. 9 dated 3 July 2014.

Where this Report indicates that information has been provided to URS by third parties, URS has made no independent verification of this information except as expressly stated in the Report. URS assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between August 2014 and April 2016 and is based on the information provided by DPC at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This Report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This Report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Except as required by law, no third party may use or rely on this Report unless otherwise agreed by URS in writing. Where such agreement is provided, URS will provide a letter of reliance to the agreed third party in the form required by URS.

To the extent permitted by law, URS expressly disclaims and excludes liability for any loss, damage, cost or expenses suffered by any third party relating to or resulting from the use of, or reliance on, any information contained in this Report. URS does not admit that any action, liability or claim may exist or be available to any third party.

Except as specifically stated in this section, URS does not authorise the use of this Report by any third party.

It is the responsibility of third parties to independently make inquiries or seek advice in relation to their particular requirements and proposed use of the site.

APPENDIX A GEOCHEMICAL INVESTIGATION SEDIMENT ANALYSIS RESULTS

TABLE 1.
East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation
Laboratory Analytical Results - Metals

Location ID	Sample ID	Interval	Date	Aluminium	Antimony	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Silver	Zinc
			Unit							mg/kg						
			Practical Quantitation Limit	50	0.50	1.0	0.1	1.0	1.0	50	1.0	10.0	0.01	1.0	0.1	10.0
			SQG LOW (NAGD 2009)	NG	2	20	1.5	80	65	NG	50	NG	0.15	21	1.0	200
			SQG HIGH (NAGD 2009)	NG	25	70	10	370	270	NG	220	NG	1.00	52	3.7	410
TP01.1	TP01.1	0-0.5	7/04/2014	20100	<0.5	10.1	<0.1	41.8	8.9	27400	13.9	267	0.02	12.6	<0.1	34.6
TP01.2	TP01.2	0.5-1	7/04/2014	19100	<0.5	9.9	<0.1	41.0	11.1	26100	13.4	282	0.02	12.0	<0.1	34.7
TP01.2	QC03_080414	0.5-1	7/04/2014	25400	<0.5	9.4	<0.1	40.9	6.2	31600	10.8	269	0.02	12.8	<0.1	30.6
TP01.3	TP01.3	1-1.5	7/04/2014	20400	<0.5	11.8	<0.1	42.0	6.8	28200	14.2	332	0.02	12.4	<0.1	34.6
TP01.4	TP01.4	1.5-2	7/04/2014	10800	<0.5	10.2	<0.1	23.6	3.6	17200	9.9	269	0.01	6.6	<0.1	18.5
TP01.5	TP01.5	2-2.5	7/04/2014	11000	<0.5	11.1	<0.1	24.1	3.2	17100	7.9	268	<0.01	7.1	<0.1	19.8
TP02.1	TP02.1	0-0.5	7/04/2014	17400	<0.5	12.2	<0.1	36.3	10.0	25600	13.0	305	0.02	11.0	<0.1	32.8
TP02.2	TP02.2	0.5-1	7/04/2014	18700	<0.5	11.0	<0.1	39.0	14.4	27100	14.9	328	0.02	11.2	<0.1	34.2
TP02.3	TP02.3	1-1.5	7/04/2014	19000	<0.5	10.1	<0.1	40.0	7.2	27400	14.7	348	0.02	11.8	<0.1	37.7
TP02.4	TP02.4	1.5-2	7/04/2014	16600	<0.5	11.5	<0.1	34.9	6.6	25200	14.0	296	0.02	10.3	<0.1	31.7
TP03.1	TP03.1	0-0.5	7/04/2014	14100	<0.5	12.4	<0.1	32.6	9.0	26000	12.4	282	0.01	10.3	<0.1	32.9
TP03.1	QC07.1	0-0.5	7/04/2014	17500	<0.5	10.0	<0.1	36.2	7.5	25200	11.6	289	0.01	10.6	<0.1	29.4
TP03.1	QC08.1	0-0.5	7/04/2014	15300	<0.5	10.7	<0.1	33.5	8.5	24400	10.8	276	0.02	10.3	<0.1	29.1
TP03.2	TP03.2	0.5-1	7/04/2014	15000	<0.5	8.8	<0.1	31.4	8.2	21700	12.3	285	0.02	9.4	<0.1	27.6
TP04.1	TP04.1	0-0.5	7/04/2014	19700	<0.5	10.7	<0.1	41.9	11.6	27700	14.1	326	0.02	12.2	<0.1	41.6
TP04.2	TP04.2	0.5-1	7/04/2014	19700	<0.5	11.4	<0.1	41.8	10.8	27300	15.4	335	0.02	12.1	<0.1	38.5
TP04.3	TP04.3	1-1.5	7/04/2014	18400	<0.5	10.5	<0.1	39.0	6.5	24700	13.4	303	0.01	11.4	<0.1	32.3
TP04.4	TP04.4	1.5-2	7/04/2014	18100	<0.5	11.6	<0.1	38.6	6.6	24800	13.8	328	0.01	11.1	<0.1	33.1
TP04.5	TP04.5	2-2.5	7/04/2014	8620	<0.5	8.1	<0.1	20.6	3.0	15900	8.5	251	0.02	5.9	<0.1	17.1
TP05.1	TP05.1	0-0.5	7/04/2014	20400	<0.5	10.9	<0.1	41.7	8.7	27700	14.5	366	0.02	12.4	<0.1	34.4
TP05.2	TP05.2	0.5-1	7/04/2014	19600	<0.5	11.0	<0.1	40.8	15.1	26800	14.0	343	0.02	11.8	<0.1	34.7
TP05.3	TP05.3	1-1.5	7/04/2014	19500	<0.5	11.3	<0.1	40.7	7.0	27200	15.1	360	0.02	12.0	<0.1	39.2
TP05.4	TP05.4	1.5-2	7/04/2014	19600	<0.5	14.2	<0.1	40.5	6.6	27000	14.3	390	0.02	12.1	<0.1	34.0
TP05.5	TP05.5	2-2.5	7/04/2014	10200	<0.5	7.3	<0.1	21.2	3.0	15600	8.2	240	0.02	6.1	<0.1	14.3
TP06.1	TP06.1	0-0.5	7/04/2014	16300	<0.5	13.6	<0.1	37.7	8.9	26600	11.8	353	0.02	11.3	<0.1	31.8
TP06.2	TP06.2	0.5-1	7/04/2014	15600	<0.5	11.2	<0.1	36.5	10.1	24100	12.0	343	0.02	10.9	<0.1	33.1
TP06.3	TP06.3	1-1.5	7/04/2014	19000	<0.5	10.7	<0.1	41.8	6.7	26200	12.7	340	0.02	12.4	<0.1	36.4
TP06.4	TP06.4	1.5-2	7/04/2014	18200	<0.5	10.8	<0.1	40.3	6.6	25700	13.1	368	0.02	12.0	<0.1	32.9
TP07.1	TP07.1	0-0.5	7/04/2014	19200	<0.5	11.0	<0.1	42.0	9.4	27900	13.6	378	0.02	12.6	<0.1	35.0
TP07.2	TP07.2	0.5-1	7/04/2014	18600	<0.5	11.2	<0.1	39.6	12.2	27700	14.9	334	0.02	11.9	<0.1	34.5
TP07.2	QC09.2	0.5-1	7/04/2014	20300	<0.5	11.2	<0.1	43.1	16.2	28600	14.3	323	0.02	12.5	<0.1	37.6
TP07.2	QC10.2	0.5-1	7/04/2014	19200	<0.5	10.3	<0.1	41.6	9.2	27800	12.8	324	0.02	12.4	<0.1	33.9
TP07.3	TP07.3	1-1.5	7/04/2014	18500	<0.5	11.0	<0.1	41.5	7.1	27300	13.4	313	0.02	12.8	<0.1	35.8
TP07.3	QC09.3	1-1.5	7/04/2014	20600	<0.5	10.3	<0.1	44.1	7.1	28800	13.2	328	0.02	13.3	<0.1	35.1
TP07.3	QC10.3	1-1.5	7/04/2014	19700	<0.5	9.5	<0.1	41.9	6.8	26700	12.7	298	0.02	12.3	<0.1	34.2
TP09.1	TP09.1	0-0.5	7/04/2014	20500	<0.5	10.0	<0.1	43.6	9.1	31600	10.7	275	0.04	13.8	<0.1	32.7
TP09.2	TP09.2	0.5-1	7/04/2014	26500	<0.5	11.0	<0.1	44.9	7.2	32700	11.0	304	0.03	14.0	0.2	32.9
TP09.2	QC02_070414	0.5-1	7/04/2014	17000	<1	8.5	<0.1	36.0	7.3	22000	11.0	230	<0.01	11.0	<0.5	31.0
TP09.3	TP09.3	1-1.5	7/04/2014	28700	<0.5	12.7	<0.1	49.6	8.0	36300	13.8	320	0.03	15.3	<0.1	37.6
TP09.4	TP09.4	1.5-2	7/04/2014	11000	<0.5	12.5	0.1	23.6	3.1	18400	8.1	279	<0.01	7.2	<0.1	15.4
TP09.5	TP09.5	2-2.5	7/04/2014	10800	<0.5	11.4	<0.1	23.7	2.9	16800	8.0	280	<0.01	7.4	<0.1	22.6
TP09.5	QC01_070414	2-2.5	7/04/2014	11000	<0.5	9.5	<0.1	23.4	2.9	17000	7.4	243	<0.01	7.0	<0.1	14.8
TP10.1	TP10.1	0-0.5	7/04/2014	19100	<0.5	9.8	<0.1	40.5	11.3	27000	13.8	295	0.02	12.4	<0.1	33.3
TP10.2	TP10.2	0.5-1	7/04/2014	19700	<0.5	10.0	<0.1	42.1	11.6	28100	14.9	279	0.02	12.2	<0.1	42.2
TP10.3	TP10.3	1-1.5	7/04/2014	22100	<0.5	10.8	<0.1	44.4	7.4	29000	15.1	346	0.02	13.4	<0.1	44.6
TP10.4	TP10.4	1.5-2	7/04/2014	9400	<0.5	10.4	<0.1	20.5	3.0	16900	8.3	276	0.01	6.0	<0.1	15.6
TP10.5	TP10.5	2-2.5	7/04/2014	12000	<0.5	14.8	0.1	24.2	3.2	18300	7.9	257	<0.01	7.2	<0.1	16.4
TP11.1	TP11.1	0-0.5	7/04/2014	18400	<0.5	10.1	<0.1	39.3	11.4	25900	13.4	290	0.02	11.8	<0.1	38.2
TP11.2	TP11.2	0.5-1	7/04/2014	20500	<0.5	9.9	<0.1	43.1	7.2	28200	14.8	293	0.02	12.6	<0.1	39.9
TP11.3	TP11.3	1-1.5	7/04/2014	10400	<0.5	9.5	<0.1	23.4	4.4	17200	9.9	240	0.01	6.7	<0.1	22.4
TP11.4	TP11.4	1.5-2	7/04/2014	12000	<0.5	11.6	<0.1	24.6	3.1	17700	7.8	266	<0.01	7.3	<0.1	15.4
TP11.5	TP11.5	2-2.5	7/04/2014	11500	<0.5	9.6	<0.1	24.5	3.2	17600	7.8	252	<0.01	7.2	<0.1	14.9
TP12.1	TP12.1	0-0.5	10/04/2014	23800	<0.5	9.2	<0.1	38.9	10.8	30000	9.6	227	0.02	12.1	<0.1	29.8
TP12.2	TP12.2	0.5-1	10/04/2014	24900	<0.5	9.5	<0.1	39.8	5.9	30500	10.5	228	0.02	12.4	<0.1	29.3
TP12.2	QC20_100414	0.5-1	10/04/2014	11000	<1	13.0	<0.1	28.0	4.0	21000	7.5	220	<0.01	7.0	<0.5	13.0
TP12.3	TP12.3	1-1.5	10/04/2014	11600	<0.5	10.0	<0.1	19.7	2.8	16900	7.0	216	0.02	6.1	<0.1	14.2
TP12.4	TP12.4	1.5-2	10/04/2014	12800	<0.5	8.9	<0.1	20.9	2.2	17800	5.3	225	<0.01	6.7	<0.1	11.1
TP12.5	TP12.5	2-2.5	10/04/2014	33100	<0.5	25.6	<0.1	59.8	8.1	47200	13.2	297	0.01	17.4	<0.1	26.0
TP12.6	TP12.6	2.5-3	10/04/2014	31200	<0.5	17.1	<0.1	53.1	6.7	38400	11.0	292	0.01	15.6	<0.1	25.2
TP12.7	TP12.7	3-3.5	10/04/2014	17200	<0.5	14.0	<0.1	31.7	3.3	25700	7.3	199	<0.01	8.6	<0.1	13.0
TP12.8	TP12.8	3.5-4	10/04/2014	17300	<0.5	12.0	<0.1	27.4	3.2	23100	6.7	209	<0.01	8.8	<0.1	13.2
TP14.1	TP14.1	0-0.5	10/04/2014	21500	<0.5	10.6	<0.1	36.6	9.8	29600	9.5	217	0.02	11.9	<0.1	28.8
TP14.2	TP14.2	0.5-1	10/04/2014	12600	<0.5	11.3	<0.1	22.0	2.4	18500	5.7	228	<0.01	6.8	<0.1	11.7
TP14.3	TP14.3	1-1.5	10/04/2014	15100	<0.5	11.4	<0.1	24.4	2.8	20600	6.3	213	<0.01	7.9	<0.1	13.4
TP14.4	TP14.4	1.5-2	10/04/2014	16300	<0.5	12.6	<0.1	25.9	3.0	22200	6.5	193	<0.01	8.4	<0.1	13.1
TP14.5	TP14.5	2-2.5	10/04/2014	16200	<0.5	10.2	<0.1	29.8	3.0	21600	6.2	187	<0.01	7.9	<0.1	12.6
TP14.6	TP14.6	2.5-3	10/04/2014	17300	<0.5	11.7	<0.1	27.6	3.3	23000	7.0	194	<0.01	8.5	<0.1	13.2
TP14.7	TP14.7	3-3.5	10/04/2014	23200	<0.5	21.6	<0.1	39.1	5.6	36800	10.5	176	0.01	12.4	<0.1	19.0
TP14.8	TP14.8	3.5-4	10/04/2014	20700	<0.5	15.4	<0.1	36.8	5.4	38200	9.8	175	<0.01	10.9	<0.1	16.1
TP14.9	TP14.9	4-4.5	10/04/2014	22100	<0.5	17.7	<0.1	43.9	6.0	32000	9.8	196	<0.01	12.1	<0.1	18.8
TP16.1	TP16.1	0-0.5	9/04/2014	25800	<0.5	10.0	<0.1	44.4	10.1	32000	10.3	239	0.02	14.1	<0.1	32.5
TP16.2	TP16.2	0.5-1	9/04/2014	23000	<0.5	10.5	<0.1	39.0	5.9	28100	9.5	210	0.02	12.1	<0.1	28.2
TP16.3	TP16.3	1-1.5	9/04/2014	18600	<0.5	10.1	<0.1	31.8	5.7	24000	10.6	259	0.02	9.8	<0.1	26.8
TP16.4	TP16.4	1.5-2	9/04/2014	13000	<0.5	10.8	<0.1	22.6	2.5	18200	6.2	265	<0.01	6.9	<0.1	12.8
TP16.4	QC17_090414	1.5-2	9/04/2014	12900	<0.5	10.2	<0.1	21.1	2.3	18500	5.4	222	<0.01	6.8	<0.1	11.2
TP16.5	TP16.5	2-2.5	9/04/2014	17200	<0.5	10.4	<0.1	27.8	3.0	21900	6.2	259	<0.01	8.5	<0.1	14.1
TP16.6	TP16.6	2.5-3	9/04/2014	20800	<0.5	14.7	<0.1	33.4	3.8	26000	8.0	241	<0.01	10.8	<0.1	16.8
TP16.6	QC18_090414	2.5-3	9/04/2014	13000	<1	15.0	<0.1	26.0	4.0	22000	7.3	230	<0.01	7.8	<0.5	15.0
TP16.7	TP16.7	3-3.5	9/04/2014	16000	<0.5	12.2	<0.1	26.5	3.0	21200	6.3	213	<0.01	8.2	<0.1	13.1
TP16.8	TP16.8	3.5-4	9/04/2014	15600	<0.5	9.2	<0.1	25.4	3.0	19600	6.2	201	<0.01	7.8	<0.1	12.0
TP16.8	QC19_090414	3.5-4	9/04/2014	15400	<0.5	11.8	<0.1	25.9	2.9	22200	6.7	179	<0.01	7.9	<0.1	12.3
TP17.1	TP17.1	0-0.5	7/04/2014	16700	<0.5	9.2	<0.1	38.0	11.6	25500	13.2	258	0.02	11.2	<0.1	39.2
TP17.2	TP17.2	0.5-1	7/04/2014	16900	<0.5	8.3	<0.1	36.5	7.0	23600	12.8	242	0.02	10.4	<0.1	35.9
TP17.3	TP17.3	1-1.5	7/04/2014	11200	<0.5	11.1	<0.1	24.9	5.1	18600	10.7	206	0.01	7.1	<0.1	23.0
TP17.3	QC04_070414	1-1.5	7/04/2014	13200	<0.5	10.1	<0.1	28.4	5.9	21500	10.4	234	0.01	8.4	<0.1	24.1
TP17.4	TP17.4	1.5-2	7/04/2014	8740	<0.5	10.9	<0.1	19.9	2.9	15800	8.2	268	<0.01	6.0	<0.1	17.0
TP17.5	TP17.5	2-2.5	7/04/2014	10300	<0.5	11.3	<0.1	21.5	2.6	15900	7.0	262	<0.01	6.4	<0.1	15.1
TP17.5	QC05_070414	2-2.5	7/04/2014	8700	<1	8.7	<0.1	19.0	2.0	13000	6.0	220	<0.01	5.6	<0.5	11.0
TP18.1	TP18.1	0-0.5	10/04/2014	26100	<0.5	10.3	<0.1	44.2	9.6	33700	11.0	246	0.03	14.2	<0.1	33.3
TP18.2	TP18.2	0.5-1	10/04/2014	26100	<0.5	9.8	<0.1	43.7	7.0	33000	11.9	246	0.02	13.5	<0.1	33.2
TP18.3	TP18.3	1-1.5	10/04/2014	13900	<0.5	9.6	<0.1	24.0	4.1	19600	7.7	214	0.02	7.5	<0.1	20.1
TP18.4	TP18.4	1.5-2	10/04/2014	13000	<0.5	12.5	<0.1	22.0	2.3	18100	5.6	247	<0.01	7.3	<0.1	11.2
TP18.5	TP18.5	2-2.5	10/04/2014	14900	<0.5	12.4	<0.1	24.7	2.7	20200	6.3	261	<0.01	8.2	<0.1	13.1
TP18.6	TP18.6	2.5-3	10/04/2014	17700	<0.5	11.6	<0.1	28.6	3.3	22500	7.0	218	<0.01	9.3	<0.1	15.2
TP18.7	TP18.7	3-3.5	10/04/2014	16600	<0.5	12.0	<0.1	27.4	3.0	22200	6.4	206	<0.01	8.1	<0.1	13.2
TP18.8	TP18.8	3.5-4	10/04/2014	19500	<0.5	13.6	<0.1	31.5	3.7	25500	7.4	193	<0.01	9.6	<0.1	15.6
TP18.9	TP18.9	4-4.5	10/04/2014	25200	<0.5	20.2	<0.1	51.0	5.8	38900	10.2	220	0.01	12.6	<0.1	19.1
TP23.1	TP23.1	0-0.5	7/04/2014	19300	<0.5	11.1	<0.1	42.5	8.6	26900	12.6	331	0.02	12.2	<0.1	34.3
TP23.2	TP23.2	0.5-1	7/04/2014	19000	<0.5	10.3	<0.1	41.0	11.5	27100	13.2	320	0.02	11.9	<0.1	34.8
TP23.3	TP23.3	1-1.5	7/04/2014	20500	<0.5	9.9	<0.1	42.8	7.2	28300	14.0	309	0.02	12.7	<0.1	36.2
TP23.4	TP23.4	1.5-2	7/04/2014	18800	<0.5	10.8	<0.1	39.9	6.5	26800	13.1	360	0.02	11.9	<0.1	32.0
TP25.1	TP25.1	0-0.5	7/04/2014	23100	<0.5	17.2	<0.1	53.9	14.2	41400	16.9	388	0.02	17.6	<0.1	48.8
TP25.2	TP25.2	0.5-1	7/04/2014	10500	<0.5	5.8	<0.1	22.5	6.5	15200	7.4	176	<0.01	6.4	<0.1	19.5
TP25.3	TP25.3	1-1.5	7/04/2014	17900	<0.5	9.4	<0.1	39.1	6.6	25100	12.1	295	0.01	11.3	<0.1	32.3
TP25.3	QC14_080414	1-1.5	7/04/2014	19300	<0.5	10.8	<0.1	41.2	6.9	27700	14.2	302	0.02	12.4	<0.1	35.2
TP25.4	TP25.4	1.5-2	7/04/2014	10400	<0.5	11.2	<0.1	24.3	3.6	18400	10.1	296	0.03	6.9	<0.1	20.6
TP25.5	TP25.5	2-2.5	8/04/2014	11000	<0.5	11.3	<0.1	23.3	3.0	17000	7.4	266	<0.01	7.0	<0.1	34.3
TP25.5	QC15_080414	2-2.5	8/04/2014	9100	<1	9.6	<0.1	19.0	3.0	14000	7.3	210	<0.01	5.6	<0.5	14.0
TP33.1	TP33.1	0-0.5	7/04/2014	26500	<0.5	13.2	<0.1	57.1	17.4	37200	17.7	368	0.03	16.9	<0.1	50.4
TP33.2	TP33.2	0.5-1	7/04/2014	11900	<0.5	11.2	<0.1	25.2	3.6	18700	8.1	253	<0.01	7.6	<0.1	14.2
TP33.3	TP33.3	1-1.5	7/04/2014	15600	<0.5	15.6	<0.1	35.6	4.9	25300	10.7	285	<0.01	9.8	<0.1	20.0
TP33.4	TP33.4	1.5-2	7/04/2014	26000	<0.5	20.7	<0.1	52.5	8.8	37900	15.4	368	<0.01	15.4	<0.1	36.5
TP33.5	TP33.5	2-2.5	7/04/2014	17900	<0.5	16.0	<0.1	38.4	6.2	26500	10.8	202	<0.01	10.9	<0.1	20.8
TP38.1	TP38.1	0-0.5	7/04/2014	14100	<0.5	9.5	<0.1	35.0	9.9	25600	11.2	236	0.02	11.6	<0.1	34.5
TP38.2	TP38.2	0.5-1	7/04/2014	20800	<0.5	11.2	<0.1	45.5	14.4	30000	14.2	325	0.02	13.2	<0.1	40.5
TP38.3	TP38.3	1-1.5	7/04/2014	18800	<0.5	10.0	<0.1	41.8	7.3	27100	13.1	289	0.02	12.4	<0.1	35.4
TP38.3	QC11_080414	1-1.5	7/04/2014	20000	<0.5	10.9	<0.1	43.7	7.6	29000	14.2	293	0.01	12.8	<0.1	36.8
TP38.4	TP38.4	1.5-2	7/04/2014	15800	<0.5	10.3	<0.1	35.8	6.8	24700	11.4	261	0.01	10.6	<0.1	30.6
TP38.4	QC12_080414	1.5-2	8/04/2014	16000	<1	10.0	<0.1	36.0	7.0	24000	12.0	220	<0.01	11.0	<0.5	31.0
Minimum	-	-	-	8620	<0.5	5.8	<0.1	19.0	2.0	13000	5.3	175	<0.01	5.6	<0.1	11.0
Maximum	-	-	-	33100	<1.0	25.6	<0.1	59.8	17.4	47200	17.7	390	0.04	17.6	<0.1	50.4
Mean	-	-	-	17481	<0.5	11.5	<0.1	34.8	6.6	25053	10.7	271	0.014	10.4	<0.1	26.4
SD	-	-	-	4973	-	2.8	-	9	3.4	6245	3.1	53	0.008	2.8	-	10.2
95%UCL	-	-	-	18253	<0.5	11.9	<0.1	36.1	7.9	25956	11.2	279	-	10.8	<0.1	27.8

Legend:
NG = No Guideline Value
Bold = Detection above Practical Quantitation Limit

TABLE 2.

East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation

Laboratory Analytical Results - TRH, TOC and TBT

Location ID	Sample ID	Interval	Date	Total Recoverable Hydrocarbons (mg/kg) $C_6 - C_{10}$	$>C_{10} - C_{16}$	$>C_{16} - C_{34}$	$>C_{34} - C_{40}$	Total $>C_{10}$-C_{40}	Total $>C_{10}$-C_{40}	TOC	TBT	TBT
			Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Normalised to 1% TOC	%	µgSn/kg	Normalised to 1% TOC
			Practical Quantitation Limit	3.0	3.0	3.0	5.0	3.0	3.0	0.02	0.5	0.5
			SQG LOW (NAGD 2009)	NG	NG	NG	NG	NG	550	NG	NG	9
			SQG HIGH (NAGD 2009)	NG	NG	NG	NG	NG	NG	NG	NG	70
TP01.1	TP01.1	0-0.5	7/04/2014	<3	4	26	8	38	44	0.86	<0.5	<0.5
TP01.2	TP01.2	0.5-1	7/04/2014	<3	7	15	6	28	34	0.82	<0.5	<0.5
TP01.2	QC03_080414	0.5-1	8/04/2014	<3	10	13	<5	23	27	0.86	<0.5	<0.5
TP01.3	TP01.3	1-1.5	7/04/2014	<3	4	23	8	35	43	0.81	<0.5	<0.5
TP01.4	TP01.4	1.5-2	7/04/2014	<3	<3	8	<5	8	18	0.44	<0.5	<0.5
TP01.5	TP01.5	2-2.5	7/04/2014	<3	<3	10	<5	10	21	0.48	<0.5	<0.5
TP02.1	TP02.1	0-0.5	7/04/2014	<3	5	15	9	29	35	0.84	<0.5	<0.5
TP02.2	TP02.2	0.5-1	7/04/2014	<3	4	21	8	33	36	0.91	<0.5	<0.5
TP02.3	TP02.3	1-1.5	7/04/2014	<3	4	13	10	27	29	0.93	<0.5	<0.5
TP02.4	TP02.4	1.5-2	7/04/2014	<3	<3	15	7	22	30	0.73	<0.5	<0.5
TP03.1	TP03.1	0-0.5	7/04/2014	<3	3	24	14	41	53	0.78	<0.5	<0.5
TP03.1	QC07.1	0-0.5	7/04/2014	<3	<3	15	<5	15	21	0.73	<0.5	<0.5
TP03.1	QC08.1	0-0.5	7/04/2014	<3	<3	16	<5	16	20	0.81	<0.5	<0.5
TP03.2	TP03.2	0.5-1	7/04/2014	<3	7	10	<5	17	21	0.80	<0.5	<0.5
TP04.1	TP04.1	0-0.5	7/04/2014	<3	13	31	13	57	75	0.76	<0.5	<0.5
TP04.2	TP04.2	0.5-1	7/04/2014	<3	6	18	7	31	38	0.82	<0.5	<0.5
TP04.3	TP04.3	1-1.5	7/04/2014	<3	5	29	9	43	56	0.77	<0.5	<0.5
TP04.4	TP04.4	1.5-2	7/04/2014	<3	7	15	6	28	37	0.76	5.2	6.8
TP04.5	TP04.5	2-2.5	7/04/2014	<3	<3	13	<5	13	30	0.44	<0.5	<0.5
TP05.1	TP05.1	0-0.5	7/04/2014	<3	4	24	9	37	42	0.88	<0.5	<0.5
TP05.2	TP05.2	0.5-1	7/04/2014	<3	6	8	<5	14	15	0.95	<0.5	<0.5
TP05.3	TP05.3	1-1.5	7/04/2014	<3	4	19	7	30	35	0.86	<0.5	<0.5
TP05.4	TP05.4	1.5-2	7/04/2014	<3	<3	6	<5	6	7	0.82	<0.5	<0.5
TP05.5	TP05.5	2-2.5	7/04/2014	<3	<3	<3	<5	<3	<3	0.49	<0.5	<0.5
TP06.1	TP06.1	0-0.5	7/04/2014	<3	16	20	6	42	50	0.84	<0.5	<0.5
TP06.2	TP06.2	0.5-1	7/04/2014	<3	20	39	11	70	81	0.86	<0.5	<0.5
TP06.3	TP06.3	1-1.5	7/04/2014	<3	13	20	6	39	49	0.79	<0.5	<0.5
TP06.4	TP06.4	1.5-2	7/04/2014	<3	7	13	<5	20	25	0.80	<0.5	<0.5
TP07.1	TP07.1	0-0.5	7/04/2014	<3	11	36	11	58	69	0.84	<0.5	<0.5
TP07.2	TP07.2	0.5-1	7/04/2014	<3	11	18	6	35	41	0.86	<0.5	<0.5
TP07.2	QC09.2	0.5-1	7/04/2014	<3	<3	15	<5	15	17	0.86	<0.5	<0.5
TP07.2	QC10.2	0.5-1	7/04/2014	<3	<3	9	<5	9	11	0.83	<0.5	<0.5
TP07.3	TP07.3	1-1.5	7/04/2014	<3	22	36	11	69	80	0.86	<0.5	<0.5
TP07.3	QC09.3	1-1.5	7/04/2014	<3	<3	30	7	37	45	0.82	<0.5	<0.5
TP07.3	QC10.3	1-1.5	7/04/2014	<3	<3	25	7	32	39	0.83	<0.5	<0.5
TP09.1	TP09.1	0-0.5	7/04/2014	<3	10	21	6	37	43	0.86	<0.5	<0.5
TP09.2	TP09.2	0.5-1	7/04/2014	<3	<3	14	<5	14	17	0.83	<0.5	<0.5
TP09.2	QC02_070414	0.5-1	7/04/2014	<25	-	-	-	-	-	1.20	<0.5	<0.5
TP09.3	TP09.3	1-1.5	7/04/2014	<3	7	14	6	27	33	0.81	<0.5	<0.5
TP09.4	TP09.4	1.5-2	7/04/2014	<3	<3	8	<5	8	17	0.47	<0.5	<0.5
TP09.5	TP09.5	2-2.5	7/04/2014	<3	<3	6	<5	6	14	0.43	<0.5	<0.5
TP09.5	QC01_070414	2-2.5	7/04/2014	<3	<3	5	<5	5	11	0.44	<0.5	<0.5
TP10.1	TP10.1	0-0.5	7/04/2014	<3	<3	<3	<5	<3	<3	0.98	<0.5	<0.5
TP10.2	TP10.2	0.5-1	7/04/2014	<3	7	6	<5	13	15	0.88	<0.5	<0.5
TP10.3	TP10.3	1-1.5	7/04/2014	<3	3	14	6	23	34	0.68	<0.5	<0.5
TP10.4	TP10.4	1.5-2	7/04/2014	<3	3	<3	<5	3	6	0.48	<0.5	<0.5
TP10.5	TP10.5	2-2.5	7/04/2014	<3	<3	4	<5	4	9	0.46	<0.5	<0.5
TP11.1	TP11.1	0-0.5	7/04/2014	<3	6	12	5	23	29	0.80	<0.5	<0.5
TP11.2	TP11.2	0.5-1	7/04/2014	<3	5	22	8	35	44	0.79	<0.5	<0.5
TP11.3	TP11.3	1-1.5	7/04/2014	<3	<3	7	<5	7	11	0.63	<0.5	<0.5
TP11.4	TP11.4	1.5-2	7/04/2014	<3	<3	9	<5	9	20	0.45	<0.5	<0.5
TP11.5	TP11.5	2-2.5	7/04/2014	<3	<3	6	<5	6	13	0.45	<0.5	<0.5
TP12.1	TP12.1	0-0.5	10/04/2014	<3	<3	14	<5	14	18	0.79	<0.5	<0.5
TP12.2	TP12.2	0.5-1	10/04/2014	<3	<3	8	<5	8	11	0.74	<0.5	<0.5
TP12.2	QC20_100414	0.5-1	10/04/2014	<25	-	-	-	-	-	0.52	<0.5	<0.5
TP12.3	TP12.3	1-1.5	10/04/2014	<3	<3	12	<5	12	22	0.54	<0.5	<0.5
TP12.4	TP12.4	1.5-2	10/04/2014	<3	<3	7	<5	7	18	0.40	<0.5	<0.5
TP12.5	TP12.5	2-2.5	10/04/2014	<3	22	40	7	69	128	0.54	<0.5	<0.5
TP12.6	TP12.6	2.5-3	10/04/2014	<3	4	12	<5	16	28	0.57	<0.5	<0.5
TP12.7	TP12.7	3-3.5	10/04/2014	<3	3	13	<5	16	31	0.52	<0.5	<0.5
TP12.8	TP12.8	3.5-4	10/04/2014	<3	<3	<3	<5	<3	<3	0.47	<0.5	<0.5
TP14.1	TP14.1	0-0.5	10/04/2014	<3	7	31	6	44	59	0.75	<0.5	<0.5
TP14.2	TP14.2	0.5-1	10/04/2014	<3	<3	<3	<5	<3	<3	0.47	<0.5	<0.5
TP14.3	TP14.3	1-1.5	10/04/2014	<3	<3	9	<5	9	18	0.50	<0.5	<0.5
TP14.4	TP14.4	1.5-2	10/04/2014	<3	<3	4	<5	4	8	0.49	<0.5	<0.5
TP14.5	TP14.5	2-2.5	10/04/2014	<3	4	18	<5	22	47	0.47	<0.5	<0.5
TP14.6	TP14.6	2.5-3	10/04/2014	<3	<3	6	<5	6	13	0.46	<0.5	<0.5
TP14.7	TP14.7	3-3.5	10/04/2014	<3	<3	3	<5	3	6	0.47	<0.5	<0.5
TP14.8	TP14.8	3.5-4	10/04/2014	<3	4	6	<5	10	17	0.59	<0.5	<0.5
TP14.9	TP14.9	4-4.5	10/04/2014	<3	<3	3	<5	3	5	0.55	<0.5	<0.5
TP16.1	TP16.1	0-0.5	9/04/2014	<3	<3	17	<5	17	20	0.84	<0.5	<0.5
TP16.2	TP16.2	0.5-1	9/04/2014	<3	6	21	8	35	49	0.71	51.5	72.5
TP16.3	TP16.3	1-1.5	9/04/2014	<3	<3	11	7	18	23	0.80	<0.5	<0.5
TP16.4	TP16.4	1.5-2	9/04/2014	<3	<3	11	<5	11	24	0.45	<0.5	<0.5
TP16.4	QC17_090414	1.5-2	9/04/2014	<3	<3	5	<5	5	11	0.45	<0.5	<0.5
TP16.5	TP16.5	2-2.5	9/04/2014	<3	<3	7	<5	7	15	0.46	<0.5	<0.5
TP16.6	TP16.6	2.5-3	9/04/2014	<3	<3	4	<5	4	9	0.44	<0.5	<0.5
TP16.6	QC18_090414	2.5-3	9/04/2014	<25	-	-	-	-	-	0.38	0.79	2.1
TP16.7	TP16.7	3-3.5	9/04/2014	<3	5	4	<5	9	20	0.45	<0.5	<0.5
TP16.8	TP16.8	3.5-4	9/04/2014	<3	4	5	<5	9	24	0.37	<0.5	<0.5
TP16.8	QC19_090414	3.5-4	9/04/2014	<3	<3	<3	<5	<3	<3	0.46	<0.5	<0.5
TP17.1	TP17.1	0-0.5	7/04/2014	<3	<3	<3	<5	<3	<3	0.88	<0.5	<0.5
TP17.2	TP17.2	0.5-1	7/04/2014	<3	<3	<3	<5	<3	<3	0.85	<0.5	<0.5
TP17.3	TP17.3	1-1.5	7/04/2014	<3	<3	6	<5	6	9	0.70	<0.5	<0.5
TP17.3	QC04_070414	1-1.5	7/04/2014	<3	<3	14	<5	14	24	0.58	<0.5	<0.5
TP17.4	TP17.4	1.5-2	7/04/2014	<3	<3	8	<5	8	17	0.48	<0.5	<0.5
TP17.5	TP17.5	2-2.5	7/04/2014	<3	<3	14	<5	14	30	0.47	<0.5	<0.5
TP17.5	QC05_070414	2-2.5	7/04/2014	<25	-	-	-	-	-	0.42	<0.5	<0.5
TP18.1	TP18.1	0-0.5	10/04/2014	<3	5	31	10	46	58	0.79	<0.5	<0.5
TP18.2	TP18.2	0.5-1	10/04/2014	<3	8	14	<5	22	28	0.78	<0.5	<0.5
TP18.3	TP18.3	1-1.5	10/04/2014	<3	5	17	6	28	57	0.49	<0.5	<0.5
TP18.4	TP18.4	1.5-2	10/04/2014	<3	<3	6	<5	6	15	0.40	<0.5	<0.5
TP18.5	TP18.5	2-2.5	10/04/2014	<3	<3	5	<5	5	11	0.45	<0.5	<0.5
TP18.6	TP18.6	2.5-3	10/04/2014	<3	<3	<3	<5	<3	<3	0.43	<0.5	<0.5
TP18.7	TP18.7	3-3.5	10/04/2014	<3	<3	9	<5	9	19	0.48	<0.5	<0.5
TP18.8	TP18.8	3.5-4	10/04/2014	<3	<3	9	<5	9	21	0.43	<0.5	<0.5
TP18.9	TP18.9	4-4.5	10/04/2014	<3	3	8	<5	11	21	0.52	<0.5	<0.5
TP23.1	TP23.1	0-0.5	7/04/2014	<3	<3	28	8	36	41	0.88	<0.5	<0.5
TP23.2	TP23.2	0.5-1	7/04/2014	<3	6	11	<5	17	20	0.86	<0.5	<0.5
TP23.3	TP23.3	1-1.5	7/04/2014	<3	<3	16	<5	16	20	0.80	<0.5	<0.5
TP23.4	TP23.4	1.5-2	7/04/2014	<3	<3	26	6	32	38	0.85	<0.5	<0.5
TP25.1	TP25.1	0-0.5	7/04/2014	<3	12	32	9	53	65	0.82	<0.5	<0.5
TP25.2	TP25.2	0.5-1	7/04/2014	<3	4	16	5	25	28	0.88	<0.5	<0.5
TP25.3*	TP25.3	1-1.5	7/04/2014	<3	5	17	6	28	27	1.02	<0.5	<0.5
TP25.3	QC14_080414	1-1.5	7/04/2014	<3	<3	6	<5	6	-	-	<0.5	-
TP25.4	TP25.4	1.5-2	7/04/2014	<3	<3	6	<5	6	11	0.55	<0.5	<0.5
TP25.5	TP25.5	2-2.5	8/04/2014	<3	<3	4	<5	<3	<3	0.47	<0.5	<0.5
TP25.5	QC15_080414	2-2.5	8/04/2014	<25	-	-	-	-	-	0.51	<0.5	<0.5
TP33.1	TP33.1	0-0.5	7/04/2014	<3	<3	4	<5	4	4	0.90	<0.5	<0.5
TP33.2	TP33.2	0.5-1	7/04/2014	<3	15	56	16	87	174	0.50	<0.5	<0.5
TP33.3	TP33.3	1-1.5	7/04/2014	<3	5	10	<5	15	30	0.50	<0.5	<0.5
TP33.4	TP33.4	1.5-2	7/04/2014	<3	6	15	6	27	50	0.54	<0.5	<0.5
TP33.5	TP33.5	2-2.5	7/04/2014	<3	8	15	<5	23	25	0.93	<0.5	<0.5
TP38.1	TP38.1	0-0.5	7/04/2014	<3	4	13	<5	17	22	0.79	<0.5	<0.5
TP38.2	TP38.2	0.5-1	7/04/2014	<3	20	31	8	59	63	0.94	<0.5	<0.5
TP38.3	TP38.3	1-1.5	7/04/2014	<3	9	30	12	51	63	0.81	<0.5	<0.5
TP38.3	QC11_080414	1-1.5	7/04/2014	<3	<3	27	8	35	41	0.86	<0.5	<0.5
TP38.4	TP38.4	1.5-2	7/04/2014	<3	14	19	6	39	57	0.69	<0.5	<0.5
TP38.4	QC12_080414	1.5-2	8/04/2014	<25	-	-	-	-	-	0.82	-	-
Minimum	-	-	-	<3	<3	<3	<5	<3	<3	0.37	<0.5	<0.5
Maximum	-	-	-	<25	22	56	16	87	174	1.20	51.5	72.5
Mean	-	-	-	<3	5	14	5	21	30	0.68	0.7	0.9
SD	-	-	-	-	5	10	3	18	25	0.19	4.7	6.7
95%UCL	-	-	-	<3	6	11	9	23	34	0.70	2.1	3.8

Legend:
TPH and TBT results normalised to 1% TOC as per Table 2 of NADG (2009)
NG = No Guideline Value
Bold = Detection above Practical Quantitation Limit
*Duplicate sample QC14_080414 (duplicate of TP25.3) analytical results for TOC have been adopted as primary results for sample TP25.3.

TABLE 3.
East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation
Laboratory Analytical Results - PAHs

Location ID	Sample ID	Interval	Date	Naphthalene	2-Methylnaphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(e) pyrene	Benzo(a) pyrene	Perylene	Benzo(g.h.i) perylene	Dibenz(a.h) anthracene	Indeno (1.2.3.cd) pyrene	Coronene	Sum of PAHs	Sum of PAHs
			Unit	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Normalised to 1% TOC
			Practical Quantitation Limit	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004
			SQG LOW (NAGD 2009)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	10	10
			SQG HIGH (NAGD 2009)	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	50	50
TP01.1	TP01.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP01.2	TP01.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP01.2	QC03_080414	0.5-1	8/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP01.3	TP01.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP01.4	TP01.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP01.5	TP01.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP02.1	TP02.1	0-0.5	7/04/2014	**0.006**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.006**	**0.007**
TP02.2	TP02.2	0.5-1	7/04/2014	**0.01**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.01**	**0.011**
TP02.3	TP02.3	1-1.5	7/04/2014	**0.011**	<0.005	**0.012**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.023**	**0.025**
TP02.4	TP02.4	1.5-2	7/04/2014	**0.008**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.008**	**0.011**
TP03.1	TP03.1	0-0.5	7/04/2014	**0.008**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.006**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.014**	**0.018**
TP03.1	QC07.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP03.1	QC08.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP03.2	TP03.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP04.1	TP04.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	**0.006**	<0.004	**0.006**	**0.005**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.017**	**0.022**
TP04.2	TP04.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP04.3	TP04.3	1-1.5	7/04/2014	**0.005**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.005**	**0.006**
TP04.4	TP04.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP04.5	TP04.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	**0.01**	**0.014**	**0.01**	**0.007**	**0.011**	**0.005**	**0.006**	**0.012**	<0.004	**0.007**	<0.004	**0.004**	<0.005	**0.086**	**0.195**
TP05.1	TP05.1	0-0.5	7/04/2014	**0.007**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.005**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.012**	**0.014**
TP05.2	TP05.2	0.5-1	7/04/2014	**0.007**	<0.005	<0.004	<0.004	<0.004	**0.005**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.012**	**0.013**
TP05.3	TP05.3	1-1.5	7/04/2014	**0.005**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.005**	**0.006**
TP05.4	TP05.4	1.5-2	7/04/2014	**0.005**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.005**	**0.006**
TP05.5	TP05.5	2-2.5	7/04/2014	**0.006**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.006**	**0.012**
TP06.1	TP06.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP06.2	TP06.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP06.3	TP06.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP06.4	TP06.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.1	TP07.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.2	TP07.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.2	QC09.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.2	QC10.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.3	TP07.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.3	QC09.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP07.3	QC10.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP09.1	TP09.1	0-0.5	7/04/2014	**0.007**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.007**	**0.008**
TP09.2	TP09.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP09.2	QC02_070414	0.5-1	7/04/2014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
TP09.3	TP09.3	1-1.5	7/04/2014	<0.005	<0.005	**0.006**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.006**	**0.007**
TP09.4	TP09.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP09.5	TP09.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP09.5	QC01_070414	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP10.1	TP10.1	0-0.5	7/04/2014	**0.01**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.004**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.014**	**0.014**
TP10.2	TP10.2	0.5-1	7/04/2014	**0.008**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.008**	**0.009**
TP10.3	TP10.3	1-1.5	7/04/2014	**0.008**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.008**	**0.012**
TP10.4	TP10.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP10.5	TP10.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP11.1	TP11.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP11.2	TP11.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP11.3	TP11.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP11.4	TP11.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP11.5	TP11.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.1	TP12.1	0-0.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.2	TP12.2	0.5-1	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.2	QC20_100414	0.5-1	10/04/2014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
TP12.3	TP12.3	1-1.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.4	TP12.4	1.5-2	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.5	TP12.5	2-2.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.6	TP12.6	2.5-3	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.7	TP12.7	3-3.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP12.8	TP12.8	3.5-4	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.1	TP14.1	0-0.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.2	TP14.2	0.5-1	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.3	TP14.3	1-1.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.4	TP14.4	1.5-2	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.5	TP14.5	2-2.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.6	TP14.6	2.5-3	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.7	TP14.7	3-3.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.8	TP14.8	3.5-4	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP14.9	TP14.9	4-4.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004

Legend:
NG = No Guideline Value
Bold = Detection above Practical Quantitation Limit

TABLE 3.

East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation

Laboratory Analytical Results - PAHs

Location ID	Sample ID	Interval	Date	Naphthalene	2-Methylnaphthalene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a) anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene	Benzo(e) pyrene	Benzo(a) pyrene	Perylene	Benzo(g.h.i) perylene	Dibenz(a.h) anthracene	Indeno (1.2.3.cd) pyrene	Coronene	Sum of PAHs	Sum of PAHs
Unit				mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	Normalised to 1% TOC
Practical Quantitation Limit				0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004
SQG LOW (NAGD 2009)				NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	10	10
SQG HIGH (NAGD 2009)				NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	50	50
TP16.1	TP16.1	0-0.5	9/04/2014	**0.005**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.004**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.009**	**0.011**
TP16.2	TP16.2	0.5-1	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.004**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.004**	**0.006**
TP16.3	TP16.3	1-1.5	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	**0.004**	**0.005**	<0.004	<0.004	**0.004**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.013**	**0.016**
TP16.4	TP16.4	1.5-2	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP16.4	QC17_090414	1.5-2	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP16.5	TP16.5	2-2.5	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP16.6	TP16.6	2.5-3	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP16.6	QC18_090414	2.5-3	9/04/2014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
TP16.7	TP16.7	3-3.5	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP16.8	TP16.8	3.5-4	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP16.8	QC19_090414	3.5-4	9/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP17.1	TP17.1	0-0.5	7/04/2014	**0.006**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.006**	**0.007**
TP17.2	TP17.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	**0.004**	<0.004	<0.004	**0.004**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.008**	**0.009**
TP17.3	TP17.3	1-1.5	7/04/2014	**0.006**	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.006**	**0.009**
TP17.3	QC04_070414	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP17.4	TP17.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP17.5	TP17.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP17.5	QC05_070414	2-2.5	7/04/2014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
TP18.1	TP18.1	0-0.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.2	TP18.2	0.5-1	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.3	TP18.3	1-1.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.005**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.005**	**0.010**
TP18.4	TP18.4	1.5-2	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.5	TP18.5	2-2.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.6	TP18.6	2.5-3	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.7	TP18.7	3-3.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.8	TP18.8	3.5-4	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP18.9	TP18.9	4-4.5	10/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP23.1	TP23.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP23.2	TP23.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.008**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.008**	**0.009**
TP23.3	TP23.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP23.4	TP23.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP25.1	TP25.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP25.2	TP25.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP25.3	TP25.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP25.3	QC14_080414	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP25.4	TP25.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP25.5	TP25.5	2-2.5	8/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	**0.005**	<0.004	**0.013**	**0.011**	**0.005**	**0.004**	**0.006**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.044**	**0.094**
TP25.5	QC15_080414	2-2.5	8/04/2014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	**0.029**	**0.028**	**0.02**	**0.016**	**0.037**	-	**0.014**	**0.026**	<0.005	**0.008**	<0.005	**0.014**	<0.005	-	<0.004
TP33.1	TP33.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP33.2	TP33.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP33.3	TP33.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP33.4	TP33.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP33.5	TP33.5	2-2.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP38.1	TP38.1	0-0.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP38.2	TP38.2	0.5-1	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP38.3	TP38.3	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	**0.004**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.004**	**0.005**
TP38.3	QC11_080414	1-1.5	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP38.4	TP38.4	1.5-2	7/04/2014	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
TP38.4	QC12_080414	1.5-2	8/04/2014	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.01	-	<0.005	**0.006**	<0.005	<0.005	<0.005	<0.005	<0.005	-	-
Minimum	-	-	-	<0.005	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
Maximum	-	-	-	**0.011**	<0.005	**0.012**	<0.005	<0.005	**0.006**	<0.004	**0.029**	**0.028**	**0.020**	**0.016**	**0.037**	**0.005**	**0.014**	**0.026**	<0.005	**0.008**	<0.005	**0.014**	<0.005	**0.086**	**0.195**
Mean	-	-	-	<0.004	<0.005	**0.009**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
SD	-	-	-	**0.003**	0.000	**0.001**	0.000	0.000	**0.001**	0.000	**0.003**	**0.003**	**0.002**	**0.002**	**0.004**	0.000	**0.002**	**0.003**	0.000	**0.001**	0.000	**0.001**	0.000	**0.010**	**0.021**
95%UCL	-	-	-	**0.006**	<0.005	<0.004	<0.004	<0.004	**0.004**	<0.004	<0.004	**0.005**	**0.020**	<0.005	**0.005**	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	**0.008**	**0.012**

Legend:

NG = No Guideline Value

Bold = Detection above Practical Quantitation Limit

TABLE 4.

East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation

Laboratory Analytical Results - Nutrients

Location ID	Sample ID	Interval	Date	Nitrite+Nitrate as N	Total KjN as N	Total Nitrogen as N	Total Phosphorus as P
			Unit	mg/kg	mg/kg	mg/kg	mg/kg
			Practical Quantitation Limit	0.1	20	20	2
			SQG LOW (NAGD 2009)	NG	NG	NG	NG
			SQG HIGH (NAGD 2009)	NG	NG	NG	NG
TP01.1	TP01.1	0-0.5	7/04/2014	<0.1	710	710	336
TP01.2	TP01.2	0.5-1	7/04/2014	<0.1	870	870	389
TP01.2	QC03_080414	0.5-1	8/04/2014	<0.1	980	980	494
TP01.3	TP01.3	1-1.5	7/04/2014	<0.1	800	800	409
TP01.4	TP01.4	1.5-2	7/04/2014	<0.1	420	420	331
TP01.5	TP01.5	2-2.5	7/04/2014	<0.1	360	360	632
TP02.1	TP02.1	0-0.5	7/04/2014	<0.1	980	980	402
TP02.2	TP02.2	0.5-1	7/04/2014	<0.1	980	980	451
TP02.3	TP02.3	1-1.5	7/04/2014	<0.1	980	980	432
TP02.4	TP02.4	1.5-2	7/04/2014	<0.1	600	600	452
TP03.1	TP03.1	0-0.5	7/04/2014	<0.1	790	790	387
TP03.1	QC07.1	0-0.5	7/04/2014	<0.1	880	880	396
TP03.1	QC08.1	0-0.5	7/04/2014	<0.1	880	880	475
TP03.2	TP03.2	0.5-1	7/04/2014	<0.1	880	880	423
TP04.1	TP04.1	0-0.5	7/04/2014	<0.1	1050	1050	402
TP04.2	TP04.2	0.5-1	7/04/2014	<0.1	1020	1020	454
TP04.3	TP04.3	1-1.5	7/04/2014	0.2	880	880	387
TP04.4	TP04.4	1.5-2	7/04/2014	<0.1	960	960	385
TP04.5	TP04.5	2-2.5	7/04/2014	<0.1	370	370	326
TP05.1	TP05.1	0-0.5	7/04/2014	<0.1	1090	1090	478
TP05.2	TP05.2	0.5-1	7/04/2014	<0.1	1090	1090	500
TP05.3	TP05.3	1-1.5	7/04/2014	0.1	980	980	443
TP05.4	TP05.4	1.5-2	7/04/2014	0.1	820	820	515
TP05.5	TP05.5	2-2.5	7/04/2014	<0.1	400	400	400
TP06.1	TP06.1	0-0.5	7/04/2014	<0.1	960	960	458
TP06.2	TP06.2	0.5-1	7/04/2014	<0.1	1010	1010	443
TP06.3	TP06.3	1-1.5	7/04/2014	<0.1	1000	1000	479
TP06.4	TP06.4	1.5-2	7/04/2014	<0.1	890	890	405
TP07.1	TP07.1	0-0.5	7/04/2014	<0.1	1160	1160	494
TP07.2	TP07.2	0.5-1	7/04/2014	0.2	970	970	399
TP07.2	QC09.2	0.5-1	7/04/2014	<0.1	970	970	432
TP07.2	QC10.2	0.5-1	7/04/2014	<0.1	960	960	434
TP07.3	TP07.3	1-1.5	7/04/2014	<0.1	1150	1150	434
TP07.3	QC09.3	1-1.5	7/04/2014	<0.1	920	920	523
TP07.3	QC10.3	1-1.5	7/04/2014	<0.1	780	780	364
TP09.1	TP09.1	0-0.5	7/04/2014	<0.1	950	950	322
TP09.2	TP09.2	0.5-1	7/04/2014	0.2	730	730	352
TP09.2	QC02_070414	0.5-1	7/04/2014	<0.5	1100	1100	450
TP09.3	TP09.3	1-1.5	7/04/2014	<0.1	680	680	354
TP09.4	TP09.4	1.5-2	7/04/2014	<0.1	310	310	241
TP09.5	TP09.5	2-2.5	7/04/2014	<0.1	310	310	310
TP09.5	QC01_070414	2-2.5	7/04/2014	<0.1	230	230	241
TP10.1	TP10.1	0-0.5	7/04/2014	<0.1	1120	1120	433
TP10.2	TP10.2	0.5-1	7/04/2014	<0.1	1090	1090	439
TP10.3	TP10.3	1-1.5	7/04/2014	0.2	1220	1220	497
TP10.4	TP10.4	1.5-2	7/04/2014	<0.1	430	430	380
TP10.5	TP10.5	2-2.5	7/04/2014	<0.1	300	300	328
TP11.1	TP11.1	0-0.5	7/04/2014	<0.1	1160	1160	478
TP11.2	TP11.2	0.5-1	7/04/2014	<0.1	1120	1120	438
TP11.3	TP11.3	1-1.5	7/04/2014	<0.1	510	510	419
TP11.4	TP11.4	1.5-2	7/04/2014	<0.1	370	370	413
TP11.5	TP11.5	2-2.5	7/04/2014	<0.1	390	390	387
TP12.1	TP12.1	0-0.5	10/04/2014	<0.1	1030	1030	444
TP12.2	TP12.2	0.5-1	10/04/2014	<0.1	900	900	439
TP12.2	QC20_100414	0.5-1	10/04/2014	<0.5	280	280	390
TP12.3	TP12.3	1-1.5	10/04/2014	<0.1	340	340	369
TP12.4	TP12.4	1.5-2	10/04/2014	<0.1	350	350	459
TP12.5	TP12.5	2-2.5	10/04/2014	0.1	290	290	478
TP12.6	TP12.6	2.5-3	10/04/2014	0.1	290	290	281
TP12.7	TP12.7	3-3.5	10/04/2014	<0.1	180	180	256
TP12.8	TP12.8	3.5-4	10/04/2014	<0.1	210	210	255
TP14.1	TP14.1	0-0.5	10/04/2014	0.2	1010	1010	448
TP14.2	TP14.2	0.5-1	10/04/2014	<0.1	240	240	332
TP14.3	TP14.3	1-1.5	10/04/2014	<0.1	320	320	340
TP14.4	TP14.4	1.5-2	10/04/2014	<0.1	180	180	223
TP14.5	TP14.5	2-2.5	10/04/2014	0.4	230	230	246
TP14.6	TP14.6	2.5-3	10/04/2014	<0.1	220	220	313
TP14.7	TP14.7	3-3.5	10/04/2014	<0.1	250	250	232
TP14.8	TP14.8	3.5-4	10/04/2014	<0.1	260	260	207
TP14.9	TP14.9	4-4.5	10/04/2014	<0.1	290	290	287
TP16.1	TP16.1	0-0.5	9/04/2014	<0.1	1060	1060	440
TP16.2	TP16.2	0.5-1	9/04/2014	<0.1	660	660	284
TP16.3	TP16.3	1-1.5	9/04/2014	<0.1	660	660	352
TP16.4	TP16.4	1.5-2	9/04/2014	<0.1	310	310	326
TP16.4	QC17_090414	1.5-2	9/04/2014	0.8	400	400	472
TP16.5	TP16.5	2-2.5	9/04/2014	<0.1	260	260	305
TP16.6	TP16.6	2.5-3	9/04/2014	0.1	290	290	392
TP16.6	QC18_090414	2.5-3	9/04/2014	<0.5	310	310	400
TP16.7	TP16.7	3-3.5	9/04/2014	<0.1	280	280	335
TP16.8	TP16.8	3.5-4	9/04/2014	<0.1	270	270	344
TP16.8	QC19_090414	3.5-4	9/04/2014	0.1	200	200	275
TP17.1	TP17.1	0-0.5	7/04/2014	<0.1	1230	1230	463
TP17.2	TP17.2	0.5-1	7/04/2014	<0.1	990	990	378
TP17.3	TP17.3	1-1.5	7/04/2014	<0.1	550	550	389
TP17.3	QC04_070414	1-1.5	7/04/2014	<0.1	470	470	394
TP17.4	TP17.4	1.5-2	7/04/2014	<0.1	410	410	387
TP17.5	TP17.5	2-2.5	7/04/2014	<0.1	340	340	378
TP17.5	QC05_070414	2-2.5	7/04/2014	<0.5	270	270	420
TP18.1	TP18.1	0-0.5	10/04/2014	<0.1	1020	1020	448
TP18.2	TP18.2	0.5-1	10/04/2014	<0.1	1020	1020	455
TP18.3	TP18.3	1-1.5	10/04/2014	0.2	590	590	481
TP18.4	TP18.4	1.5-2	10/04/2014	<0.1	220	220	349
TP18.5	TP18.5	2-2.5	10/04/2014	0.1	370	370	351
TP18.6	TP18.6	2.5-3	10/04/2014	<0.1	280	280	338
TP18.7	TP18.7	3-3.5	10/04/2014	<0.1	230	230	281
TP18.8	TP18.8	3.5-4	10/04/2014	0.1	260	260	304
TP18.9	TP18.9	4-4.5	10/04/2014	<0.1	230	230	195
TP23.1	TP23.1	0-0.5	7/04/2014	<0.1	870	870	429
TP23.2	TP23.2	0.5-1	7/04/2014	<0.1	1020	1020	506
TP23.3	TP23.3	1-1.5	7/04/2014	0.1	1040	1040	440
TP23.4	TP23.4	1.5-2	7/04/2014	<0.1	910	910	419
TP25.1	TP25.1	0-0.5	7/04/2014	<0.1	1390	1390	614
TP25.2	TP25.2	0.5-1	7/04/2014	<0.1	450	450	214
TP25.3	TP25.3	1-1.5	7/04/2014	<0.1	690	690	403
TP25.3	QC14_080414	1-1.5	7/04/2014	<0.1	980	980	489
TP25.4	TP25.4	1.5-2	7/04/2014	<0.1	400	400	411
TP25.5	TP25.5	2-2.5	8/04/2014	<0.1	280	280	326
TP25.5	QC15_080414	2-2.5	8/04/2014	<0.5	330	320	420
TP33.1	TP33.1	0-0.5	7/04/2014	<0.1	1100	1100	615
TP33.2	TP33.2	0.5-1	7/04/2014	<0.1	290	290	316
TP33.3	TP33.3	1-1.5	7/04/2014	<0.1	280	280	394
TP33.4	TP33.4	1.5-2	7/04/2014	<0.1	320	320	702
TP33.5	TP33.5	2-2.5	7/04/2014	<0.1	340	340	227
TP38.1	TP38.1	0-0.5	7/04/2014	<0.1	790	790	351
TP38.2	TP38.2	0.5-1	7/04/2014	<0.1	1140	1140	398
TP38.3	TP38.3	1-1.5	7/04/2014	<0.1	950	950	444
TP38.3	QC11_080414	1-1.5	7/04/2014	<0.1	940	940	413
TP38.4	TP38.4	1.5-2	7/04/2014	<0.1	740	740	336
TP38.4	QC12_080414	1.5-2	8/04/2014	<0.5	900	900	400
Minimum	-	-	-	<0.1	180	180	195
Maximum	-	-	-	0.8	1,390	1,390	702
Mean	-	-	-	<0.1	662	662	394
SD	-	-	-	0.0	343	343	88
95%UCL	-	-	-	<0.1	797	797	408

Legend:
NG = No Guideline Value
Bold = Detection above Practical Quantitation Limit

TABLE 5.
East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation
Laboratory Analytical Results - Radionuclides

Location ID	Sample ID	Interval	Date	Gross Alpha	Gross Beta	Total Activity
			Unit	Bq/kg	Bq/kg	Bq/kg
			Practical Quantitation Limit	500/1,000	500	500
			SQG LOW (NAGD 2009)	NG	NG	35,000
TP01.1	TP01.1	0-0.5	7/04/2014	**1250**	**530**	**1780**
TP01.2	TP01.2	0.5-1	7/04/2014	**550**	<500	**550**
TP01.2	QC03_080414	0.5-1	7/04/2014	**780**	**510**	**1290**
TP01.3	TP01.3	1-1.5	7/04/2014	**960**	<500	**960**
TP01.4	TP01.4	1.5-2	7/04/2014	**610**	<500	**610**
TP01.5	TP01.5	2-2.5	7/04/2014	**960**	<500	**960**
TP02.1	TP02.1	0-0.5	7/04/2014	**780**	**530**	**1310**
TP02.2	TP02.2	0.5-1	7/04/2014	**780**	<500	**780**
TP02.3	TP02.3	1-1.5	7/04/2014	**550**	**500**	**1050**
TP02.4	TP02.4	1.5-2	7/04/2014	<500	**530**	**530**
TP03.1	TP03.1	0-0.5	7/04/2014	<500	<500	<500
TP03.1	QC07.1	0-0.5	7/04/2014	**820**	**510**	**1330**
TP03.1	QC08.1	0-0.5	7/04/2014	<500	<500	<500
TP03.2	TP03.2	0.5-1	7/04/2014	**590**	<500	**590**
TP04.1	TP04.1	0-0.5	7/04/2014	<500	**600**	**600**
TP04.2	TP04.2	0.5-1	7/04/2014	<500	<500	<500
TP04.3	TP04.3	1-1.5	7/04/2014	**670**	**600**	**1270**
TP04.4	TP04.4	1.5-2	7/04/2014	**1370**	<500	**1370**
TP04.5	TP04.5	2-2.5	7/04/2014	<500	<500	<500
TP05.1	TP05.1	0-0.5	7/04/2014	**550**	**790**	**1340**
TP05.2	TP05.2	0.5-1	7/04/2014	**720**	<500	**720**
TP05.3	TP05.3	1-1.5	7/04/2014	**1020**	**530**	**1550**
TP05.4	TP05.4	1.5-2	7/04/2014	**1190**	**560**	**1750**
TP05.5	TP05.5	2-2.5	7/04/2014	**610**	<500	**610**
TP06.1	TP06.1	0-0.5	7/04/2014	<500	**570**	**570**
TP06.2	TP06.2	0.5-1	7/04/2014	<500	<500	<500
TP06.3	TP06.3	1-1.5	7/04/2014	**640**	**640**	**1280**
TP06.4	TP06.4	1.5-2	7/04/2014	<500	**520**	**520**
TP07.1	TP07.1	0-0.5	7/04/2014	**920**	**670**	**1590**
TP07.2	TP07.2	0.5-1	7/04/2014	<500	**540**	**540**
TP07.2	QC09.2	0.5-1	7/04/2014	**780**	<500	**780**
TP07.2	QC10.2	0.5-1	7/04/2014	<500	**580**	**580**
TP07.3	TP07.3	1-1.5	7/04/2014	**730**	<500	**730**
TP07.3	QC09.3	1-1.5	7/04/2014	**680**	**520**	**1200**
TP07.3	QC10.3	1-1.5	7/04/2014	<500	**510**	**510**
TP09.1	TP09.1	0-0.5	7/04/2014	**1020**	<500	**1020**
TP09.2	TP09.2	0.5-1	7/04/2014	**960**	**570**	**1530**
TP09.2	QC02_070414	0.5-1	7/04/2014	<30	**131**	**131**
TP09.3	TP09.3	1-1.5	7/04/2014	**840**	**500**	**1340**
TP09.4	TP09.4	1.5-2	7/04/2014	**1140**	<500	**1140**
TP09.5	TP09.5	2-2.5	7/04/2014	**550**	<500	**550**
TP09.5	QC01_070414	2-2.5	7/04/2014	**640**	<500	**640**
TP10.1	TP10.1	0-0.5	7/04/2014	**1140**	<500	**1140**
TP10.2	TP10.2	0.5-1	7/04/2014	**780**	**610**	**1390**
TP10.3	TP10.3	1-1.5	7/04/2014	**1190**	**510**	**1700**
TP10.4	TP10.4	1.5-2	7/04/2014	**960**	<500	**960**
TP10.5	TP10.5	2-2.5	7/04/2014	**1080**	<500	**1080**
TP11.1	TP11.1	0-0.5	7/04/2014	**1140**	<500	**1140**
TP11.2	TP11.2	0.5-1	7/04/2014	**1080**	<500	**1080**
TP11.3	TP11.3	1-1.5	7/04/2014	**610**	<500	**610**
TP11.4	TP11.4	1.5-2	7/04/2014	**1480**	<500	**1480**
TP11.5	TP11.5	2-2.5	7/04/2014	**1190**	<500	**1190**
TP12.1	TP12.1	0-0.5	10/04/2014	<500	**640**	**640**
TP12.2	TP12.2	0.5-1	10/04/2014	**840**	<500	**840**
TP12.2	QC20_100414	0.5-1	10/04/2014	<30	**393**	**393**
TP12.3	TP12.3	1-1.5	10/04/2014	**1020**	<500	**1020**
TP12.4	TP12.4	1.5-2	10/04/2014	<500	<500	<500
TP12.5	TP12.5	2-2.5	10/04/2014	**1660**	**530**	**2190**
TP12.6	TP12.6	2.5-3	10/04/2014	**840**	**600**	**1440**
TP12.7	TP12.7	3-3.5	10/04/2014	**1080**	<500	**1080**
TP12.8	TP12.8	3.5-4	10/04/2014	**960**	<500	**960**
TP14.1	TP14.1	0-0.5	10/04/2014	**1250**	**590**	**1840**
TP14.2	TP14.2	0.5-1	10/04/2014	<500	<500	<500
TP14.3	TP14.3	1-1.5	10/04/2014	**670**	<500	**670**
TP14.4	TP14.4	1.5-2	10/04/2014	**960**	<500	**960**
TP14.5	TP14.5	2-2.5	10/04/2014	**720**	**550**	**1270**
TP14.6	TP14.6	2.5-3	10/04/2014	**780**	<500	**780**
TP14.7	TP14.7	3-3.5	10/04/2014	**1080**	<500	**1080**
TP14.8	TP14.8	3.5-4	10/04/2014	**1190**	**630**	**1820**
TP14.9	TP14.9	4-4.5	10/04/2014	**720**	**550**	**1270**
TP16.1	TP16.1	0-0.5	9/04/2014	<500	**560**	**560**
TP16.2	TP16.2	0.5-1	9/04/2014	**550**	**670**	**1220**
TP16.3	TP16.3	1-1.5	9/04/2014	**840**	<500	**840**
TP16.4	TP16.4	1.5-2	9/04/2014	<500	<500	<500
TP16.4	QC17_090414	1.5-2	9/04/2014	**610**	<500	**610**
TP16.5	TP16.5	2-2.5	9/04/2014	<500	<500	<500
TP16.6	TP16.6	2.5-3	9/04/2014	**780**	<500	**780**
TP16.6	QC18_090414	2.5-3	9/04/2014	<30	**332**	**332**
TP16.7	TP16.7	3-3.5	9/04/2014	**720**	<500	**720**
TP16.8	TP16.8	3.5-4	9/04/2014	**550**	<500	**550**
TP16.8	QC19_090414	3.5-4	9/04/2014	**780**	<500	**780**
TP17.1	TP17.1	0-0.5	7/04/2014	**900**	**630**	**1530**
TP17.2	TP17.2	0.5-1	7/04/2014	**720**	**560**	**1280**
TP17.3	TP17.3	1-1.5	7/04/2014	**1540**	**590**	**2130**
TP17.3	QC04_070414	1-1.5	7/04/2014	<500	<500	<500
TP17.4	TP17.4	1.5-2	7/04/2014	**720**	<500	**720**
TP17.5	TP17.5	2-2.5	7/04/2014	**610**	<500	**610**
TP17.5	QC05_070414	2-2.5	7/04/2014	**32**	**119**	**151**
TP18.1	TP18.1	0-0.5	10/04/2014	<500	**580**	**580**
TP18.2	TP18.2	0.5-1	10/04/2014	**720**	<500	**720**
TP18.3	TP18.3	1-1.5	10/04/2014	**780**	<500	**780**
TP18.4	TP18.4	1.5-2	10/04/2014	**670**	<500	**670**
TP18.5	TP18.5	2-2.5	10/04/2014	**670**	<500	**670**
TP18.6	TP18.6	2.5-3	10/04/2014	**960**	<500	**960**
TP18.7	TP18.7	3-3.5	10/04/2014	**780**	<500	**780**
TP18.8	TP18.8	3.5-4	10/04/2014	**1370**	<500	**1370**
TP18.9	TP18.9	4-4.5	10/04/2014	**610**	**610**	**1220**
TP23.1	TP23.1	0-0.5	7/04/2014	**540**	**640**	**1180**
TP23.2	TP23.2	0.5-1	7/04/2014	**730**	<500	**730**
TP23.3	TP23.3	1-1.5	7/04/2014	<500	<500	<500
TP23.4	TP23.4	1.5-2	7/04/2014	**640**	**550**	**1190**
TP25.1	TP25.1	0-0.5	7/04/2014	**540**	**570**	**1110**
TP25.2	TP25.2	0.5-1	7/04/2014	<500	**620**	**620**
TP25.3	TP25.3	1-1.5	7/04/2014	<500	<500	<500
TP25.3	QC14_080414	1-1.5	7/04/2014	<500	<500	<500
TP25.4	TP25.4	1.5-2	7/04/2014	<500	<500	<500
TP25.5	TP25.5	2-2.5	7/04/2014	<500	<500	<500
TP25.5	QC15_080414	2-2.5	8/04/2014	<30	**214**	**214**
TP33.1	TP33.1	0-0.5	7/04/2014	<500	**590**	**590**
TP33.2	TP33.2	0.5-1	7/04/2014	**920**	**680**	**1600**
TP33.3	TP33.3	1-1.5	7/04/2014	<500	<500	<500
TP33.4	TP33.4	1.5-2	7/04/2014	**780**	**610**	**1390**
TP33.5	TP33.5	2-2.5	7/04/2014	**1200**	**590**	**1790**
TP38.1	TP38.1	0-0.5	7/04/2014	**640**	**700**	**1340**
TP38.2	TP38.2	0.5-1	7/04/2014	<500	**540**	**540**
TP38.3	TP38.3	1-1.5	7/04/2014	**730**	**530**	**1260**
TP38.3	QC11_080414	1-1.5	7/04/2014	**1100**	**560**	**1660**
TP38.4	TP38.4	1.5-2	7/04/2014	**820**	**700**	**1520**
TP38.4	QC12_080414	1.5-2	8/04/2014	**52**	**668**	**720**
Minimum	-	-	-	<30	**119**	**131**
Maximum	-	-	-	**1660**	**790**	**2190**
Mean	-	-	-	**672**	**392**	**905**
SD	-	-	-	**370**	**173**	**481**
95%UCL	-	-	-	**788**	**747**	**970**

Legend:
NG = No Guideline Value
Bold = Detection above Practical Quantitation Limit

TABLE 6.

East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation

Field Testing and Laboratory Analytical Results - Acid Sulfate Soils

Location ID	Sample ID	Interval	Sample date	Moisture Content (%)	pH_F	pH_{FOX}	ΔpH	Reaction	pH KCl	TAA (mole H^+/t)	TAA (%S)	S_{Cr} (%S)	Net Acidity (%S)	ANC (%S)	Liming Rate (kg $CaCO_3$/t)
			Practical Quantitation Limit	0.1	0.1	0.1	0.1	1	0.1	2	0.02	0.005	0.02	-	1
			WA DEC (2013) ACTION CRITERIA	NG	≤4	≤4	>1	3	NG	NG	0.03	0.03	0.03	NG	NG
TP01.1	TP01.1	0-0.5	7/04/2014	62.6	8.7	7.0	1.7	2	8.9	<2	<0.02	0.212	<0.02	8.8	<1
TP01.2	TP01.2	0.5-1	7/04/2014	60.2	8.7	7.4	1.3	4	9.0	<2	<0.02	0.284	<0.02	8.8	<1
TP01.2	QC03_080414	0.5-1	8/04/2014	59.8	8.3	7.0	1.3	3	9.0	<2	<0.02	0.282	<0.02	8.3	<1
TP01.3	TP01.3	1-1.5	7/04/2014	57.3	8.9	7.6	1.3	4	9.0	<2	<0.02	0.270	<0.02	7.9	<1
TP01.4	TP01.4	1.5-2	7/04/2014	42.6	8.8	6.8	2.0	2	9.3	<2	<0.02	0.097	<0.02	15.1	<1
TP01.5	TP01.5	2-2.5	7/04/2014	39.9	8.8	6.7	2.1	2	9.2	<2	<0.02	0.239	<0.02	11.4	<1
TP02.1	TP02.1	0-0.5	7/04/2014	62.6	8.4	7.1	1.3	4	8.9	<2	<0.02	0.217	<0.02	7.5	<1
TP02.2	TP02.2	0.5-1	7/04/2014	61.0	8.4	6.9	1.5	2	8.9	<2	<0.02	0.262	<0.02	9.7	<1
TP02.3	TP02.3	1-1.5	7/04/2014	60.3	8.4	7.5	0.9	4	8.9	<2	<0.02	0.294	<0.02	9.2	<1
TP02.4	TP02.4	1.5-2	7/04/2014	54.0	8.7	7.0	1.7	3	9.0	<2	<0.02	0.252	<0.02	9.3	<1
TP03.1	TP03.1	0-0.5	7/04/2014	59.8	8.7	7.5	1.2	4	9.0	<2	<0.02	0.162	<0.02	10.0	<1
TP03.1	QC07.1	0-0.5	7/04/2014	58.7	8.5	7.4	1.1	4	9.0	<2	<0.02	0.163	<0.02	8.4	<1
TP03.1	QC08.1	0-0.5	7/04/2014	59.0	8.5	6.8	1.7	2	9.0	<2	<0.02	0.149	<0.02	8.4	<1
TP03.2	TP03.2	0.5-1	7/04/2014	54.2	8.6	6.8	1.8	2	9.1	<2	<0.02	0.188	<0.02	11.3	<1
TP04.1	TP04.1	0-0.5	7/04/2014	63.6	8.5	7.6	0.9	4	9.2	<2	<0.02	0.194	<0.02	6.8	<1
TP04.2	TP04.2	0.5-1	7/04/2014	61.0	8.6	7.3	1.3	4	8.9	<2	<0.02	0.225	<0.02	9.5	<1
TP04.3	TP04.3	1-1.5	7/04/2014	58.4	8.9	7.0	1.9	2	8.9	<2	<0.02	0.258	<0.02	9.1	<1
TP04.4	TP04.4	1.5-2	7/04/2014	53.7	8.8	7.0	1.8	2	9.0	<2	<0.02	0.278	<0.02	9.1	<1
TP04.5	TP04.5	2-2.5	7/04/2014	37.9	8.8	6.7	2.1	2	9.3	<2	<0.02	0.090	<0.02	15.6	<1
TP05.1	TP05.1	0-0.5	7/04/2014	63.6	8.3	7.3	1.0	4	8.9	<2	<0.02	0.176	<0.02	7.5	<1
TP05.2	TP05.2	0.5-1	7/04/2014	60.6	8.6	7.1	1.5	3	8.9	<2	<0.02	0.086	<0.02	9.2	<1
TP05.3	TP05.3	1-1.5	7/04/2014	59.7	8.4	7.6	0.8	4	8.9	<2	<0.02	0.238	<0.02	9.1	<1
TP05.4	TP05.4	1.5-2	7/04/2014	57.5	8.8	7.6	1.2	4	9.0	<2	<0.02	0.256	<0.02	9.1	<1
TP05.5	TP05.5	2-2.5	7/04/2014	38.2	8.9	6.8	2.1	2	9.3	<2	<0.02	0.108	<0.02	15.3	<1
TP06.1	TP06.1	0-0.5	7/04/2014	64.9	8.6	7.1	1.5	4	9.0	<2	<0.02	0.175	<0.02	7.9	<1
TP06.2	TP06.2	0.5-1	7/04/2014	60.5	8.7	7.0	1.7	4	9.0	<2	<0.02	0.212	<0.02	10.2	<1
TP06.3	TP06.3	1-1.5	7/04/2014	57.7	8.7	7.5	1.2	4	9.0	<2	<0.02	0.254	<0.02	9.7	<1
TP06.4	TP06.4	1.5-2	7/04/2014	56.3	8.7	6.9	1.8	3	9.0	<2	<0.02	0.249	<0.02	9.7	<1
TP07.1	TP07.1	0-0.5	7/04/2014	64.9	8.6	7.6	1.0	4	8.9	<2	<0.02	0.171	<0.02	6.8	<1
TP07.2	TP07.2	0.5-1	7/04/2014	62.8	8.8	7.2	1.6	3	9.0	<2	<0.02	0.182	<0.02	9.1	<1
TP07.2	QC09.2	0.5-1	7/04/2014	61.8	8.5	7.0	1.5	3	8.9	<2	<0.02	0.221	<0.02	8.8	<1
TP07.2	QC10.2	0.5-1	7/04/2014	61.9	8.5	7.3	1.2	4	8.9	<2	<0.02	0.241	<0.02	8.8	<1
TP07.3	TP07.3	1-1.5	7/04/2014	60.1	8.4	7.4	1.0	4	9.0	<2	<0.02	0.252	<0.02	8.7	<1
TP07.3	QC09.3	1-1.5	7/04/2014	60.2	8.5	7.4	1.1	4	9.0	<2	<0.02	0.257	<0.02	8.8	<1
TP07.3	QC10.3	1-1.5	7/04/2014	58.9	8.6	7.4	1.2	4	9.0	<2	<0.02	0.272	<0.02	8.7	<1
TP09.1	TP09.1	0-0.5	7/04/2014	60.0	8.4	6.9	1.5	3	8.9	<2	<0.02	0.210	<0.02	8.9	<1
TP09.2	TP09.2	0.5-1	7/04/2014	59.7	8.9	7.2	1.7	3	9.0	<2	<0.02	0.268	<0.02	9.0	<1
TP09.2	QC02_070414	0.5-1	7/04/2014	60.0	8.5	6.9	1.6	1	8.8	<5	<0.01	0.310	<0.01	8.3	<0.75
TP09.3	TP09.3	1-1.5	7/04/2014	58.1	8.9	7.2	1.7	3	9.0	<2	<0.02	0.313	<0.02	7.9	<1
TP09.4	TP09.4	1.5-2	7/04/2014	42.8	8.6	6.8	1.8	2	9.3	<2	<0.02	0.104	<0.02	15.6	<1
TP09.5	TP09.5	2-2.5	7/04/2014	39.5	8.8	6.7	2.1	2	9.2	<2	<0.02	0.156	<0.02	15.6	<1
TP09.5	QC01_070414	2-2.5	7/04/2014	39.4	8.8	6.7	2.1	2	9.3	<2	<0.02	0.204	<0.02	15.8	<1
TP10.1	TP10.1	0-0.5	7/04/2014	63.1	8.6	6.8	1.8	2	8.9	<2	<0.02	0.252	<0.02	8.7	<1
TP10.2	TP10.2	0.5-1	7/04/2014	61.0	8.6	6.8	1.8	2	8.9	<2	<0.02	0.275	<0.02	8.5	<1
TP10.3	TP10.3	1-1.5	7/04/2014	59.2	8.3	7.4	0.9	4	9.1	<2	<0.02	0.218	<0.02	10.1	<1
TP10.4	TP10.4	1.5-2	7/04/2014	41.1	8.5	6.8	1.7	3	9.3	<2	<0.02	0.098	<0.02	15.6	<1
TP10.5	TP10.5	2-2.5	7/04/2014	39.4	8.7	6.8	1.9	3	9.2	<2	<0.02	0.176	<0.02	15.3	<1
TP11.1	TP11.1	0-0.5	7/04/2014	61.8	8.6	6.7	1.9	2	8.9	<2	<0.02	0.227	<0.02	7.9	<1
TP11.2	TP11.2	0.5-1	7/04/2014	58.8	8.6	7.5	1.1	3	8.9	<2	<0.02	0.295	<0.02	7.9	<1
TP11.3	TP11.3	1-1.5	7/04/2014	39.3	8.8	6.8	2.0	2	9.1	<2	<0.02	0.243	<0.02	12.0	<1
TP11.4	TP11.4	1.5-2	7/04/2014	36.4	8.9	6.8	2.1	2	9.3	<2	<0.02	0.188	<0.02	15.6	<1
TP11.5	TP11.5	2-2.5	7/04/2014	40.3	8.9	6.8	2.1	2	9.1	<2	<0.02	0.254	<0.02	12.4	<1
TP12.1	TP12.1	0-0.5	10/04/2014	60.0	8.4	6.8	1.6	3	9.0	<2	<0.02	0.247	<0.02	8.6	<1
TP12.2	TP12.2	0.5-1	10/04/2014	58.9	8.1	6.7	1.4	3	9.0	<2	<0.02	0.304	<0.02	8.2	<1
TP12.2	QC20_100414	0.5-1	10/04/2014	40.0	9	6.6	2.4	1	9.0	<5	<0.01	0.300	<0.01	13.0	<0.75
TP12.3	TP12.3	1-1.5	10/04/2014	38.1	8.5	6.8	1.7	3	9.3	<2	<0.02	0.068	<0.02	15.4	<1
TP12.4	TP12.4	1.5-2	10/04/2014	39.2	8.6	6.8	1.8	3	9.3	<2	<0.02	0.171	<0.02	15.5	<1
TP12.5	TP12.5	2-2.5	10/04/2014	50.7	8.2	7.5	0.7	4	8.5	<2	<0.02	1.080	<0.02	2.5	<1
TP12.6	TP12.6	2.5-3	10/04/2014	47.4	8.8	6.8	2.0	3	8.8	<2	<0.02	0.670	<0.02	4.5	<1
TP12.7	TP12.7	3-3.5	10/04/2014	38.4	8.5	6.7	1.8	3	9.0	<2	<0.02	0.398	<0.02	9.8	<1
TP12.8	TP12.8	3.5-4	10/04/2014	42.1	8.5	6.7	1.8	3	9.2	<2	<0.02	0.315	<0.02	11.9	<1
TP14.1	TP14.1	0-0.5	10/04/2014	59.5	8.1	6.7	1.4	3	9.0	<2	<0.02	0.250	<0.02	7.8	<1
TP14.2	TP14.2	0.5-1	10/04/2014	40.6	8.6	6.7	1.9	3	9.3	<2	<0.02	0.198	<0.02	15.2	<1
TP14.2	QC21_100414	0.5-1	10/04/2014	-	8.6	6.8	1.8	3	9.3	<2	<0.02	0.190	<0.02	15.6	<1
TP14.3	TP14.3	1-1.5	10/04/2014	40.1	8.2	6.7	1.5	3	9.3	<2	<0.02	0.236	<0.02	15.2	<1
TP14.4	TP14.4	1.5-2	10/04/2014	38.0	8.6	6.6	2.0	3	9.2	<2	<0.02	0.289	<0.02	11.8	<1
TP14.5	TP14.5	2-2.5	10/04/2014	40.0	8.4	6.8	1.6	3	9.2	<2	<0.02	0.300	<0.02	11.8	<1
TP14.6	TP14.6	2.5-3	10/04/2014	40.1	8.5	6.7	1.8	3	9.1	<2	<0.02	0.280	<0.02	11.8	<1
TP14.7	TP14.7	3-3.5	10/04/2014	44.0	8.6	6.5	2.1	3	9.0	<2	<0.02	0.412	<0.02	9.8	<1
TP14.8	TP14.8	3.5-4	10/04/2014	42.9	8.4	7.0	1.4	4	8.8	<2	<0.02	0.564	<0.02	2.7	<1
TP14.9	TP14.9	4-4.5	10/04/2014	42.6	8.5	7.3	1.2	4	8.9	<2	<0.02	0.598	<0.02	3.1	<1
TP16.1	TP16.1	0-0.5	9/04/2014	62.4	8.2	6.6	1.6	3	9.0	<2	<0.02	0.257	<0.02	7.8	<1
TP16.2	TP16.2	0.5-1	9/04/2014	50.3	8.6	7.0	1.6	3	9.1	<2	<0.02	0.226	<0.02	9.9	<1
TP16.3	TP16.3	1-1.5	9/04/2014	47.7	8.6	7.0	1.6	3	9.2	<2	<0.02	0.190	<0.02	13.6	<1
TP16.4	TP16.4	1.5-2	9/04/2014	39.8	8.8	6.8	2.0	3	9.4	<2	<0.02	0.165	<0.02	15.7	<1
TP16.4	QC17_090414	1.5-2	9/04/2014	40.1	8.6	6.8	1.8	3	9.4	<2	<0.02	0.146	<0.02	15.8	<1
TP16.5	TP16.5	2-2.5	9/04/2014	40.7	8.8	6.8	2.0	3	9.3	<2	<0.02	0.206	<0.02	15.5	<1
TP16.6	TP16.6	2.5-3	9/04/2014	39.7	8.8	6.5	2.3	3	9.3	<2	<0.02	0.271	<0.02	14.2	<1
TP16.6	QC18_090414	2.5-3	9/04/2014	43.0	8.7	6.8	1.9	1	8.9	<5	<0.01	0.280	<0.01	14.0	<0.75
TP16.7	TP16.7	3-3.5	9/04/2014	39.5	8.7	6.7	2.0	3	9.3	<2	<0.02	0.282	<0.02	12.8	<1
TP16.8	TP16.8	3.5-4	9/04/2014	36.9	8.7	6.6	2.1	3	9.2	<2	<0.02	0.274	<0.02	12.0	<1
TP16.8	QC19_090414	3.5-4	9/04/2014	38.5	8.7	6.6	2.1	3	9.2	<2	<0.02	0.305	<0.02	11.6	<1
TP17.1	TP17.1	0-0.5	7/04/2014	61.8	8.5	6.8	1.7	3	8.9	<2	<0.02	0.242	<0.02	8.6	<1
TP17.2	TP17.2	0.5-1	7/04/2014	56.6	8.4	6.8	1.6	3	9.0	<2	<0.02	0.325	<0.02	8.3	<1
TP17.3	TP17.3	1-1.5	7/04/2014	37.8	8.5	7.5	1.0	4	9.1	<2	<0.02	0.306	<0.02	10.1	<1
TP17.3	QC04_070414	1-1.5	7/04/2014	45.9	8.9	6.8	2.1	2	9.2	<2	<0.02	0.205	<0.02	8.4	<1
TP17.4	TP17.4	1.5-2	7/04/2014	35.7	8.7	6.8	1.9	3	9.3	<2	<0.02	0.135	<0.02	15.9	<1
TP17.4	QC06_070414	1.5-2	7/04/2014	-	9	6.8	2.2	3	9.4	<2	<0.02	0.105	<0.02	16.0	<1
TP17.5	TP17.5	2-2.5	7/04/2014	38.3	9	6.7	2.3	2	9.2	<2	<0.02	0.181	<0.02	15.1	<1
TP17.5	QC05_070414	2-2.5	7/04/2014	40.0	9	6.9	2.1	1	9.0	<5	<0.01	0.220	<0.01	16.0	<0.75
TP18.1	TP18.1	0-0.5	10/04/2014	61.6	8.3	6.6	1.7	3	9.0	<2	<0.02	0.211	<0.02	8.7	<1
TP18.2	TP18.2	0.5-1	10/04/2014	58.0	8.2	6.6	1.6	3	9.0	<2	<0.02	0.292	<0.02	8.4	<1
TP18.3	TP18.3	1-1.5	10/04/2014	47.5	8.6	6.9	1.7	3	9.4	<2	<0.02	0.064	<0.02	15.3	<1
TP18.4	TP18.4	1.5-2	10/04/2014	38.0	8.6	6.8	1.8	3	9.4	<2	<0.02	0.184	<0.02	15.9	<1
TP18.5	TP18.5	2-2.5	10/04/2014	39.4	8.8	6.8	2.0	3	9.2	<2	<0.02	0.275	<0.02	15.2	<1
TP18.6	TP18.6	2.5-3	10/04/2014	39.0	8.8	6.8	2.0	3	9.2	<2	<0.02	0.281	<0.02	12.0	<1
TP18.7	TP18.7	3-3.5	10/04/2014	40.9	8.8	6.6	2.2	3	9.2	<2	<0.02	0.292	<0.02	12.0	<1
TP18.8	TP18.8	3.5-4	10/04/2014	40.3	8.6	6.7	1.9	3	9.2	<2	<0.02	0.328	<0.02	11.2	<1
TP18.9	TP18.9	4-4.5	10/04/2014	45.4	8.7	7.0	1.7	4	8.9	<2	<0.02	0.685	<0.02	5.3	<1
TP23.1	TP23.1	0-0.5	7/04/2014	62.9	8.6	7.5	1.1	4	8.9	<2	<0.02	0.217	<0.02	7.5	<1
TP23.2	TP23.2	0.5-1	7/04/2014	60.7	8.4	7.0	1.4	3	9.0	<2	<0.02	0.232	<0.02	9.2	<1
TP23.2	QC16_080414	0.5-1	7/04/2014	-	8.8	7.3	1.5	4	9.0	<2	<0.02	0.230	<0.02	9.2	<1
TP23.3	TP23.3	1-1.5	7/04/2014	58.7	8.5	7.6	0.9	4	9.0	<2	<0.02	0.272	<0.02	8.6	<1
TP23.4	TP23.4	1.5-2	7/04/2014	56.3	8.7	6.8	1.9	2	9.0	<2	<0.02	0.300	<0.02	8.3	<1
TP25.1	TP25.1	0-0.5	7/04/2014	73.9	8.4	6.8	1.6	2	8.9	<2	<0.02	0.177	<0.02	7.1	<1
TP25.2	TP25.2	0.5-1	7/04/2014	31.0	8.4	6.8	1.6	3	9.0	<2	<0.02	0.231	<0.02	8.7	<1
TP25.3*	TP25.3	1-1.5	7/04/2014	59.2	8.6	6.8	1.8	3	9.0	<2	<0.02	0.307	<0.02	8.7	<1
TP25.3	QC14_080414	1-1.5	7/04/2014	58.0	-	-	-	-	-	-	-	-	-	-	-
TP25.4	TP25.4	1.5-2	7/04/2014	44.3	8.7	6.8	1.9	2	9.2	<2	<0.02	0.128	<0.02	13.7	<1
TP25.5	TP25.5	2-2.5	8/04/2014	40.1	8.7	6.7	2.0	2	9.2	<2	<0.02	0.188	<0.02	15.1	<1
TP25.5	QC15_080414	2-2.5	8/04/2014	39.0	9	6.9	2.1	1	8.9	<5	<0.01	0.200	<0.01	17.0	<0.75
TP33.1	TP33.1	0-0.5	7/04/2014	72.4	8.7	6.7	2.0	2	9.0	<2	<0.02	0.268	<0.02	8.8	<1
TP33.1	QC13_080414	0-0.5	7/04/2014	-	8.8	6.7	2.1	2	9.0	<2	<0.02	0.284	<0.02	8.5	<1
TP33.2	TP33.2	0.5-1	7/04/2014	42.0	8.6	6.7	1.9	2	9.1	<2	<0.02	0.219	<0.02	8.4	<1
TP33.3	TP33.3	1-1.5	7/04/2014	47.3	8.6	6.7	1.9	2	9.0	<2	<0.02	0.404	<0.02	7.5	<1
TP33.4	TP33.4	1.5-2	7/04/2014	55.4	8.6	7.8	0.8	4	8.9	<2	<0.02	0.670	<0.02	3.5	<1
TP33.5	TP33.5	2-2.5	7/04/2014	38.0	8.7	4.9	3.8	4	8.8	<2	<0.02	0.846	<0.02	2.8	<1
TP38.1	TP38.1	0-0.5	7/04/2014	59.3	8.5	6.9	1.6	2	8.9	<2	<0.02	0.190	<0.02	5.9	<1
TP38.2	TP38.2	0.5-1	7/04/2014	63.5	8.7	6.8	1.9	2	8.9	<2	<0.02	0.300	<0.02	7.5	<1
TP38.3	TP38.3	1-1.5	7/04/2014	59.8	8.8	6.9	1.9	3	9.0	<2	<0.02	0.350	<0.02	7.5	<1
TP38.3	QC11_080414	1-1.5	7/04/2014	60.6	8.7	6.8	1.9	3	8.9	<2	<0.02	0.339	<0.02	7.5	<1
TP38.4	TP38.4	1.5-2	7/04/2014	51.8	8.8	6.8	2.0	2	9.0	<2	<0.02	0.299	<0.02	5.4	<1
TP38.4	QC12_080414	1.5-2	8/04/2014	55.0	8.9	6.8	2.1	1	9.0	<5	<0.01	0.200	<0.01	3.1	<0.75
Minimum	-	-	-	31.0	8.1	4.9	0.7	1	8.5	<2	<0.01	0.064	<0.01	2.5	<0.75
Maximum	-	-	-	73.9	9.0	7.8	3.8	4	9.4	<5	<0.02	1.080	<0.02	17.0	<01
Mean	-	-	-	51.0	8.6	6.9	1.7	3	9.1	<2	<0.01	0.262	<0.01	10.3	<1
SD	-	-	-	10.3	0.2	0.4	0.4	0.8	0.2	-	-	0.140	-	3.5	-
95%UCL	-	-	-	-	8.6	7.0	1.8	3	9.1	<2	<0.02	0.285	<0.02	10.8	<1

Legend:
Reaction Rate - 1 = Slight, 2 = Moderate, 3 = Strong, 4 = Extreme
NG = No Guideline Value
Bold = Detection above Practical Quantitation Limit
*Duplicate sample QC14_080414 (duplicate of TP25.3) analytical results for ASS have been adopted as primary results for sample TP25.3.

TABLE 7.
East Arm Wharf Expansion Project - Tug Pen Sediment Geochemical Investigation
Laboratory Analytical Results - Particle Size Distribution

Location ID	Sample ID	Interval	Sample date	Percent Composition (%)					Laboratory Description
				Clay	Silt	Sand	Gravel	Cobbles	
				<2 µm	2-60 µm	0.06-2.00 mm	>2 mm	>6 cm	
TP01.1	TP01.1	0-0.5	7/04/2014	**57**	**34**	**9**	<1	<1	Silty clay
TP01.2	TP01.2	0.5-1	7/04/2014	**49**	**43**	**8**	<1	<1	Silty clay
TP01.2	QC03_080414	0.5-1	8/04/2014	**54**	**38**	**8**	<1	<1	Silty clay
TP01.3	TP01.3	1-1.5	7/04/2014	**55**	**34**	**11**	<1	<1	Silty clay and sand
TP01.4	TP01.4	1.5-2	7/04/2014	**31**	**20**	**49**	<1	<1	Silty clay and sand
TP01.5	TP01.5	2-2.5	7/04/2014	**31**	**14**	**55**	<1	<1	Sand and silty clay
TP02.1	TP02.1	0-0.5	7/04/2014	**39**	**55**	**6**	<1	<1	Silty clay
TP02.2	TP02.2	0.5-1	7/04/2014	**43**	**47**	**10**	<1	<1	Silty clay
TP02.3	TP02.3	1-1.5	7/04/2014	**43**	**50**	**7**	<1	<1	Silty clay
TP02.4	TP02.4	1.5-2	7/04/2014	**40**	**52**	**8**	<1	<1	Silty clay
TP03.1	TP03.1	0-0.5	7/04/2014	**41**	**46**	**13**	<1	<1	Silty clay and sand
TP03.1	QC07.1	0-0.5	7/04/2014	**48**	**37**	**15**	<1	<1	Silty clay and sand
TP03.1	QC08.1	0-0.5	7/04/2014	**41**	**42**	**17**	<1	<1	Silty clay and sand
TP03.2	TP03.2	0.5-1	7/04/2014	**39**	**43**	**18**	<1	<1	Silty clay and sand
TP04.1	TP04.1	0-0.5	7/04/2014	**53**	**37**	**10**	<1	<1	Silty clay
TP04.2	TP04.2	0.5-1	7/04/2014	**54**	**37**	**9**	<1	<1	Silty clay
TP04.3	TP04.3	1-1.5	7/04/2014	**52**	**40**	**8**	<1	<1	Silty clay
TP04.4	TP04.4	1.5-2	7/04/2014	**54**	**36**	**10**	<1	<1	Silty clay
TP04.5	TP04.5	2-2.5	7/04/2014	**28**	**12**	**60**	<1	<1	Sand and silty clay
TP05.1	TP05.1	0-0.5	7/04/2014	**53**	**36**	**11**	<1	<1	Silty clay and sand
TP05.2	TP05.2	0.5-1	7/04/2014	**53**	**39**	**8**	<1	<1	Silty clay
TP05.3	TP05.3	1-1.5	7/04/2014	**57**	**31**	**12**	<1	<1	Silty clay and sand
TP05.4	TP05.4	1.5-2	7/04/2014	**32**	**39**	**29**	<1	<1	Silty clay and sand
TP05.5	TP05.5	2-2.5	7/04/2014	**28**	**15**	**56**	**1**	<1	Sand and silty clay
TP06.1	TP06.1	0-0.5	7/04/2014	**38**	**49**	**13**	<1	<1	Silty clay and sand
TP06.2	TP06.2	0.5-1	7/04/2014	**42**	**43**	**15**	<1	<1	Silty clay and sand
TP06.3	TP06.3	1-1.5	7/04/2014	**42**	**46**	**12**	<1	<1	Silty clay and sand
TP06.4	TP06.4	1.5-2	7/04/2014	**43**	**32**	**25**	<1	<1	Silty clay and sand
TP07.1	TP07.1	0-0.5	7/04/2014	**45**	**46**	**9**	<1	<1	Silty clay
TP07.2	TP07.2	0.5-1	7/04/2014	**43**	**51**	**6**	<1	<1	Silty clay
TP07.2	QC09.2	0.5-1	7/04/2014	**43**	**45**	**12**	<1	<1	Silty clay and sand
TP07.2	QC10.2	0.5-1	7/04/2014	**41**	**52**	**7**	<1	<1	Silty clay
TP07.3	TP07.3	1-1.5	7/04/2014	**50**	**40**	**10**	<1	<1	Silty clay
TP07.3	QC09.3	1-1.5	7/04/2014	**48**	**38**	**14**	<1	<1	Silty clay and sand
TP07.3	QC10.3	1-1.5	7/04/2014	**46**	**48**	**6**	<1	<1	Silty clay
TP09.1	TP09.1	0-0.5	7/04/2014	**49**	**44**	**7**	<1	<1	Silty clay
TP09.2	TP09.2	0.5-1	7/04/2014	**55**	**39**	**6**	<1	<1	Silty clay
TP09.2	QC02_070414	0.5-1	7/04/2014	**41.9**	*	*	*	*	-
TP09.3	TP09.3	1-1.5	7/04/2014	**52**	**40**	**8**	<1	<1	Silty clay
TP09.4	TP09.4	1.5-2	7/04/2014	**32**	**14**	**54**	<1	<1	Sand and silty clay
TP09.5	TP09.5	2-2.5	7/04/2014	**34**	**13**	**53**	<1	<1	Sand and silty clay
TP09.5	QC01_070414	2-2.5	7/04/2014	**30**	**21**	**49**	<1	<1	Silty clay and sand
TP10.1	TP10.1	0-0.5	7/04/2014	**53**	**42**	**5**	<1	<1	Silty clay
TP10.2	TP10.2	0.5-1	7/04/2014	**56**	**38**	**6**	<1	<1	Silty clay
TP10.3	TP10.3	1-1.5	7/04/2014	**53**	**34**	**13**	<1	<1	Silty clay and sand
TP10.4	TP10.4	1.5-2	7/04/2014	**30**	**10**	**59**	**1**	<1	Sand and silty clay
TP10.5	TP10.5	2-2.5	7/04/2014	**33**	**12**	**55**	<1	<1	Sand and silty clay
TP11.1	TP11.1	0-0.5	7/04/2014	**54**	**38**	**8**	<1	<1	Silty clay
TP11.2	TP11.2	0.5-1	7/04/2014	**55**	**38**	**7**	<1	<1	Silty clay
TP11.3	TP11.3	1-1.5	7/04/2014	**32**	**18**	**50**	<1	<1	Sand and silty clay
TP11.4	TP11.4	1.5-2	7/04/2014	**31**	**14**	**55**	<1	<1	Sand and silty clay
TP11.5	TP11.5	2-2.5	7/04/2014	**54**	**22**	**24**	<1	<1	Silty clay and sand
TP12.1	TP12.1	0-0.5	10/04/2014	**53**	**39**	**8**	<1	<1	Silty clay
TP12.2	TP12.2	0.5-1	10/04/2014	**53**	**41**	**6**	<1	<1	Silty clay
TP12.2	QC20_100414	0.5-1	10/04/2014	**37.8**	*	*	*	*	-
TP12.3	TP12.3	1-1.5	10/04/2014	**29**	**20**	**50**	**1**	<1	Sand and silty clay
TP12.4	TP12.4	1.5-2	10/04/2014	**31**	**19**	**50**	<1	<1	Silty clay and sand
TP12.5	TP12.5	2-2.5	10/04/2014	**62**	**26**	**11**	**1**	<1	Silty clay and sand
TP12.6	TP12.6	2.5-3	10/04/2014	**54**	**32**	**14**	<1	<1	Silty clay and sand
TP12.7	TP12.7	3-3.5	10/04/2014	**47**	**30**	**23**	<1	<1	Silty clay and sand
TP12.8	TP12.8	3.5-4	10/04/2014	**36**	**17**	**47**	<1	<1	Silty clay and sand
TP14.1	TP14.1	0-0.5	10/04/2014	**52**	**37**	**11**	<1	<1	Silty clay and sand
TP14.2	TP14.2	0.5-1	10/04/2014	**27**	**21**	**52**	<1	<1	Sand and silty clay
TP14.3	TP14.3	1-1.5	10/04/2014	**30**	**24**	**46**	<1	<1	Silty clay and sand
TP14.4	TP14.4	1.5-2	10/04/2014	**34**	**21**	**44**	**1**	<1	Silty clay and sand
TP14.5	TP14.5	2-2.5	10/04/2014	**31**	**27**	**42**	<1	<1	Silty clay and sand
TP14.6	TP14.6	2.5-3	10/04/2014	**35**	**29**	**36**	<1	<1	Silty clay and sand
TP14.7	TP14.7	3-3.5	10/04/2014	**44**	**34**	**22**	<1	<1	Silty clay and sand
TP14.8	TP14.8	3.5-4	10/04/2014	**45**	**21**	**31**	**3**	<1	Silty clay and sand
TP14.9	TP14.9	4-4.5	10/04/2014	**58**	**21**	**20**	**1**	<1	Silty clay and sand
TP16.1	TP16.1	0-0.5	9/04/2014	**53**	**43**	**4**	<1	<1	Silty clay
TP16.2	TP16.2	0.5-1	9/04/2014	**35**	**38**	**27**	<1	<1	Silty clay and sand
TP16.3	TP16.3	1-1.5	9/04/2014	**40**	**27**	**32**	**1**	<1	Silty clay and sand
TP16.4	TP16.4	1.5-2	9/04/2014	**29**	**16**	**55**	<1	<1	Sand and silty clay
TP16.4	QC17_090414	1.5-2	9/04/2014	**26**	**16**	**58**	<1	<1	Sand and silty clay
TP16.5	TP16.5	2-2.5	9/04/2014	**31**	**24**	**45**	<1	<1	Silty clay and sand
TP16.6	TP16.6	2.5-3	9/04/2014	**35**	**20**	**45**	<1	<1	Silty clay and sand
TP16.6	QC18_090414	2.5-3	9/04/2014	**39.4**	*	*	*	*	-
TP16.7	TP16.7	3-3.5	9/04/2014	**34**	**18**	**48**	<1	<1	Silty clay and sand
TP16.8	TP16.8	3.5-4	9/04/2014	**33**	**22**	**45**	<1	<1	Silty clay and sand
TP16.8	QC19_090414	3.5-4	9/04/2014	**31**	**24**	**45**	<1	<1	Silty clay and sand
TP17.1	TP17.1	0-0.5	7/04/2014	**47**	**48**	**5**	<1	<1	Silty clay
TP17.2	TP17.2	0.5-1	7/04/2014	**52**	**41**	**7**	<1	<1	Silty clay
TP17.3	TP17.3	1-1.5	7/04/2014	**38**	**25**	**37**	<1	<1	Silty clay and sand
TP17.3	QC04_070414	1-1.5	7/04/2014	**32**	**21**	**46**	**1**	<1	Silty clay and sand
TP17.4	TP17.4	1.5-2	7/04/2014	**29**	**14**	**57**	<1	<1	Sand and silty clay
TP17.5	TP17.5	2-2.5	7/04/2014	**33**	**15**	**52**	<1	<1	Sand and silty clay
TP17.5	QC05_070414	2-2.5	7/04/2014	**31.5**	*	*	*	*	-
TP18.1	TP18.1	0-0.5	10/04/2014	**38**	**55**	**7**	<1	<1	Silty clay
TP18.2	TP18.2	0.5-1	10/04/2014	**44**	**50**	**6**	<1	<1	Silty clay
TP18.3	TP18.3	1-1.5	10/04/2014	**23**	**15**	**61**	**1**	<1	Sand and silty clay
TP18.4	TP18.4	1.5-2	10/04/2014	**28**	**16**	**56**	<1	<1	Sand and silty clay
TP18.5	TP18.5	2-2.5	10/04/2014	**35**	**21**	**44**	<1	<1	Silty clay and sand
TP18.6	TP18.6	2.5-3	10/04/2014	**30**	**25**	**45**	<1	<1	Silty clay and sand
TP18.7	TP18.7	3-3.5	10/04/2014	**36**	**17**	**47**	<1	<1	Silty clay and sand
TP18.8	TP18.8	3.5-4	10/04/2014	**41**	**24**	**35**	<1	<1	Silty clay and sand
TP18.9	TP18.9	4-4.5	10/04/2014	**43**	**24**	**33**	<1	<1	Silty clay and sand
TP23.1	TP23.1	0-0.5	7/04/2014	**46**	**43**	**11**	<1	<1	Silty clay
TP23.2	TP23.2	0.5-1	7/04/2014	**44**	**46**	**10**	<1	<1	Silty clay
TP23.3	TP23.3	1-1.5	7/04/2014	**49**	**42**	**9**	<1	<1	Silty clay
TP23.4	TP23.4	1.5-2	7/04/2014	**45**	**47**	**8**	<1	<1	Silty clay
TP25.1	TP25.1	0-0.5	7/04/2014	**41**	**52**	**7**	<1	<1	Silty clay
TP25.2	TP25.2	0.5-1	7/04/2014	**45**	**43**	**12**	<1	<1	Silty clay and sand
TP25.3	TP25.3	1-1.5	7/04/2014	**48**	**47**	**5**	<1	<1	Silty clay
TP25.3	QC14_080414	1-1.5	7/04/2014	**46**	**45**	**9**	<1	<1	Silty clay
TP25.4	TP25.4	1.5-2	7/04/2014	**34**	**31**	**35**	<1	<1	Silty clay and sand
TP25.5	TP25.5	2-2.5	8/04/2014	**29**	**14**	**57**	<1	<1	Sand and silty clay
TP25.5	QC15_080414	2-2.5	8/04/2014	**36**	*	*	*	*	-
TP33.1	TP33.1	0-0.5	7/04/2014	**45**	**49**	**6**	<1	<1	Silty clay
TP33.2	TP33.2	0.5-1	7/04/2014	**36**	**28**	**36**	<1	<1	Silty clay and sand
TP33.3	TP33.3	1-1.5	7/04/2014	**45**	**24**	**31**	<1	<1	Silty clay and sand
TP33.4	TP33.4	1.5-2	7/04/2014	**57**	**25**	**18**	<1	<1	Silty clay and sand
TP33.5	TP33.5	2-2.5	7/04/2014	**53**	**15**	**29**	**3**	<1	Silty clay, sand and shell
TP38.1	TP38.1	0-0.5	7/04/2014	**41**	**58**	**1**	<1	<1	Silty clay
TP38.2	TP38.2	0.5-1	7/04/2014	**55**	**42**	**3**	<1	<1	Silty clay
TP38.3	TP38.3	1-1.5	7/04/2014	**44**	**51**	**5**	<1	<1	Silty clay
TP38.3	QC11_080414	1-1.5	7/04/2014	**45**	**52**	**3**	<1	<1	Silty clay
TP38.4	TP38.4	1.5-2	7/04/2014	**31**	**62**	**7**	<1	<1	Silty clay
TP38.4	QC12_080414	1.5-2	8/04/2014	**34.8**	*	*	*	*	-
			Total %	**43%**	**32%**	**24%**	<1	<1	

Legend:
Bold = Detection above Practical Quantitation Limit
* Laboratory particle size groupings were not comparable between the primary and secondary laboratories with the exception of Clay (<2 µm), hence the secondary laboratory results have not been presented in the table.

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