Appendix C

Draft Dredging and Dredge Spoil Disposal Management Plan

Prepared for
Department of Infrastructure, Planing and Logistics
ABN: 84 085 734 992

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Dredging and Dredge Spoil Placement Management Plan

17-Jun-2022
Darwin Ship Lift Project
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Dredging and Dredge Spoil Placement Management Plan

Client: Department of Infrastructure, Planing and Logistics

ABN: 84 085 734 992

Prepared by

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1.0 Introduction

1.1 Darwin Ship Lift Project

1.1.1 Overview

The Northern Territory Government (NTG) is delivering the Darwin Ship Lift Project (the Project) which comprises construction and operation of a ship lift facility and an adjacent maintenance facility at East Arm.

The Project will enable maintenance and servicing of a broad range of industries, including the Australian Defence Force (ADF) and Australian Border Force (ABF) vessels, as well as commercial and private vessels, including those servicing the oil, gas, pearling, fishing and other marine industries. It will be northern Australia's largest common user ship lift and will provide marine infrastructure that will deliver key services to northern Australia, acting as an enabler for the continued economic growth of Darwin as the logistics and marine services hub of the Northern Territory (NT) and northern Australia.

1.1.2 Project description

The Project site is situated approximately 6.5 km south-east of the Darwin Central Business District (CBD), on the East Arm Peninsula within Darwin Harbour, east of East Arm Wharf (EAW) and on the seaward side of Berrimah Road (Figure 1).

The Project is planned to be operational by 2025 and the concept design currently includes:

- ship lift of approximately 26 metres (m) width and 103 m length, capable of lifting vessels weighing up to 5,500 tonnes (t) plus associated platform, trestles and vessel transfer system
- self-propelled modular transporter (SPMT) vessel transfer system
- approximately 13 hectares (ha) of hardstand area for ship repair and maintenance
- vessel wash area with separate contained drainage and treatment system
- stormwater system to capture and treat runoff water before discharge
- enclosed blast and paint facility with separate contained drainage system as well as a negative pressure and air filtration system
- site services and utilities
- security infrastructure
- ancillary facilities including:
- administration building
- ship lift control room
- SPMT garage
- dredged manoeuvring and berthing areas (six wet berths)
- heavy lift platforms suitable for a 100 t crane at each berth
- revetments and quay structures.

Once constructed, the Project will comprise:

- an NTG owned facility that will lease areas/berths on a common user basis under a principal operator (Darwin Ship Lift Facility), and
- a privately owned berthing and maintenance facility.

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Figure 1 Darwin Ship Lift Project Location

Figure 2 shows the overall conceptual design of the facility. Development of the Project will require dredging of a manoeuvring basin, berth areas and ship lift zone to provide safe navigable water depths for the proposed vessel sizes and access to the deeper waters within East Arm. Based on concept design, the areas to be dredged will comprise:

- ship lift and wet berths at -6.8 m lowest astronomical tide (LAT); 6 ha
- manoeuvring basin areas at -3.3 m LAT; 3.2 ha.

There are two components to the dredging program:

- removal of approximately 185,000 cubic metres (m^3) of unconsolidated marine material
- removal of approximately 315,000 m^3 of consolidated materials.

The dredging campaign will be undertaken by either:

- Option 1: using a cutter suction dredge (CSD), similar to that used for the neighbouring Multi User Barge Ramp Facility (MUBRF) dredging campaign, to remove the unconsolidated material to the EAW settling ponds, then a backhoe dredge (BHD) to remove the consolidated stiff clays and rock for land reclamation.
- Option 2: using a BHD to mix all dredged material and utilise for land reclamation.

Details of the proposed dredging and dredged material placement methodologies are presented in Section 2.0.

1.2 Purpose of this Plan

This document relates to the management and monitoring of the proposed dredging operations and onshore placement of the dredged material. It 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 dredged material placement activities to be undertaken.

The DDSPMP details how the potential impacts of the dredging and dredged material 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 dredged material placement activities.

1.3 Proponent

The Proponent of the Project is the NTG. The early stages of the Project have been managed by the Department of the Chief Minister and Cabinet (DCMC), which is responsible for economic development and supporting business growth and sustainability in the NT. The Project is expected to be managed through the construction and operational phases by the Department of Infrastructure, Planning and Logistics (DIPL), responsible for land use and transport planning, infrastructure investment and effective logistics supply chains for the NT.

Proponent’s address:
Northern Territory Government – Department of Infrastructure, Planning and Logistics
GPO Box 4396
Darwin NT 0801
Attention: Mr Craig Smith

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Figure 2 Darwin Ship Lift Project General Layout and Dredging Footprint

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1.4 Project approvals

1.4.1 Northern Territory approvals

On 24 April 2018, a Notice of Intent (NOI) for the original Project was submitted to the NT EPA. Following submission, the NT EPA circulated the NOI to the relevant advisory bodies and compiled their comments. A response to the comments raised was prepared and provided to the NT EPA on 22 August 2018. The NT EPA considered all material provided and issued a Statement of Reasons (SoR) on 14 November 2018. The NT EPA decision outlined in the SoR notes that a formal Environmental Impact Statement (EIS) would be required.

While the Terms of Reference (ToR) for the EIS were in preparation, the NTG Project Team informed the NT EPA of proposed changes to the Project. The NT EPA determined that the changes could be addressed in the ToR and subsequent EIS without the need to resubmit a NOI.

On 12 November 2021, the Draft EIS (AECOM 2021) was released by the NT EPA for public comment up until 14 January 2022. A Supplementary EIS is currently in preparation, in which the Proponent's responses to received submissions on the Draft EIS are presented.

Prior to the commencement of dredging, the following will be required under NT legislation:

- Project approval under the *Environment Protection Act 2019* (i.e. via the EIS process).
- An approved DDSPMP (refer Section 1.8).
- A Waste Discharge Licence (WDL) pursuant to Section 74 of the NT *Water Act 1992* for the discharge of tailwater from the EAW settling ponds.
- Development consent under the *Planning Act 1999.*

1.4.2 Commonwealth approvals

On 24 April 2018, a referral for the original Project was submitted to the Commonwealth Department of Environment and Energy (DoEE, now the Department of Agriculture, Water and the Environment [DAWE]) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Following submission of the referral, on 25 September, DoEE issued its decision that the referred action was determined to be Not a Controlled Action.

When the NTG became the proponent of the Project, the overall design and scale of works proposed was amended to improve overall functionality and allow for the delivery of additional marine industry facilities.

A revised EPBC Referral was submitted to DAWE on 8 November, 2021. Following a period of public comment, on 9 December 2021 DAWE deemed the Project to be a Controlled Action, with the controlling provisions cited as:

- listed threatened species and communities (sections 18 & 18A)
- listed migratory species (sections 20 & 20A).

As such, Commonwealth approval of the Project is required, with the assessment approach designated as 'assessed by preliminary documentation'. The required preliminary documentation is presently in preparation.

1.5 Legislative framework and guidelines

Legislative frameworks relevant to the dredging activities are presented in Table 1 (NT) and Table 2 (Commonwealth). International conventions and guidelines relevant to the dredging activities are listed in Table 3. A number of NT and Commonwealth Government strategy and guideline documents, including the *Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory* (NT EPA 2013) 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 4 and Table 5 have been taken into account.

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Table 1 NT legislative framework

Northern Territory	
Title	Description
Northern Territory Aboriginal Sacred Sites Act 1989 and Regulations	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.
Crown Lands Act 1992	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.
Port of Darwin Act 2015	An Act to authorise and facilitate the transfer of assets, rights and liabilities relating to, or connected with, the Port of Darwin, and for related purposes.
Ports Management Act 2015	An Act to provide for the control, management and operation of ports, and for related purposes.
Environment Protection Act 2019	An Act to provide for the protection of the environment and for related purposes. Superseded the NT *Environmental Assessment Act* in June 2020 in providing for the assessment of the environmental effects of development proposals and for the protection of the environment.
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*. NEPMs 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 1988	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 1972	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 1981 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 1999 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 1998	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 Environment Protection Council. It is designed to prevent

Northern Territory	
Title	Description
	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 1992	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 2 Commonwealth legislative framework

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.
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.
Biosecurity Act 2015 and Biosecurity Regulations 2016	This Act provides for the management of diseases and pests that may cause harm to human, animal or plant health or the environment including risks related to ballast water.
Biosecurity Amendment (Ballast Water and Other Measures) Act 2017, Biosecurity (Ballast Water and Sediments) Determination 2017 and the Biosecurity (Ballast Water Same Risk Area) Instrument 2017.	These Acts amended the *Biosecurity Act 2015* to provide for the management of ballast waters by vessels in Australian Waters.

Table 3 International conventions and guidelines

International Conventions	
Title	Description
Guidelines for the Development of Garbage Management Plans for compliance with Regulation 9(2), Annex V	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

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International Conventions	
Title	Description
of the International Convention for the Prevention of Pollution from Ships (MARPOL)	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 4 NT Government strategy and guideline documents

Northern Territory
A Strategy for the Conservation of Marine Biodiversity in the Northern Territory of Australia, Parks and Wildlife Commission of the NT (PWCNT 2000)
A Review of Environmental Monitoring of the Darwin Harbour Region and Recommendations for Integrated Monitoring (NTG 2005)
Declaration of beneficial uses and water quality objectives for Darwin Harbour region (NTG 2010)
Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA 2013)
Recommendations for sampling and analysis of Darwin Harbour sediment (Munksgaard 2013)
Darwin Harbour Water Quality Protection Plan (DLRM 2014)
Interim Turbidity Water Quality Objectives for Dry Season Neap Tide Conditions in Darwin Harbour (Cassilles Southgate & Fortune 2018)
NT EPA Environmental Factors and Objectives (NT EPA 2018)
Sediment Quality Sampling Design for Darwin Harbour (Brinkman & Logan 2019)
Development of Pressure Indicators for Darwin Harbour (Radke et al 2019)
2020-2025 Darwin Harbour Strategy (Darwin Harbour Advisory Committee 2020)

Table 5 Commonwealth Government strategy and guideline documents

Commonwealth
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 (Commonwealth of Australia 2005)

Commonwealth
National Assessment Guidelines for Dredging (NAGD, Commonwealth of Australia 2009)
National Acid Sulfate Soils Guidance. Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management (Simpson et al,2018)
Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments (ANZG 2018)

1.6 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 1992*), improvements to monitoring activities and evaluation of pollutant loads (former Department of Natural Resources, Environment, the Arts and Sport [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 proposed Project dredging activities fall within the Darwin Harbour Declaration of Beneficial Uses and Objectives of Surface Water. The declared beneficial uses are aquaculture, environment and cultural (NTG 2010).

Performance against the water quality objectives described in the WQPP is assessed by the NT Department of Environment, Parks and Water Security (DEPWS, formerly the Department of Environment and Natural Resources [DENR]) on the basis of the annual mean value of the measured parameter. It is noted that the guidelines in the WQPP 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 Management Frameworks (MFs) detailed in Section 8.0 of this Plan. The MFs have been developed in a manner that is consistent with the risk-based decision framework discussed above.

1.7 Stakeholder consultation

The proposed dredging works were addressed within the stakeholder consultation process undertaken during preparation of the Draft EIS and the EPBC referral. Targeted consultation on specific aspects of the proposed dredging works was undertaken via the provision of letters and fact sheets to the stakeholders listed in Table 6.

Table 6 Fact sheet distribution list

Stakeholders
Government
Commonwealth DAWE
Darwin Harbour Advisory Committee
Defence NT
Development Consent Authority
Interagency Working Group

Stakeholders
Job Standing Committee Ship Lift Project Steering Committee
NT Department of Industry, Tourism and Trade, Heritage Branch
NT EPA
NT Land Development Corporation
NT Minister for Major Projects and Territory Economic Reconstruction
Leaseholders
Darwin Port Harbourmaster
Darwin Port Landbridge
Paspaley Pty Ltd
Indigenous organisations
Larrakia Nation, including Larrakia Rangers
Larrakia Development Corporation
Northern Land Council
Business groups
Chamber of Commerce NT/NT Manufacturers Council
Darwin Major Business Group
Industry Capability Network Northern Territory (ICN NT)
NT Seafood Council
Palmerston Regional Business Association
Property Council of the NT
Tourism Top End
Urban Development Industry Association (UDIA)
Community and special interest groups
Amateur Fishermen's Association of the NT (AFANT)
Environment Centre NT
Environmental Defenders Office
Keep Top End Coasts Healthy Alliance
Planning Action Network (PLan)

1.8 DDSPMP approval and review

This DDSPMP presents the environmental management and monitoring strategies that will need to be employed during the Project dredging and reclamation works. These will form the basis of the strategies within a DDSPMP prepared by the appointed Dredging Contractor; this will require approval by the NT Environment Minister before works can commence.

Prior to submission of the Dredging Contractor's DDSPMP for approval, an independent review of the Plan will be carried out by a suitably experienced person and a written endorsement of the mitigation, management and monitoring programs outlined will be provided.

Should circumstances require any amendments to the approved DDSPMP, it will be the responsibility of the Dredging Contractor to undertake such amendments, and of the Proponent to ensure that the amendments do not increase the levels of potential environmental risk to any greater than those levels within the approved Plan. For example, if deficiencies in the effectiveness of this DDSPMP, changes in

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environmental risks, improved processes for monitoring of environmental performance, or any relevant emerging environmental issues currently not addressed are identified, then a review of the relevant components of the DDSPMP will be undertaken. If deemed necessary (through consultation with DEPWS), the Dredging Contractor will submit the revised Plan to the NT EPA for their consideration of any changes that are made.

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2.0 Dredging and Dredge Spoil Placement

2.1 Introduction

Two options for dredging and dredged material placement were described in the Project Draft EIS:

- Option 1: using a CSD to remove the unconsolidated material to settling ponds, then a BHD to remove the consolidated stiff clays and rock for land reclamation.
- Option 2: using a BHD to mix all dredged material and utilise for land reclamation required for construction of the Project.

Either of these options may be used by the Dredging Contractor and this DDSPMP addresses both methodologies; these provide the basis upon which the Dredging Contractor will manage the dredging activities to meet the required environmental outcomes detailed in this Plan.

Following publication of the Draft EIS, as part of the ongoing refinement of the Project construction methodologies, it has been determined that:

- Prior to any reclamation activity occurring, a rock revetment will be constructed at the seaward extent of the reclamation area.
- The rock material to be used within the revetment will be screened to remove the majority of fine materials prior to its placement into the marine environment.
- Geofabric will be placed in a manner to effectively mitigate the extent to which any fines can penetrate through the revetment.
- Dredged material will subsequently be placed on the landward side of the revetment.
- Silt curtains will be deployed wherever there may be the potential for fines from within the placed dredged material to migrate into the surrounding marine waters.
- Runoff from the reclamation area will be managed (e.g. through the deployment of silt fences and silt curtains) to ensure that it does not result in elevations in turbidity seaward of the revetment.

At this stage two potential construction strategies are proposed to develop the reclaim area:

1. The rock revetment will be developed to fully enclose the reclaim area prior to the placement of dredge spoil within the bund wall.
2. The rock revetment will be constructed such that it mostly encapsulate the reclaim area, with an opening along the western side to allow barges to enter the reclaim area to deposit the dredged material. The opening will have silt curtains across its width to minimise suspended sediment entering the harbour.

The location of the works within a tidal zone, sediment characteristics, limited available draught for vessels, and the method of placement of the dredged material will be the determining factors for the selection of the preferred dredging methodology. The current seabed surface levels within the proposed dredging footprint range from +1.0 m LAT to -3.0 m LAT. The typical geotechnical profile of the unconsolidated surface materials to be dredged consists of sand and gravel surface sediments (with gravel potentially comprising shell fragments) with silt and clay content generally increasing with depth. During sediment sampling undertaken at the site sample recovery of between 0.2 and 1.5 m was achieved before encountering consolidated material (AECOM 2020). These unconsolidated sediments are underlaid by a thin layer of ‘stiffer’ consolidated residual soils, typically silty sand / sandy silt, which are overlaying shallow rock material.

2.2 Option 1

If Option 1 is selected, dredging of unconsolidated material would be undertaken using a small CSD. Dredged material would be transported via a temporary pipeline (floating, submerged and/or overland) to the settling ponds at EAW. The final pipeline route would be determined by the Dredging Contractor in conjunction with the Proponent and Harbour Master.

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The EAW ponds have previously been used for the disposal of capital dredging material from the initial development of EAW and from two developments undertaken as part of the EAW expansion project (Marine Supply Base [MSB] and Multi User Barge Ramp Facility [MUBRF]), as well as from the Darwin City Waterfront Redevelopment.

It is expected that tailwater flow rates into the pond system would be approximately 500 L/s at a water to sediment ratio of 9:1. A sediment loss rate of 5% at the CSD cutter head could be expected and a dry bulk density of 857 kg/m^3 is considered to be likely; these are in line with those characteristics assumed for the MUBRF dredging campaign (URS 2015).

An indicative material placement scenario is shown in Figure 3:

- The dredged material would be initially pumped into the ponds at a location in Pond K, in which the larger particles (sands and silts) will settle out. If necessary, internal bunds may be constructed within Pond K to enhance the settlement process, or tailwater held within Pond K for a longer settling period.
- The supernatant tailwater will then flow into Pond E (North), in which retention will managed such that there is sufficient time for finer particles to settle out, using the weir box into Pond E south to control the level in Pond E north. Silt curtains may be installed in Pond E (North) to assist in this process.
- Pond E (South) will provide a final settlement stage before the tailwater, under tidal influence, enters Frances Bay (Darwin Harbour) via a permeable section of the bund wall.

The primary method of control over tailwater quality discharged from the pond system would be through the use of silt curtains, internal diversion walls (bunds), control of the dredging regime and through the management of weir boxes. The flow direction and flow rate of tailwater into the ponds would be controlled so that sufficient residence time is achieved to result in suspended sediment concentrations (SSCs) within allowable limits at the point of entry of the tailwater to Pond E (South).

The reclamation area would be bunded and then progressively filled with consolidated material until the extent of the proposed reclamation is reached. Consolidated material would be removed by a BHD, placed into hopper barges and transferred into the reclamation area within the Project footprint. Sediment control measures such as silt curtains would be used to further minimise the release of sediments into the receiving environment from the reclamation area.

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Figure 3 Aerial image showing indicative settling pond configuration (Option 1)

2.3 Option 2

Under Option 2, a BHD would be used to remove both unconsolidated and consolidated materials from the dredging footprint. The materials would be deposited into hopper barges, from which the material would be transferred into the Project reclamation area. As under Option 1, the bunded reclamation area would be progressively filled until the extent of the proposed reclamation is reached.

2.4 Stormwater flow paths

If Option 1 is selected, then the maintenance of stormwater flow paths through the EAW pond network will require consideration. Stormwater from the pond network and adjacent Darwin Port land ultimately flows into Pond E (South) for return to the harbour via the permeable section of the railway bund wall (refer Figure 4). During dredging operations, particularly where dredging is undertaken over the Wet Season, consideration will be given to possible storm events and the Dredging Contractor will ensure that a flow path is always available for stormwater to find its way through the ponds.

Stormwater from the Pond K road bund and a catchment area near the gatehouse, estimated to be 20,000 m^2, is diverted into a stormwater channel in place along the boundary between Pond K and the former Pond C area, into Pond D, instead of flowing into Pond K (refer Figure 4). Stormwater from the highpoint on the road to the south of Pond K flows along a stormwater channel and through a culvert into Pond E (North).

The runoff from Darwin Port 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 disposal pond.

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Figure 4 Stormwater flow paths through the EAW pond system

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3.0 Environmental Management System and Procedures

This Project will be undertaken in accordance with the Dredging Contractor's Environment Policy and Environmental Management System (EMS). The EMS will be required to include procedures, work method statements and sufficient resources to achieve the Dredging Contractor's environmental targets and to minimise the risk of pollution from its activities.

The Dredging Contractor's EMS will have been audited and approved under a recognised standards organisation (e.g. ISO International Standard for Environmental Management Systems) which provides a framework for the achievement of continual environmental improvement.

The EMS and procedures will guide all dredging operations. On appointment, the Dredging Contractor will develop any additional Project-specific detailed plans required to meet the requirements of the dredging environmental approvals. The EMS and any associated policies and procedures will be reviewed and approved by the Proponent before dredging commences.

3.1 Key roles and responsibilities

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

Site management responsibilities will be defined and documented by the Dredging Contractor before dredging commences; these will include reporting and communication pathways between the Contractor and Proponent 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 Inductions and training requirements

Inductions and training requirements will be determined by the Proponent, Darwin Port and the Dredging Contractor on appointment, and will be in accordance with the Proponent's and the 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 Dredging Contractor.

3.2.1 Environmental inductions

The Dredging Contractor's Environmental Policy or EMS shall commit them to providing sufficient resources and training to achieve the targets defined in its EMS. The Dredging Contractor will be required to fulfil this commitment by ensuring all persons involved with the dredging operations complete a Project General Induction (to be developed by the Dredging Contractor and approved by the Proponent).

Dredging work program specific environmental inductions will also be developed by the Dredging Contractor and 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 hydrocarbon or chemical spills.

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3.2.2 Environmental awareness

Daily prestart / toolbox meetings will be conducted by the Dredging Contractor, with input from the Proponent, and will be primarily aimed at operational staff. All Dredging 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 will be 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 will include environmental items such as new procedures or reinforcement of existing procedures, handling of hazardous chemicals, management of waste/ recycling, need to report all incidents and hazards/near misses, etc.

3.2.3 Training

Only suitably qualified and experienced personnel will be engaged on the Project. All personnel will have appropriate qualifications and experience for their role on the Project. Training and qualifications are to be demonstrated to the Proponent by the Dredging Contractor prior to the commencement of the dredging work.

3.3 Environmental documents and records management

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

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

Such records include, but are not limited to:

- correspondence to/from the Proponent and interested parties
- dredge working logs (including daily logs of locations worked, site conditions and operational controls in place in the pond networks
- permits, licenses and approvals
- induction training records
- inspection, monitoring and test documentation (including calibration)
- non-conformance and corrective action / complaints
- environmental incidents
- audits and inspections
- daily monitoring site records
- delivery / waste dockets.

3.4 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 dredged material placement activities are minimised. The success of these objectives is measured with key performance indicators (KPIs) defined for environmental management (see Section 8.0).

3.4.1 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.

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- 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 that dredging and dredge spoil placement are undertaken in accordance with regulatory approvals, licenses, permits or authorisations.

3.4.2 Performance criteria

The DDSPMP is the key reference document which identifies actions and commitments to be followed by the Dredging Contractor and any 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 program outlined in Section 9.4 of this Plan.
- No net long-term adverse impacts on coral habitats and protected species (dolphins, dugongs, turtles, sawfish or migratory birds) or critical habitat for these species.
- No injuries to protected marine species (refer to Section 4.3.2).
- No complaints received in relation to dredging-related noise or 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 DDSPMP, in addition to initiating corrective actions specific to the scenario.

3.4.3 Environmental management KPIs

In the environmental management frameworks detailed in Section 8.0 of this plan, specific objectives and targets, and KPIs related to these, are set for each significant environmental aspect.

General objectives and targets are:

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

3.4.4 Environmental incident reporting

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

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 designated Proponent representative and to the NT EPA Pollution Hotline (1800-064-567) or, for marine fauna incidents, Marine Wildwatch line (1800-453-941) within 24 hours. When in any doubt as to the seriousness of the event, the Dredging Contractor will notify the authorities, in liaison with the Proponent. The Proponent will be notified of any notices received from authorities.

3.5 Management review

3.5.1 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.

3.5.2 Internal audits

An internal audit of this DDSPMP will be undertaken prior to commencement of dredging to assess the likely effectiveness of the Plan in the field and to identify any opportunities for improvement. A second internal audit will be undertaken three months after the commencement of dredging to assess the effectiveness of the implementation of the Plan, and of the monitoring and reporting procedures being applied. The intent of this audit is to identify any opportunities for improvement to ensure monitoring, reporting and record keeping are sufficient to support required reporting.

3.5.3 External audits

External audits can be conducted by the Proponent 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. The Dredging Contractor's 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.

3.5.4 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 Dredging Contractor. The corrective actions register will detail the non-conformance, the corrective action required, the responsible person(s), the timeframes by which the action is to be completed, and the actual completion date. Each non-conformance will be reviewed and it will be established if there are any actions available to reduce the severity or likelihood of re-occurrence.

3.5.5 Continuous improvement

The Dredging 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 the Proponent.

Mechanisms may include but will not be limited to:

- prestart meetings
- toolbox meetings
- progress reports.

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4.0 Existing Environment and Relevant Studies

4.1 Background

This section of the Plan 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 dredging associated with the Project proposal. This information provides the context for determining the monitoring programs and management strategies detailed in Section 8.0.

The Darwin Harbour region extends from Gunn Point in the east, to Charles Point in the west, covering an area of over 3200 km^2 comprising 65% terrestrial and 35% marine habitats (at high tide) (Fortune 2016). The Darwin Harbour region 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.

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 the lowest average daily temperatures (19°C minimum to 31°C maximum) are normally experienced in July (Bureau of Meteorology [BoM] 2022). The mean annual rainfall for Darwin is 1724 mm, with rain falling on an average of 94 days, mainly from November to March (BoM 2022).

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 result from strong onshore winds and reduced atmospheric pressure 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, the speed and direction of tidal flows and the bathymetry of the affected area (NT Emergency Service 2011).

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 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 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 modified by dredging for the development of EAW and the INPEX LNG processing facilities located at Bladin Point.

4.2.3 Marine sediments

4.2.3.1 Darwin Harbour seafloor

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).

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The typical geological profile of the Darwin Harbour seafloor comprises 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.

Sediments in the river catchments are predominantly fine-grained, mainly clay and silt. Creeks and rivers may transport coarser material (e.g. sand) into the estuary during the Wet Season, though much is trapped by coastal vegetation, both riparian and mangrove (McKinnon et al. 2006). The fine sediment delivered to the upper arms of the harbour settles out of suspension and is then eroded and re-deposited mainly by tidal currents, especially at spring tides (Munksgaard 2013).

Hydrodynamic modelling of the fate of suspended sediment plumes has shown that substantial sediment fluxes are directed up-estuary where fine sediments are trapped; the sediment fraction exported to the ocean is relatively small (Williams, Wolanski & Spagnol 2006).

4.2.3.2 Contaminants of potential concern

DLRM (2014) estimated that 30% of the land within the Darwin Harbour catchment was developed. About 13% of the developed area was subject to urban and other intensive land-uses in and around the cities of Darwin and Palmerston, including residential living, manufacturing, industry, roads, airport infrastructure and defence facilities. Skinner et al (2009) note that runoff from urban areas contain a disproportionately high pollutant load relative to that from non-urban areas. The remainder of the developed area comprised rural land-uses, including horticulture and agriculture. Non-polluting uses (e.g. remnant native vegetation, surface water supply, conservation areas) were considered by the Darwin Harbour Advisory Committee (2003) to occupy the remaining 70% of the Darwin Harbour catchment.

The Elizabeth River has the second largest catchment of the rivers entering Darwin Harbour (the largest is the Blackmore River that enters Middle Arm [Padovan 2001]). Skinner et al (2009) estimated that 58% of the Elizabeth River catchment area comprised native vegetation with minimal disturbance, rural land use (such as irrigated crops and rural living) accounted for approximately 39% of the catchment area and only 2% was considered to support urban or industrial land uses. Undeveloped land (predominantly mangrove communities) fringes the river over a distance of some 25 km between the rural land use areas and East Arm; this has the potential to act as a buffer to reduce the amounts of pollutants reaching East Arm from sources in the upper catchment.

Some 3 km upstream of the Project location is Hudson Creek, which has a history of livestock export and light industrial uses and which receives inputs from the Darwin Correctional Centre's Sewage Treatment Plant (KBR 2020). It also includes rural and urban land; Skinner et al (2009) calculated that 50% of the catchment supported urban or industrial land uses.

Approximately 6 km upstream of the Project location, the Palmerston Wastewater Treatment Plant discharges treated effluent into Myrmidon Creek; this enters the Elizabeth River estuary at the head of East Arm. The mass loadings of the nutrients in the release from the Plant in 2005-06 were 40 tonnes of ammonia, 69 tonnes of Kjeldahl nitrogen and 18 tonnes of phosphorus (Power and Water Corporation 2006); it appears that no more recent data are publicly available. Skinner et al (2009) note that treated sewage effluent is the dominant anthropogenic point source of nutrients to Darwin Harbour. However, based upon the data of Butler et al (2013), Munksgaard et al (2018) considered that the water body in Darwin Harbour is generally nitrogen limited. Burford et al (2008) determined that the main input of nitrogen to the harbour was from the open ocean, while inputs from rivers and wastewater treatment plants entering the harbour were relatively minor.

Industrial, urban and rural land uses all represent sources of potential pollutants that may accumulate in the Project dredging area. The mean annual pollutant loads contributed to the harbour from the Elizabeth River, Hudson Creek and Myrmidon Creek catchments were estimated by Padovan (2001) based upon the 1995-96 and 1996-97 Wet Seasons, and by Skinner et al (2009) for the 2006-07 Wet Season; these estimates are presented in Table 7. A fourth catchment, Palmerston South, also discharges into the Elizabeth River, though the pollutant loads predicted by Padovan (2001) and Skinner et al (2009) were markedly lower than those from the Elizabeth River and Hudson Creek catchments.

Table 7 Estimated mean annual pollutant loads to East Arm from Elizabeth River and Hudson Creek

	Elizabeth River			Hudson Creek			Myrmidon Creek		
	1995-97	2006-07	Change	1995-97	2006-07	Change	1995-97	2006-07	Change
Nitrogen (t)	69	72	+3	15	14.4	-0.6	1.4	1.76	+0.36
Phosphorus (t)	3.5	3.56	+0.06	3	1.32	-1.78	0.1	0.15	+0.05
Arsenic (kg)	70	54	-16	40	14	-26	2.0	1.64	-0.36
Cadmium (kg)	14	18.6	+4.6	6	3.17	-2.83	0.2	0.4	+0.2
Chromium (kg)	156	202	+46	220	55.9	-164.1	3.0	6.51	+3.51
Copper (kg)	373	576	+203	189	308	+119	10.0	31.6	+21.6
Lead (kg)	132	428	+296	327	287	-40	2.0	33.2	+31.2
Nickel (kg)	138	98.8	-39.2	43	19.2	-23.8	2.0	2.35	+0.35
Zinc (kg)	1,638	2,300	+662	1,860	969	-891	12.0	108.0	+96.0

4.2.3.3 Distribution of contaminants

Environmental factors that may potentially affect the distribution of contaminants within Darwin Harbour, and hence could influence the concentrations of contaminants in the sediments of the dredging footprint, include:

- Strong tidal currents that readily mobilise seafloor sediments on flood and ebb tides, especially during spring tide periods.
- Eddies in water flows that enhance the settlement of sediments from the water column in certain areas (such as at the eastern end of EAW).
- Wind-driven water circulation that can redistribute large amounts of seafloor sediments, particularly during tropical storms and cyclones.

Each of these factors would primarily influence the distribution of fine sediment fractions, to which many metals are typically bound at higher densities (Batley 1995, Munksgaard & Parry 2002, Welch et al 2008).

Munksgaard et al (2018) noted that sediments provide time-integrated measures of net accumulation of contaminants at a location; these are independent of the seasonal and tidal variations in contaminant concentrations within the overlying water column.

4.2.3.4 Potential acid sulfate soils (PASS)

In the Darwin region, PASS has been identified in association with mangrove sediments (e.g. Hill & Edmeades 2008).

The materials to be dredged as part of the Project were sampled by AECOM (2020) and an assessment of the potential risk associated with acid sulfate soils was undertaken. All sediments sampled were identified as having the potential to be acid generating (to varying degrees) if left in an oxygenated environment post-dredging. The outcome of that assessment is summarised below:

- No existing acidity (indicated by titratable actual acidity) was reported in any of the samples.
- However, all samples reported potential acidity (chromium reducible sulfur %) ranging between 0.04%S and 0.23%S, indicating presence of PASS (i.e. un-oxidised sulfides) which could generate acidity upon oxidation.
- Hence, the sum of existing and potential acidity in all samples exceeded the action criterion (as per Simpson et al [2018]) of 0.03%S.

- All samples reported some acid neutralising capacity (ANC) ranging between 1.57 %S and 18.5%S. ANC is noted potentially due to the abundance of naturally occurring calcium carbonate such as shell fragments and coral skeletons as observed in the field. The ANC ranged between 19 and 231 times greater than the sum of existing and potential acidity concentrations; well within the adopted criterion of ANC being greater than 15 times the total acidity of samples (as per Simpson et al [2018]).

4.2.4 Hydrodynamics and sediment transport

The tidal range in Darwin Harbour is between 0 m (i.e. LAT) and approximately 8.2 m above LAT (Table 8). The mean spring tide range is approximately 5.6 m and the approximate mean neap tide range is 1.8 m. Tides within Darwin Harbour are predominantly semidiurnal, with a slight inequality between the successive tides during a single day.

Rigby et al. (2014) indicate that the wave climate in the region is dominated by locally generated waves, with little incident swell entering the harbour from the west, except under monsoonal cyclone or tropical low events. Between November and March, north-westerly winds blow over the uninterrupted fetch of the Timor Sea, increasing incident wave energy in Beagle Gulf and at the entrance to Darwin Harbour. Due to the alignment and narrow nature of the harbour entrance and the presence of the Tiwi Islands to the north, the interior of the harbour is sheltered from long period swell, and any swell that does enter the harbour is quickly dissipated by the generally shallow bathymetry and indented nature of the harbour shoreline.

The daily harbour inflow and outflow is approximately 216 million m^3 on a spring tide and 71 million m^3 on a neap tide. These flows represent 69% and 29% of water flows in Darwin Harbour respectively (Williams et al 2006). Tidal flows are strongest in the narrowest sections of the harbour, including sections of the East Arm channel.

Table 8 Darwin Harbour tidal planes

Tidal Plane	Description	LAT (m)
HAT	Highest Astronomical Tide	8.2
MHWS	Mean High Water Springs	7.0
MHWN	Mean High Water Neaps	5.1
MSL	Mean Sea Level	4.24
AHD	Australian Height Datum	4.105
MLWN	Mean Low Water Neaps	3.3
MLWS	Mean Low Water Springs	1.4
LAT	Lowest Astronomical Tide	0.0

Modelling by Brinkman and Logan (2019) indicates that flood tidal current velocities within the harbour are generally higher than ebb tide velocities. Elevated tidal energy, particularly during spring tides, results in the regular resuspension of fine sediments from the seabed, leading to naturally high turbidity levels within the harbour. The suspended sediments are then carried into areas within the harbour where they are deposited, but are not resuspended on ebb tides (Williams et al 2006, Brinkman & Logan 2019).

It is noted that Baird (2019) found ebb tidal flows (measured between May and July 2019) at a site within the body of East Arm tended to be stronger than flood tidal flows, with peak current speeds of 0.6-0.7 m/s during spring tides and 0.2-0.25 m/s during neap tides. This suggests that the relative ebb/flood tidal flows within the main East Arm channel are contrary to those within the harbour in general. As the Project location is outside of the channel, the relative flows at the site are likely to be aligned with those within the harbour in general.

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Brinkman and Logan (2019) consider that, during the Wet Season, there is a significant contribution of fine sediments to the harbour from terrestrial sources draining into the harbour via the reaches of West, Middle and East Arms. McKinnon et al. (2006) calculated that the annual total suspended sediment load transported to the harbour had increased by a factor of 1.3 compared to the pre-urbanisation load. Nawaz (2010) estimated that in the order of 80% of terrestrial sediment transported into the harbour was from channel erosion rather than from sheet erosion; the latter being a more likely source of contaminant inputs than the former.

Previous investigations within the harbour have demonstrated that complex circulation occurs near headlands and embayments that includes jets, eddies, separation points and stagnation zones. This may result in trapping of fine sediments at headlands and in embayments; modelling by Brinkman and Logan (2019) predicts that the nearshore portion of the Project footprint lies within an area of net sediment deposition, while net erosion is predicted in the portion further from shore.

4.2.5 Geochemical assessment of material to be dredged

In August 2020, AECOM undertook a geochemical assessment of the sediments within the dredging footprint. A summary of the potential contaminant inputs to the dredging area is provided above.

Following the completion of the geochemical assessment sediment sampling campaign, the area to be dredged was modified as part of the ongoing engineering design phase of the Project; the modified Project layout is presented in Section 1 and in the Draft EIS (Chapter 2). It is emphasised that further changes in dredging areas and volumes are likely to occur as part of the detail design process; therefore, the Dredging Contractor’s Dredging Management Plan will be reviewed by the Proponent to ensure that:

- A sufficient number of the locations sampled during the AECOM survey lie within the final design dredging footprint to meet NAGD recommendations.
- The depths of sampling undertaken during the AECOM survey are sufficient to meet NAGD recommendations.
- Adequate account is taken of any new potential sources of toxicants (e.g. spills, new discharges into the harbour) that may have arisen between the time of the AECOM survey and the scheduled commencement of dredging.

The full geochemical assessment report (AECOM 2020) is included as Appendix H of the Draft EIS for the Project. Key findings from the assessment were:

- Within the dredging footprint for the ship lift, berth and manoeuvring basin no contaminants of potential anthropogenic origin were detected at levels above the criteria levels within the NAGD. That is, all contaminants of potential anthropogenic origin in these areas were present at concentrations at which, under the NAGD, toxic effects on organisms are not expected. Hence there was no evidence of inputs of contaminants to the sediments arising from the operation of EAW.
- All samples collected within the dredging footprint returned TBT concentrations below the laboratory limit of detection and therefore the NAGD Low Screening level.
- Arsenic concentrations typically exceeded NAGD criteria levels. Previous studies (e.g. Padovan 2003, Fortune 2006, URS 2009) have attributed elevated arsenic concentrations in Darwin Harbour sediments to local geological influence (e.g. weathering of bedrock in the catchment). Some of these studies (e.g. URS 2009) have demonstrated that, in the natural marine environment, the arsenic has low bioavailability. That is, the arsenic is bound to the sediment in such a way that it will not readily enter the food chain.
- The distribution of potentially acid producing sediments within the material to be dredged cannot be accurately mapped. Hence it must be assumed that potentially acid-producing sediments could be dredged at any time during the campaign. It should be noted that only the surface layer of the deposited sediments will be exposed to air and hence potentially acid producing. As sediments are progressively buried as the dredging campaign progresses, they will again become anoxic and their potential to generate acid will decrease accordingly.

If Option 1 is selected as the preferred dredging methodology, then there will be a need to ensure that the tailwater discharged from the settling pond system complies with pH criteria levels, and also to monitor metals concentrations in the tailwater as decreased pH levels could stimulate the release of metals into the overlying water column; this monitoring is detailed in Section 9.4.3 of this Plan. There will need to be a particular focus on arsenic; whilst it is considered to have low bioavailability in the natural seawater of Darwin Harbour, in the presence of reduced pH the concentrations of arsenic in the tailwater may gradually trend upwards over the course of dredging. As described in Section 8.3 of this Plan, management measures will be implemented in the event that tailwater pH levels become unacceptably low, or metals concentrations become unacceptably high.

With respect to the reclamation area within the Project site, the porewater will not be retained within the dredged material for a sufficient period of time for release of toxicants (from the sediment into the porewater) to occur; rather, the porewater will percolate into the harbour waters and be rapidly diluted under the influence of the prevailing currents.

In conclusion, the investigation has shown that the sediments are suitable, from a geochemical standpoint, to be disposed into both the settling ponds at EAW and within the reclamation area within the Project site.

4.2.6 Marine water quality – Darwin Harbour

Water quality in Darwin Harbour is typically described as generally high, although naturally turbid most of the time. Water quality parameters vary greatly with the tide phase (spring versus neap; flood versus ebb), location (inner versus outer harbour), and with the season (Wet Season versus Dry Season). 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 within the harbour in general, with rainfall considered to have the greatest impact on water quality (increasing nutrients, suspended solids and chlorophyll a).

Tidal movement can play an important role in re-suspending material from the harbour floor into the water column and water quality in the dredging areas is predominantly impacted by suspended sediments resulting from fast moving currents.

Water quality is typically higher in outer harbour waters than within the inner harbour, though turbidity at the harbour mouth can be elevated in shallow areas due to re-suspension of sediments from intertidal flats, especially during spring tides.

A typical Darwin Wet Season extends from November to April and is characterised by warm air temperatures, convective storms and monsoonal weather which brings heavy rain and strong north-westerly winds and, in some years, cyclonic weather (Fortune 2016). These Wet Season conditions affect harbour water quality due to high surface runoff from the land (URS 2011).

There is no evidence of widespread water or sediment pollution in the Harbour (Fortune 2016, DENR 2020), although there some localised pollution has been identified in the past (e.g. Padovan 2003, Water Monitoring Branch 2005, Drewry et al 2011). Anthropogenic influences on Harbour water quality include the EAW port operations, historic industrial activities at Darwin Waterfront, Sadgroves Creek and wastewater outfalls (URS 2004); however, there has been no evidence of widespread or persistent hydrocarbon or pesticide pollution in the harbour (Darwin Harbour Advisory Committee 2007).

The harbour may be subject to occasional pollution events such as hydrocarbon spills, from potential sources such as:

- seasonal stormwater inflow from Darwin and Palmerston stormwater drainage networks
- creeks with industrial developments in their catchments (e.g. Hudson Creek, Sadgroves Creek)
- bulk hydrocarbon storage (e.g. at East Arm Peninsula, Darwin LNG plant and Channel Island Power Station)
- inventories in recreational vessels and commercial ships
- refuelling locations (e.g. HMAS Coonawarra, Cullen Bay, Fishermans Wharf).

Darwin Harbour water quality has been monitored against a series of Water Quality Objectives (WQOs) and reported by DENR (now DEPWS) in annual report cards since 2009. The annual report cards provide a score based on the following parameters:

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- dissolved oxygen (DO)
- Total Suspended Solids (TSS) (by way of a TSS – turbidity relationship)
- chlorophyll a (as an indicator of algae)
- nutrients (nitrogen and phosphorus)
- temperature, pH and salinity are also measured but not included in the determination of the report card score.

In 2020, water quality in East Arm was monitored at 23 sites through this process. The East Arm region has consistently met water quality objectives over the period since the program began in 2009. In the first year of the monitoring program, East Arm received a B grade rating, meaning three out of four of the water quality indicators met desired levels. Between 2010 and 2012 an A grade was given, meaning all four indicators met desired levels. The long-term trend in water quality in East Arm since 2009, based on this program, is shown in Figure 5 (DEPWS 2021). The 2013 report card for East Arm delivered a B grade as a result of DO concentrations outside of the WQO limits on four occasions. These exceedances were not harmful and were considered within the limits of natural variation for this area and not indicative of pollution (DLRM 2013). The B grade received in 2014 was attributed to nutrients (specifically total nitrogen), while those recorded in 2015 and 2017 were attributed to water clarity. The results of this program suggest that water quality in East Arm during Dry Season neap tides is generally very high.

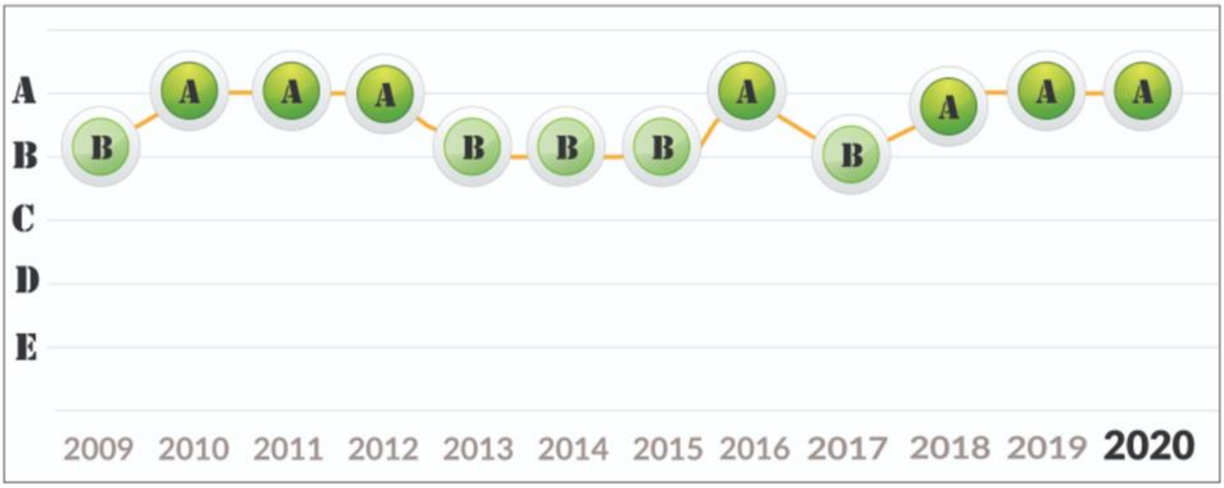

Figure 5 Darwin Harbour water quality report card long term trend

4.2.7 Water quality baseline data

Between 2008 and 2011, a number of water quality investigations were undertaken by URS on behalf of INPEX to characterise the existing conditions in East Arm (URS 2009, 2011). Table 9 presents summary statistics for Dry and Wet Season water quality, as recorded at a site off the southern tip of South Shell Island (URS 2011).

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 considered applicable to the dredging and reclamation works as this site has the nearest sensitive receptors (hard coral communities) to them, although modelling does not predict that the communities are at risk of detectable impacts from the works (refer Section 6.0).

Table 9 Summary water quality statistics for East Arm Wet and Dry Season (URS 2011)

	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
SSC (mg/L)*	10.8	7.1	46.4	14.1	7.2	64.7

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

4.3 Environmental receptors

4.3.1 Marine communities

Darwin Harbour has a complex assemblage of marine ecological communities, including rocky shore biota, hard corals, filter feeders (primarily soft corals and sponges), macroalgae, seagrasses, soft sediment biota, mangroves and fish communities. Smit, Penny and Griffiths (2012), in their summary of previous benthic habitat mapping of Darwin Harbour, suggest that the benthic habitats present in the inner and outer harbour differ significantly and are typically characterised as follows:

- Outer harbour:
  - extensive seagrass communities occur in shallow waters
  - corals and algae dominate on hard substrates in shallow waters.
  - deeper waters are characterised by filter feeder communities (e.g. sponges, soft corals).
- Inner harbour:
  - hard substrates in shallow and deeper waters consist of mixed communities or are dominated by sponge communities
  - no seagrass communities are present (though it is noted that, subsequent to the Smit, Penny and Griffiths [2012] report, there have been unpublished records of seagrasses around Wickham Point, and opposite the Channel Island boat ramp in Middle Arm).

Predictive modelling of the benthic habitats within, and in the vicinity of, the Project area was encompassed within the modelling of major habitat classes within Darwin and Bynoe Harbours that was undertaken by the AIMS in 2019 (Galaiduk et al 2019). This extensive program considered bathymetric, physical seabed and biological data collected during Project-specific and historical field sampling campaigns to produce spatial predictive habitat models (Galaiduk et al 2019).

It is noted that the model did not take account of water column characteristics such as turbidity, or factors such as sediment accumulation rates, any of which may preclude the establishment of certain biological communities (such as hard corals and seagrass) in areas that may otherwise be modelled as potentially suitable habitat for them. While the model provided a baseline for predicted benthic biodiversity, it was noted that improvements could be made in the future to better predict less common benthic classes (e.g. hard coral and seagrass) in the shallow subtidal and intertidal areas (Galaiduk et al 2019).

Subsequent habitat modelling undertaken by the Australian Institute of Marine Science (2021) built on the 2019 habitat modelling by incorporating additional field observation data and new and higher resolution datasets. The resultant benthic habitat predictions were presented at a 1 m x 1 m resolution and showed habitat suitability for six biological communities in Darwin Harbour: Filter Feeders / Octocorals, Hard Corals, Macro Algae, Seagrasses, Sponges and Bare Ground and Bare Ground (Figure 6). .

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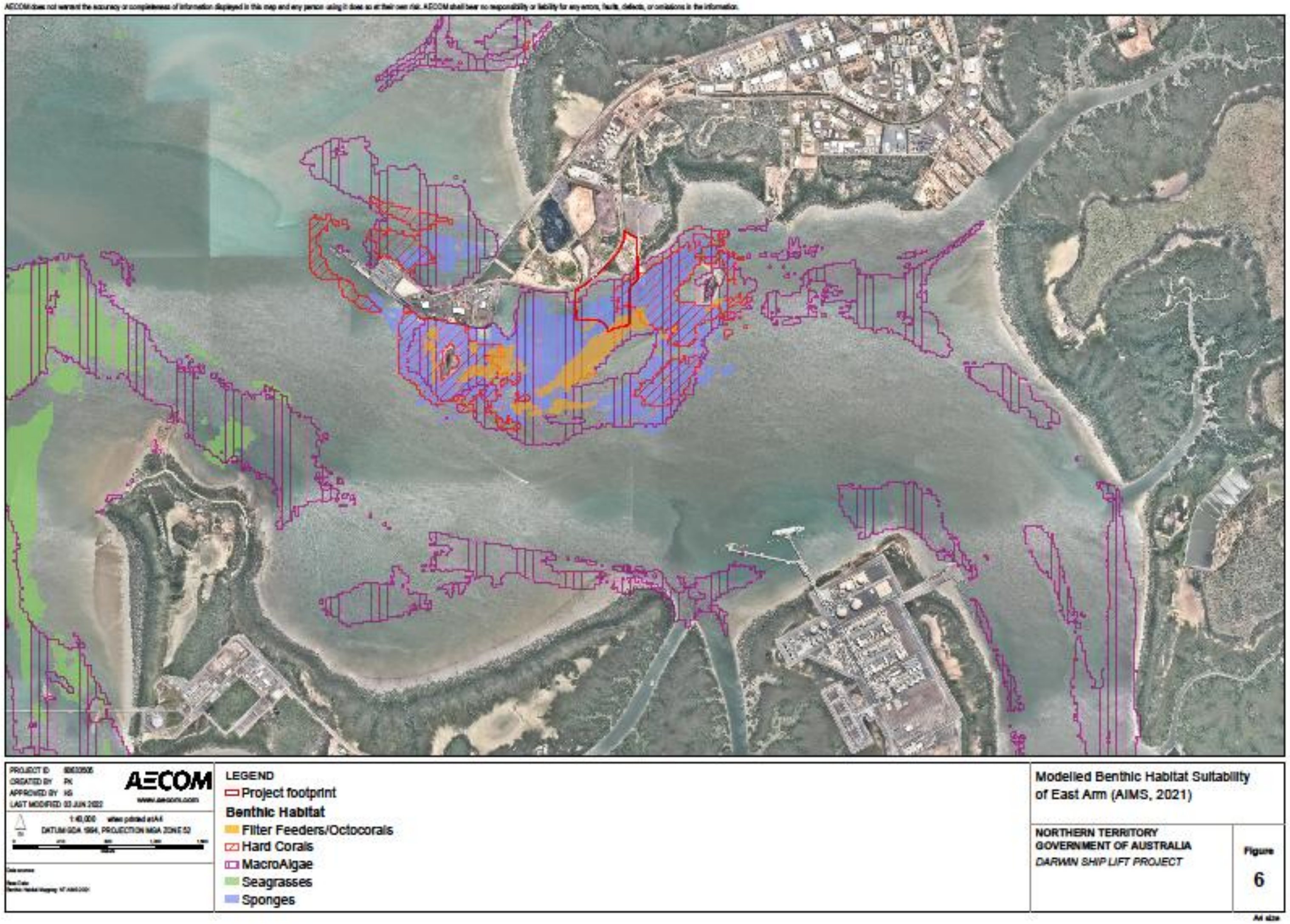

Figure 6 Modelled benthic habitats of the Project region

The map presented by AIMS (2021) showed predicted habitat suitability for each habitat type, with the following interpretations provided by AIMS (2021):

- Bare ground having the most extensive coverage across the southern Darwin Harbour region.
- Filter feeder/octocoral habitats were predicted to occur in deeper waters of the outer harbour, with some small patches of suitable habitat also predicted south of the EAW for both habitat types.
- Small patches of habitat suitable for filter feeders/octocorals were predicted south-west of Channel Island.
- Hard coral habitats were far more restricted within Darwin Harbour but predicted in shallower regions of the outer- and mid- Harbour, as well as an area to the south of EAW.
- The areas surrounding South Shell Island and Catalina Island in East Arm were identified as potentially suitable habitats for hard corals.
- Macro Algae habitats were typically predicted in shallower habitats, with the thresholded model predicting extensive patches throughout the mid harbour and within East Arm.
- Suitable habitats for seagrasses were not predicted within East Arm; however, they were predicted in patches throughout the mid-Harbour, with the largest patch predicted within Fannie Bay, and smaller patches predicted to line the top of the Middle Arm channel.
- Overall, areas adjacent to Fannie Bay and the mouth of the East Arm were identified as areas with potentially substantial benthic habitat coverage.

Within the northern East Arm region in the vicinity of the Project, mapping by AIMS (2021) shows:

- Suitable hard coral habitat is predicted to occur surrounding South Shell Island and shallow waters west of Catalina Island and encroaching into the Project footprint.
- Suitable filter feeder habitat within the offshore extremity of the Project footprint, extending offshore into the main channel of East Arm. Further areas are identified as suitable filter feeder habitat to the east and west of South Shell Island.
- No suitable habitat was identified for seagrass in the vicinity of the Project area.
- Large areas of suitable habitat for macroalgae and sponges were identified across wide areas of the northern East Arm region, including within the Project footprint.

For the Project EIS and Supplementary EIS it was necessary for benthic habitat surveys to be undertaken to assess the accuracy of the model predictions in areas of direct and potential indirect disturbance from the construction and operation of the Project. The first of these surveys was undertaken by AIMS in November 2020 (Case et al 2021), with the objective of refining the model in these areas, although the modelling undertaken by AIMS (2021) was deemed to provide a better representation of modelled habitats in East Arm. A review of all of the video records from the AIMS November 2020 survey transects within the area of direct disturbance from the Project was conducted, supplementing the five-points-per-frame analysis of selected frames from the video records undertaken by AIMS. This review confirmed AIMS' conclusion that the seabed in this area was predominantly bare substrate, with only scattered filter feeders and no visible hard corals or seagrasses.

The second survey was conducted by SLR Australia in May 2022 and focussed on collecting data in the vicinity of South Shell Island and Catalina island, the closest sponge and hard coral communities to the Project location. The results of this survey were not available at the time of preparation of this document but will be incorporated into the Dredging Contractor's DDSPMP.

4.3.1.1 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. A total of 123 species of corals have been recorded in Darwin Harbour (Wolstenholme, Dinesen & Alderslade 1997). Hard coral communities are typically dominated by colonies with massive (e.g. Faviidae, *Porites* spp.), foliose (e.g. *Turbinaria* spp.) or encrusting (e.g. Faviidae) growth forms (INPEX 2010). Habitat modelling undertaken by AIMS (2021) (Figure 6) predicted potential hard coral habitat in East Arm to occur at a small number of locations, with previous surveys also identifying hard coral communities in the vicinity of South Shell

Island and Catalina Island. Hard corals are dominant within some of the benthic communities around South Shell Island, mainly on the western side of the island. A reduction in hard coral cover was recorded at one South Shell Island monitoring site during the INPEX capital dredging campaign conducted between 2012 and 2014; this was concluded to be as a result of a combination of elevated turbidity and increased sedimentation (Cardno 2014a).

Reductions in hard coral cover at South Shell Island monitoring sites were also detected during the MSB capital dredging campaign that was undertaken within the same period as the much larger INPEX campaign (Macmahon 2013, Department of Infrastructure [DoI] 2014). Sediment plume modelling for the dredging works covered in this Plan (Section 5.0) predicts that the South Shell Island coral community is sufficiently distant from the works to not be at risk of detectable impact.

Other well-known hard coral communities in Darwin Harbour include the following:

- Off the north-east shore of Wickham Point.
- Weed Reef, Plater Rock and Kurumba Shoal, on the western side of the harbour, and Dudley Point at the northern end of Fannie Bay.
- 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 *Heritage Act 2011*.

All of these communities are sufficiently remote from the dredging, reclamation and tailwater discharge locations that there is no credible risk of impact to them.

4.3.1.2 Filter feeder communities

Filter feeder communities are those that primarily comprise sponges, gorgonians (sea fans and sea whips) and other soft corals. They primarily occur on intertidal or subtidal hard substrates and may co-occur with hard corals, giving rise to “mixed species” communities. However, they also occur at depths shallower than, and deeper than, those at which hard corals thrive and can be the dominant component of the benthic community in some areas.

Habitat modelling undertaken by AIMS (2021) identified areas of potential filter feeder habitat in the vicinity of the Project footprint and across much of the northern side of East Arm (Figure 6) Sponge habitat was modelled separately by AIMS (2021), though it is noted that sponges are also filter feeders and are typically mapped together with them.

It is recognised that filter feeder communities around South Shell Island may contain species that could be of importance to bio-prospecting. However, it is also recognised that large areas of filter feeder communities are present both within East Arm and across the broader harbour (Geo Oceans 2011, 2012a,b; Siwabessy et al 2015, Galaiduk et al 2019).

Benthic habitat monitoring during the MSB capital dredging campaign (undertaken in 2012 and 2013) found no statistically significant changes in filter feeder communities across the three surveys (Macmahon 2013, DoI 2014). This is somewhat unsurprising as these communities are generally less sensitive than corals to the physiological pressures of reduced benthic light availability and sedimentation associated with dredging activities or natural environmental conditions. Filter feeder communities were not monitored as part of the INPEX dredging campaign that was conducted within the same period as the MSB dredging (INPEX 2013).

4.3.2 Protected marine species

4.3.2.1 Cetaceans

Three species of coastal dolphin are the most commonly recorded cetaceans in Darwin Harbour: the Australian humpback (*Sousa sahulensis*; formerly known as the Indo-Pacific humpback), Indo-Pacific bottlenose (*Tursiops aduncus*) and Australian snubfin (*Orcaella heinsohni*) dolphins (Palmer 2008). INPEX (2011) details knowledge of the taxonomy, distribution, microhabitats, residency and site fidelity of the three species of coastal dolphins, while Brooks and Pollock (2014), Brooks et al (2017) and Griffiths et al (2020) present data from the extensive surveys undertaken for the INPEX Ichthys LNG project. In addition, the conservation status of coastal dolphins in the NT has been assessed by Palmer et al (2017).

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Other species of dolphin that may be present in Darwin Harbour include common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), spotted dolphin (*Stenella attenuata*) and bottlenose dolphin (*Tursiops truncatus*). Pods of false killer whales (*Pseudorca crassidens*) are considered by Palmer et al (2009) to be regular visitors to the harbour. It is notable that all cetaceans are protected under the EPBC Act.

Griffiths et al (2020) summarise the outcomes of studies of the abundance, movements and habitat use of coastal dolphins (Australian humpback, Indo-Pacific bottlenose and Australian snubfin) in the Darwin region (Darwin Harbour, Bynoe Harbour and Shoal Bay). On the basis of data from surveys undertaken between 2011 and 2019, and model outputs based upon capture-recapture data from these surveys, Griffiths et al (2020) concluded the following:

- All three species typically occurred at low densities, exhibited substantial emigration and had fluctuating population size.
- Humpback dolphins were the most commonly observed of the three species and there was demonstrable movement of this species between the three monitoring areas. Over the course of the monitoring program, there was a significant decrease in estimated abundance in Darwin Harbour a non-significant increase in Bynoe Harbour and a non-significant decrease at Shoal Bay.
- The snubfin dolphin population was small, and was considered to have the greatest variability in population size and the greatest degree of temporary emigration (i.e. temporarily leaving the study area). Modelling indicated a significant negative trend in estimated abundance over the course of the monitoring program.
- The bottlenose dolphin population was the smallest, with an apparently high degree of temporary emigration and a significant overall decrease in estimated abundance.
- The reasons for the significant declines were considered to be unclear, but were thought to potentially be related to population dynamics, environmental or anthropogenic factors.
- The estimated population density of each species appeared to be similar to average densities in NT coastal waters.
- The estimated population densities of humpback and snubfin dolphins appeared to be within the ranges of densities recorded in Western Australia and Queensland, while the estimated densities of bottlenose dolphins in the Darwin Harbour region and the NT appeared to be lower than in similar northern Australian locations.
- The estimated temporary emigration rates were considered to be similar to those in coastal dolphin populations elsewhere in Australia and overseas.
- Apparent survival rates were considered to be similar to, or lower than, those reported elsewhere for the same species, though the difficulty in accurately assessing survival rates was recognised. It was considered that emigration probably had a greater influence on population growth than deaths.

It is noted that there are no known areas of critical feeding or breeding habitat for dolphins within the zone of potential effects from the development and operation of the Project. The Indo-Pacific humpback and the Australian snubfin dolphin appear to be opportunistic generalist feeders, eating a wide variety of fish both on the seabed and within the water column (Parra 2006). No calving areas have been identified in Australian waters for either species and little is known of their reproductive biology or population structure (Ross 2006, Parra et al 2006).

The EPBC protected matters database also lists the following as "species or species habitat [that] may occur within area", though the species are not known to occur within Darwin Harbour:

- Blue whale (*Balaenoptera musculus*).
- Bryde's whale (*Balaenoptera edeni*).
- Humpback whale (*Megaptera novaeangliae*).
- Killer whale (*Orcinus orca*).

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4.3.2.2 Dugongs

Dugongs (*Dugong dugon*) 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 (2014b) 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 variations) were evident. There was a higher number of dugong observed in shallower waters (6 – 10 m), generally in foraging areas where seagrass was present. Variation in dugong observed between surveys within sites was concluded to most likely be a result of short term movement of dugongs 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 (Cardno, 2014b).

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 (Cardno, 2014b).

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 2014b).

In general, it is considered that dugongs could occur anywhere in the harbour that could support seagrasses or macroalgae. Within Darwin Harbour, dugongs have been observed at Channel Island in Middle Arm, where they were thought to be feeding on macroalgae (Whiting 2002). However, there are anecdotal records of seagrass occurrence in the vicinity of the Channel Island boat ramp and this may have been a contributory factor to their presence. While some macroalgal communities may be present in the vicinity of the Project area, substantially greater areas of potential foraging habitat for dugong exist elsewhere in the harbour (INPEX 2011).

4.3.2.3 Turtles

Six species of marine turtles are known to occur in NT waters. Of these, four (green [*Chelonia mydas*], hawksbill [*Eretmochelys imbricata*], olive Ridley [*Lepidochelys olivacea*] and flatback [*Natator depressus*]) are considered to occur in the Darwin region, though olive Ridleys are thought to occur only occasionally within the harbour (Cardno 2014b). Loggerhead turtles (*Caretta caretta*) are suspected to be infrequent users of the harbour and the leatherback turtle (*Dermochelys coriacea*) is considered to be an oceanic species which is unlikely to occur in Darwin Harbour (Whiting 2003).

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 (INPEX 2010). 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 2011).

Cardno (2014b) implemented the Turtle and Dugong Monitoring Program for the INPEX Ichthys project; this included aerial and land survey techniques to monitor the abundance and distribution of turtles around Darwin Harbour. They concluded that:

- Statistical analysis of population and density estimates formed in this study did not indicate that the distribution or abundance of these animals had changed since the baseline phase.
- During survey D4 (during dredging) 813 turtles were sighted, which was higher than the average number of turtles sighted per survey during the baseline phase (634 turtles), but approximately 17% lower than the number of turtles recorded during baseline survey B3 (984 turtles), undertaken at the same time of year (October 2012).
- Statistical analyses of turtle population densities did not detect any significant difference between the impact and control treatments in either phase, or between baseline and dredging phases, for either treatment. In contrast, estimates of turtle density based on raw observations were significantly higher at the control blocks compared with the impact block during the baseline phase, but not during the dredging phase. The observed temporal and spatial variation in turtle distribution and abundance was considered possibly to be a result of short-term movements in and out of specific areas, possibly due to avoidance behaviour and/or the pursuit of more optimal foraging areas.
- Turtle sightings were most frequently recorded within relatively shallow water habitat, most commonly in waters less than 5 m in depth; however, a small number were sighted in the deep water channels near the Vernon Island (outside of Darwin Harbour) in waters greater than 30 m depth.
- Where benthic habitat type had been identified and mapped, turtles were primarily sighted in association with gravel, sand and reef. Only 3% of turtle sightings were associated with mud habitat, the predominant habitat within, and around, the Project area.

4.3.2.4 Sawfish

The EPBC protected matters database indicates that dwarf sawfish (*Pristis clavata*), green sawfish (*Pristis zijsron*), freshwater sawfish (*Pristis microdon*) and narrow sawfish (*Anoxypristis cuspidata*) may potentially inhabit Darwin Harbour, or that their habitats may be present in the harbour. While these species are widely distributed throughout Australian tropical waters, within the Atlas of Living Australia (ALA 2021), in Darwin Harbour the following are recorded:

- One record of a dwarf sawfish caught in a gill net in the creek leading to the Gardens Golf Course. This species inhabits shallow (2-3 m) coastal waters and estuarine habitats (Department of the Environment, Water, Heritage and the Arts [DEWHA] 2009) and is not known to move into freshwater areas (Thorburn et al 2007). Estuarine habitats in north-western Australia are used as nursery areas, with immature juveniles remaining in those areas up until three years of age (Thorburn et al 2007). Adults have been found to seasonally migrate back into inshore waters (Peverell 2007).
- One record of a green sawfish caught on a line and released off Lee Point, in the outer harbour. This record was made by a ‘citizen scientist’ and the identification verification status on the ALA database is deemed to be ‘uncertain’. However, elsewhere in northern Australia most records of the species have been from marine and estuarine areas (Thorburn et al 2003, Peverell et al 2004) and they have been noted to move into estuarine or more fresh waters to breed during the wet season and subsequently move into marine waters after the wet season (Peverell 2005).
- There are no records of freshwater sawfish within harbour waters. Elsewhere in northern Australia, it has been reported that their first three to four years of life are spent in freshwater (Larson et al 2006, Thorburn et al 2007) before moving into marine waters. They are thought to breed either in freshwater (Peverell 2005) or in marine waters (Thorburn et al 2007).
- There are no records of narrow sawfish within harbour waters.

Although there is a limited number of records of the four sawfish species within harbour waters, studies elsewhere in northern Australia indicate that there is the potential for them to occur in the vicinity of the Project area during parts of their lifecycles; this may only be transitory as they move between freshwater and marine habitats before and after the wet season.

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4.3.3 Migratory bird species

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

Since November 2009, shorebird monitoring has been undertaken at EAW and the settling ponds through the program developed in accordance with EPBC Approval 2010/5304 for the EAW Expansion project.

Field assessments identified that the Project area is not a known or potential roost site for threatened or migratory shorebirds (Lilleyman, Lawes & Garnett 2013). These studies noted that during high tides small numbers of birds were observed to be roosting on saline flats and in mangrove areas along other areas of the East Arm Peninsula; however, no large aggregations (>30 birds) of roosting birds were detected anywhere other than the EAW settling ponds, with very few birds observed foraging or roosting on the foreshore areas within the Project area.

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 EAW 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 EAW area at numbers greater than 0.1% of the fly away population by Chatto (2003).
- 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, Lawes and Garnett (2013).
- At least 2000 migratory birds have been recorded
- Twenty-two migratory shorebird species have been recorded within the study area (EMS 2011).

Nationally significant numbers of some migratory birds listed under the EPBC Act roost on Pond D at EAW. Recent survey data indicates that the total abundance of roosting shorebirds has increased at EAW since 2010 (Lilleyman et al 2020). Previous survey work in Darwin Harbour has shown that the EAW roost site is the only available roost site for shorebirds when the tide is greater than 7.6 m as available roosting space at all other survey sites is greatly reduced (Lilleyman et al. 2018). Further preliminary tagging studies have indicated that separate shorebird sub-populations roost at EAW to those tagged at other known natural roosting sites within Darwin Harbour (Lilleyman et al 2020). Surveys have not identified any use of the intertidal area within the Project area as being utilised by EPBC listed bird species for roosting.

Based on a literature review and three field observation periods in 2022 (during which two common sandpipers [*Actitis hypoleucos*] were the only migratory shorebirds observed within the Project area), AECOM (2022) noted that, while migratory shorebirds may occasionally forage within the Project area, this appears to be uncommon and is unlikely to contribute to EAW's status as important habitat, which is derived from the populations utilising habitat at the EAW ponds. The Project area provides feeding habitat only during spring low tides, during which time such habitat would be plentiful throughout the Darwin Harbour shoreline.

4.3.4 Other EPBC listed species

The EPBC protected matters database indicates that the following threatened “species or species habitat may occur within [the] area”, though there are no records (in the Atlas of Living Australia) of these species occurring within Darwin Harbour:

- Great white shark (*Carcharodon carcharias*)
- Northern river shark (*Glyphis garricki*)
- Whale shark (*Rhincodon typus*).

The database also indicates that the following migratory marine “species or species habitat may occur within [the] area”:

- Estuarine crocodile (*Crocodylus porosus*) – this is known to occur within Darwin Harbour but is likely to typically avoid areas of high vessel activity, such as the dredging location. Because only limited nesting sites for the estuarine crocodile are available inside Darwin Harbour, the area is not considered critical habitat for crocodile survival in the NT (Whiting, 2003).
- Coastal manta ray (*Manta alfredi*) and oceanic manta ray (*Manta birostris*) – manta rays are known (from anecdotal accounts) to occur in the harbour, though there are no records (in the Atlas of Living Australia) from which to determine which particular species have been present.

4.4 Historical site use

The Project site appears to have been vegetated by natural scrub and mangrove until 1927, when the Commonwealth of Australia acquired East Arm properties for the purpose of establishing a quarantine station, with associated facilities located to the north of the Project site (KBR 2020).

The Project site and its surrounds were used during World War II for a range of activities, with a flying boat base and the lugger maintenance section located within the area. The flying boat base comprised a number of components, including a large tarmac hardstand, hangar, workshop and stores with associated maritime infrastructure. The latter included a large concrete ramp enabling Catalinas to be taken in and out of the water (the RAAF Catalina Ramp) anda concrete slipway with iron rails to serve the Marine Section vessels. Some of this infrastructure falls outside of the Project site, such as the timber jetty located to the east of the flying boat base site (Cosmos 2015).

The flying boat base also included a range of offshore marine infrastructure, including permanent Catalina and vessel moorings comprised of at least 22 seaplane moorings, nine marine craft buoys, five lugger buoys, three warping and steadying buoys, three marker buoys, and one submarine buoy (Cosmos 2015).

Maintenance and repair activities, including refuelling, were largely conducted on the hardstand area at the base; however, some maintenance works such as engine tuning, minor repairs and supply activities were carried out on the Catalinas whilst they were on their moorings, under tow or taxiing (Cosmos 2015).

In the 1980s, the former RAAF Catalina Ramp was opened to the public by the NTG for use as a recreational boat ramp. The boat ramp became one of the most popular ramps in Darwin Harbour due to its length, which enabled small craft to easily access the harbour waters during most tidal phases. However, in 2005 the boat ramp was no longer required to support recreational boating as a new recreational boat ramp was constructed at East Arm, north of Catalina Island (KBR 2020).

At present, the site is currently used for a marine services business. It has a car park, site office and hardstand areas which are used to conduct marine services activities (including marine equipment and material hardstand/laydown), a works depot and marine workshop.

During the FEED stage of the Project a geophysical survey was undertaken for the identification of potential unexploded ordnance (UXO) (G-Tek 2017). Prior to dredging commencing, a geotechnical investigation will be conducted, which will also include a diver survey to investigate and remove any potential targets identified in that survey.

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4.5 Cultural heritage

4.5.1 Indigenous cultural heritage

Advice sought from the NT Heritage Branch in April 2018 confirmed that there are no existing registered Aboriginal archaeological sites within the proposed Project area. The AAPA certificate issued for the Project (RA2018/46, dated 18 January, 2019) indicates that there are no sacred sites within the Stage 1 dredging footprint, while two registered sacred sites are within 1 km of the Project area:

5073-66 - Yirra (also known as Catalina Island), including the sand bar that extends in a north-westerly direction form the northern tip of the island; approximately 650 m to the east.

5073-90 – described on the AAPA certificate as ‘a rock in the harbour at East Arm’; this is known locally as Old Man Rock; approximately 900 m to the south-east.

4.5.2 European heritage

A number of cultural heritage surveys and archaeological assessments have been completed for the East Arm area as part of the EAW expansion and MUBRF projects. These assessments included field investigations and review of both cultural and indigenous heritage within portions of the proposed Project footprint, including:

- East Arm Multi-User Barge Ramp Facility, Recovered Cultural Objects, Maritime Archaeological Analysis Report (Cosmos 2015).
- Multi User Barge Ramp Facility – Archaeological Report (Aurecon 2015).
- Archaeological Survey of the EAW Expansion and Surrounding Area, Darwin NT (Earth Sea Heritage Surveys 2011).

While a search of the NT Heritage Register indicated that no nominated or declared heritage places are located within the immediate Project area, the East Arm Flying Boat Base (described in Section 4.4) included a range of offshore marine infrastructure, including permanent Catalina and vessel moorings comprised of at least twenty-two seaplane moorings, nine marine craft buoys, five lugger buoys, three warping and steadying buoys, three marker buoys, and one submarine buoy (Cosmos, 2015); some remnants of this infrastructure may be within the dredging footprint.

An archaeological assessment was undertaken for the adjacent MUBRF in 2014/2015 (Cosmos 2015). This investigation noted that the seabed within and surrounding the footprint of the MUBRF had served as a ‘rubbish dump’ from the early to middle years of the 20th century, and up to the present day. The majority of artefacts recovered during the survey represented discards into the harbour associated with various land-based and water-based activities, primarily relating to World War II use of the area. Similar material may be present within the Project dredging footprint.

A search of the Australian National Shipwreck Database noted that there are no registered shipwrecks within the dredging footprint. The search identified, within the general East Arm area, four registered shipwrecks including two Vietnamese refugee boats (ID3429 and ID3430), a two-part barge (ID3428) and *HMAS Kelat*. None of these registered shipwrecks have been placed on a heritage register.

The database search also identified a number of aircraft wreck sites within the general East Arm area. The Catalina 2 (RAAF Catalina A24-69) site was located within the database search area, but approximately 500 m to the south of the dredging footprint. It is charted as rising to 4 m below LAT. The Catalina 3 (RAAF Catalina A24-206) site is located to the south of Catalina Island, over 1 km from the Project site. Neither of the Catalinas are a registered heritage site.

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5.0 Environmental Factors and Objectives

Environmental factors are those features of the environment that may be impacted by an aspect or activity of a proposal. The NT EPA has identified 14 environmental factors, categorised under five themes: Land, Water, Sea, Air and People and Communities (NT EPA 2018).

Each environmental factor has an associated environmental objective against which the Project can be assessed, and which guides the development of impact mitigation and management measures set out within this Plan.

Table 10 lists the environmental factors that have been identified in the Project EIS Terms of Reference (NT EPA 2019) as those that may potentially be impacted by the Project activities set out in this Plan (i.e. the dredging and reclamation activities), the EPA objective for each and the potential impact pathway associated with the Project.

The Environmental Performance Objectives, management targets and measures for each environmental factor are defined in the Environmental Management Frameworks in Section 8.0.

Table 10 Environmental factors, objectives and potential impact pathways

Theme	Environmental Factor	Objective	Potential Impact Pathway
Sea	Marine flora and fauna	Protect marine flora and fauna so that biological diversity and ecological integrity are maintained.	Direct impact to or loss of marine habitats within or in close proximity to the dredge footprint due to dredging.
			Indirect impacts to marine ecosystems due to increased turbidity and subsequently reduced benthic light availability as a result of dredging and tailwater discharge.
			Underwater noise and vibration associated with dredging and other Project-related vessel movements.
			Smothering of benthic flora, fauna and infauna as a result of sedimentation during and following dredging.
			Interaction between vessels and marine fauna including entrainment in dredge and collisions with Project-related vessels.
			Introduced invasive marine pest (IMP) species may compete with, or prey on, local marine fauna.
			Potential impacts to coral spawning due to increased turbidity associated with dredging during or around the time of coral spawning events
			Introduction of IMP species from Project-related vessels may impact benthic communities through competition for food and resources.

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Theme	Environmental Factor	Objective	Potential Impact Pathway
	Marine environmental quality	Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.	Impacts to water quality resulting from suspended sediment loads created by dredging potentially impacting marine ecosystem values.
			Potential hydrocarbon release associated with vessel operations, equipment operation (hydraulic fluids), bunkering or vessel collision.
			Changes to the physico-chemical properties of the water column resulting from dredging and tailwater discharge.
			Introduction of IMP species may impact local environment by altering population dynamics of local species through competition and predation.
People and communities	Social, economic and cultural surroundings	Protect the rich social, economic, cultural and heritage values of the NT.	Suspended sediments generated by dredging activities settling upon cultural heritage sites.
			Physical impacts upon cultural heritage sites by Project vessels.

6.0 Sediment Transport Modelling and Impact Assessment

6.1 Synthesis of assessment approach

Sediment transport modelling was undertaken by AIMS to assess the potential impact of dredging for the Project on local water quality, and potential sedimentation impacts in the local area (Simão & Tonin 2020; Appendix I to the Project Draft EIS).

It is noted that:

- At the time of modelling, the Option 2 dredging methodology (only BHD and reclamation at the Project site; refer Section 2.3) was not under consideration. Hence, only modelling of Option 1 was undertaken. However, the Dredging Contractor will be required to undertake the works in a manner that enables compliance with the turbidity trigger levels detailed in Section 8.2.2 of this Plan.
- The modelling was conducted on a preliminary Project layout, using indicative estimates of dredging volumes; these differ in some respects to the layout and volumes presented in the Project Draft EIS. However, the modelling is considered to be sufficiently representative of the extents and magnitudes of potential changes in water quality that could occur in the vicinity of the dredging works to be of value for informing the environmental management framework presented in Section 8.2.4 of this Plan.

The following assessment of potential environmental impacts from the dredging works at the Project site was informed by:

- three-dimensional hydrodynamic models that incorporated water levels, wind, 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.

Details of the hydrodynamic and sediment transport models applied are presented in Simão and Tonin (2020) and are not repeated here. The outcomes of this modelling are discussed in Sections 6.2 and 6.3.

Modelling of elevated SSC associated with tailwater discharge from the settling ponds at EAW has not been repeated for this Project. Modelling of tailwater discharge from the same location (Pond E [South]), meeting the same water quality criteria, was completed for the MUBRF dredging program and has therefore been applied to assess potential impacts associated with tailwater discharge for the Project dredging program.

6.2 Tolerance limits for biological communities

6.2.1 Suspended sediment concentrations

Tolerance limits applied to the assessment of potential impacts from the MSB and MUBRF dredging campaigns are adopted for this Project. These tolerance limits were derived from turbidity data collected by URS (2011) in a long-term water quality study conducted in Darwin Harbour. The URS data were collected every 15 minutes at two sites in East Arm (South Shell Island and North-east Wickham Point) 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 gave 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.

This dataset is considered to be relevant in the context of the current Project as the South Shell Island monitoring location is in the vicinity of the benthic communities of value that are closest to the Project site and it provides the longest continuous water quality dataset for this region. Further, as reported in the Project Draft EIS a study was undertaken to review TSS[1] concentrations in the region using remote

[1] It is noted that turbid plume dispersion modelling, and dredging monitoring and management measures, utilise measures of SSC. However, satellite imagery interpretation provides data in terms of TSS as the contribution of suspended sediments to the

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sensing methods (EnSTaR 2021). This assessment applied the semi-analytic sediment model from Dorji et al (2016) to estimate TSS concentrations in surface waters, based on reflectance from MODIS satellite imagery. Using this methodology, TSS concentrations in East Arm were derived for the period February 1, 2010 – January 31, 2011; the period that data were collected by URS (2011), and then again for the period January 1, 2016 – October 30, 2020. While TSS derived through remote sensing methods and in situ turbidity measurements are not directly comparable, EnSTaR (2021) showed that, generally, based on the satellite-derived TSS results, TSS in Darwin Harbour during the period that the URS (2011) turbidity dataset was collected (median TSS = 4.72 mg/L, 95th percentile = 14.89 mg/L), was lower than that estimated for the period between 2016 – 2020 (median TSS = 5.4 mg/L, 95th percentile = 20.6 mg/L). Hence, it is evident that the tolerance limits derived for the INPEX dredging campaign, and adopted for the Project, are conservatively low relative to those that would be calculated from contemporary (2016-2020) data.

As there may be a need to dredge during either or both of the Dry and Wet Seasons, tolerance limits for these seasons will be adopted from the appropriate (Dry or Wet Season) subset of the one-year baseline dataset of water quality (URS 2011), 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 2011).

As the sediment transport model calculates excess (above background) SSC caused by the dredging 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 tolerance limit of 25 mg/L.

6.2.2 Sedimentation

Tolerance limits for sediment deposition on mangroves were derived by INPEX (2010, 2011) 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 and MUBRF dredging programs and will also be applied to the Project dredging program. The tolerance limits are based on the literature suggesting that 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 (2011) 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. Notwithstanding this, a sedimentation tolerance limit of 15 mm was included in the approved Dredging and Spoil Disposal Management Plans for both the Ichthys capital dredging campaign (INPEX 2013) and for the Ichthys maintenance dredging campaigns (INPEX 2018). It is noted by INPEX (2018) that “*the tolerance limit values were extensively discussed with and endorsed by the Ichthys Project Dredging Expert Panel*”.

6.3 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 WA EPA (2016) Technical Guidance for the Environmental Impact Assessment of Dredging Proposals were adopted:

- **Zone of High Impact**: this zone constitutes the direct footprint of the dredged area and a 20 m wide annulus around the footprint 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 (beyond a period of five years) modification of the benthic habitats in this zone. The outer edge of the Zone of Moderate Impact is

total amount of suspended solids in the water column cannot be determined in isolation from other (non-sediment) suspended solids.

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 6.2.1). 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 6.2.1).

6.4 Modelling results

Model outputs are presented as:

- 90th percentile plot of modelled SSC (mg/L) (Figure 7)
- 95th percentile plot of modelled SSC (mg/L) (Figure 8)
- Sediment deposition (mm) following the completion of dredging and the 30-day post dredge period (Figure 9).

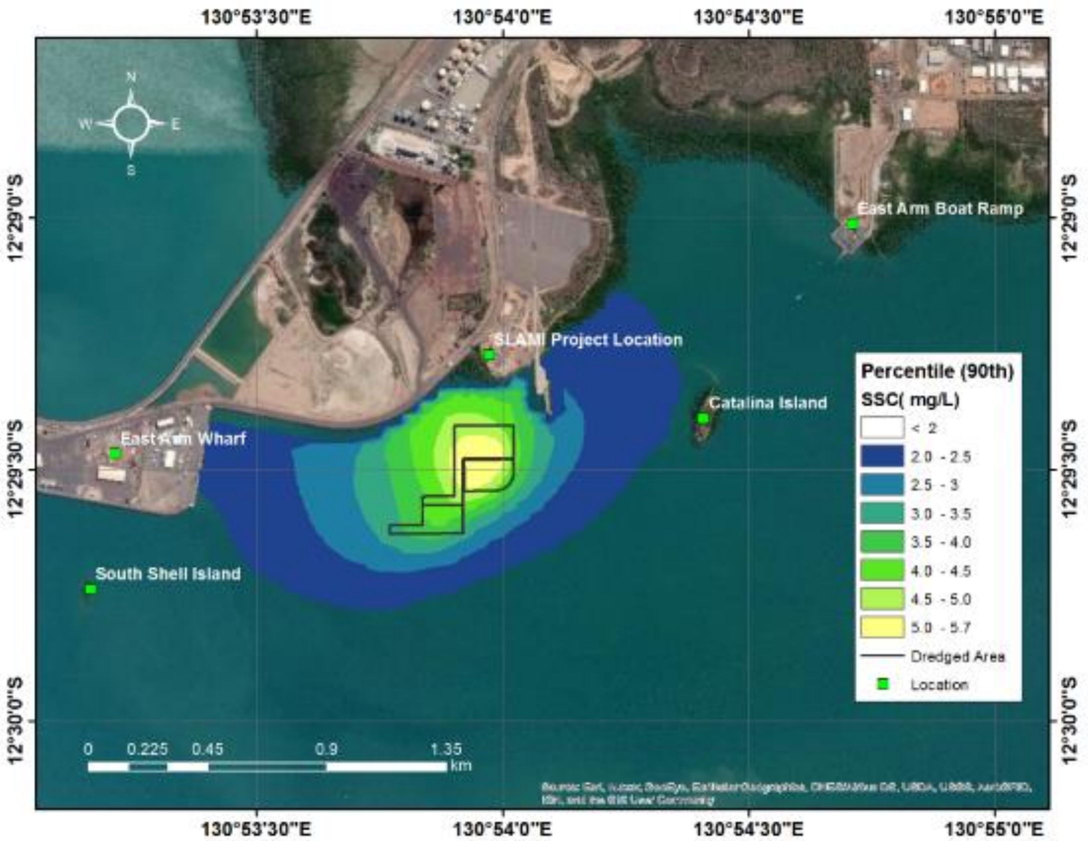

Figure 7 90th Percentile modelled SCC (above background level) (mg/L)

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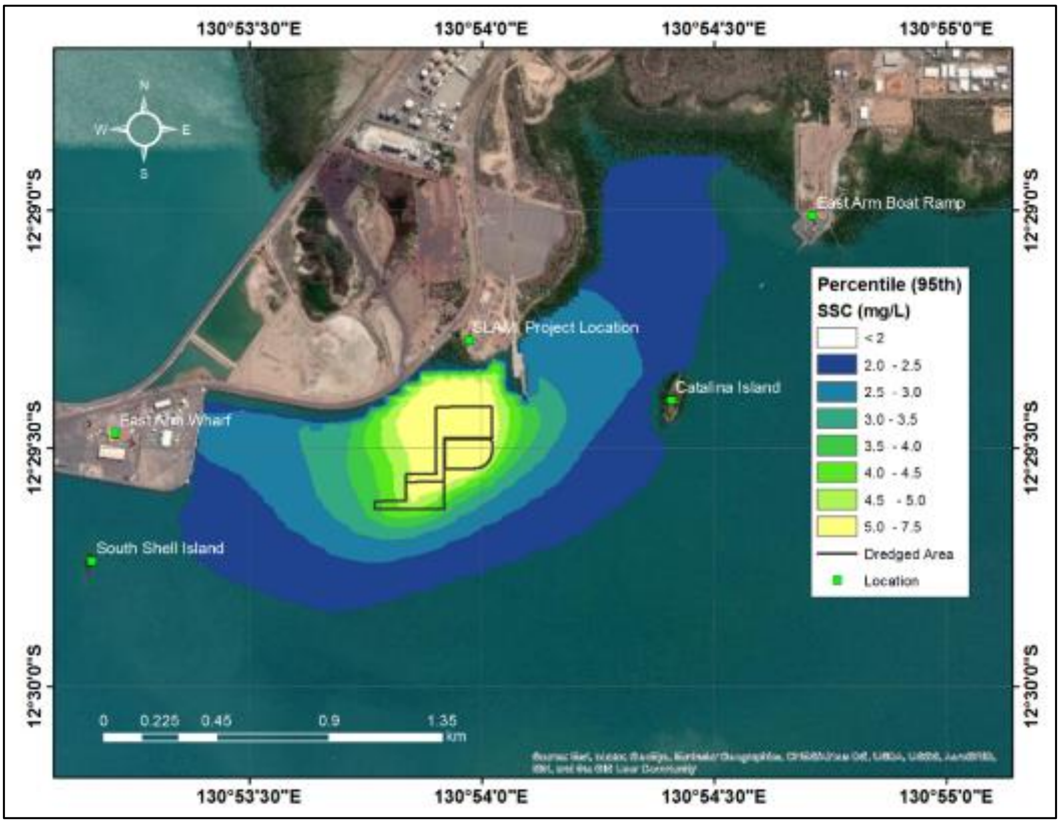

Figure 8 95th Percentile modelled SCC (above background level) (mg/L)

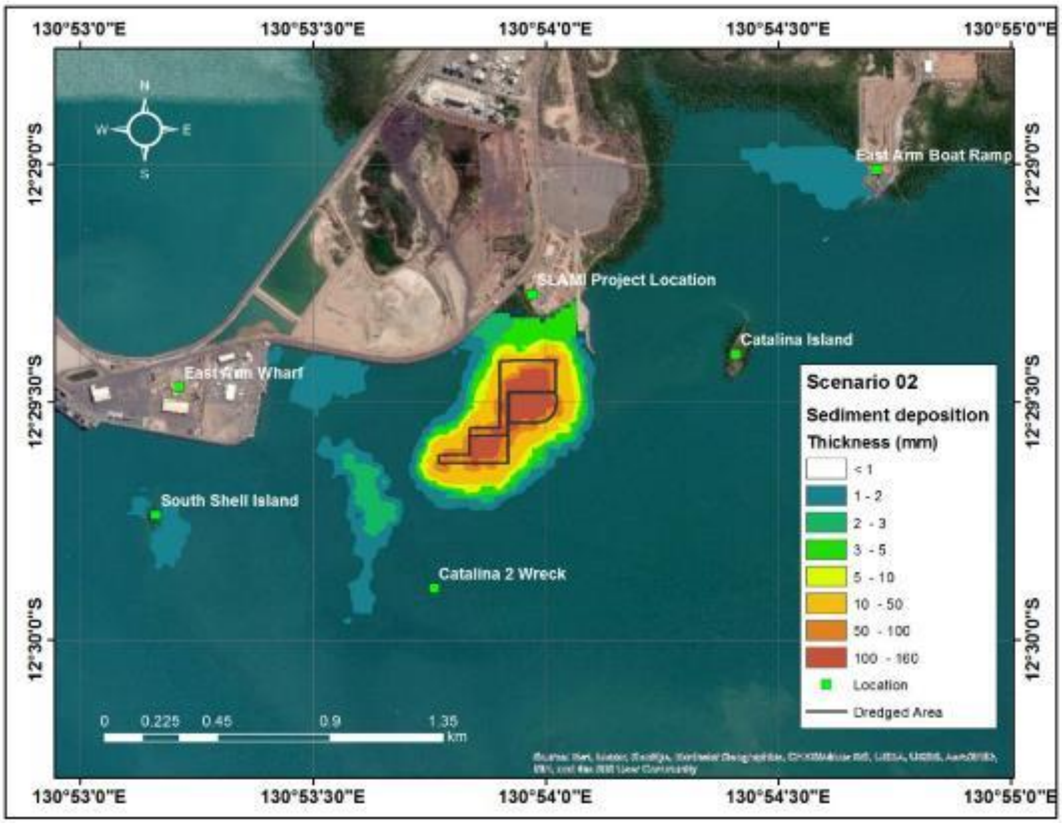

Figure 9 Sediment deposition at the completion of dredging and the 30-day post dredge period (in mm)

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6.4.1 Suspended sediments

6.4.1.1 Dredging

Sediment modelling predicts a 90th percentile SSC of up to only 5.7 mg/L (Figure 7), which is less than the Dry Season and Wet Season tolerance limits of 10 mg/L and 25 mg/L respectively. Hence, the Zone of Moderate Impact falls completely within the Zone of High Impact. Similarly, a 95th percentile SSC of 7.5 mg/L is predicted at the cutter head (Figure 8) meaning that the Zone of Influence also falls entirely within the Zone of High Impact (i.e. within 20 m of the proposed dredging footprint boundary). As a result, suspended sediments mobilised from the dredge are not predicted to extend beyond the dredging area at concentrations that could result in detectable changes to environmental quality.

6.4.1.2 Tailwater discharge

Boundaries of the Zones of Moderate Impact and Influence at the tailwater discharge point at the permeable section of the railway bund wall (based upon a tailwater SSC criterion of 100 mg/L; refer Section 8.3.4) were also defined by the 90th and 95th percentile plots produced by the modelling as follows:

- The outer edge of the Zone of Moderate Impact is delineated by the 90th percentile contour plot for SSC. On Figure 10, the outer edge of the Zone of Moderate Impact for the Dry Season is shown as the purple contour, extending a maximum of approximately 100 m from the railway bund wall. For the Wet Season, there are no areas seawards of the railway bund wall where an SSC of 25 mg/L is exceeded more than 90% of the time; hence the Zone of Moderate Impact does not extend seaward of the railway bund wall.
- The outer boundary of the Zone of Influence is delineated by the 95th percentile contour plot for SSC. On Figure 10, the outer edge of the Zone of Influence for the Dry Season is shown as the red contour, extending a maximum of approximately 120 m from the railway bund wall. For the Wet Season, there are no areas seawards of the railway bund wall where an SSC of 25 mg/L is exceeded more than 95% of the time; hence the Zone of Influence does not extend seaward of the railway bund wall.

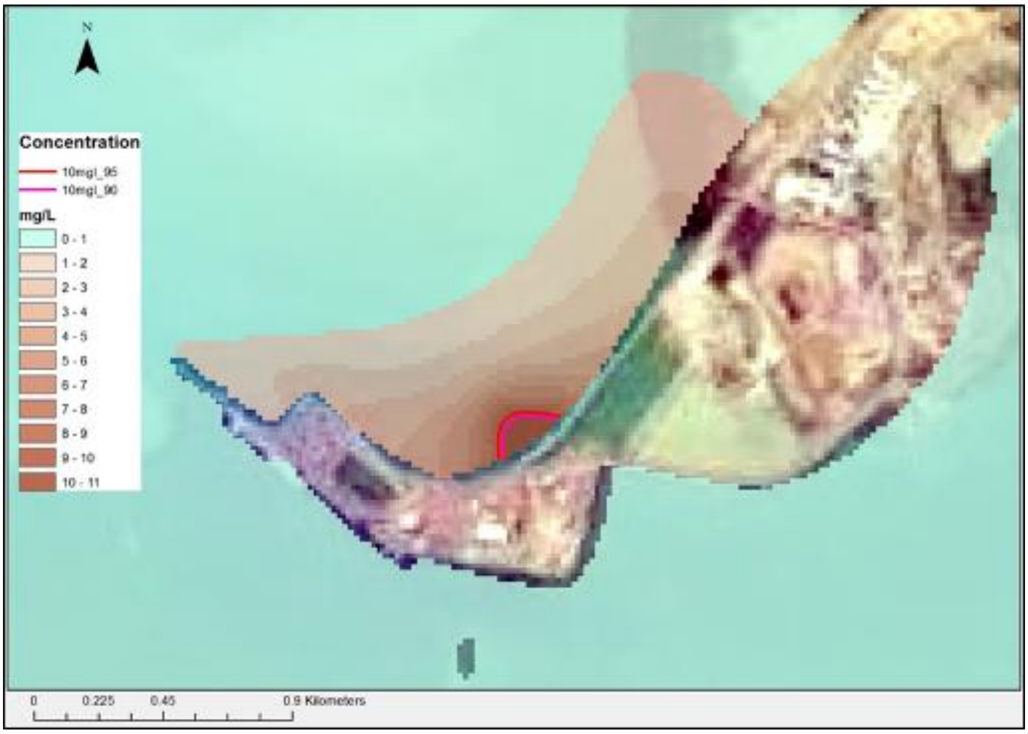

Figure 10 Predicted Dry Season zones of Impact and Influence (SSC) at the tailwater discharge location.

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Suspended sediments may potentially impact a small area of benthic habitat up to 120 m from the Pond E (South) discharge point. While the habitat within this small area has not been mapped in detail, observations from low tide aerial imagery indicate that it is an intertidal mud/sandflat which would 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 tailwater discharge has ceased. It should also be noted that no exceedance of suspended sediment limits set during the MSB or MUBRF dredging were observed at the outflow point from the pond system.

6.4.2 Sedimentation

6.4.2.1 Dredging

Sedimentation after 30 days of completion of dredging was modelled to identify any potential areas for concern for the exceedance of the sedimentation tolerance limits in mangrove areas. Figure 9 shows that sediment deposition above 50 mm is predicted to remain within the dredging footprint and does not extend beyond the Zone of High Impact defined for SSC (i.e. within 20 m of the dredging footprint). As such, no mangrove stands are predicted to be exposed to sediment accumulation beyond the tolerance levels proposed for mangroves (50 mm and 100 mm for reduced mangrove health, and likely mangrove mortality respectively). Hence sediment accumulation is not expected to impact on mangrove communities in areas such as upper reaches of East Arm, 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).

A pocket of sediment deposition of between 1-2 mm (well below the 15 mm tolerance limit in the approved INPEX [2013, 2018] dredging management plans) is predicted to occur near South Shell Island (Figure 9). However, the modelling does not account for:

- The ability of hard corals to actively remove sediment from their surfaces (e.g. through the production of mucus) or for the influence of colony morphology in aiding sediment removal (e.g. Jones et al 2019).
- The active removal of sediments from the water column by filter feeders (e.g. Strehlow et al 2017, Abdul Wahab et al 2018) which may reduce the amount of sediment settling upon their surfaces, reducing the potential for impacts from smothering.

The wreck of Catalina 2 is located offshore from the proposed dredging footprint. It can be seen that sediment transport and sedimentation modelling does not predict sedimentation to occur in this area (Figure 9). Similarly, there is no net sedimentation predicted at either of the registered sacred sites (Catalina Island and Old Man Rock) that are present within 1 km of the dredging footprint.

6.4.2.2 Tailwater discharge

Previous modelling of sediment accumulation associated with the discharge of tailwater with SSC up to 100 mg/L (modelled for the MUBRF dredging) indicated sedimentation up to 2.88 mm may occur in close proximity to the outfall, well below the tolerance limits proposed for mangroves.

If the rate of sediment deposition adjacent to the settling pond discharge point is sufficiently high, then some of the benthic fauna may be smothered. However, any impacted areas would be expected to 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.

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7.0 Environmental Risk Assessment

7.1 Purpose

A systematic environmental risk assessment process has been applied to address the potential risks associated with dredging to be carried out for the Project. It takes into account guidance within the Guideline for the Preparation of an Environmental Management Plan (NT EPA 2015) and is aligned with the standard AS/NZS ISO 31000: 2009 Risk Management and with Environment Institute of Australia and New Zealand guidelines (EIANZ 2015).

The risk assessment is sufficiently broad as to be applicable to both Option 1 and Option 2 for the dredging and dredged material placement activities.

The purpose of the risk assessment process was to identify the activities, and the environmental aspects associated with those activities, that have the potential to result in environmental impacts; and to guide the development of management measures and controls to avoid or reduce those potential impacts. The assessment of environmental risk is an essential component of the environmental impact assessment process. It forms the basis for ongoing management and review of significant environmental risks that may arise over the course of dredging activities. Management controls identified through the risk assessment process are included in the MFs presented in Section 8.0 of this Plan.

7.2 Risk assessment methodology

The risk assessment methodology ensured that a systematic approach was applied to the assessment and management of environmental risk; it comprised two main steps – risk scoping and risk assessment.

7.2.1 Risk scoping

The risk scoping step comprised the identification of:

- Environmental aspects - features or characteristics of a project activity that have the potential to affect the environment.
- Potential environmental impacts - any potential change to the environment, whether adverse or beneficial, wholly or partly resulting from a project's environmental aspects.

Each environmental aspect was considered in turn against each sensitive receptor in the surrounding environment for a potential pathway or interaction. Where pathways existed, each potential environmental impact was considered.

7.2.2 Risk assessment

The risk assessment process considered two factors:

- The magnitude of direct or indirect impacts on environmental receptors from project activities (Table 11).
- The sensitivity of these receptors to direct or indirect impacts (Table 12).

Following the matrix in Figure 11, the predicted magnitude of impact, and receptor sensitivity, were used to produce a risk ranking (Table 13) for each impact. The outcomes of the risk assessment process are presented in Table 14.

It should be noted that the risk assessment encompasses activities that are directly related to operation of the dredge and to disposal of dredged material. General vessel-related environmental aspects (e.g. unplanned hydrocarbon releases, waste disposal, marine pest introduction) are managed under other auspices (e.g. Oil Spill Response Plan, Project Environmental Management Plan, biosecurity regulations).

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Table 11 Criteria for assessment of magnitude of impacts

Rank	Water Quality	Ecology
Negligible	Change from baseline conditions is immeasurable, undetectable or within the range of normal variation.	Negligible effect on known population or range of species.
Small	Minor detectable change from baseline conditions over a limited distance (hundreds of metres) from source. Baseline conditions return within one month of cessation of activity.	Affects a specific group of localised individuals within a population over a short time period (one generation or less), but does not affect other trophic levels or the population itself.
Medium	Readily discernible change in quality beyond 1 km from source. Baseline conditions return within weeks of cessation of activity.	Affects a portion of a population and may bring about a change in abundance and/or distribution over more than one generation, but does not threaten the integrity of that population or any population dependent on it.
Large	Readily discernible change in quality over a large area (>10 km^2) that persists over several months, with likely secondary impacts on marine ecology.	Affects a high portion of a population and may bring about a change in abundance and/or distribution over two or more generations, potentially threatening the integrity of that population or a population dependent on it.
Severe	Major alteration to baseline conditions over a large area (>10 km^2) that persists for more than 12 months, with probable secondary impacts on marine ecology.	Affects an entire population or species in sufficient magnitude to cause a decline in abundance and/or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would not return that population or species, or any population or species dependent upon it, to its former level within several generations.

Table 12 Criteria for assessment of receptor sensitivity

Rank	Water Quality	Ecology
Low	Existing water quality is good and the ecological resources that it supports are not sensitive to a change in water quality.	The ecological features are abundant, common or widely distributed and are generally adaptable to changing environments. Species are not endangered or protected.
Moderate	Existing water quality already shows some signs of stress and/or supports ecological resources that could be sensitive to change in water quality.	Some ecological features have low abundance, restricted ranges, are currently under pressure or are slow to adapt to changing environments. Species are valued locally/regionally and may be endemic, endangered or protected.
High	Existing water quality is already under stress and/or the ecological resources it supports are very sensitive to change (secondary ecological impacts are likely).	Some ecological features in the area are rare or endemic, under significant pressure and / or highly sensitive to changing environments. Species are valued nationally /globally and are listed as endangered or protected.

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Figure 11 Risk matrix

		Sensitivity		
		Low	**Moderate**	**High**
Magnitude	Negligible	Minor	Minor	Minor
	Small	Minor	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major
	Severe	Major	Major	Major

Table 13 Risk categories

Risk	Description
Minor	Negligible risk of persistent changes to receptors. No management measures beyond those routinely applied to operations are required for the risk to be considered as low as reasonably practicable (ALARP).
Moderate	Reversible changes to receptors may occur. Corrective actions (i.e. management measures that are additional to those routinely applied to operations) are likely to be required to reduce risk to ALARP.
Major	Unacceptable risks to receptors. Project modifications or additional management measures are required to reduce risk to ALARP.

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Table 14 Risk assessment outcome

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
Project vessels	Arrival of dredge(s) and other Project vessels into Darwin Harbour from other biogeographical regions.	Potential introduction of invasive marine species.	Large	Low	Moderate	The introduction of invasive marine species would have the potential to severely impact upon native benthic invertebrate species and upon human infrastructure. However, it is considered unlikely that these impacts would lead to significant impacts upon protected marine species. To reduce the risk to of introductions to ALARP, all Project vessels (and the dredge[s] in particular) arriving into Darwin Harbour will need to comply with the requirements of the NT Aquatic Biosecurity Unit. These typically comprise vessel risk assessments and, if deemed necessary by the outcomes of the assessments, hull inspections to verify that the vessels are free from potential invasive marine species. Management measures to mitigate the risk of introduction of invasive marine species will be included in the Environmental Management Plans for each Project vessel and are not detailed within this DDSPMP.
Seabed disturbance	Dredging of material from Project footprint	Mortality of biota entrained within dredged sediments.	Small	Moderate	Minor	Colonisation of the disturbed seabed is likely to occur in the short term, most likely by species present in unconsolidated sediment habitats nearby. Biota within the Project footprint unlikely to represent a significant component of the harbour food web as similar habitats are widespread within the harbour.
		Mortality of benthic communities present on the seabed.	Small	Moderate	Minor	The proportion of those benthic communities mapped as present within the dredging footprint is considered to be small in a harbour wide context.
Sediment plumes		Increased SSC in water column.	Small	Moderate	Minor	It is predicted from modelling (Section 6.0) that tidal currents will rapidly disperse the suspended sediments. Modelling also suggests that SSCs will

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Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
						rapidly return to background levels upon the completion of dredging.
Sediment plumes (cont'd)	Dredging of material from Project footprint (cont'd)	Increased toxicant concentrations in water column.	Negligible	Moderate	Minor	A recent sediment geochemistry investigation (AECOM 2020) did not detect elevated toxicants in samples from the dredging footprint, with the exception of arsenic, which is known to occur naturally in elevated concentrations in Darwin Harbour sediments and has been found to have low bioavailability (URS 2009).
		Increased nutrient concentrations in water column.	Negligible	Low	Minor	The mean nitrogen concentration in sediments sampled by AECOM (2020) was within the range of concentrations recorded by Radke et al (2020) in sediments at the closest sampling sites to the dredging footprint. The widespread sampling by Radke et al (2020) found nitrogen concentrations to be markedly higher at sites within the upper reaches of creeks, or in close proximity to mangroves, relative to concentrations in sediments in settings such as the dredging footprint.
		Reduction in incident light levels to benthic biota, potentially leading to reduced growth or to mortality.	Small	Moderate	Minor	Benthic biota within the area over which reduced light levels may occur are well represented within the harbour. No benthic communities of conservation significance are known to occur in the vicinity of the dredging and reclamation activities. In the past, a degree of research importance has been ascribed to the filter feeder communities around South Shell Island. However, it is predicted from modelling (Section 6.0) that elevations in SSC will not reach the predicted tolerance limits (Section 6.2) over these communities.
		Clogging of fauna feeding or respiratory structures, potentially leading to	Small	Moderate	Minor	The habitats for biota which may come into contact with suspended sediments from the dredging are well represented within the harbour.

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Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
		reduced growth or to mortality.				
Sediment plumes (cont'd)	Dredging of material from Project footprint (cont'd)	Reduction in food availability or foraging habitat for protected marine species, potentially leading to displacement.	Small	Moderate	Minor	No benthic communities of critical importance to protected marine species are known to occur in the vicinity of the dredging activities. Some individuals may temporarily forage in alternative harbour areas for the duration of the activities.
Indirect sedimentation	Dredging of material from Project footprint	Smothering of biota distant from activity, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	It is predicted from modelling that net sedimentation in mangroves, and on benthic biota, in the vicinity of the Project will be imperceptible from that which occurs in the absence of dredging.
		Sediment deposition upon Indigenous or European cultural heritage sites	Negligible	Low	Minor	Modelling predicts that there will be no detectable net sedimentation upon Indigenous sacred sites or European heritage sites in the vicinity of the dredging footprint.
Tailwater flow	Dredged material placement into EAW ponds (Option 1 only)	Disturbance to migratory birds at roost sites in Pond D.	Negligible	Moderate	Minor	Pond D is a protected habitat used by shorebirds at EAW. This pond will not be used for direct placement of dredge spoil or tailwater storage and the Dredging Contractor will ensure that there is no direct disturbance to the pond. Adding further dredge spoil to Pond K is not expected to create any significant disturbance to migratory shorebirds roosting on Pond D. Birds have continued to roost in the vicinity during similar activities undertaken previously and there is a long history of vehicular movements in the general vicinity of Pond D (Dr Stephen Garnett, pers. comm., 20 November 2017).
Tailwater release		Increased SSC in receiving waters.	Negligible	Low	Minor	During previous dredging campaigns, tailwater clarity has typically been higher (i.e. SSC has been lower) than in the receiving waters of Frances Bay. During the MUBRF dredging the turbidity limit was not exceeded at any of the monitoring locations within the ponds and turbidity measurements prior to

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Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
						release into the receiving environment (within Pond E [South]) were considerably lower.
Tailwater release (cont'd)	Dredged material placement into EAW ponds (Option 1 only) (cont'd)	Increased acidity or alkalinity in receiving waters.	Negligible	Low	Minor	Prior to its release, tailwater will be tested to ensure the pH is within a range over which adverse impacts to biota are unlikely.
		Increased toxicant concentrations in receiving waters.	Negligible	Low	Minor	Prior to its release, tailwater will be tested to ensure toxicant concentrations are below levels at which adverse impacts to biota may occur. A recent geochemical assessment of sediment to be placed within the ponds (AECOM 2020) indicated that (with the exception of arsenic) the likelihood of elevated metals in the dredged material is very low.
		Increased nutrient concentrations in receiving waters.	Negligible	Low	Minor	Any nutrients within the tailwater will be rapidly dispersed once they enter the Frances Bay environment and are likely to be imperceptible from background concentrations within a short distance from the bund wall.
		Reduction in incident light levels to benthic biota, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	During previous dredging campaigns, tailwater clarity has typically been higher than in the receiving waters of Frances Bay; hence in the immediate vicinity of the tailwater release location: • Incident light levels may increase, rather than decrease. • There is reduced risk of clogging of fauna feeding and respiratory structures. • There is a reduced risk of smothering of biota.
		Clogging of fauna feeding or respiratory structures, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	
		Smothering of biota, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	

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Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
Tailwater release (cont'd)	Dredged material placement into EAW ponds (Option 1 only) (cont'd)	Reduction in food availability or foraging habitat for protected marine species, potentially leading to displacement.	Negligible	Moderate	Minor	The tailwater will not have any characteristics that may cause a reduction in food availability for protected marine species.
Reclamation sediment and entrained water release	Reclamation within Project footprint	Increased SSC in receiving waters.	Small	Low	Minor	A rock revetment (entirely enclosing the reclamation area, or mostly enclosed, with any opening filled by silt curtains, to allow entry to workboats) will be constructed prior to reclamation activities being undertaken. Dredged material will be placed on the landward side of the revetment. Geofabric and silt curtains will be used to mitigate the generation of turbid plumes on the seaward side of the revetment. Turbidity monitoring undertaken around the dredging works will detect whether implementation of additional mitigation measures may be required.
		Increased acidity in receiving waters.	Small	Low	Minor	Any potentially acid-generating material (if present) will be covered by subsequently placed material and not exposed to the atmosphere for sufficient periods of time for oxidation to occur. Engineered fill (i.e. from a quarry) will be used to cap the dredged material placed within the reclamation area.
		Increased toxicant concentrations in receiving waters.	Small	Low	Minor	A recent geochemical assessment of sediment to be placed within the ponds (AECOM 2020) indicated that (with the exception of arsenic) the likelihood of elevated metals in the dredged material is very low.
		Increased nutrient concentrations in receiving waters.	Negligible	Low	Minor	Any nutrients in the entrained water within the dredged material will be rapidly dispersed once they enter the receiving environment adjacent to the seaward edge of the reclamation area.
		Reduction in food availability or foraging habitat for	Small	Moderate	Minor	There are no indications that sediment or entrained water emanating from the reclamation area will have

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Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
		protected marine species, potentially leading to displacement.				any characteristics that may cause a reduction in food availability for protected marine species.
Underwater noise and vibration	Operation of dredge and support vessels	Displacement of protected marine species.	Small	Moderate	Minor	Some individuals of protected marine species may temporarily relocate to alternative locations in the harbour for the duration of the dredging activities. There are no known areas within the vicinity of the Project that are of critical importance to feeding or breeding for protected marine species. The area in which dredging will take place is currently subjected to underwater noise and vibration from vessel activity at EAW and nearby marine industries.
Vessel movements	Dredging support vessels in transit	Vessel collision with protected marine species.	Small	Moderate	Minor	The area in which dredging will take place is currently subjected to substantial vessel activity, including small, fast-moving craft that pose a greater risk of impact to marine fauna than slow-moving work vessels associated with dredging operations. The dredge itself will be essentially stationary whilst operational. A marine fauna observer (MFO) will be on board the dredge and operators of Project vessels will have been notified of marine fauna risks during Project inductions.
		Physical disturbance of Catalina 2 heritage site	Negligible	Low	Minor	As the Catalina 2 is outside of the dredging footprint, there is no risk of direct impacts from the dredge itself. An exclusion zone will be established around the Catalina 2 wreck for the duration of dredging and no Project related vessels will traverse the site.
		Physical disturbance of Catalina Island Restricted Works Area (RWA)	Medium	Moderate	Moderate	The Project area is sufficiently distant from the Catalina Island RWA that the latter is not at risk of direct impact from Project vessels when engaged in the dredging works. However, all Project vessels will be required to have clear demarcation of the RWA

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Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
						on their navigation systems to reduce the potential for impacts to occur when not directly engaged in dredging operations (e.g. when in transit or at anchor). Management measures to mitigate the risk of physical disturbance within the RWA will be included in the Environmental Management Plans for each Project vessel and are not detailed within this DDSPMP.

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8.0 Environmental Management

8.1 Introduction

This section describes the MFs that have been developed for the risks associated with the dredging works, as identified through the environmental risk assessment process (Section 7.0). The MFs are instrumental to effectively manage and mitigate environmental risks to sensitive receptors identified in Section 4.0, and to achieving the objectives set by the NT EPA for each of the Environmental Factors identified in Section 5.0 of this Plan.

MFs have been developed for the following receptors:

- water quality – Darwin Harbour
- water quality – EAW settling ponds
- protected marine species – physical interaction
- protected marine species – underwater noise.

Each MF states the relevant Project commitments made and objectives to be met, and contains specific, measurable targets to achieve the objective for each of the applicable Environmental Factors. 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 to 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 MF
- 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 9.0. Each MF also indicates the relevant reporting requirements (detailed further in Section 10.0) and the responsibilities of Project personnel.

8.2 Water quality – Darwin Harbour

8.2.1 Potential impacts

8.2.1.1 Suspended sediments

Plumes of suspended sediments (‘turbid plumes’) may impact upon marine organisms through clogging of feeding or respiratory structures or through a reduction in light penetration through the water column.

If Option 1 is the selected dredging methodology, then turbid plumes containing elevated levels of suspended sediments will be generated:

- At the cutter head of the CSD.
- From any improperly sealed joints within the pipeline leading from the dredge to the EAW settling ponds.
- As the BHD bucket interacts with the seabed and lifts the dredged material through the water column.
- At the seaward face of the reclamation area, as a result of the return of entrained water from the dredged material.

If Option 2 is selected, then only the latter two sources of turbid plumes will be present.

Modelling undertaken for the Project suggests that turbid plumes generated by dredging are not predicted to extend beyond the dredging footprint at concentrations above the tolerance levels of sensitive receptors (see Section 6.4.1). The nearest such receptors of value are the coral and filter feeder communities at Catalina Island and South Shell Island (Section 4.3.1).

Given that dredging-related SSC is not predicted to approach these receptors, a precautionary monitoring program (detailed in Section 9.2) will be implemented to determine whether SSCs in the vicinity of the operating dredge are sufficiently low as to pose a negligible risk of exceedance of tolerance limits at the nearest sensitive receptor sites. In addition, monitoring of benthic communities will occur at selected locations around South Shell Island (refer Section 9.3).

If Option 1 is selected as the preferred dredging methodology, then the tailwater discharge from the settling ponds will also contribute suspended sediments to the receiving environment in the vicinity of the permeable railway bund wall at East Arm Port, though on occasions (e.g. during spring tides) the concentrations of suspended sediments in the tailwater may be less than those in the receiving environment.

Monitoring during the MSB and MUBRF dredging provides a relevant comparison with which to compare likely suspended sediment dispersion and sedimentation resulting from the use of the pond system. No exceedances of SSC trigger levels occurred in the natural environment at the outflow point of the pond system, indicating that the ponds are capable, with effective management, of maintaining tailwater outflow to the environment within the set limits for dredge programs utilising similar dredging equipment. Based on this experience, it is expected that the use of the ponds as described in this Plan (including the Water Quality Management Framework [WQMF] presented in Section 8.3.6) will result in outflow to the receiving environment at acceptable SSCs, with negligible risk of unacceptable degrees of sedimentation.

8.2.1.2 Toxicants

The potential for toxicants to be released from the porewater within the unconsolidated seabed materials to be dredged is recognised. However, on the basis of the results from the sediment geochemical assessment undertaken by AECOM (2020) it is considered that there is negligible risk of these being released at sufficient concentrations to significantly impact upon the beneficial uses, water quality objectives or identified environmental values of Darwin Harbour.

If Option 1 is selected as the dredging methodology, then the following aspects of the dredge operation will further mitigate the potential for changes in toxicant concentrations to occur in the water column beyond the dredging footprint:

- CSDs utilise powerful suction to transport the dredged material to the disposal location. This entrains the majority of porewater (within the dredged material) into the dredge, then into the pipeline to the disposal location.
- While there is typically some release of fine sediment particles from CSD cutter heads (conservatively estimated as 5% of the volume of dredged material), these are only carried away from the cutter head if currents are sufficiently strong. These currents will have the effect of rapidly diluting any porewater (and any toxicants therein) that may become entrained in the flow away from the cutter head.
- It is anticipated that the loss at the cutter head will be considerably lower than 5% when dredging unconsolidated materials as the CSD would primarily operate in ‘suction-only’ mode. The release of sediments from a cutter head typically occurs when it is activated in order to fracture consolidated material, within which there is limited porewater.
- During BHD operations, much of the sediment porewater will be retained within the dredged material as it is raised through the water column. While this will be released as the material is deposited into the reclamation area, it is reiterated that the toxicant concentrations within the sediments to be dredged have been determined (by AECOM 2020) to be sufficiently low as to not pose a risk of significant impacts upon the receiving environment.

If Option 2 is selected as the dredging methodology, then the above mitigation attendant to BHD operations will apply.

Therefore, whether Option 1 or Option 2 is selected, it is considered that the monitoring of turbidity levels, as an indication of the veracity of the plume dispersion modelling, is an appropriate strategy to also mitigate the risk of impacts from nutrients and toxicants.

8.2.2 Trigger levels

A turbidity trigger level of 100 mg/L (140 NTU) has been set at a distance of 150 m down-current from the operating dredge, the pipeline, or the seaward edge of the reclamation area; this is based on the need to retain SSCs at sensitive receptor sites (e.g. South Shell Island) below the tolerance limits for those communities (10 mg/L for Dry Season and 25 mg/L for Wet Season; Section 6.2.1).

Given the distance between the proposed dredging location and the nearest significant sensitive receptor site at South Shell Island, this trigger level is considered suitable to provide an early warning that SSCs are elevated above those predicted and that management measures may be required to reduce the risk of the relevant SSC tolerance limit being exceeded at South Shell Island.

8.2.3 Response to trigger exceedance

Where a trigger level (140 NTU at a distance of 150 m from the operating dredge, from its associated pipeline, or from the seaward edge of the reclamation area) is exceeded, this will be reported by the Dredging Contractor to the Proponent within 24 hours. Also within 24 hours, additional monitoring and corrective actions (see Section 8.2.4 and Table 15) will be implemented in a manner aimed at determining which of them have the greatest potential to reduce the dispersion of plumes from the dredging and reclamation activities towards South Shell Island.

Concurrently, an attributability assessment will be initiated by the Dredging Contractor and submitted to the Proponent to determine whether or not the exceedance was likely to have been caused by dredging or reclamation activities. This assessment will be completed within three business days of the exceedance occurring and will include consideration of information such as:

- Changes in TSS levels within East Arm that are evident from the analysis of daily satellite imagery (refer Section 9.2.2) – these may indicate whether there are increases in TSS due to natural factors such as storm activity, or to other anthropogenic sources.
- Wind, wave, current direction and tidal data.

If it is deemed that the exceedance is potentially due to the dredging or reclamation activities, then those corrective actions (Table 15) that are most effective in adequately reducing turbidity emanating from these sources will continue to be implemented until such time as the turbidity levels fall to below the trigger level.

8.2.4 Management measures

The following inherent characteristics of the dredging operation are anticipated to minimise the generation of turbid plumes:

- Dredging and reclamation activities are situated close to shore, at locations which are afforded some protection from the effects of tidal currents.
- During CSD operations, the feed of sediments into the suction pipe is maximised by its location directly behind the cutter head. This minimises the release of sediment into the water column surrounding the dredge. When dredging unconsolidated materials the cutter will be disengaged for much of the time, while dredge pumps will operate at the maximum speed possible.
- During BHD operations, the bucket will be raised through the water column at a speed that minimises the loss of material from the bucket. The dredged material will be placed into barges from which there will be no overflow of entrained water or porewater. Silt curtains will be deployed along the seaward edge of the reclamation area and runoff from the area will be managed to minimise the entry of sediments into the marine environment.

Consideration of trends in the water quality data collected during the monitoring program (Section 9.2) will be used to adaptively manage the dredging operations to minimise the potential for water quality trigger levels to be exceeded. The monitoring will provide advanced warning of any impending trigger level exceedance, allowing precautionary corrective actions (refer Table 15; these take account of contemporary guidance, such as that in Mills & Kemps [2016]) to be implemented before the trigger level is exceeded. For example, observations during monitoring will indicate the times within the tidal cycle when the migration of dredge-generated plumes towards South Shell Island is highest; maintenance or relocation of the dredge can then be scheduled to coincide with those times.

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Table 15 WQMF – Darwin Harbour

Water Quality Management Framework – Darwin Harbour	
Element	Maintenance of water quality in East Arm
Commitments	Any WDL conditions
Objective	To minimise the potential for impacts upon the hard coral and filter feeder communities at South Shell and Catalina Islands from turbid plumes emanating from dredging and reclamation activities.
Target	1. No instances of exceedance of turbidity trigger levels at a distance of 150 m down-current of the operating dredge (or its associated pipeline under Option 1) or the seaward face of the reclamation. 2. No detectable decline in proportion of living hard corals or filter feeders within benthic communities at South Shell Island and Catalina Island monitoring sites.
Key Performance Indicators	• Number of instances of exceedance of reactive water quality monitoring criteria (trigger levels) at the sampling locations 150 m down-current from the sources that require corrective actions to be implemented to return water quality in East Arm to an acceptable level. • Number of instances in which monitoring of hard coral and filter feeder communities at South Shell Island and / or Catalina Island monitoring sites is triggered.
Management	CSD: • Cutter head and pump speeds managed to minimise dispersion of fine sediments from the cutter head. • Pipeline integrity maintained to reduce the potential for spoil leakage from joints between sections. BHD: • Speed of bucket movement through water column managed to minimise loss of sediments into the water column. • No overflow from barges. • Silt curtains along seaward edge of reclamation area. • Management of runoff from reclamation area.
Monitoring (Sections 9.2 and 9.3)	• Reactive water quality monitoring 150 m down-current of the operating dredge, the pipeline (under Option 1; if a plume is emanating from it) and the reclamation area. • Review of daily satellite images. • Baseline and post-dredging assessments of proportions of live hard corals and filter feeders within benthic communities at South Shell Island monitoring sites. • If required due to exceedance of turbidity trigger levels at 150 m down-current from sources, assessment of hard coral and filter feeder communities at South Shell Island and / or Catalina Island monitoring sites.
Reporting (Section 10.0)	• Daily reporting of monitoring data by Dredging Contractor to the Proponent. • Monitoring report to the NT EPA at the conclusion of dredging. • Trigger level exceedances 150 m down-current of any sources of turbid plumes from the dredging and reclamation activities will be reported by the Dredging Contractor to the Proponent within 24 hours of the exceedance occurring. • A report on corrective actions implemented to address the cause of the exceedance will be submitted by Dredging Contractor to the Proponent within two business days of the notification. • Dredging Contractor will notify the Proponent of the outcome of their investigation into attributability of the exceedance to dredging within three business days of the notification.

Water Quality Management Framework – Darwin Harbour	
	• Dredging Contractor will notify the Proponent of the outcomes of any monitoring of the South Shell Island or Catalina Island benthic communities that is triggered by turbidity level exceedences; this will be provided within five business days of completion of the monitoring.
Corrective Actions	• Slowing the CSD cutter head speed or slew speed of the dredge, reducing the rate of disturbance at the cutter head (Option 1). • Repairing pipeline joints to eliminate leakage of spoil (Option1). • Slowing the speed of raising the BHD bucket through the water column (Options 1 & 2). • Reducing or suspending dredging activity during certain tidal periods when the migration of dredge plumes towards South Shell Island or Catalina Island is greatest. • Relocating the dredge to an alternate dredge face. • Temporary cessation of dredging.
Term	For the duration of dredging.
Responsibility	• Dredging Contractor to ensure that works are undertaken in compliance with the approved WQMF. • Dredging Contractor's Project Manager to ensure monitoring program and water quality management measures are implemented.

8.3 Water quality – EAW settling ponds (Option 1 only)

8.3.1 Potential impacts

If Option 1 is selected as the preferred dredging methodology, there will be two primary sources of potential impact upon the receiving environment in Frances Bay from tailwater discharge from the EAW settling ponds:

- Elevated concentrations of suspended sediments; these are addressed in Section 8.2.1.1.
- Increased acidity (i.e. reduced pH) and/or elevated toxicant concentrations. These could result in acute or chronic adverse impacts upon biota in the vicinity of the permeable section of the railway bund wall.

8.3.2 Acid sulfate soils

Potential impacts upon the water quality within the settling ponds (reduced pH) may occur as a result of generation of acid if dredged sediments that contain ASS are exposed to air within the ponds for extended periods. Synergistic impacts may arise if these sediments are subsequently re-wet (e.g. by water from the dredging process, or from rainfall); the water would be acidified and would potentially leach metals (including arsenic) from the dredged sediments, or from the existing sediments within the ponds.

If acidic tailwater is released from the Pond E (South) into Francis Bay, 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.

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8.3.3 Potential indications of acid sulfate soil impacts

Some indicators for the presence of acid leachate arising from oxidation of PASS 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").

8.3.4 Water quality criteria for tailwater release

The key water quality guidelines that are relevant to the management of the dredging and dredged material placement activities are the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) 2018 (which superseded, but draw heavily on, the ANZECC Guidelines [ANZECC & ARMCANZ 2000]) and the Darwin Harbour Region WQOs (Fortune 2010, Cassilles Southgate & Fortune 2018). The Darwin Harbour Region Report Cards (e.g. DEPWS 2021) 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 ANZG (2018) Guidelines.

The most stringent water quality criterion for Darwin Harbour was considered by NRETAS (2010) to be the environmental beneficial use category. This was because the intent of the environmental beneficial use was 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.

NRETAS (2010) adopted the ANZECC Guidelines approach for physico-chemical indicators for 'slightly to moderately disturbed' systems. The ANZECC (now ANZG) Guidelines have defined acceptable effect sizes for each level of protection for different indicator types (Table 16).

Table 16 ANZG 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.

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The Darwin Harbour Region WQOs and the ANZG (2018) 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 ANZG (2018) Guidelines and Darwin Harbour Region WQOs apply to the receiving environment, rather than to the tailwater. However, if the tailwater meets the following criteria before discharge from the settling ponds then it will be considered suitable for continued release:

- The daily mean pH of the three water samples collected during monitoring at the weir box between Pond E (North) and Pond E (South) (see Section 9.4.2) is greater than 6.0. This will meet the criterion for an Upper Estuary setting, as presented in the Darwin Harbour Region Water Quality Objectives.
- For toxicants[2] (including arsenic) the Darwin Harbour Region WQOs defer to the ANZG (2018) default guideline values (DGVs). Hence concentrations of toxicants will be compared against the ANZG (2018) DGVs for slightly to moderately disturbed ecosystems (i.e. for 95% species protection). For some toxicants (including arsenic) ANZG (2018) has no DGV for marine waters as there are considered to be insufficient data to derive reliable trigger levels. In these instances, it is proposed to adopt the criteria levels for fresh water. The list of metallic toxicants to be tested (Table 17) is based on the potential presence and toxicity of these metals in Darwin Harbour.
- The target SSC for the tailwater will be 100 mg/L (140 NTU). As SSC cannot be monitored directly in the environment, turbidity (in NTU) is used as a surrogate measure. A mathematical relationship between NTU and SSC was derived from water samples collected within the pond system and analysed for both SSC and turbidity as part of the MSB capital dredging monitoring program (DoI 2014). This relationship (100 mg/L = 140 NTU) will be applied during interpretation of water quality monitoring undertaken during the dredging campaign.

Table 17 Toxicant trigger levels for tailwater released to Darwin Harbour.

Toxicant	Trigger Level
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

8.3.5 Response to trigger exceedances

Prior to the release of tailwater from Pond E (South), if the laboratory analytical results indicate that the mean concentrations of any (dissolved) toxicants exceed ANZG DGVs, or if the pH is below 6.0, then further investigations and contingency measures (e.g. dilution of tailwater with seawater, refer Table 18) will be instigated and tailwater will be retained within Pond K and Pond E (North).

[2] The ANZG 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.

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It is acknowledged that a period of time will elapse between the collection of water samples and receipt of the laboratory analytical results. Hence, if monitoring shows an increasing trend in any toxicant concentrations in Pond E (North) that may indicate a potential for trigger level exceedance, then tailwater will not be released into Pond E (South) until such time that the analytical results are received and it can be confirmed that no trigger levels are exceeded.

During tailwater discharge, if the mean turbidity level at the weir box between Pond E (North) and Pond E (South) exceeds the trigger level (140 NTU), then (subject to the need to keep the weir open under high stormwater flow conditions) the weir box will be closed until turbidity levels have fallen to below 140 NTU.

8.3.6 Management of Water Quality (EAW settling 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 8.3.4. If trigger levels are exceeded within any of the ponds, then this will be reported to the Proponent within 24 hours of the exceedance occurring. Should the exceedance occur at either of the two critical monitoring locations – where tailwater enters Pond E (North) or in Pond E (North) at the weir into Pond E (South), the Dredging Contractor will notify the Proponent.

Exceedances occurring in Pond E (North) at the weir into Pond E (South) will 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 the point where water flows into Pond E (North) from Pond K will 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). Where an exceedance requires the closing of the weir into Pond E (South), Pond E (South) will remain isolated from the tailwater management system until corrective actions (see Table 18) 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 9.4) 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 18 WQMF – EAW settling ponds

Water Quality Management Framework – EAW settling ponds	
Element	Maintenance of water quality within the EAW settling ponds.
Commitments	Conditions on the WDL for the Project.
Objectives	Protection of receiving waters from impacts arising from the physico-chemical properties of discharged tailwater. 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.
Targets	1. No increase in tailwater acidity within Pond E (North) to the extent that it is unacceptable for discharge into Pond E (South) and receiving waters due to low pH (<6.0). 2. No exceedances of ANZG DGVs for toxicants (refer Table 17) in tailwater within Pond E (North) prior to the commencement of transfer into Pond E (South). 3. 100% of tailwater discharging from Pond E (North) into Pond E (South) has SSC less than 100 mg/L (measured as turbidity [140 NTU], refer Section 8.3.4). 4. 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.

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Water Quality Management Framework – EAW settling ponds	
	b. Causes or generates odours which would adversely affect the use of surrounding waters. c. Causes algal blooms. d. Causes adverse impacts on plants.
Key Performance Indicators	• Number of instances when pH or bioavailable toxicant concentrations are outside of acceptable guidelines (pH <6.0; bioavailable toxicant concentrations >ANZG DGVs) in Pond E (North), prior to discharge into Pond E (South). • Number of instances when SSC at the weir box between Pond E (North) and Pond E (South) is >100 mg/L (measured as turbidity), • Number of instances when target criteria 4 (a)-(d) 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 (only into Pond K or Pond E [North]), and tailwater residence time is managed to allow for settlement of suspended sediments within the ponds. • Internal pond system maintained with a minimum freeboard to ensure sufficient water to facilitate settlement of suspended sediments and to minimise mobilising existing sediments.
Monitoring (Section 9.4)	• Water quality monitoring within ponds – pH, toxicants, NTU as detailed in Section 9.4. • Visual monitoring of target criteria 4 (a)-(d) outside the permeable section of railway bund (during the water quality monitoring events).
Reporting (Section 10.0)	• Weekly reporting of data to the Proponent. • Monitoring report to the Proponent at conclusion of dredging and reclamation. • Trigger level exceedances at any monitoring location will be reported to the Proponent within 24 hours of the exceedance occurring. • Should a trigger level exceedance occur in Pond E (North) at the weir into Pond E (South), this will be reported by Dredging Contractor to the Proponent within 24 hours of the exceedance occurring and a report on corrective actions implemented to address the cause of the exceedance provided within five business days of the notification.
Corrective Actions	• If pH falls below 6.0, toxicant concentrations exceed ANZG DGVs, or SSC exceeds 100 mg/L in Pond E (North) at the weir into Pond E (South), then tailwater flows out of Pond E (North) will be blocked at the weir within one hour of detection. • If pH is <6.0, tailwater will be recirculated until the pH at each point of tailwater transfer between ponds is >6.0. • If toxicant concentrations exceed ANZG DGVs, 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 ANZG DGV levels. • If SSC exceeds 100 mg/L, then tailwater will be retained within Pond E (North) until the SSC (measured as turbidity, 140 NTU) is reduced to below 100 mg/L due to settlement of sediments out of suspension. If deemed necessary, silt curtains may be installed within Pond E (North) to increase the flowpath of tailwater through the pond; this will increase the settlement of suspended sediments from the tailwater.
Term	For the duration of tailwater flow from Pond E (North) into Pond E (South).
Responsibility	• Dredging Contractor to ensure that works are undertaken in compliance with the approved WQMF.

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Water Quality Management Framework – EAW settling ponds	
	• Dredging Contractor's Project Manager to ensure monitoring program and water quality management measures are implemented.

8.4 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 CSD cutter head or BHDF bucket) 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 or entrainment. It is noted that exclusion devices to reduce the risk of entrainment of marine megafauna into dredges are only able to be applied to mobile dredges (e.g. trailer hopper suction dredges [TSHDs]) and not to stationary dredges such as the (potential) CSD and BHD to be used for the Project.

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 TSHDs are used, or when dredged material is disposed offshore. Neither of these scenarios is applicable to the dredging for the Project.

Nevertheless, there will be monitoring (refer Section 8.4) and management measures implemented to reduce the risk of physical interaction with protected marine species, as described in the following Protected Marine Species Management Framework (PMSMF). 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).

Table 19 PMSMF - physical interaction

Protected Marine Species Management Framework – physical interaction	
Element	Vessel interaction with protected marine species.
Objectives	Minimise the risk of injury to, or mortality of, protected marine species. Develop and maintain awareness of the need to conserve protected marine species.
Targets	1. No incidents of vessel interaction with protected marine species. 2. All dredging personnel to complete an HSE induction, including protected marine species awareness and management requirements. 3. All vessel masters competent in protected marine species interaction procedures.
Key Performance Indicators	Number of incident reports. Number of reported sightings of live, injured or dead protected marine species. Number of personnel completing an HSE site induction.
Management	• Training of Vessel Masters in interaction procedures • During movements of Project vessels, if protected marine species are sighted within 50 m of a vessel then avoidance actions will be taken by the vessel (e.g. change of direction or slowing to less than 6 kn) until the individuals are no longer within this distance. • Vessels will adhere to Darwin Port speed restrictions. • Vessels will not approach, circle or wait in front of protected marine species for the purposes of casual viewing. • Support vessels will not approach, circle or wait in front of wildlife for the purposes of casual viewing.
Monitoring	Watch will be maintained for stranded, injured or dead protected marine fauna; if observed, the NT Government Marine Wildwatch line (1800-453-941) will be contacted for retrieval, treatment or post-mortem of the fauna.

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Protected Marine Species Management Framework – physical interaction	
Reporting	Daily submission of marine fauna observations sheets by Dredging Contractor to the Proponent (example shown in Figure 12). Weekly summary reporting by Dredging Contractor to the Proponent of number of sightings, incidents and corrective actions. Monitoring report to the Proponent at the conclusion of dredging. Any vessel interaction incidents and protected species injury or mortality will be reported to the Proponent within 24 hours of the incident occurring. The Proponent will also notify the NT EPA and DAWE.
Corrective Actions	• 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 associated with the Project, 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.
Term	For the duration of dredging activities.
Responsibility	• Vessel Operators to ensure Vessel Masters implement protected marine species interaction procedures in compliance with this PMSMF. • Project Manager for Vessel Operators to liaise with Proponent and DEPWS on response to stranded, injured or dead protected marine species and potential recovery, treatment or post-mortem.

Name : **Date** :
Employer : **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.

Figure 12 Example MFO record sheet

8.5 Protected marine species – underwater noise

Dredging will create additional underwater noise in various forms and intensity that may be distinguishable from current ambient levels in Darwin Harbour.

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. 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 Project site by the increase in noise levels. Alternatively, the dolphins may adapt (dolphins are known to frequent busy harbours such as Fremantle and Singapore) or may tolerate the increased noise to feed on fish attracted to the operating dredge in search of food.

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). 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.

Little information is available on the auditory systems of dugongs and little research has been undertaken to investigate the sensitivity of dugongs to noise. There are only anecdotal reports of dugongs avoiding areas with high boat traffic.

Monitoring of protected marine species is described in Section 9.4.5. Management measures implemented to reduce the risk of disturbance of protected marine species by underwater noise generated by the dredging works are listed in Table 20.

Dredging activities that commence prior to sunset, or prior to a period of low visibility (defined as where continuous visual observations to a distance of 1000 m from the dredge are not possible), will continue unless:

- Within the preceding 12 hours, there have been three or more suspensions of dredging activities due to protected species encroaching within the Dredging Response Zone (a zone around the activity that is of smaller dimensions than the Observation Zone, and within which it is considered that there is a greater potential for adverse effects to occur).
- There is a non-operational period exceeding 30 minutes.

If either of these 'exclusions to continuity' occur, then dredging will not recommence until the Observation Zone is once again able to be effectively monitored by a trained MFO. The rationale for this approach is that the main potential source of behavioural disturbance to protected species is when dredging is commencing after a non-operational period. If dredging continues uninterrupted into a period of reduced visibility (including night-time) and protected species enter the Exclusion Zone, then this is indicative that they are unlikely to be experiencing significant adverse impacts.

Table 20 PMSMF - underwater noise

Protected Marine Species Management Framework – underwater noise	
Element	Impact of underwater noise on protected marine species.
Objectives	• Minimise the risk of disturbance to protected marine species from underwater noise. • Establish and maintain awareness of the importance of protecting marine species.
Targets	1. No avoidable disturbance to protected marine species as a result of noise generated during dredging activities. 2. All dredging personnel to complete an HSE induction. 3. At all times that dredge is operational, at least one crew member is a trained MFO.
Key Performance Indicators	• 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 crew member on operating dredge.

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Protected Marine Species Management Framework – underwater noise	
Management	• MFO to undertake assessments of the Observation, Start-up Exclusion and Dredging Response Zones as follows. • On each occasion that the dredge has been non-operational for a period exceeding 30 minutes, a visual assessment will be undertaken of the 750 m radius Observation Zone by the MFO for a period of 20 minutes. Dredging will not recommence until no protected marine species have been sighted within the 500 m radius Start-up Exclusion 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 will not be engaged in any other activities during the 20-minute assessment period. • Every 30 minutes whilst the dredge is operating, the MFO will dedicate a period of five minutes for scanning (from an elevated position) for protected marine species within the Observation Zone. • Once dredging operations have commenced, if protected marine species enter within 50 m of the dredge, or a dolphin with calf enter within 150 m of the dredge (i.e. the Dredging Response Zones), then dredging will be temporarily suspended. Dredging will not recommence until no protected marine species have been sighted within the 500 m radius Start-up Exclusion Zone for a period of 30 minutes. • Dredging that commences prior to sunset, or prior to a period of low visibility (defined as where continuous visual observations to a distance of 1000 m from the dredge are not possible), will continue unless, within the preceding 12 hours, there have been three or more suspensions of dredging due to protected marine species encroaching within the Dredging Response Zone. • The generation of underwater noise by all vessels will be reduced by ensuring that: - All equipment is maintained in good operating condition (balancing, greasing, etc.) and have proper noise control systems in place. - All noise minimisation measures such as mufflers, special enclosures and sound-insulation mounts are fitted and working. - Revolving equipment such as propellers and drive shafts are balanced to reduce vibration. - Equipment such as thrusters and auxiliary plant are switched off when not in use (i.e. not running in standby mode).
Monitoring (Section 9.5)	• Protected marine species observations (as per Management section above). • Watch will be maintained for the presence of stranded, injured or dead protected marine species. If observed, the NT Government Marine Wildwatch line (1800-453-941) will be contacted for retrieval, treatment or post-mortem of the animal(s).
Reporting (Section 10.0)	• Daily submission of marine fauna observations sheets from Contractor to the Proponent. • Weekly summary reporting to Proponent of number of sightings of protected marine species. • Monitoring report to the Proponent at the conclusion of dredging. • Any suspected noise-related incidents will be reported by Contractor to Proponent 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 Proponent.
Corrective Actions	• In the event that noise-related impact is suspected, the incident will be investigated to confirm a noise-related impact has occurred and identify

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Protected Marine Species Management Framework – underwater noise	
	the most appropriate action(s) to reduce the impact. This may include one or more of the following: • Implementation of further noise reduction measures. • Restriction on vessel movements/activities. • Increase in the radius of the Observation Zone to 900 m.
Term	For the duration of dredging activities
Responsibility	• Dredging Contractor to ensure works are conducted in compliance with this PMSMF. • Dredging Contractor to implement noise management aboard all vessels.

9.0 Environmental Monitoring

9.1 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 EAW settling pond system if Option 1 is selected as the preferred dredging methodology) and reclamation (Section 9.2).
- Monitoring of hard coral and filter feeder communities around South Shell Island (Section 9.3).
- If Option 1 is selected, the monitoring of water quality within the EAW settling ponds (Section 9.4).
- Monitoring for presence of protected marine species in the vicinity of the dredging works (Section 9.5).

Key aspects of each of the monitoring programs are summarised in Section 9.6.

9.2 Darwin Harbour water quality - dredge, pipeline and reclamation

9.2.1 Objectives

The objectives of monitoring water quality in the vicinity of the dredge (BHD and, if Option 1 is selected, CSD and pipeline) and reclamation are to:

- Determine if the maximum turbidity levels within observable plumes exceed the allowable SSC of 100 mg/L (measured as turbidity, 140 NTU) at a distance of 150 m from these sources.
- Provide a trigger for corrective actions to be implemented to reduce the dispersion of any non-compliant plumes from these sources.

9.2.2 Methodology

A visual survey of the areas surrounding the sources of turbid plumes (dredge, pipeline and reclamation) will be undertaken on a regular basis to determine the extents of the plumes. Should the visual survey determine that a plume may be extending beyond 150 m from its source, a small vessel or dredge tender will be used to inspect the distance from the source to the edge of the plume using a GPS. The GPS will be used to locate and record a point 150 m from the source; at this point a turbidity measurement will be taken, using a hand held water quality probe to measure a profile through the entire water column. The maximum turbidity within the water column will be compared against the allowable limit of 140 NTU. Procedures detailing instrument calibration, sample collection and processing methods will be developed by the Dredging Contractor.

To assist with any attributability assessments that may be required during dredging (refer Section 8.2.3) daily satellite imagery will be acquired by the Dredging Contractor. This will assist in determining whether the turbidity level at 150 m from the dredge and pipeline can be attributed to the dredging activity, or whether it is a result of broader regional influences (e.g. due to a period of high rainfall or elevated wave action, or to other turbidity-generating activities within the harbour). It is noted that the broadscale indications of turbidity presented in the satellite imagery would provide a more reliable measure of potential impacts to benthic communities than turbidity measures made by submersed turbidity probes at discrete locations (at which turbidity levels may be either higher or lower than in the surrounding area, and may therefore be un-representative of the risk of potential impacts to the benthic communities in the broader area).

9.2.3 Data Analysis

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

9.2.4 Outcomes

Based on the SSC determined at a distance of 150 m from the dredge or reclamation, management procedures will be initiated to reduce the maximum SSC to below 100 mg/L at distances greater than

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150 m from the source. This may include modification of dredging and reclamation activities during certain tidal phases or other steps deemed appropriate by the dredge operator (refer Section 8.2.4). These management measures shall remain in place until the maximum SSC within the plume at 150 m from the source falls below 100 mg/L (measured as turbidity, 140 NTU).

If a plume of unacceptably high turbidity (i.e. >140 NTU) is extending further than 150 m from the pipeline, then maintenance of the pipeline will be undertaken to eliminate the source of the plume.

The data outputs from the monitoring will enable ongoing assessments to be made of the need to implement management measures within the dredging and reclamation operations, in order to reduce the potential for them to contribute to turbidity levels at sensitive receptor sites further afield (e.g. South Shell Island and/or Catalina Island).

9.3 South Shell Island and Catalina Island benthic communities

9.3.1 Objectives

This component of the monitoring program aims to provide information on the health of certain benthic communities (those in which hard corals or filter feeders are well represented) around South Shell Island and Catalina Island before, during (if required by turbidity trigger level exceedances [Section 9.2.4) and after the dredging and reclamation activities.

It is noted that approvals for the substantial INPEX capital dredging campaign undertaken adjacent to these communities at South Shell Island did not include the need for management of turbidity levels to protect these communities from impacts. Rather, the hard coral communities were monitored in an ‘informative’ rather than a ‘reactive’ manner (INPEX 2013). The purpose of the informative monitoring was to determine whether any detectable changes in the communities arose over the course of the dredging campaign; there was no requirement to modify dredging practices to reduce the potential for impact upon them.

It is considered that the South Shell Island and Catalina Island benthic communities are sufficiently distant from the predicted Zones of Impact and Influence from the dredging and reclamation activities (refer Section 6.4) that an appropriate degree of protection of the communities from significant Project-related impacts will be bestowed by:

- The monitoring of turbidity levels around the Project-related sources (as described in Section 9.2.2).
- The application of corrective actions in response to any exceedances of trigger levels (as described in Section 8.2.4).

Nonetheless, monitoring of South Shell Island and Catalina Island benthic communities is included within this Plan to meet the predicted contemporary expectations of the regulators responsible for approval of the Plan.

9.3.2 Monitoring locations

Specific monitoring locations around South Shell Island and Catalina Island will be identified during a baseline survey of the hard coral and filter feeder communities around the islands. The baseline survey will be conducted as soon before the commencement of dredging as practicable, with an allowance of adequate time for data processing to inform the selection of monitoring sites. It is noted that if a baseline survey is conducted too far in advance of the commencement of dredging, there will be the potential for declines in benthic community health to occur which are not a result of the Project.

It is anticipated that three hard coral and three filter feeder communities will be selected for monitoring ad each of South Shell Island and Catalina Island, on the basis that the percentage cover of these communities within the overall benthic communities are sufficiently high for effective monitoring of change to be undertaken. The monitoring locations will be laterally separated to enable the assessment of potential impacts to communities around the islands.

Three reference monitoring locations will be established within the heritage-listed coral community at Channel Island in Middle Arm, well beyond the potential Zone of Influence of the Project dredging and reclamation activities. Data from these locations will assist the assessment (should it be necessary) of whether any changes in the benthic communities at the South Shell Island or Catalina Island sites are due to the dredging and reclamation works, or represent broader-scale responses to other stressors (e.g. physical impacts or degradation of water quality due to storm activity, bleaching, disease outbreak, etc.).

9.3.3 Methodology

The Dredging Contractor will implement a habitat monitoring methodology that is appropriate for the application of statistical analysis using a 'Before, After, Control and Impact' (BACI) design (Underwood 1994), with replication within each monitoring location and between different locations (i.e. reference and putative impact sites). The survey design will involve repeated measurements over time being made at reference sites and potentially impacted sites, both before and after impacts have occurred.

Technology such as towed cameras or mini-ROVs will be used to collect video records and high resolution still images of the benthic communities at the monitoring locations. The imagery will be analysed using appropriate software (e.g. Coral Point Count with Excel extensions or Geographic Information Systems where image mosaics are able to be developed at monitoring sites) to provide a quantitative data set of the composition and biota percent cover at each location.

Monitoring will be undertaken:

- Just prior to the commencement of dredging (to establish a baseline of benthic community composition and health).
- At the completion of dredging (to ascertain whether any detectable changes have occurred to benthic community composition and health).
- During dredging, if indicated by the results of the turbidity monitoring undertaken in the vicinity of the plume sources (refer Section 9.2.4).

9.3.4 Data Analysis

Statistical power analysis of benthic community data collected around South Shell Island by Geo Oceans (2012) indicated that the minimum detectable difference (change) in percent cover varied between sites, from 2% to 14%. This variability was primarily due to the typically patchy distribution of benthic biota along the transects, and to the high variability in cover between transects. Given these characteristics of the benthic communities, it is considered that it is only feasible to detect (with sufficient statistical confidence) a change of 10% in biota cover at the monitoring locations.

To detect a 10% change in biota cover with a power of at least 0.8 and a statistical confidence of 5%, the power analysis showed that analysis was required of 50 still images per transect, with five points analysed per image. The recommended number of replicate transects (each 50 m long) required per site varied between monitoring sites from five to nine transects.

The results of the Geo Oceans (2012) study will be taken into account by the Dredging Contractor in developing the data analysis protocols for this Project. These protocols will be reviewed and approved by the Proponent prior to implementation, noting (as per Section 1.8) that the Proponent carries the responsibility for ensuring that the monitoring program will be adequate to meet their commitments as presented within this Plan.

In addition to measurements of benthic cover of hard corals and filter feeders, the proportion of biota showing evidence of stress (e.g. bleaching or excessive mucus production) will also be recorded and comparisons made between the South Shell Island and/or Catalina Island and Channel Island sites.

9.3.5 Outcomes

If attributability assessments are triggered in response to the monitoring of turbid plumes arising from the dredging and reclamation activities (refer Section 9.2.4), and any of these assessments indicate that the activities are responsible for the trigger (i.e. 'positive attributability'), then:

- Fortnightly monitoring of the benthic communities at the South Shell Island and/or Catalina Island and Channel Island sites will be initiated.
- Monitoring will continue over four fortnightly periods following the positive attributability assessment. It is recognised that elevated turbidity levels at the South Shell Island and/or Catalina Island sites are unlikely to result in immediate changes to benthic community health, but that indications of reduced health may become evident over time.

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- If the monitoring does not indicate any trend in decreasing health of the benthic communities at the monitoring sites (as indicated by increasing stress or mortality of hard corals or filter feeders), and there have been no further positive attributability assessments over the monitoring period, then monitoring will be suspended.

9.4 EAW settling ponds – water quality (Option 1 only)

9.4.1 Objectives

If Option 1 is selected as the preferred dredging methodology, then the objectives of monitoring water quality within the EAW settling ponds will be 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 Redevelopment, etc.).
- Confirm the physico-chemical properties (pH, toxicants and SSC) of the tailwater are suitable for discharge from the ponds to the harbour waters.

9.4.2 Monitoring locations

The water quality monitoring locations are shown in Figure 13. The pH, turbidity and toxicant concentrations of the tailwater will be monitored at any pond discharge point where tailwater is flowing and within Pond E (South).

In the event that stormwater enters Ponds D or E (North) from existing reclamation areas or ponds within East Arm Port, then pH and toxicants will be monitored weekly at the point of stormwater entry to Pond E (North). This will inform the assessment of potential causes of any changes in pH and toxicant concentrations that may become evident in Ponds E (North) or (South) (i.e. it will determine if contaminants are present in the stormwater).

9.4.3 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 will 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. A rapid turnaround time for analysis will be specified, to minimise the time that elapses before any required corrective actions are able to be implemented.

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

Based on potential toxicity and presence within Darwin Harbour sediments, the metallic toxicants to be monitored through collection of water samples are presented in Table 17 (refer Section 8.3.4). The toxicant trigger levels are set at the 95% species protection level as per ANZG (2018). Where marine water quality triggers are not available due to insufficient data, freshwater trigger levels applicable to slightly–moderately disturbed systems are adopted. Speciated toxicants (arsenic and chromium) will be analysed for total concentrations, and if any total exceeds the trigger level of one of the species, then the samples will be reanalysed for the individual species.

9.4.4 Data analysis

Data for tailwater pH, turbidity and metals (toxicants) will be plotted and assessed for trends after each data collection period. Any trends towards allowable limits will be used as an early warning mechanism, and dredging operations and tailwater or stormwater management procedures will be assessed to

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ascertain whether corrective actions (such as those presented in Table 18, Section 8.3.6) may need to be implemented to avoid exceedance of water quality limits.

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Figure 13 Water quality sampling locations within settling ponds

9.4.5 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) (refer Section 8.3.6).

9.5 Protected marine species

At all times that the dredge is operational, the crew will include at least one member that is trained (by a suitably qualified trainer) as an MFO. As described in Table 20 (Section 8.5) the MFO will be responsible for undertaking visual assessments (for protected marine species) of the 750 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.

Procedures for the protection of marine fauna potentially vulnerable to dredging noise will be as follow:

- Prior to the commencement of any dredging, an Observation Zone extending 750 m in all seaward directions from the dredge will be established.
- From 20 minutes prior to the commencement of any dredging, an MFO will monitor the Observation Zone to check for the presence of any protected marine species (dolphins, dugongs and turtles).
- If any individual of a protected marine species is observed within a 500 m radius Start-up Exclusion Zone, then noise-intensive dredging activities will not commence until the animal is observed to have left this zone, or until 30 minutes have elapsed since the last sighting.

During dredging, at 30-minute intervals the designated MFO will check the Observation Zone for a period of five minutes. Once dredging activities have commenced, if any protected marine species approach within 50 m of the dredge, or a dolphin with calf enters within 150 m of the dredge (i.e. the Dredging Response Zones), the sightings will be recorded (including details of the time and results of observation) and the management measures described in Section 8.5 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 and mitigation measures to minimise the potential for impacts or collisions with marine fauna. The purpose of the training will be to raise awareness; to encourage recording and reporting of protected marine species sightings; and to emphasise the requirement to report stranded, injured or dead protected marine species regardless of what caused the injuries or deaths.

All sightings of protected marine species will be recorded by the MFO on marine fauna observation forms similar to that presented in Figure 12 (Section 8.4); these will be available on all Project vessels. These records will be provided to the Proponent and logged into the Project’s protected marine fauna sighting register.

The Dredging Contractor will be responsible for reporting sightings of any EPBC-listed marine fauna to the Proponent, who will in turn report these sightings to the relevant authorities within 24 hours. This includes 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 will be 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.

9.6 Summary of monitoring programs

Key aspects of each of the monitoring programs are summarised in Table 21.

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Table 21 Summary of environmental monitoring programs

Locations	Parameter	Methods	Frequency	Triggers	MF
TURBID PLUME 150 m FROM DREDGE, PIPELINE OR RECLAMATION AREA					
Section 9.2 Throughout the water column where the turbid plume extends beyond 150 m from the source	Turbidity	Visual Hand-held probe	As required by visual monitoring	Maximum SSC >100 mg/L (measured as turbidity, 140 NTU) 150 m from source. Continue to monitor and implement corrective actions to reduce SSC levels to below 100 mg/L at a distance of 150 m from source. Monitoring locations: within the plume at a point 150 m from source.	Water Quality Management – Darwin Harbour
Section 9.3 Sites around South Shell Island and Catalina Island and at Channel Island	Percent cover of hard corals and filter feeders Proportion of biota exhibiting signs of stress (e.g. bleaching, excessive mucus production)	Remote sensing (e.g. drop camera and/or mini-ROV)	As required by turbid plume monitoring	Attributability assessment concludes that turbidity level in excess of 140 NTU at distances of greater than 150 m from any source is due to dredging or reclamation activities. Fortnightly monitoring to continue until no evidence of downward trend in community health over successive monitoring periods. Monitoring locations: as selected during baseline assessment of benthic habitat cover by hard corals and filter feeders.	
EAW SETTLING PONDS (Option 1 only. Monitoring locations in Figure 13 are shown as ⊗ in the text)					
Section 9.4 Pond K at the weir prior to flow into Pond E (North). If required: Where stormwater enters Pond E (North)	pH	Hand-held probe	Daily from commencement of dredging until cessation of tailwater discharge	pH<6.0 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). Implement corrective actions if trigger exceeded (Section 8.3.6). Relevant monitoring locations: ③ ④ ⑤	Water Quality Management – EAW Settling Ponds

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Locations	Parameter	Methods	Frequency	Triggers	MF
	Toxicants	Laboratory	Sample collected once per week from commencement of dredging	Exceedance of any ANZG (2018) DGVs (refer Table 17, Section 8.3.4). 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). Implement corrective actions if trigger level exceeded. Relevant monitoring locations: ③ ④ ⑤.	
	Turbidity (NTU)	Hand-held probe	Daily from commencement of dredging until cessation of tailwater discharge	Use established SSC/NTU relationship (Section 8.3.4) 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), Implement corrective actions if trigger level exceeded. Relevant monitoring locations: ③ ④ ⑤.	
Section 9.4 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 commencement of dredging until cessation of tailwater discharge	pH<6.0 Discharge from Pond E (North) into Pond E (South) discontinued if trigger level exceeded (Section 8.3.6). Relevant monitoring locations: ① ②	Water Quality Management – EAW Settling Ponds
	Toxicants	Laboratory	Once per week from the commencement of dredging until the cessation of tailwater discharge	Discharge from Pond E (North) into Pond E (South) discontinued if any ANZG (2018) DGVs exceeded (refer Table 17, Section 8.3.4). Relevant monitoring locations: ① ②	

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Locations	Parameter	Methods	Frequency	Triggers	MF
	Turbidity (NTU)	Hand-held probe	Daily from the commencement of dredging until the cessation of tailwater discharge.	Discharge from Pond E (North) into Pond E (South) discontinued if trigger level (100 mg/L SSC = 140 NTU) exceeded. Relevant monitoring locations: ① ②	
Section 9.4.5 Observation Zone and Start-up Exclusion Zone and Dredging Response Zones 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 750 m radius Observation Zone by the MFO, for a period of 20 minutes prior to the recommencement of dredging. 2. While the dredge is operational, 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 Dredging Response Zones: • 150 m for dolphin with calf • 50 m for all other protected marine species, including dolphin without calf. Dredging shall not recommence until no protected marine species have been sighted within the 500 m radius Start-up Exclusion Zone for a period of 30 minutes. (Table 20, Section 8.5)	Protected Marine Species Management – physical interaction and underwater noise

10.0 Reporting

10.1 Routine reporting

10.1.1 Beginning of dredging

The Dredging Contractor will notify the Proponent and the NT EPA at least seven days prior to the planned start of dredging. This notification will include confirmation that all of the necessary measures are in place to comply with this DDSPMP.

The Proponent will provide details of the dredging works to the Regional Harbourmaster so that a Notice to Mariners can be issued. The Notice to Mariners will be the mechanism through which stakeholders, and other members of the general public, will receive notification of the intention to commence dredging.

10.1.2 Daily reporting

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

- a summary of the dredging completed in the last 24 hours 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 9.4.5)
- dredge daily logs showing work area and availability.

10.1.3 Weekly monitoring report

Each week during the dredging, reclamation and tailwater discharge activities, a weekly summary report of monitoring data will be submitted by the Dredging Contractor to the Proponent for dissemination to relevant stakeholders that may be designated by the NT EPA. The report will include:

- tailwater pH and turbidity (NTU) data within the EAW settling ponds, from the commencement of dredging and dredged material placement until the cessation of tailwater discharge into Pond E (South) (Section 9.4)
- toxicants data for tailwater, once available from the laboratory (Section 9.4)
- comments on any apparent trends in the tailwater data, both over time and between ponds (Section 9.4)
- summary of daily data reports (Section 10.1.2)
- discussion of any trigger level exceedances (Section 10.2)
- corrective actions taken to address exceedances (Section 8.0)
- South Shell Island and/or Catalina Island and Channel Island benthic community data (including analysis of trends), if any surveys triggered within the previous fortnight (Section 9.3)
- details of any injuries to, or mortalities of, turtles, dugongs, dolphins or migratory birds as a result of dredging or reclamation activities, or settling pond water management (Section 10.3)
- 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 10.3).

10.1.4 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 the proponent weekly, and the findings from hydrographic surveys confirming dredge volumes and locations will be included in the Dredging Contractor’s report to the Proponent fortnightly and on completion of the dredging (see Section 10.1.5). Copies of the daily environmental inspection checklists and other relevant environmental records will be provided by the Dredging Contractor to the Proponent for circulation as appropriate. All records will be provided in a format that allows auditing by relevant environmental regulators if required.

10.1.5 End of dredge phase reporting

Within one month of the conclusion of dredging, the Dredging Contractor will submit a monitoring report to the Proponent, who will in turn provide this report to the NT EPA and DAWE. The report will include 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.

10.1.6 Compliance reporting

The Proponent, as the holder of the NT EPA approvals and WDL, will report to the NT EPA in accordance with the pertinent approval and WDL conditions. The Dredging Contractor will provide information to the Proponent 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, reclamation and tailwater management in response to monitoring exceedances.

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

10.2 Exceedance notification and reporting

The following notifications of exceedances will be made by the Dredging Contractor to the Proponent within 24 hours of the exceedances occurring:

- Within the EAW settling 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.
- At the location 150 m down-current of the dredge, pipeline or reclamation area, where management measures are implemented.

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

Exceedances will also be reported to the NT EPA in accordance with conditions of the Project approvals and WDL, and as required under the *Waste Management and Pollution Control Act 1998* and the *Water Act 1992*.

For each exceedance at Pond E (North) at the weir into Pond E (South), or in Pond E (South), the Dredging Contractor will provide the NT EPA (via the Proponent) 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 Project approvals and WDL.

10.3 Environmental incident notification and reporting

In the event of the following environmental incidents, the Dredging Contractor will notify the Proponent within 24 hours of the incident occurring (the Proponent will then notify any other relevant stakeholders):

- vessel interaction with protected marine species, including details of injury to, or mortality of, individuals (Section 8.4)
- suspected disturbance of protected marine species related to noise generated by dredging activities (Section 8.5).

Other environmental incidents (spills, etc.) will also be recorded and reported in environmental monitoring reports to the Proponent. If the incident is a notifiable incident under the *Waste Management and Pollution Control Act 1998*, then the NT EPA will be notified by the Proponent within 24 hours.

All incidents will be investigated and recorded on a Dredging Contractor ‘Incident Report Form’, ‘Environmental Incident Details Form’ or similar in accordance with the 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.

10.4 Complaints reporting

In the event of a complaint received as a result of dredging activities, they will be entered and tracked using the Dredging Contractor's 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 Proponent and authorities upon request, taking into account any privacy issues of the complainant as appropriate.

10.5 Reporting and notification summary

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

Proponent: Craig Smith (craig.smith@nt.gov.au)

NT EPA: https://ntepa.nt.gov.au/make-a-report

The reporting and notification requirements for the Project are summarised in Table 22.

Table 22 Reporting and notifications summary

Reporting Type	Time	Reporting to	Content/Comments
Routine reporting			
Commencement of dredging notification. (Section 10.1.1)	Seven days before intended commencement of dredging	Proponent NT EPA Regional Harbourmaster	Notification of intent to commence dredging works and confirmation that all required measures are in place to comply with the requirements of this DDSPMP. This notification will include any other reporting requirements of other environmental approvals and the WDL.
Protected marine species sightings (Section 9.4.5)	24 hours (from sighting)	Proponent	Marine fauna observations sheet (Figure 12).
Daily reports (Section 10.1.2)	Daily	Proponent	Daily work completed, monitoring undertaken and any exceedances detected. If an exceedance is detected the report will include a summary of proposed corrective actions and timeframes for implementation.
Weekly monitoring reports (Sections 10.1.3 and 10.1.4)	Weekly	Proponent	Water quality data from tailwater monitoring within the EAW settling ponds and at 150 m down-current from the dredge, pipeline and reclamation area.

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Reporting Type	Time	Reporting to	Content/Comments
			Benthic community monitoring data (if triggered). Protected marine species sightings (summary from daily observations sheets). Summary of dredge operation records for the week.
End of dredging report (Section 10.1.5)	Within one month of conclusion of dredging.	Proponent NT EPA	Monitoring report as per any relevant approvals and WDL conditions.
Exceedance reporting			
Water quality exceedance – initial notification (Section 10.2)	24 hours (from occurrence)	Proponent	Location and value of exceedance.
Water quality exceedance – attributability review (Section 10.2)	24 hours (from end of three-day attributability review period)	Proponent	Details of determination and logic used to support the conclusions.
Water quality exceedance – corrective actions (Section 10.2)	Five business days (from notification)	Proponent NT EPA	As per relevant approvals and WDL conditions.
Environmental incident reporting			
Injury to, mortality of, or disturbance of, a protected species (Section 10.3)	24 hours (from occurrence)	Proponent NT EPA	Time, location and photos.
Other environmental incidents (Section 10.3)	24 hours (from occurrence)	Proponent NT EPA	Report generated from Dredging Contractor's incident management system.
Complaints reporting			
Complaints (Section 10.4)	48 hours (from occurrence)	Proponent	Report generated from Dredging Contractor's incident management system.

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11.0 References

Abdul Wahab MA, Fromont J, Pineda MC, Strehlow B, Duckworth A, Jones R, Webster N, 2019. *Defining thresholds and indicators of filter feeder responses to dredging-related pressures - final synthesis report*. Report of Theme 6 – prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia 26 pp.

AECOM 2020. *Darwin Ship Lift Project Sediment Geochemical Investigation*. Report prepared for NT Government by AECOM Australia Pty Ltd. September 2020. Appendix H to AECOM (2021).

AECOM 2021. *Draft Environmental Impact Statement: Darwin Ship Lift Project.* Prepared for Department of the Chief Minister and Cabinet by AECOM Australia Pty Ltd. November 2021.

ALA 2021. *Atlas of Living Australia*. https://www.ala.org.au/.

ANZECC & ARMCANZ 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment & Conservation Council and Agriculture & Resource Management Council of Australia & New Zealand, October 2000.

ANZG 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

Aurecon 2015. *Multi User Barge Ramp Facility – Archaeological Report.* Report prepared for Department of Infrastructure, Aurecon Australia Pty Ltd, April 2015.

Australian Institute of Marine Science 2021. *Revised Predictive Benthic Habitat Map for Darwin Harbour*. Report Prepared for the Department of Environment, Parks and Water Security. October 2010.

Baird 2019, *Technical Report for Hydrodynamic Modelling of Discharge*. Appendix O of TNG Limited Draft Environmental Impact Statement, Darwin Processing Facility, Baird Australia Pty Ltd, October 2019.

Batley GE, 1995. *Heavy Metals and Tributyltin in Australian Coastal and Estuarine Waters*. In Zann, L (ed.), State of the Marine Environment Report for Australia, Technical Annex 2, Department of the Environment, Sport and Territories, Canberra.

BoM 2022. *Climate statistics for Australian locations*. Bureau of Meteorology website, viewed 23 June 2022 at: http://www.bom.gov.au/climate/averages/tables/cw_014015.shtml

Brinkman R and Logan M, 2019. *Sediment Quality Sampling Design for Darwin Harbour*. Report prepared for Northern Territory Government, Department of Environment and Natural Resources. Australian Institute of Marine Science, Townsville.

Brooks L and Pollock K, 2014. *Abundance, movements and habitat use of coastal dolphins in the Darwin region: Analysis of the first six primary samples (October 2011 to March 2014).* Final report to the Northern Territory Government Department of Land Resource Management.

Brooks L, Palmer C, Griffiths AD and Pollock KH, 2017. Monitoring variation in small coastal dolphin populations: An example from Darwin, Northern Territory, Australia. *Frontiers in Marine Science* 4: 4, doi:103389/fmars.2017.00094.

Burford MA, Alongi DM, McKinnon AD and Trott LA, 2008. Primary production and nutrients in a tropical macrotidal estuary, Darwin Harbour, Australia. *Estuarine and Coastal Shelf Science*, 79, 440–448.

Butler ECV, Streten-Joyce C, Tsang JJ, Williams DK, Alongi DM, Furnas MJ and McKinnon AD, 2013. *A Procedure for Evaluating the Nutrient Assimilative Capacity of Darwin Harbour.* Report for Aquatic Health Unit, NT Department of Land Resource Management. Australian Institute of Marine Science, Darwin, Australia.

Cardno 2014a. *Nearshore Environmental Monitoring Summary Report*. Prepared for INPEX, October 2014.

Cardno 2014b. *Turtle and Dugong Monitoring End of Dredging Report Ichthys Nearshore Environmental Monitoring Program*. Prepared for INPEX, September 2014.

Case M, Galaiduk R, Harries S, Biggs J, Radford B and Streten C, 2021. *Towed video report for the Darwin Ship Lift EIS*. Report prepared for AECOM. Australian Institute of Marine Science, Perth. Appendix F to AECOM (2021).

DRAFT

Cassilles Southgate N and Fortune J, 2018. *Interim Turbidity Water Quality Objectives for Dry Season Neap Tide Conditions in Darwin Harbour.* Report No. 5/2018D. Aquatic Health Unit, Water Resources Division. Department of Environment and Natural Resources. Palmerston, NT. https://territorystories.nt.gov.au/10070/754529

Chatto M, 2003. *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. PWCNT, Technical Report 73.

Commonwealth of Australia 1992. *National Water Quality Management Strategy*.

Commonwealth of Australia 2005. *Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pest Incursions, April 2005.*

Commonwealth of Australia 2009. *National Assessment Guidelines for Dredging.*

Commonwealth of Australia 2018. *National Acid Sulfate Soils Guidance. Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management*.

Cosmos 2015. *East Arm Multi-User Barge Ramp Facility, Recovered Cultural Objects, Maritime Archaeological Analysis Report*. Prepared by Cosmos Archaeology Pty Ltd for Land Development Corporation, NT Government, August 2015.

Darwin Harbour Advisory Committee (DHAC) 2005, *A review of Environmental Monitoring of the Darwin Harbour Region and Recommendations for Integrated Monitoring*, Darwin Harbour Advisory Committee, Darwin.

Darwin Harbour Advisory Committee 2003. *Darwin Harbour Regional Plan of Management*. Department of Infrastructure, Planning and Environment, Darwin.

Darwin Harbour Advisory Committee 2007*. Status on the Implementation of the Darwin Harbour Regional Plan of Management 2005–2006.*

Darwin Harbour Advisory Committee 2020. *2020-2025 Darwin Harbour Strategy*, July 2020. https://nt.gov.au/__data/assets/pdf_file/0008/915038/darwin-harbour-strategy-2020-2025.pdf

DENR 2016, *Darwin Harbour Region Report Card 2016*. Department of Environment and Natural Resources.

DENR 2020. *Darwin Harbour Region Report Card 2019*. Aquatic Health Unit, Department of Environment and Natural Resources, Palmerston NT.

Department of Environment Water Heritage and the Arts (DEWHA) 2009. *Approved Conservation Advice for Pristis clavata (Dwarf Sawfish),* Department of the Environment, Water, Heritage and the Arts, Canberra, ACT.

DEPWS 2021*. Darwin Harbour Region Report Cards – Zone 2: East Arm*, Department of Environment, Parks and Water Security, viewed 31 May 2022. Available at: https://depws.nt.gov.au/water/water-management/darwin-harbour/darwin-harbour-region-report-cards/darwin-harbour-report-card-2020/zone-2-east-arm

DEWHA 2009. *Approved Conservation Advice for Pristis clavata (Dwarf Sawfish),* Department of the Environment, Water, Heritage and the Arts, Canberra, ACT.

DLRM 2013. *Darwin Harbour Region Report Card 2013.* Northern Territory Department of Land Resource Management, Darwin, NT, Australia.

DLRM 2014. *Darwin Harbour Water Quality Protection Plan*, Northern Territory Department of Land Resource Management, Darwin, NT, Australia. https://denr.nt.gov.au/__data/assets/pdf_file/0011/254855/Water-Quality-Protection-Plan-Feb2014-web.pdf

DoI 2014. *Annual Monitoring Report for the Darwin Marine Supply Base Dredging and Dredge Spoil Placement Activities 2013 Reporting Period*. March 204. Prepared by Department of Infrastructure, Northern Territory Government on behalf of Department of Lands, Planning and Environment.

Dorji P, Fearns P, Broomhall M, 2016. A Semi-Analytic Model for Estimating Total Suspended Sediment Concentration in Turbid Coastal Waters of Northern Western Australia Using MODIS-Aqua 250 m Data*. Remote Sensing* 8(7):556.

DRAFT

Drewry J, Fortune J, Majid M, Schult J, Lamche G, Townsend S, Cusack S, 2011. *Darwin Harbour Region Report Cards 2011*. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport. Report No 17/2011D. Palmerston, NT, Australia.

Duggan S, 2006. *The Water Quality of Darwin Harbour: December 2002 - December 2004.* AIMS Report No. 37, Australian Institute of Marine Science.

Earth Sea Heritage Surveys (2011). *Archaeological Survey of the EAW Expansion and Surrounding Area, Darwin NT.* Report prepared for URS Corporation, March 2011.

EMS 2011. *East Arm Wharf Expansion Project: Terrestrial flora and fauna assessment*. Report to URS Australia/NT DLP by Ecological Management Services, Queensland. Appendix M to DLP 2011a.

EnSTaR 2021, *Historical Water Quality Assessment*, Historical Total Suspended Sediment Concentration Assessment using Satellite Remote Sensing in Coastal Waters of Darwin Harbour, Assessment Report No. E015 for AECOM Australia Pty Ltd, Perth, WA.

Fortune J, 2006. *The grain size and heavy metal content of sediment in Darwin Harbour*. Report No. 14/2006D. Aquatic Health Unit, Environmental Protection Agency. Fortune J, 2010. *Water Quality Objectives for the Darwin Harbour Region – Background Document*. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport.

Fortune J, 2010. *Water Quality Objectives for the Darwin Harbour Region – Background Document*. Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport.

Fortune J, 2016. *Darwin Harbour Region 2016 Report Card Water Quality Supplement*. Report No. 22/2016D. Aquatic Health Unit, Department of Environment and Natural Resources. Palmerston, NT.

Galaiduk R, Radford B, Harries S, Case M, Williams D, Low Choy D and Smit N, 2019. *Technical Report: Darwin – Bynoe Harbours predictive mapping of benthic communities*. Australian Institute of Marine Science, Perth. Available at https://www.researchgate.net/publication/340374082_Technical_Report_Darwin_-_Bynoe_Harbours_Predictive_Mapping_of_Benthic_Communities_httppidgeosciencegovaudatasetga127389

Geo Oceans 2011. *Ichthys Gas Field Development Project: Benthic Habitat Mapping of the Darwin region – Methods of Data Collection, Collation, and Map Production*. Technical Appendix S6 to INPEX (2011).

Geo Oceans 2012. *NT Department of Lands and Planning – East Arm Wharf Expansion Project. Baseline Marine Habitat Monitoring Survey*. Report to URS Australia Pty Ltd, Document code DLPEAWMON.401, October 2012.

Griffiths AD, Groom RA, Low Choy D, Mackarous K. and Brooks L, 2020. *Darwin Region Coastal Dolphin Monitoring Program: Final Report – 2011 to 2019*, Department of Environment, Parks and Water Security, Northern Territory Government.

G-Tek 2017. *Unexploded Ordinance Desktop Investigation. SLAMI Site - East Arm, Darwin, Northern Territory*. Version 2_01. Report Prepared for SMEC Australia Pty Limited. 19 December 2017. Project ref. 17078SMEC.

Hill JV and Edmeades BF, 2008. *Acid Sulfate Soils of the Darwin Region*. Department of Natural Resources, Environment, the Arts and Sport.

INPEX 2010. *Ichthys Gas Field Development Project: Draft Environmental Impact Statement*. Report prepared by INPEX Browse, Ltd.

INPEX 2011. *Ichthys Gas Field Development Project: Supplement to the Draft Environmental Impact Statement*. Report prepared by INPEX Browse, Ltd.

INPEX 2013. *Dredging and Spoil Disposal Management Plan – East Arm.* Prepared by INPEX Ichthys Project, December 2013.

INPEX 2018. *Maintenance Dredging and Spoil Disposal Management Plan.* Prepared by INPEX Ichthys Project, March 2018. Accessed at: https://ntepa.nt.gov.au/__data/assets/pdf_file/0005/590171/plan_wdl240_inpex_maintenance_dredging_spoil_disposal_management.pdf

Jensen FH, Bejder L, Wahlberg M, Aguiar Soto N, Johnson M, Madsen PT, 2009. Vessel noise effects on delphinid communication. *Marine Ecology Progress Series* 395: 161-175.

Jones R, Fisher R, Bessell-Browne P, 2019. Sediment deposition and coral smothering. *PLoS ONE* 14(6): e0216248. https://doi.org/10.1371/journal.pone.0216248

KBR 2020. *Darwin Ship Lift and Marine Industries Facility Sediment Sampling and Analysis Plan*. Report prepared for the NT Department of Trade, Business and Innovation. BEN961-TD-EV-REP-0001 Rev. 0. 5 February 2020.

Lilleyman A, Alley A, Jackson D, O'Brien G, Garnett ST, 2018. Distribution and abundance of migratory shorebirds in Darwin Harbour, Northern Territory, Australia. *Northern Territory Naturalist* 28, 31–43.

Lilleyman A, Lawes MJ, Garnett ST, 2013. *Migratory shorebirds in Darwin Harbour, Northern Territory*. Report to the Department of Business, Northern Territory Government. 31 October 2013.

Lilleyman A, Rogers DI, Jackson MV, Fuller RA, O'Brien G, Garnett ST, 2020. An artificial site provides valuable additional habitat to migratory shorebirds in a tropical harbour. *Pacific Conservation Biology* 26: 249-257. https://doi.org/10.1071/PC19036.

Macmahon 2013. *Dredging and Dredge Spoil Placement Management Plan (DDSPMP) End of Phase 1 Environmental Monitoring Report – Revision 0*

McKinnon AD, Smit N, Townsend S and Duggan S 2006. *Darwin Harbour: water quality and ecosystem structure in a tropical harbour in the early stages of development*, In: 'The Environment in Asia Pacific Harbours' (Ed: Wolanski, E). Springer, Dordrecht, the Netherlands.

Mills D and Kemps H, 2016. *Generation and release of sediments by hydraulic dredging: a review*. Report of Theme 2 - Project 2.1 prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia.

Moein Bartol S and Musick JA, 2003. *Sensory biology of sea turtles*. In: Lutz PL, Musick JA and Wyneken J (eds) The biology of sea turtles, Vol 2. CRC Press, Boca Raton, FL, pp. 79–102.

Munksgaard NC and Parry DL, 2002. Metals, arsenic and lead isotopes in near pristine estuarine and marine coastal sediments from Northern Australia. *Marine and Freshwater Research*, 53(3), 719–729.

Munksgaard NC, 2013. *Recommendations for sampling and analysis of Darwin Harbour sediment*. Environmental Chemistry and Microbiology Unit (ECMU), Charles Darwin University. November 2013. https://denr.nt.gov.au/__data/assets/pdf_file/0010/253738/darwin_harbour_sediment_analysis_protocol_2014.pdf

Munksgaard, NC, Hutley, LB, Metcalfe, KN, Padovan, AC, Palmer, C & Gibb, KS 2018. *Environmental challenges in a near-pristine mangrove estuary facing rapid urban and industrial development*, Darwin Harbour, Northern Australia, Regional Studies in Marine Science, 25

Nawaz S, 2010. *Sediment Sources Near the Extreme Ends of the Catchment Continuum and the Topographic Dependence of Denudation in a Global Context*. PhD, thesis Charles Darwin University.

NRETAS 2010. *Water Quality Objectives for the Darwin Harbour Region - Background Document.* Aquatic Health Unit, Department of Natural Resources, Environment, The Arts and Sport, February 2010. https://denr.nt.gov.au/__data/assets/pdf_file/0003/254856/WQGO_for_DH_Feb_2010_final.pdf

NT Emergency Service 2011. *Darwin Storm Surge.* NT Emergency Service brochure.

NT EPA 2013. *Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory*, Northern Territory Environment Protection Authority, Darwin. https://ntepa.nt.gov.au/__data/assets/pdf_file/0007/287422/guideline_assessments_marine_dredging.pdf.

NT EPA 2015. *Guideline for the Preparation of an Environmental Management Plan*, Northern Territory Environment Protection Authority, Darwin. https://ntepa.nt.gov.au/__data/assets/pdf_file/0006/284883/guideline_prep_emp.pdf

NT EPA 2018. *NT EPA Environmental Factors and Objectives, Version 1, 2018*. https://ntepa.nt.gov.au/__data/assets/pdf_file/0005/546791/guideline_environmental_factors_objectives.pdf

NT EPA 2019. *Terms of Reference for the Preparation of an Environmental Impact Statement – Darwin Ship Lift and Marine Industries Project*. Northern Territory Environment Protection Authority, Darwin, 12 December 2019.

NTG 2005. *A Review of Environmental Monitoring of the Darwin Harbour Region and Recommendations for Integrated Monitoring.*

NTG 2010. *Northern Territory Government gazette: no. G27*. https://hdl.handle.net/10070/226956

Padovan AV, 2003. *Darwin Harbour water and sediment quality*. Marine and Estuarine Environments of Darwin Harbour. Proceedings of the Darwin Harbour Public Presentations, February 2003.

Padovan, AV 1997. *The water quality of Darwin Harbour: October 1990–November 1991*, Water Quality Branch, Water Resources Division, Department of Lands, Planning and Environment, NT Government, Report No. 34/1997D December 1997.

Padovan, AV 2001. *The Quality of Run-off and Catchment Loads to Darwin Harbour*. Report No. 29/2000D. Resource Management Branch, Natural Resources Division, Department of Lands, Planning and Environment, NT Government.

Padovan, AV 2003. *Darwin Harbour water and sediment quality*, pp. 5–18 in Darwin Harbour Region: current knowledge and future needs, Proceedings of public presentations hosted by the Darwin Harbour Advisory Committee at the Northern Territory University, Darwin, on 11, 19 and 26 February 2003, NT Department of Infrastructure, Planning and Environment, Darwin.

Palmer C 2008, *Coastal dolphin research in the Northern Territory*. PowerPoint presentation to “Coast to Coast 2008” Conference, Convention Centre, Darwin, 18–22 August 2008.

Palmer C, Brooks L, Fegan M and Griffiths AD, 2017. *Conservation Status of Coastal Dolphins in the Northern Territory: Final Report*. Marine Ecosystems Group, Flora and Fauna Division, Department of Environment and Natural Resources, Darwin.

Palmer C, Fitzgerald P, Wood A, Harley S and McKenzie A, 2009. False killer whales *Pseudorca crassidens*: regular visitors to Port Essington and Darwin Harbour in the Northern Territory, Australia. *Northern Territory Naturalist* 21: 49–53.

Parra GJ, 2006. Resource partitioning in sympatric delphinids: Space use and habitat preferences of Australian snubfin and Indo-Pacific humpback dolphins. *Journal of Animal Ecology* 75: 862–874.

Parra GJ, Schick RS and Corkeron PJ 2006. *Spatial distribution and environmental correlates of Australian snubfin and Indo-Pacific humpback dolphins*, Ecography 29: 396–406.

Peverell S, 2007. *Dwarf Sawfish* Pristis clavata, The State of Queensland Department of Primary Industries & Fisheries.

Peverell S, Gribble N, and Larson H, 2004. *Sawfish.* In: Description of key species groups in the northern Planning Area, pp, 75-83. National Oceans Office, Hobart.

Peverell SC, 2005. Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentaria, Australia, with notes on their ecology, *Environmental Biology of Fishes* 73: 391-402.

Power and Water Corporation 2006. *Wastewater Treatment, Reuse and Discharge Report 2006*.

PWCNT 2000. *A Strategy for the Conservation of Marine Biodiversity in the Northern Territory of Australia*. Parks and Wildlife Commission of the NT.

Radke LC, Fortune J, Majid M, Mummery A, 2020. *Sediment quality assessment of East Arm, Darwin Harbour (2019): Survey record and data report.* Technical Report No.9/2020, Department of Environment and Natural Resources, Northern Territory Government. https://territorystories.nt.gov.au/10070/756439

Radke LC, Fortune J, Townsend S, Schult J, Staben G, Skarlatos-Simoes M, Palmer C, Dostine P, 2019. *Anthropogenic Pressures Pilot Project: Development of Pressure Indicators for Darwin Harbour.* Report No 25/2019D. NT Department of Environment and Natural Resources, Palmerston, June 2019. https://territorystories.nt.gov.au/10070/774781.

Rigby P, Steinberg C, Williams DK, Brinkman G, Brinkman R, Tonin H and Hughes D, 2014. Real-time marine observing systems: Challenges, benefits and opportunities in Australian coastal waters, *Australian Journal of Civil Engineering*, 12, 83-99.

Ross GJB, 2006. *Review of the Conservation Status of Australia’s Smaller Whales and Dolphins,* Australian Government, Canberra, ACT.Simão C and Tonin H, 2020. *Modelling the Sediment Plume*

DRAFT

Associated with Dredging for the Darwin Ship Lift, Prepared for AECOM, Australian Institute of Marine Science, Darwin. pp 45, including appendices.

Simpson SL, Mosley L, Batley GE, Shand P, 2018. *National Acid sulfate soils guidance: Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management*, Department of Agriculture and Water Resources, Canberra, ACT. CC BY 4.0

Siwabessy J, Tran M, Howard FJF, Smit N, Williams DK, Dando N, Atkinson I, Harries S, 2015. *Outer Darwin Harbour Marine Survey 2015: High resolution bathymetry grid*. Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/100093

Skinner, L, Townsend, S & Fortune, J 2009. *The impact of urban land-use on total pollutant loads entering Darwin Harbour*, Report 06/2008D Aquatic Health Unit, Northern Territory Department of Natural Resources, Environment, the Arts and Sport, Palmerston, NT, Australia.

Smit N, Penny SS and Griffiths AD 2012. *Assessment of marine biodiversity and habitat mapping in the Weddell region, Darwin Harbour*, Report to the Department of Lands, Planning and Environment. Department of Land Resource Management, Palmerston.

Strehlow BW, Pineda M, Duckworth A, Kendrick GA, Renton M, Abdul Wahab MA, Webster NS, Clode PL, 2017. Sediment tolerance mechanisms identified in sponges using advanced imaging techniques. *PeerJ* 5:e3904. https://doi.org/10.7717/peerj.3904

Thorburn DC, Morgan DL, Rowland AJ and Gill HS, 2007. Freshwater sawfish *Pristis microdon* Latham, 1794 (Chondrichthyes: Pristidae) in the Kimberley region of Western Australia, *Zootaxa* 1471: 27–41.Thorburn DC, Peverell S, Stevens S, Last JD and Rowland AJ, 2003. *Status of Freshwater and Estuarine Elasmobranchs in Northern Australia,* Report to Natural Heritage Trust, Canberra.

URS 2004. *Darwin City Waterfront Redevelopment Project: Draft Environmental Impact Assessment*. Prepared for Department of Infrastructure, Planning and Environment, May 2004.

URS 2009. *Nearshore Marine Water Quality and Sediment Study*. Report prepared for INPEX Browse, Ltd, R1382, August 2009. Technical appendix 9 to INPEX (2010).

URS 2011. *Ichthys Gas Field Development Project: summary of the long-term water-quality and program for Darwin Harbour*. Report prepared for INPEX Browse, Ltd, R1589, March 2011. Technical appendix S9 to INPEX (2011).

URS 2015. Multi User Barge Ramp Facility Dredging and Dredge Spoil Placement Management Plan. Report prepared for Land Development Corporation, R1755, March 2015.

WA EPA 2016. *Technical Guidance for the Environmental Impact Assessment of Dredging Proposals*. Environmental Protection Authority, Western Australia, 2016.

Water Monitoring Branch 2005. The Health of the Aquatic Environment in the Darwin Harbour Region. Report No. 5/2005D. Water Monitoring Branch, Natural Resources Management Division, Department of Natural Resources, Environment and the Arts, Darwin, Northern Territory.

Welch M, Schult J and Padovan A, 2008. *Effects of Urban Stormwater on Heavy Metal and Nutrient Concentrations in Mangrove Sediments of Darwin Harbour.* Report 08/2008D Aquatic Health Unit, Department of Natural Resources, Environment, the Arts and Sport.

Whiting SD 2003. *Marine mammals and marine reptiles of Darwin Harbour*, In: Darwin Harbour Region: current knowledge and future needs. Proceedings of public presentations hosted by the Darwin Harbour Advisory Committee at the Northern Territory University, Darwin, on 11, 19 and 26 February 2003, Department of Infrastructure, Planning and Environment, Darwin, Northern Territory.

Whiting SD 2008. *Movements and distribution of dugongs (Dugong dugon) in a macro tidal environment in northern Australia*, Australian Journal of Zoology 56: 215–222.

Whiting SD 2002. Rocky reefs provide foraging habitat for dugongs in the Darwin region of northern Australia. *Australian Mammalogy* 24: 147–150.

Whiting SD 2003. *Marine Mammals and Marine Reptiles of Darwin Harbour*, In: Darwin Harbour Region: current knowledge and future needs. Proceedings of public presentations hosted by the Darwin Harbour Advisory Committee at the Northern Territory University, Darwin, on 11, 19 and 26 February 2003, Department of Infrastructure, Planning and Environment, Darwin, Northern Territory.

D R A F T

Whiting SD, 2008. Movements and distribution of dugongs (*Dugong dugon*) in a macro tidal environment in northern Australia. *Australian Journal of Zoology* 56: 215–222.

Williams, D, Wolanski, E and Spagnol, S 2006. *Hydrodynamics of Darwin Harbour.* In 'The environment in Asia Pacific Harbours' (Ed: E. Wolanski) pp 461-476. Springer, Dordrecht, the Netherlands.

WMB 2005. *The health of the aquatic environment in the Darwin Harbour region*, Report No. 5/2005D. Water Monitoring Branch, Natural Resources Management Division, Department of Natural Resources, Environment and the Arts, Darwin, Northern Territory.

Wolstenholme J, Dinesen ZD and Alderslade P 1997. *Hard Corals of the Darwin region, Northern Territory, Australia*, In Hanley JR, Caswell G, Megirian D and Larson HK (eds) Proceedings of the Sixth International Marine Biological Workshop ("The marine flora and fauna of Darwin Harbour, Northern Territory, Australia"). Museums and Art Galleries of the Northern Territory and the Australian Marine Sciences Association, Darwin, Northern Territory.