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Dampier Cargo Wharf Extension and Landside Redevelopment Project

Marine Water Quality Baseline Report

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Acronyms and Abbreviations

Acronyms/Abbreviation	Description
ALOF	Alternative Load-Out Facility
ANZG	Australia and New Zealand Environment and Conservation Council Guidelines
BoM	Bureau of Meteorology
BSC	Burrup Services Corridor
Burrup SIA	Burrup Strategic Industrial Area
CALM	Conservation and Land Management
DBLB	Dampier Bulk Liquids Berth
DCW	Dampier Cargo Wharf
DGV	Default guideline values
DLI	Daily Light Integral
DO	Dissolved Oxygen
ECU	Ecosystem units
EQC	Environmental quality criteria
EQG	Environmental quality guidelines
EQI	Environmental quality indicators
EQMF	Environmental quality management framework
EQO	Environmental quality objectives
EQS	Environmental quality standards
EPA	Environmental Protection Authority
EV	Environmental values
HLOF	Heavy Load Out Facility and Alternative Load-Out Facility (ALOF)
LEP	Level of ecological protection
LNG	Liquid Natural Gas
LOR	Limit of reporting
MEQSAP	Marine Environmental Quality Sampling and Analysis Plan
NWQMS	National Water Quality Management Strategy
NTU	Nephelometric Turbidity Units
PAH	Polycyclic Aromatic Hydrocarbons
PQL	Practical Quantitation Limit
TC	Tropical cyclone
TN	Total nitrogen
TP	Total phosphorus
TPH	Total Petroleum Hydrocarbons
TRH	Total Recoverable Hydrocarbons
TSS	Total suspended solids

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1. Introduction

1.1. Project Description

Pilbara Ports Authority (**PPA**) is the proponent for the Dampier Cargo Wharf Extension and Landside Redevelopment Project (**the Project**). PPA is proposing to construct and operate a land-backed wharf extension to the Dampier Cargo Wharf (**DCW)** at the Port of Dampier (**the Port**). The scope of the Project incorporates the development of a new (adjoining) southern section of wharf and associated mooring dolphin, wharf connecting structure, dredged berth pocket and vessel manoeuvring area (Figure 1). The final design of the wharf structure is yet to be finalised, however, key construction elements of the Project are proposed to include pile driving works, construction of rock revetment and installation of a suspended wharf deck. Up to 380,000m^3 of capital dredging will be undertaken to establish a new berth pocket and associated manoeuvring basin to design depths of -13.2m (Chart Datum (CD)) and -11.0m (C D) respectively (plus an allowance for up to 1m of over-dredging to achieve these depths). This volume includes an estimated ~100,000m^3 of underlying and surface granophyre rock at the south-east end of the dredging footprint. To undertake dredging of this material it must be broken up first using drilling and blasting techniques. Dredging will be undertaken using either a cutter suction or backactor dredge. Material dredged as part of the Project will be placed within the three established spoil grounds within the Port depending on the type of material to be disposed. These spoil grounds are named East Lewis Island Spoil Ground (ELI), Spoil Ground A/B and Spoil Ground 2B (locations displayed in Figure 2). Note: Suitable rock material may be beneficially reused for other approved Port projects and / or be placed within established Spoil Grounds within the Port. Where possible, PPA will seek to place rock material in such a way within ELI Spoil Ground that it can be colonised by corals.

A short summary of the proposal is provided in Table 1. The proposed Development Envelope and Project Footprint are presented in Figure 1.

Table 1 General Project content description

Project title	Dampier Cargo Wharf Extension and Landside Redevelopment Project
Proponent name	Pilbara Ports Authority
Short description	The Proposal is for the construction and operation of a land-backed wharf extension to the DCW at the Port. The Project incorporates the development of a new (adjoining) southern section of wharf, dredged berth pocket and vessel manoeuvring area. The Proposal will enable larger vessels (up to Panamax class) to access the terminal and facilitate new trades and products being handled at the Port.

1.2. Location

The Port is located approximately 1,540 kilometres (by road) north of Perth, WA and 260 kilometres (by road) west of Port Hedland. The Port is located on the western side of Murujuga on the Pilbara coastline (Figure 2), approximately 20 km west of Karratha. The Port consists of ten port terminals with separate navigational

channels, which facilitate the export of iron ore, salt, gas products and the transfer of general cargo, break-bulk and bulk liquid fuels. PPA is responsible for managing Port waters and vessel traffic operating within the Port.

The Port extends out into Mermaid Sound and the Indian Ocean beyond the limits of State Waters (3 nautical miles) and incorporates the waters surrounding Murujuga and some waters of the Dampier Archipelago (Figure 2).

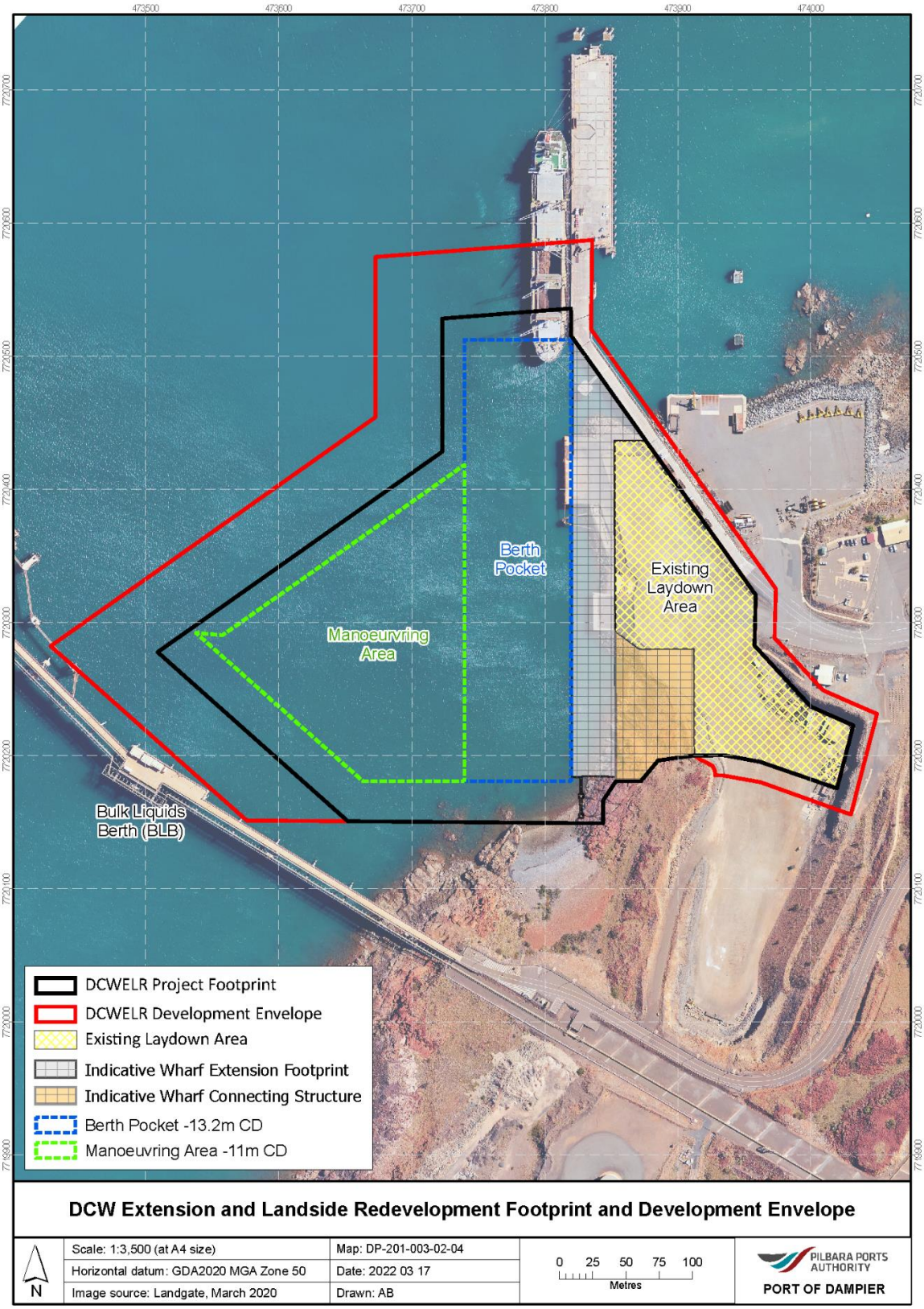

Figure 1 Project Development Envelope and Footprint

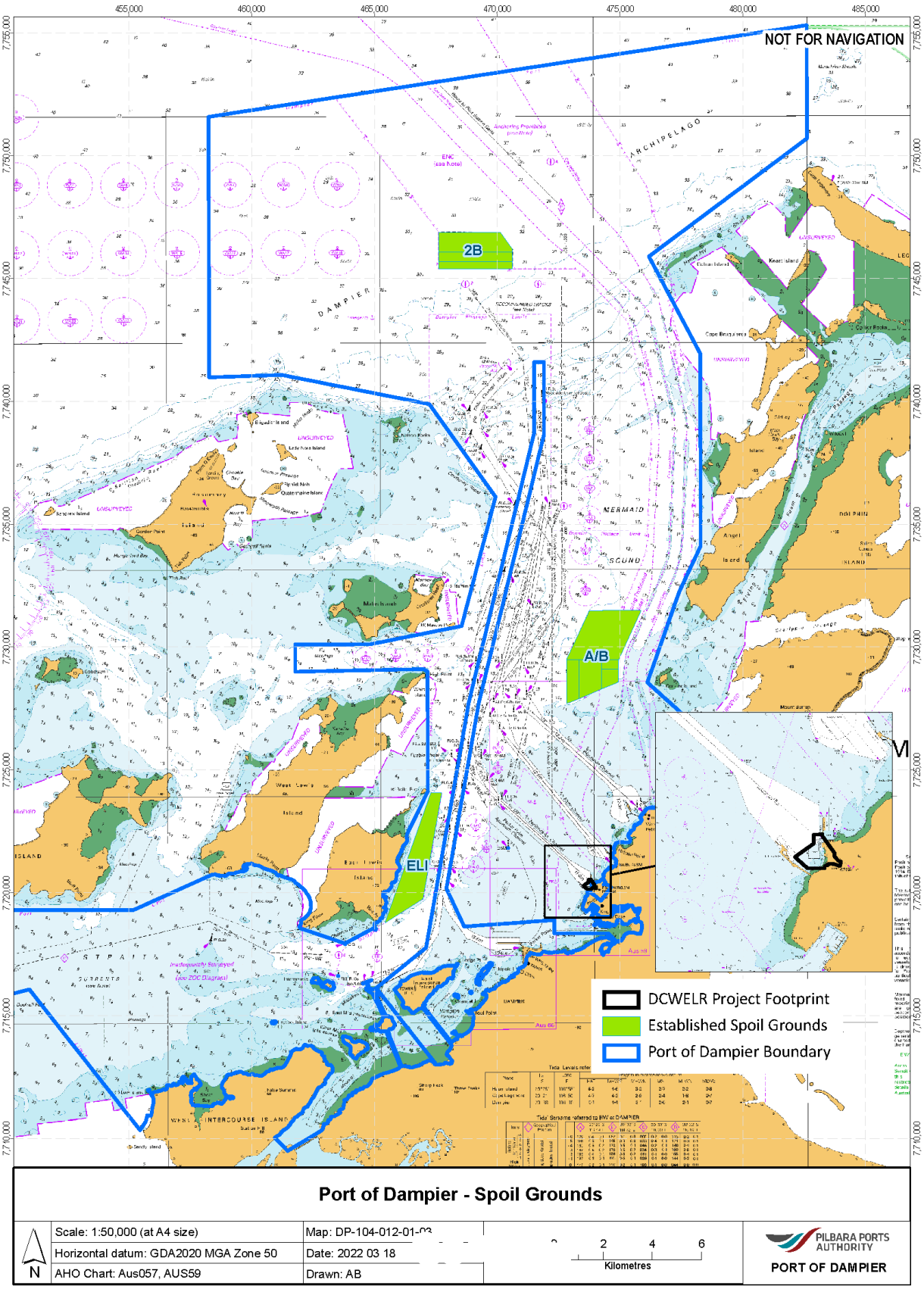

Figure 2 Location of Project and Dampier Spoil Grounds

1.3. Background

The Port services major industries located in the Port and the nearby Burrup Strategic Industrial Area (**Burrup SIA**) and is an important logistics hub for the offshore oil and gas industry, downstream gas processing and mining operations in the central Pilbara.

Major exports from the Port are iron ore, salt, Liquid Natural Gas (**LNG**), condensate and anhydrous ammonia. PPA operates two multi-user facilities in the Port; namely the Dampier Bulk Liquids Berth (**DBLB**) to support bulk liquid imports and exports (including diesel fuel and anhydrous ammonia), and the DCW providing for general cargo and offshore supply vessels (Figure 1). Additional facilities managed by others within the vicinity of the DCW and DBLB are also shown in Figure 3.

There is currently no multi-user bulk solid export cargo capacity in the Port. The need for a new multi-user facility has been recognised by PPA, to support new and existing trades and proposed industrial developments in the Burrup SIA. PPA is proposing to develop and operate a land-backed wharf extension to the DCW at the Port. The extension of the DCW as proposed will connect to the existing land-based operational areas currently used by PPA as lay-down and project cargo off-loading and storage areas. The scope of the Project incorporates the development of a new (adjoining) southern section of piled wharf and associated mooring dolphin, wharf connecting structure, dredged berth pocket and vessel manoeuvring area (Figure 1).

The new multi-user wharf will align and extend directly south from the DCW, enabling larger vessels to access this terminal and support new trades and products being handled at the Port. The Project will be connected to the Burrup SIA by the existing Burrup Services Corridor (**BSC**), a dedicated infrastructure corridor designed to accommodate services which facilitate the export of a range of liquid and solid products.

The Project Footprint includes highly modified seabed environments which have undergone previous capital dredging and are subject to ongoing maintenance dredging in accordance with PPA's Commonwealth 5-year Sea Dumping Permit (SD2019/3962) and approved Long-Term Dredge Management Plan. The Project Footprint (Figure 1) also includes developed and operational port infrastructure, including laydown areas, coastal revetments, an existing mooring dolphin associated with the DCW and two wharf facilities: the Heavy Load Out Facility (**HLOF**) and Alternative Load-Out Facility (**ALOF**). However, as this port infrastructure continues to be operated and maintained by PPA, any existing and ongoing works to maintain, remediate or otherwise modify these port lands and associated port infrastructure are outside the scope of the Project.

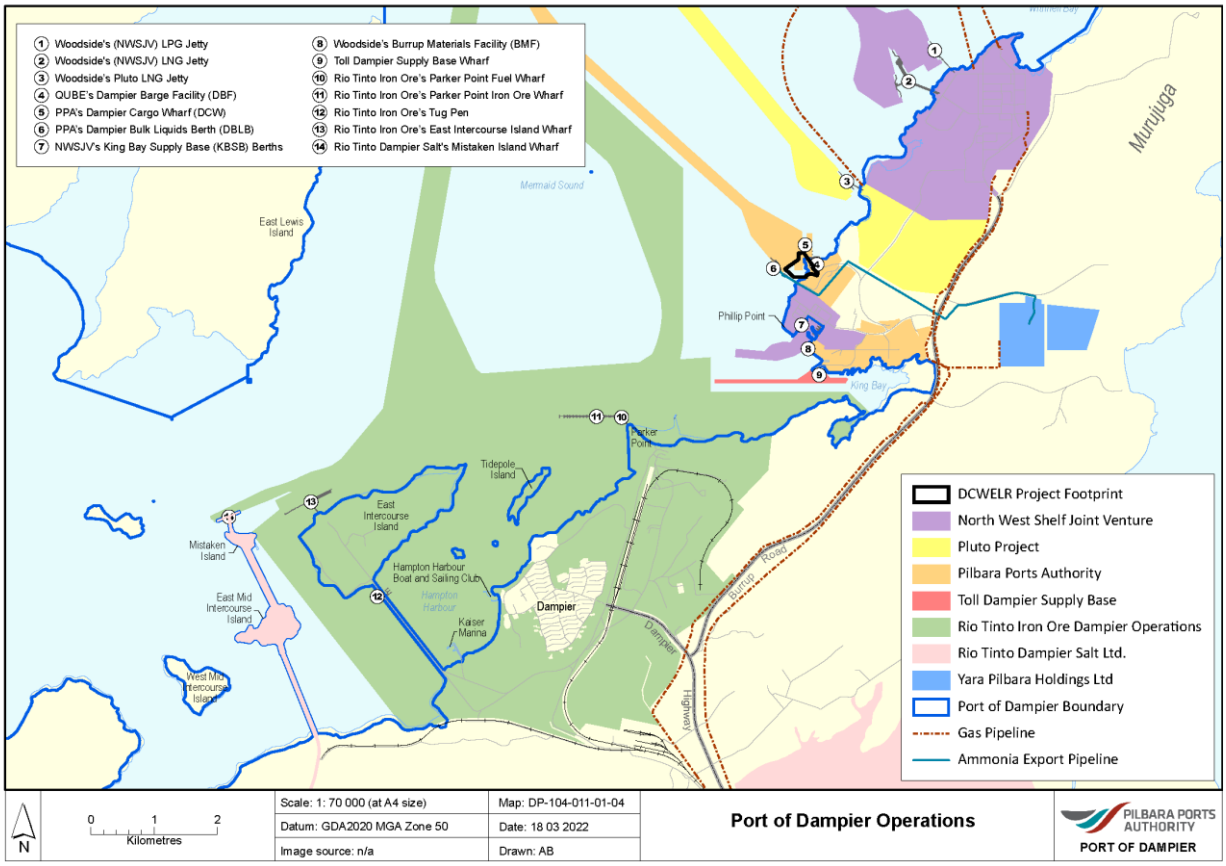

Figure 3 Location of the Project and other Port of Dampier operations

1.4. Purpose of this Document

The objectives of this document are to:

- Provide an overview of the Environmental Protection Authority's (EPA) Environmental Quality Management Framework (EQMF) that is applied within the Port.
- Characterise the existing water quality conditions within Port waters to inform environmental impact assessment (EIA) of the Project.
- Document spatial and temporal variation of background marine water quality in the Port.
- Determination of background turbidity and total suspended solids (TSS) values to inform dredge plume modelling.

The document includes a summation of results from the current water quality monitoring program being implemented by PPA within the Port (as described in Section 2), which is now in its third year and is comprised annually of four (4) quarterly sampling events per year. The first three years represent the initial baseline data collection phase of the Port's water quality monitoring program.

2. Port of Dampier Existing Environment

The Port includes inshore, relatively calm and turbid environments that are sheltered by the 42 islands of the Dampier Archipelago and Murujuga. Offshore areas of the Port are influenced by clearer oceanic waters and rougher seas. With its variety of conditions, the Port supports a wide range of marine benthic communities and habitats including mangroves, rocky, sandy and muddy shores, macroalgal communities and coral reefs. Within these habitats there is a high diversity of marine fauna including species of special significance such as migratory humpback whales, migratory shorebirds and marine turtles (CALM 2005). The islands are frequented by tourists, recreational fishers and divers and hold social and cultural significance.

2.1. Climate

Air temperatures vary from mean maximum temperatures in the mid to high twenties during the cooler months (May to September) and low to mid-thirties during the warmer months (October to April) (BOM 2018). Records show March to have the highest mean maximum temperature of 34.8°C, with July the lowest mean maximum of 25.8°C (BOM 2018). On average over two hundred days per annum exceed 30°C, five of which exceed 40°C. February has the highest mean minimum temperature of 26.6°C with July further recording the lowest mean minimum temperature of 17.3°C.

Monthly and annual rainfall is highly variable with the majority of rain falling during the warmer months as a result of tropical low-pressure systems. Mean annual rainfall for the Port is 326.0 mm with highest mean rain falling in February 74.0 mm and lowest mean rainfall in November 0.1 mm (BOM,2018).

Prevailing winds are west to south-westerly during the warmer months (September to April) and easterly during the cooler months (May to August). During the warmer months wind strength tends to increase throughout the day and are strongest in the afternoons, whilst the opposite occurs in the cooler months (BOM 2018).

The official tropical cyclone season runs from November to April although cyclones have occurred outside of this period. On average up to five cyclones per year pass the region in which three may track near the Port of Dampier (BOM, 2018). Since 1910, the Port of Dampier has recorded 48 cyclones where wind gusts have exceeded 90km/h, approximately one every two years (BOM 2018).

2.2. Oceanography

Typically, swell and waves enter the Port of Dampier from the north as a result of Southern Ocean swell refraction around the Montebello Islands, 120 km to the west. The Port is protected to the west and east by the islands of the Dampier Archipelago and south by mainland Australia. As a result, these islands reduce swell and wave height by up to 50% as they propagate down Mermaid Strait towards the inner Port region (Pearce *et al.* 2003). Swell heights tend to be greater in winter (June/July, typically 2 m in height) and smaller in summer (~1 m in height) (Pearce *et al.* 2003). Tropical cyclone swells may reach 10 m in the outer Port and are usually reduced to 2.5 m in the inner Port. Ninety percent of locally generated wind waves within the Port are less than 0.6 m in height (Pearce *et al.* 2003).

The tidal regime of the Port of Dampier is semi-diurnal with a slight diurnal inequality (difference in height between the two highs or two lows) (Pearce *et al.* 2003). The Port of Dampier experiences mean high water springs tides of 4.5 m and mean low water springs tides of 0.8 m approximately 2 days after the full and new moon (Pearce

et al. 2003). Tidal currents in the waters off the Burrup Peninsula are locally influenced by surrounding islands and channels that form the Dampier Archipelago. During springtides seaward reaches of Mermaid Sound (outer Port) can experience currents of 40- 50 cm/s with inner Sound (inner Port) currents about half that observed further offshore (Pearce *et al.* 2003). Currents through Sea Ripple and Flying Foam Passages to the east can reach in excess of 2 m/s asa result of the large difference in sea-level gradients between Mermaid Sound and Nickol Bay (Forde 1985).

2.3. Water Quality

Numerous water quality programs have been undertaken in the Dampier region. The purpose of the programs varies from broad investigative studies to regulatory and compliance monitoring for specific projects such as dredging or wastewater treatment plant outfalls. The existing and historical water quality monitoring that has been undertaken is provided in Table 2.

Table 2 Historical and ongoing water quality monitoring programs and studies in Port of Dampier.

Program/study	Proponent	Program Summary
Forde (1985) Technical report on suspended matter in Mermaid Sound, Dampier Archipelago	Department of Environment and Conservation	Series of six weekly investigative surveys conducted in 1982/83 involving vertical profiling for temperate, salinity and turbidity along a transect line in Mermaid Sound from nearby East Intercourse Island to outside state waters.
Pearce *et al.* (2003) A review of the oceanography of the Dampier Archipelago, WA	CSIRO	Described the oceanography of the Dampier Archipelago including tides, waves, currents, winds, temperature, salinity, chlorophyll-a, turbidity.
Stoddart and Anstee (2005) Water quality, plume modelling and tracking before and during dredging in Mermaid Sound, Dampier, WA	MScience	Summarises the outcomes of two separate water quality programs implemented during concurrent capital dredging in the Port of Dampier by Hammersley Iron (monitoring at 13 sites) and Dampier Port Authority (monitoring at 14 sites). Monitoring was undertaken over a full range of tidal and weather conditions. At each site, water quality was measured at near bottom, and near surface. In situ readings were recorded during a multi-parameter probe, including: Depth; Dissolved Oxygen (DO); pH; Turbidity (NTU); Temperature; and Salinity. Total suspended solids at each monitoring sit was measured by laboratory analysis of collected water samples. Throughout the dredging program aerial surveys of the dredging location, monitoring locations and surrounding areas were undertaken on a weekly basis.
Stoddart and Anstee (2005). Bulk Liquids Berth Dredging Project	Dampier Port Authority (PPA)	Assessment of turbidity, total suspended solids (TSS), temperature, dissolved oxygen and salinity during Dampier Port Authority's Bulk Liquids Berth capital dredging program in 2004. Sites established were consistent with monitoring by Rio Tinto
Stoddart and Anstee (2005). Parker Point channels, approaches and berth pockets	Rio Tinto	Turbidity, total suspended solids (TSS), temperature, dissolved oxygen and salinity during parallel capital dredging programs in 2004.

DEC (2006) Background quality for coastal marine waters of the North West Shelf, WA.	Department of Environment and Conservation	Cadmium, chromium, copper, lead, zinc, total mercury, polyaromatic hydrocarbons, phenols and BTEX. Various locations within the Dampier Archipelago. Samples from King Bay had slightly elevated levels of some heavy metals, however these were still below ANZECC 99% species protection guidelines.
MScience (2007), Pluto LNG Development, Baseline Water Quality Assessment Report	Woodside Energy Limited	Baseline water quality data for this monitoring was collected over a nine-month period (October 2006 to May 2007) at eight sites in Mermaid sound. The baseline study involved the continuous recording of water quality (suspended sediments, sedimentation, light and temperature) and sedimentation data with monthly monitoring of coral sites.
SKM (2008), Pluto LNG Development, Dredging and	Woodside Energy Limited	The aim of this programme was to monitor water quality and sediment deposition data regularly to assist in the management of the dredging.
Spoil Disposal Management Plan / Dredge Impact Management Plan.	Woodside Energy Limited	The aim of this programme was to monitor water quality and sediment deposition data regularly to assist in the management of the dredging operations and minimise any environmental effects relating to the Pluto LNG Development. This included monitoring 25 sites for water quality. At each monitoring location a series of continuous loggers were placed at the same depth as the coral habitat and data from each logger were either telemetered or downloaded at the same time as coral health assessments.
MScience (2009), Dampier Marine Services Facility: Water Quality Impacts of the Pluto Program in an Area of Intensive Dredging.	Dampier Port Authority (PPA)	An examination of water quality undertaken immediately adjacent to the most intense dredging over the first three months of the Pluto LNG Project, providing a capacity to evaluate the relationship between water quality and coral health impacts in the context of the proposed Dampier Port Authority *Dampier Marine Services Facility* Project.
MScience (2009) Dampier Port Wharf Construction: Water Quality Descriptors.	Dampier Port Authority (PPA)	This report provides summary statistics of turbidity from intensive monitoring programs conducted at sites within a few kilometres of the proposed Dampier Port Authority Dampier Marine Services Facility (DMSF) construction (reclamation and dredging) footprint. Data reviewed as part of the analysis included: (a) 23 months of turbidity data recorded at 10 minute or 30 minute intervals during Woodside Burrup Pty Ltd's Pluto dredging campaign (data here includes four sites around the proposed project that are likely to have been impacted by plumes from dredging and a site outside of the modelled zone of influence); and (b) seven months of turbidity data recorded at 10 minute intervals from a site close to the proposed DMSF project footprint, prior to the commencement of the Pluto dredging project.
MScience (2009) Summary of Woodside Capital dredging campaign	Woodside (report prepared for PPA)	Turbidity and temperature prior to (baseline) and during Pluto Capital Dredging. November 2007 to September 2009.
Mermaid Marine – Dampier Supply Base: Ongoing marine monitoring program (Ministerial Statement 535)	Toll	Water Quality monitoring in King Bay as part of a broader environmental monitoring program originally established by Mermaid Marine Australia and continued by Toll under licence L8511/2010/2
Ongoing monitoring program (Environmental Licence)	Rio Tinto	Monitoring part of licence (L7182/1997/11) conditions for bulk loading and salt export activities. Hydrocarbons, BTEX, TRH aroundMistaken Island and East Mid Intercourse Island six sites inside Port Waters.

Ongoing marine monitoring program (Environmental Licence)	Rio Tinto	Monitoring under licence (L6755/1996/9). Prior to discharge, monitoring includes physico-chemical parameters, nutrients, *E. coli*, heavy metals.
Oceanica (2015) MUBRL ongoing marine monitoring program (Environmental Licence)	Water Corporation	Baseline data collection commenced in 2003 prior to commissioning of the MUBRL Cadmium, chromium, copper, zinc, lead and mercury collected quarterly from King Bay (SKM 2005). In-line monitoring under licence (L7997/2002/11), marine water, sediment and sentinel monitoring for a range of toxicants, chemicals, physico-chemical properties, biotoxins, pathogens, nutrients, inorganics, chlorophyll-a in King Bay.
MScience (2016) Environmental Monitoring Report for Pilbara Iron Dredge Campaign 2016	Rio Tinto	A three-week environmental monitoring program (including sediment plume tracking and turbidity monitoring) conducted during Maintenance dredging activities within the Port of Dampier which confirm that environmental performance was consistent with impact predictions generated within the sea dumping permit application
PPA (2017 - 2019) Marine Water Quality Monitoring Program (MWQP)	PPA	Quarterly program including monitoring for Turbidity, total suspended solids (TSS), temperature, dissolved oxygen and salinity continued from Stoddart and Anstee (2005). In 2017, two additional sites were added and collection of samples for laboratory analysis - nutrients, organics, hydrocarbons, heavy metals.
O2 Marine (2019 - ongoing) MWQP incorporated into Marine Environmental Quality Sampling and Analysis Plan (MEQSAP)	PPA	Provides a framework to monitor, characterise and report on the long-term trends in marine water and sediment quality within the Port and surrounding waters. Prescribes quarterly water quality and annual sediment quality monitoring and defines sampling and analysis procedures.

These studies have found that water quality within the Port of Dampier responds to natural influences, port operations and anthropogenic inputs but is generally consistent in the long-term. Wind and tidally driven currents effectively create a flushing effect in port waters (Pearce *et al.* 2003; DEC 2006). There are few reports of significantly reduced water quality outside of cyclonic events or *Trichodesmium* blooms. Terrestrial and riverine inputs to Mermaid Sound occur only during and after heavy rainfall (such as in cyclones). Significant wave and current action can cause substantial resuspension of sediments leading to elevated turbidity throughout the water column (Forde 1985).

Coastal waters of the Dampier Archipelago generally display low metal and organic contaminant concentrations (Mackey 1984). Concentrations of contaminants were below the 99% species protection guideline (consistent with maximum level of ecological protection) for each respective contaminant and were comparable to water quality of the North West Shelf. However, water samples collected from King Bay did display elevated cadmium and copper concentrations compared with all other sites (DEC 2006). Metals in the water column are generally bound to suspended solids thus total metal concentrations (principally copper and zinc) occasionally exceeded ANZECC/ARMCANZ 2000 guidelines but filtered samples did not (SKM 2005).

Mean water temperature within Dampier Archipelago varies significantly throughout the year and is highly site dependent. Seasonal temperature variation of nearly 10°C with temperatures ranging from 31°C (Summer) to 21°C (Winter) (Pearce *et al.* 2003; Stoddart and Anstee 2005). Diurnal variability of up to 1°C has been noted in shallow habitats. Salinity remains relatively constant (34.6-35.6 ppt) temporally, although it can vary spatially. Within the Dampier Archipelago, surface salinity increases from inshore (about 36.7 ppt west of King Bay in March) to further

offshore (about 35.5 ppt, around 35 km north of East Intercourse Island in March). Mermaid Sound displays a 'winter hydrographic regime' whereby cooler and more saline water forms within the Archipelago and wedges seaward beneath open North West Shelf waters. During summer, a 'summer hydrographic regime' is characterised by vertical stratification on the open continental shelf and elevated salinity in shallower coastal waters (Pearce *et al.* 2003). Nitrogen levels, in particular, total nitrogen and nitrate-nitrite, in the surface and bottom waters of the area often exceeded the ANZECC/ARMCANZ 2000 guidelines; however, the chlorophyll levels did not (SKM 2005). This finding was also supported by the PPA sampling, although was confined to samples collected during May and June (PPA 2017).

Turbidity is a measure of the degree to which water loses its transparency due to the presence of suspended particulates. Turbidity reduces light penetration making water appear darker and murkier leading to reduced primary production and the loss of benthic habitats. Typically, the waters in the inner Archipelago, closer to the mainland, are characterised as having naturally higher levels of turbidity than the clearer offshore environment. Turbidity can be attributed to wind and currents which can resuspend fine sediments, particularly during cyclone events and spring tides. Periodic events, such as major sediment transport associated with tropical cyclones, may influence turbidity on a regional scale (CSIRO, 2007). Increases in suspended sediments is also attributed to dredging, shipping movements and coastal development. During dredging works for Woodside's Pluto LNG Development, turbidity and TSS were elevated within 1km of dredging operations and were generally localised to small temporal scales (MScience 2009a).

2.3.1. Trichodesmium

Trichodesmium is a filamentous blue-green alga or cyanobacteria that naturally occurs as phytoplankton, commonly known as 'Sea Sawdust', in the world's tropical and subtropical oceans, including Western Australia's northern marine waters. As a diazotrophic cyanobacteria, *Trichodesmium* fixes atmospheric nitrogen, thereby playing an important role in the marine nutrient cycle (Bergmann, et al. 2013). The fixation of nitrogen gas occurs primarily with increased solar radiation and benefits greatly from the increased ambient air temperatures that are characteristic of Western Australia's Pilbara region, particularly during summer.

Extensive blooms are known to occur in the Pilbara between September and April (PPA 2019), when water temperatures are elevated above 20°C and algae are concentrated in the thermally-stratified euphotic zone (Bergmann, et al. 2013). Additionally, buoyancy in *Trichodesmium* is aided by gas vesicles that allow colonies to regulate their position in the water column in response to fluctuating levels of solar radiation (Bergmann, et al. 2013).

Favourable growth conditions for *Trichodesmium* blooms occur when there is excess nutrient supply (particularly phosphorous), high sunlight levels and warm temperatures, creating conditions which allow algal populations to multiply rapidly (Westberry and Siegel 2006). Cyanobacteria produce neurotoxins that can accumulate in fish and shellfish and can be poisonous when ingested (O'Neil and Roman 1992). These blooms can also result in the depletion of dissolved oxygen at night during respiration, or due to bacterial decomposition when blooms die off, often resulting in 'dead zones' where other biota cannot survive (Westberry and Siegel 2006).

A *Trichodesmium* Desktop Study is due to be incorporated into the MEQSAP following the initial baseline data collection phase and the quarterly MEQSAP reporting will include a Red Tides water quality summary, unless otherwise requested separately by PPA.

3. Environmental Quality Management Framework

PPA has developed a Marine Environmental Quality Sampling and Analysis Plan (MEQSAP) (O2 Marine 2019) in the context of an EQMF, as defined in the EPA's Technical Guidance for Protecting the Quality of Western Australia's Marine Environment (EPA 2016). The approach to establishing an EQMF, including identification of Environmental Values (EVs), Environmental Quality Objectives (EQOs), Levels of Ecological Protection (LEPs) and Environmental Quality Criteria (EQC) is clearly described in EPA (2016). The approach is based on the principles and guidelines of the National Water Quality Management Strategy (NWQMS), with particular regard to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). The focus of the approach is on maintaining existing marine environmental quality and identifying where management and/or remediation may be required and to measure its effectiveness. The EQMF can also be used to provide measurable performance objectives for unplanned events or discharges (EPA 2016).

3.1. Environmental Values and Environmental Objectives

EVs are defined as particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits (ANZG 2018). EQOs are high level management objectives that describe what must be achieved to protect each EV (EPA 2016).

The EVs and associated EQOs for the local marine environment are already well established in the Pilbara Coastal Waters Consultation Outcomes (DoE 2006). Five EVs and eight corresponding EQOs apply to the Port (Table 3).

Table 3 Environmental Values and Environmental Quality Objectives applicable to the Port of Dampier and surrounding waters

Environmental Values	Environmental Quality Objectives
Ecosystem Health	EQO1: Maintenance of ecosystem integrity. EQO1 is split into four sub-objectives, being: Maximum, High, Moderate and Low Levels of Ecological Protection (LEPs) (Refer Section 3.2 below).
Fishing & Aquaculture	EQO2: Seafood (caught) is of a quality safe for human consumption. EQO3: Water quality is suitable for aquaculture purposes
Recreation & Aesthetics	EQO4: Water quality is safe for primary contact recreation (e.g. swimming and diving). EQO5: Water quality is safe for secondary contact recreation (e.g. fishing and boating). EQO6: Aesthetic values of the marine environment are protected.
Cultural & Spiritual	EQO7: Cultural and spiritual values of the marine environment are protected
Industrial Water Supply	EQO8: Water quality is suitable for industrial supply purposes

3.2. Levels of Ecological Protection

In accordance with EPA (2016), the 'Ecosystem Health' EQOs are spatially allocated into four LEPs: Maximum, High, Moderate and Low. Each LEP area is assigned an acceptable limit of change, allowing for areas important for conservation to be maintained within the limits of natural variation, whilst recognising that societal uses may preclude either a 'Maximum' or 'High' LEP limit from being achieved within other areas.

The LEPs adjacent to the Port are defined in the Pilbara Coastal Water Quality Consultation Outcomes (DoE 2006) (Figure 4). Marine areas associated with the Dampier Archipelago Island Reserves are assigned a Maximum LEP. Most of the area is assigned as a high LEP. Waters around the established dredge spoil disposal areas and within 250m of inner port facilities (e.g. ship turning basins and loading berths) are allocated a moderate LEP. Approved outfall discharge locations are allocated a low LEP.

This Project is not expected to require any modification to the existing LEP's associated with the Port.

3.3. Environmental Quality Criteria

EQC are scientifically derived quantitative benchmarks used to measure the performance of environmental management for the Project in achieving the EQOs, and protection of the corresponding EVs. EQC are generally quantitative and are usually described numerically. They are comprised of Environmental Quality Guidelines (EQG) and more robust Environmental Quality Standards (EQS):

> Environmental Quality Guidelines: EQG are threshold numerical values or narrative statements which if met, indicate that there is a high degree of certainty that the associated EQO has been achieved. If the EQG is not met, then there is uncertainty as to whether the associated EQO has been achieved, and a more detailed assessment against an 'Environmental Quality Standard' (EQS) is triggered. This assessment is risk-based and investigative in nature.
>
> Environmental Quality Standards: EQS are threshold numerical values or narrative statements that indicate a level beyond which there is a significant risk that the associated EQO has not been achieved and a management response is triggered. The response would normally focus on identifying the cause/source of the exceedance and eradicating or reducing the contaminant of concern.

ANZG (2018) identifies a series of default guideline values (DGVs) which provide appropriate levels of species protection for the development of EQC for toxicants. Works undertaken by DEC (2006) within waters of the Dampier Archipelago provide an estimate of background concentrations for selected metals and organics in the marine waters of the North West Shelf which support the application of the ANZG (2018) DGVs for the region. The recommended EQC from these documents are presented within Section 4.3.

4. Environmental Management in the Port of Dampier

PPA implements a range of environmental monitoring programs in the Port. Some of this monitoring is driven by compliance; however, the majority of PPA's programs are designed to better understand PPA's operations and the changes occurring within the Port setting. During 2017, in an effort to gain a better understanding of the background water quality within the Port and surrounding waters, PPA commenced implementation of a Port-wide Marine Water Quality Monitoring Program (MWQMP) (PPA 2017). Then in 2019, PPA commissioned O2 Marine to develop a MEQSAP for the Port and surrounding waters to provide context for the data being collected and to align the monitoring program with current EPA Guidance.

4.1. Marine Environmental Quality Sampling and Analysis Plan

The MEQSAP (Appendix 1) was developed to achieve the following specific objectives:

- provide a framework to monitor, characterise and report on the long-term trends in marine water and sediment quality within the Port and surrounding waters
- identify key pressures and threats that influence marine environmental quality (MEQ)
- prescribe quarterly water quality and annual sediment quality monitoring
- define Environmental Quality Indicators (EQI) for water and sediment quality and establish associated EQC that are locally relevant and appropriate to the Port surrounding waters
- define sampling and analysis procedures to be applied during these sampling events.

The MEQSAP is to be implemented in two distinct monitoring phases:

- Phase 1 (Years 1-3) – Initial Baseline Data Collection; and
- Phase 2 (Post-year 3) – Monitor & Investigate.

During the initial baseline monitoring phase (i.e. Years 1-3), the MEQSAP is entirely focussed on baseline data collection and is not intended as a tool to elicit a management response. However, future iterations of the MEQSAP may include investigation options to inform development of appropriate management strategies as required to be in line with an EQMF approach.

All EVs, EQOs, EQCs and EQGs are discussed in detail in the MEQSAP. The MEQSAP includes interim EQGs for each of the EVs including the following:

- Ecosystem Health (Maximum, High and Moderate LEPs apply):
  - Physico-chemical parameters in water;
  - Toxicants in water; and
  - Toxicants in sediment.
- Recreation and Aesthetics:
  - Toxic algae;
  - Nuisance organisms and bacteria;
  - Fauna deaths;
  - Oil/debris/wrack;
  - pH; and
  - visual clarity and colour.

These interim EQGs have been developed in order to provide context for comparison of data collected during the baseline data collection phase (Phase 1).

EQI are not specified for the EVs '*Fishing and Aquaculture*', '*Cultural and Spiritual*', and '*Industrial Water Supply*', as these are considered to be protected through monitoring EQI for the EVs '*Ecosystem Health*' and '*Recreation and Aesthetics*'.

No EQS are proposed during Phase 1 (i.e. Years 1-3), as this phase is focussed on collection of baseline data. EQS will be defined once sufficient baseline data is collected (i.e. post Year 3) and the natural background water and sediment quality of the Port and surrounding waters can be accurately characterised.

4.2. Environmental Quality Indicators

The Environmental Quality Indicators (EQIs) are measurable parameters selected to monitor changes in environmental quality for each EQO. Relevant EQIs for a marine water and sediment quality monitoring program in the Port are summarised in Table 4.

Table 4 Environmental Quality Indicators selected for the Port of Dampier

EQO	EQI	Constituents
Ecosystem Health (EQO1)	Toxicants in water	Aluminium
		Antimony
		Arsenic
		Cadmium
		Chromium
		Cobalt
		Copper
		Iron
		Lead
		Manganese
		Mercury
		Nickel
		Silver
		Vanadium
		Zinc
		Poly Aromatic Hydrocarbons (PAH)
		Total Recoverable Hydrocarbons (TRH) and Total Petroleum Hydrocarbons (TPH).
		BTEXN
		Organotin Compounds (Soluble)
	Physico-chemical constituents in water	Temperature
		Dissolved oxygen
		Salinity
		pH
		Turbidity
		Total Suspended Solids
		Chlorophyll a
		Nutrients (NH_3, NO_2, NO_3, TKN, N, P)
		Total Organic Carbon (TOC)

EQO	EQI	Constituents
Recreation and Aesthetics (EQO4, EQO5 & EQO6)	Physico-chemical constituents in water	pH
	Targeted Pathogen counts	Faecal Coliform
		E.coli & Enterococci
		Algal biotoxins
	Biota	Nuisance organisms
		Faunal deaths
	Aesthetics	Visual Clarity & Reflectance
		Odour
		Oil/Debris/Wrack

* [1] EQI are not specified for the EVs '*Fishing and Aquaculture*', '*Cultural and Spiritual*', and '*Industrial Water Supply*', as these are considered to be protected through monitoring EQI for the EVs '*Ecosystem Health*' and '*Recreation and Aesthetics*'.

4.3. EQG - Ecosystem Health

The Port and surrounding waters have been classified into LEPs comprising of Maximum (XEPA), High (HEPA) Moderate (MEPA) and Low (LEPA). The XEPA contains the reference sites, which will be used to establish lower and upper criteria guidelines for sites within the HEPA and MEPA and in accordance with the MEQSAP. LEPA sites within the Port are not relevant to the MEQSAP.

4.3.1. Toxicants in Water

EQG for toxicants in water are shown in

Table 5. EQS are to be established following completion of the initial (Phase 1) baseline data collection phase (i.e. Years 1-3). Specifically, EQG for toxicants in water were derived from either ANZG (2018) or CSIRO (2006). Historic water quality monitoring results from the PPA MWQMP (PPA 2017) were also reviewed, however naturally elevated contaminants in water (i.e. Arsenic and Nickel) were found to be below the CSIRO (2006) guideline values, therefore the less conservative value CSIRO (2006) value was adopted.

Where no guideline trigger values are available for naturally occurring contaminants in water, EQG are defined based on comparison against the 95th and 99th percentile of natural background concentrations and applied to high and moderate/low LEP areas, respectively. Maximum LEP areas should have no detectable change from known natural background levels.

Table 5 EQG for Toxicants in Water

EQI	Units	EQG			
		Low	Moderate	High	Maximum
Aluminium	(µg/L)	Low < Reference 99th percentile		0.5*	No detectable
Arsenic (III/V)	(µg/L)	Low < Reference 99th percentile		2.3/ 4.5	No change from natural background
Cadmium	(µg/L)	36	14	0.7	
Chromium III/VI	(µg/L)	N/A	49/20	27.4/4.4	
Cobalt	(µg/L)	N/A	20	4.4	
Copper	(µg/L)	N/A	3	1.3	
Iron	(µg/L)	Low < Reference 99th percentile		Low < Reference 95th percentile	
Lead	(µg/L)	N/A	6.6	4.4	
Manganese	(µg/L)	Low < Reference 99th percentile		80*	
Mercury	(µg/L)	1.4	7	0.1	
Nickel	(µg/L)	N/A	200	7	
Silver	(µg/L)	N/A	1.8	1.4	
Vanadium	(µg/L)	N/A	160	100	
Zinc	(µg/L)	N/A	23	15	
TRH C6-C14	(µg/L)		25		
TRH C15-C36	(µg/L)		100		
Chlorine (total residual)	(µg/L)	Low < reference 99th percentile		3*	
BTEXN - Benzene - Napthalene	(µg/L)	1300 120	900 90	700 70	
Mixed toxicants	(µg/L)	Total Toxicity of Mixture: Sum of concentration of (up to 5) primary toxicants < 1			

4.3.2. Physico-chemical Parameters in Water

EQG for physicochemical constituents in water are presented in

Table 6. EQG are not provided for nutrients (Total nitrogen, Nitrate/Nitrite, Ammonia, Total Phosphorus and Orthophosphorus) due to limited available information at the time of preparing the MEQSAP. These EQG should be derived following completion of the initial baseline data collection phase (i.e. Post Year 3).

Table 6 EQG for physicochemical constituents in water

Parameters	Units	EQG			
		Low	Moderate	High	Maximum
Dissolved oxygen	% saturation	60%	80%	90%	No change from natural background*
Temperature	°C	No EQG apply	Between 5th and 95th percentiles of reference sites	Between 20th and 80th percentiles of reference sites	
Salinity	o/oo				
pH					
Turbidity	NTU				
Chlorophyll-α	µg/L				

**natural background to be established following the three years of initial sampling.*

For the purpose of comparison during the Phase 1 baseline data collection period, additional interim EQGs have also been included. These are defined as the minimum guideline values derived from ANZG (2018) and ANZECC (2000) for nearshore Pilbara waters and are presented in Table 7. Note that no guideline value is available for turbidity. These interim EQGs are a guideline only to provide context for the results and are not intended as pass/fail triggers.

Table 7 Interim EQG values applied to the XEPA

	Dissolved Oxygen	Oceanic Temperature	pH	Salinity
Summer	90	32.1	8	35.756
Winter	90	23	8	35.45
Spring	90	27.3	8	35.624

4.4. EQG - Recreation and Aesthetics

The proposed EQG applicable to the EV *'Recreation & Aesthetics'* and corresponding EQO4: '*Water quality is safe for primary contact recreation (e.g. swimming and diving)'*, EQO5: '*Water quality is safe for secondary contact recreation (e.g. fishing and boating)'*, and EQO6: '*Aesthetic values of the marine environment are protected'* are presented in Table 8.

Table 8 Environmental Quality Guidelines for the protection of the EV 'Recreation and Aesthetics'

EQI	Primary contact	Secondary contact	Aesthetics
Pathogenic Bacteria	The 95th percentile^ bacterial content of marine waters should not exceed 200 enterococci/100 mL.	The 95th percentile^ bacterial content of marine waters should not exceed 2,000 enterococci/100 mL.	

Nuisance Organisms	The toxic phytoplankton cell count* from a single site, should not: – Exceed 10 000 cells/mL; or – Detect DoHWA watch list species or exceed their trigger levels. OR There should be no reports of skin, eye or respiratory irritation or potential algal poisoning of recreational users considered by a medical practitioner as potentially resulting from toxic algae when less than 10 000 cells/mL is present in the water column.	The median toxic phytoplankton cell count* for a defined sampling area (either from one sampling run or from a single site over an agreed period of time) should not exceed 25 000 cells/mL. OR There should be no reports of skin, eye or respiratory irritation or potential algal poisoning of recreational users considered by a medical practitioner as potentially resulting from toxic algae when less than 25 000 cells/mL is present in the water.	Phytoplankton scums, filamentous algal mats, blue- green algae and sewage fungus should not be present in excessive amounts.
Visual Clarity and Colour	To protect the visual clarity of waters used for swimming, the horizontal sighting of a 200 mm diameter secchi disc should exceed 1.6 m.		The natural visual clarity of the water should not be reduced by more than 20% of Secchi disk measurements at any one site. The natural reflectance of the water should not be changed by more than 50%.
pH	The median of the depth profile should not exceed the range of 5– 9 pH units.		
Fauna Deaths			There should be no reported incidents of large-scale deaths of marine organisms resulting from un-natural causes.
Oil/Debris/Wrack			Oil and petrochemicals should not be noticeable as a visible film on the water nor should they be detectable by odour. Water surfaces should be free of floating debris, dust and other objectionable matter, including substances that cause foaming. Floating seagrass wrack should not exceed 25% cover.

Odour			There should be no objectionable odour.

^ The Department of Health has produced The Enterotester for calculating 95th percentile statistics from five consecutive years of data for enterococci bacteria.

* Phytoplankton cell counts include cyanobacteria and eukaryotic organisms.

† Algal scums are defined as dense accumulations of algal cells at or near the surface of the water forming a layer of distinct discolouration (green, blue, brown or red) (Gov QLD, 2002).

The Department of Health WA (DoHWA) has developed EQC for toxic algae in marine recreational water (DoHWA 2017). These numerical guidelines are based upon an understanding, that recreational contact and exposure to potentially toxic algae may pose varying levels of public health risk. The DoHWA watch list species and associated trigger levels that are defined as EQG for the EQI *'Nuisance Organisms'* are identified in Table 9. DoHWA (2017) have also developed a risk assessment for algal scum in marine waters shown in Table 10.

Table 9 DoHWA watch List for potentially toxic algae in recreational waters

Algal Group	Algal Genus/Complex	Key Species	DoHWA Watch List Trigger Levels (cells/L)	DoHWA Watch List Action Levels (cells/L)
Cyanobacteria	*Lyngbya*	*L. majuscula*	≥0.01	Relatively widespread visible presence of algal filaments (NHMRC 2008)
	Trichodesmium		Detected	Presence of algal scums (NHMRC 2008)
	Other		≥5,000	≥15,000
Dinoflagellates	*Karenia*	*K. brevis*	≥5,000	≥10,000*
		Other sp.	≥50,000	≥100,000*
	Pfiesteria		≥0.01	Presence of algal scums (NHMRC 2008)

* This is a temporarily assigned action level for which the DoHWA may consider it appropriate to issue a public health warning and/or provide information/advice, having consideration for the specific monitoring event and result in the overall situation/context.

Table 10 DoHWA risk assessment for algal scum in marine waters

	Algal Scum	~ Total Area of Scum		
patchy/sporadic in nature	1. along shoreline at recreational beach/area	Moderate	High	High
	2. within swimming zone at recreational beach (< 500m from shoreline)	Low	Moderate	High
	3. > 500m offshore	Low	Low	Moderate

	4. along shoreline (nonrecreational area) e.g. rocky outcrop, boat harbour/marina.	Low	Low	Moderate
	5. < 500m from shoreline (nonrecreational area) e.g. rocky outcrop, boat harbour/marina	Low	Low	Moderate
continuous aggregated	1. along shoreline at recreational beach/area	Moderate	High	High
	2. within swimming zone at recreational beach (< 500m from shoreline)	Moderate	High	High
	3. > 500m offshore	Low	Low	Moderate
	4. along shoreline (nonrecreational area) e.g. rocky outcrop, boat harbour/marina.	Low	Low	Moderate
	5. < 500m from shoreline (nonrecreational area) e.g. rocky outcrop, boat harbour/marina	Low	Low	Moderate

4.5. Fishing and Aquaculture

Fishing is a popular recreational activity throughout the Dampier Archipelago and the EV '*Fishing and Aquaculture*' and the corresponding EQO2: '*Seafood (caught) is of a quality safe for human consumption*' are applicable to the Port of Dampier waters.

The EPA (2015a) advises that the primary threats to human consumers of seafood relate to contamination of filter feeding shellfish by faecal pathogens (e.g. bacteria), the accumulation of biotoxins from toxic algae and/or the accumulation of toxic chemicals in the flesh of the shellfish. Filter feeding shellfish need to filter large quantities of water to obtain their food and in the process can potentially accumulate significant quantities of pathogens and other contaminants that can cause serious illness in humans (EPA 2015a). However, for other species of seafood and for those shellfish where only the adductor muscle is eaten (e.g. scallops and pearl oysters) the DoHWA advises that there is only a low risk of potential impacts on human health and therefore monitoring programs may not need to consider assessment of faecal bacteria and/or toxic algae (EPA 2015a).

For people that collect and eat wild shellfish the DoHWA suggests that they may be putting their health at risk and recommends that the public only eat shellfish harvested commercially under strict quality assurance monitoring programs (DoH, 2010). It should be noted that these EQC do not protect the fish populations themselves. To protect the wild seafood populations from the effects of environmental contamination the environmental quality guidelines and standards for maintaining ecosystem integrity (EQO1) are recommended. These should aim to protect the harvested species as well as the food webs, habitats and other environmental processes that support them. For these reasons, under the scope of this Plan, EQO2 is deemed to be met if EQO1, 4, 5 and 6 are achieved.

Several aquaculture and pearling leases are held in the area (outside port waters) such as the Pilbara rock oyster research and development project. As such, the EQO3: '*Water quality is suitable for aquaculture purposes*' is

relevant to the area. However, EPA guidance states that EQC for this EQO are only to be applied at the boundary of the approved aquaculture lease and targeted to the species that are grown there (EPA, 2016). This is beyond the scope of the MEQSAP and as a result, EQC for aquaculture (EQO3) will be omitted from consideration in this document.

4.6. Cultural and Spiritual

Inclusion of the EV, *'Cultural and Spiritual Values'* in this Plan recognises the cultural and spiritual values of Dampier Archipelago to the indigenous people of the area. However, consistent with EPA (2016) and ANZG (2018), no specific EQC are provided for assessment against EQO7: *'Cultural and spiritual values of the marine environment are protected'.*

In the absence of environmental quality criteria for this value, ensuring that the quality of these waters is sufficient to maintain ecosystem integrity (EQO1), protect the quality of seafood (EQO2), allow people to recreate safely (EQO4 & EQO5), and maintain aesthetic values (EQO6), is considered to protect cultural and spiritual values (EQO7) for the purpose of the MEQSAP.

4.7. Industrial Water Supply

The EV for Industrial Water Supply is protected through EQO8: *'Water quality is suitable for industrial supply purposes'.* Water quality requirements for Industrial Water Supply are industry and process specific and, in many cases, industrial processes can treat intake water to the quality required. Various intakes for industrial water supply are located around the Port and marine water is predominantly used for process water, which is treated by separate operators. The EPA guidance specifies that EQC for this EQO may need to be applied at approved salt water intakes to protect the desalination process (EPA, 2016). In each case, monitoring may be carried out at the intakes by the respective operators and EQCs will be specific to the process and use of the water. For the purpose of the MEQSAP, water quality assessed as acceptable for an area zoned with at least a MEPA under EQO1: *'Maintenance of ecosystem integrity'* will meet the requirements for EQO8: *'Water quality is suitable for industrial supply purposes'.*

5. Methods

The annual monitoring program includes quarterly water quality sampling, and a single sediment sampling event during summer (O2 Marine, 2019). Quarterly sampling dates since commencement of the MEQSAP program are summarised in Table 11**.** All field sampling methods were conducted in accordance with those described in the MEQSAP.

Table 11 All sampling dates since commencement of MEQSAP program

Sample Event	Date	Water	Sediment
Q1 Year 1	7 August 2019	✓	
Q2 Year 1	7 November 2019	✓	
Q3 Year 1	13 and 14 February 2020	✓	✓
Q4 Year 1	24 June 2020	✓	
Q1 Year 2	3 September 2020	✓	
Q2 Year 2	7 December 2020	✓	
Q3 Year 2	11 and 12 March 2021	✓	✓
Q4 Year 2	18 May 2021	✓	
Q1 Year 3	19 August 2021	✓	
Q2 Year 3	21 November 2021	✓	

5.1. Sampling Locations

In accordance with the MEQSAP, general observations, aesthetic observations, physico-chemical water column profiles and water sample collection (laboratory analysis) were conducted at each of the ten (10) monitoring locations identified in

Table 12. Sampling locations and LEP areas are displayed in Figure 4. During the Quarter 3 sampling event, sediment samples were also collected at each of the ten (10) sites.

Table 12 Port of Dampier and surrounding waters sampling sites, tasks conducted during the sampling event and analysis undertaken

Site Name	Level of Ecological Protection	Easting	Northing	Aesthetic Observation	Physicochemical water column profiling	General water sample analysis	Bacterial sample analysis	Phytoplankton sample analysis	Sediment sampling
ANGL	Maximum	478763 E	7736454 N	✓	✓	✓	✓	✓	✓
MALI	Maximum	467225 E	7733002 N	✓	✓	✓			✓
WLIS	Maximum	457615 E	7720893 N	✓	✓	✓			✓
BRCK	High	467540 E	7724436 N	✓	✓	✓			✓
CONI	High	475611 E	7729380 N	✓	✓	✓			✓
KGBY	High	472810 E	7719469 N	✓	✓	✓	✓	✓	✓
ICI	High	462181 E	7716612 N	✓	✓	✓			✓
TDPL	Moderate	469757 E	7717425 N	✓	✓	✓	✓	✓	✓
PLBE	Moderate	473239 E	7721667 N	✓	✓	✓			✓
EII	Moderate	465397 E	7716148 N	✓	✓	✓			✓

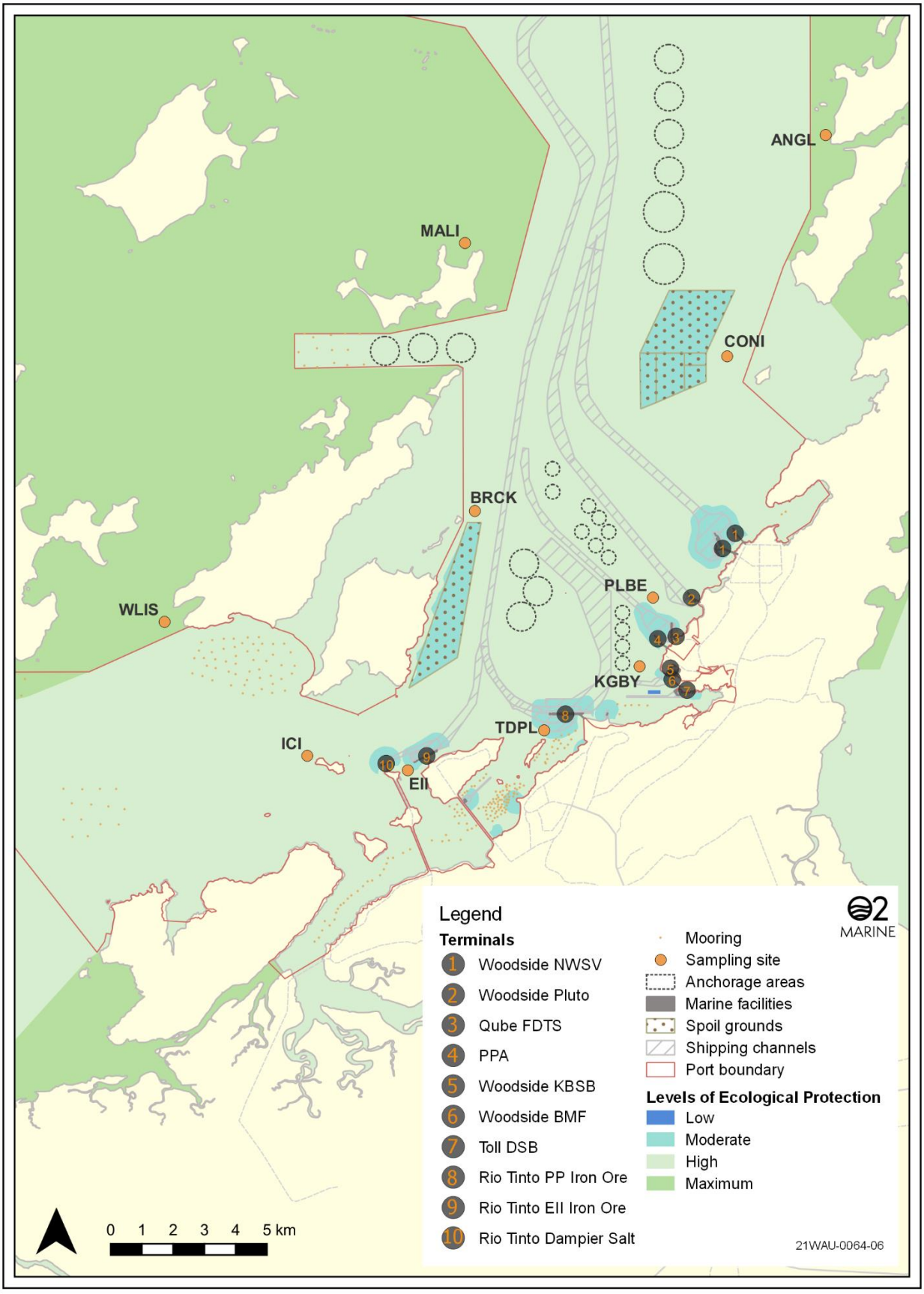

Figure 4 Water quality sampling locations and Levels of Ecological Protection (LEP) boundaries for Port of Dampier and surrounding waters (O2 Marine 2019).

6. MEQSAP Summary of Results

The results, key findings and recommendations from the MEQSAP reporting period, which to date includes ten (10) quarterly monitoring events from August 2019 to November 2021, are presented in the MEQSAP quarterly sampling reports and annual reports. The information presented below is a summary and discussion of this information.

6.1. Ecosystem Health

6.1.1. Toxicants in Water

Dissolved Metals and Metalloids

Metal results throughout the 2019-2021 monitoring period are considered low, with the majority of concentrations below their respective EQGs. There did not appear to be any differences between LEP areas, with any record of elevated value being consistent over all sites and not restricted to a certain sampling area.

During the May 2021 monitoring event, results for copper and silver (across all monitoring sites) were elevated above typical levels. This suggests either a field QA/QC error, or a laboratory testing error. The secondary laboratory returned copper and silver results that were below PQL for the duplicate sample (collected at ANGL). This suggests that there was no field collection error, and that the abnormal results originate from the primary laboratory testing processes. O2 Marine are confident the true concentration for both copper and silver were comparable to the remainder of the monitoring locations and therefore likely below the PQL. The most recent available data sets for metals, sampled during August and November 2021 contained no elevations of any dissolved metals.

Table 13 Analytes tested for during Port of Dampier MEQSAP sampling (2019-2021), with ANZG (2018) EQGs for marine water quality. Analytes that exceeded EQGs for any sample or site are marked.

Analyte grouping/ Analyte	Unit	PQL	Environmental Quality Guidelines (EQG) Low	Moderate	High	Maximum	Exceedance reported
Dissolved Metals and Metalloids							
Aluminium	µg/L	10	Low < Reference 99th			No detectable change from natural background	
Arsenic	µg/L	1	Low < Reference 99th				
Cadmium	µg/L	0.1	36	14	0.7		
Chromium	µg/L	1	N/A	49/20	27.4/4.4		
Chromium (VI)	µg/L	0.2	N/A	49/20	27.4/4.4		
Cobalt	µg/L	1	N/A	20	4.4		
Copper	µg/L	0.3	N/A	3	1.3		X
Iron	µg/L	5	Low <reference 99th percentile		Low <reference 95th percentile		
Lead	µg/L	1	N/A	6.6	4.4		
Manganese	µg/L	10	Low < reference 99th percentile		80*		
Mercury	µg/L	0.1	1.4	0.7	0.1		

Nickel	µg/L	1	N/A	200	7		
Silver	µg/L	0.3	N/A	1.8	1.4		X
Vanadium	µg/L	10	N/A	160	100		
Zinc	µg/L	5	N/A	23	15		

Hydrocarbons

Laboratory results for Total Petroleum Hydrocarbons (TPHs) and Polycyclic Aromatic Hydrocarbons (PAHs) indicate concentrations were below practical quantitation limits (PQLs) throughout the entire MEQSAP sampling period.

6.1.2. Physico-chemical Water Quality

Results from the IMO-CTD (temperature, depth & salinity), IMO-pHIDO (pH & Dissolved Oxygen) and IMO-NTU (Nephelometric Turbidity Units) are presented below for all XEPA, HEPA and MEPA sites during Port of Dampier MEQSAP sampling (2019-2021). Median physico-chemical profile results for the annual monitoring period are displayed below in

Table 14. Upper and lower percentiles have also been calculated and presented in accordance with

Table 6.

Results show that site variability within each quarterly event was low. Each parameter is discussed in further detail below, including a comparison with calculated percentiles as applicable.

Table 14 Physico-chemical parameters (median) recorded during Port of Dampier MEQSAP sampling (2019-2021).

		XEPA			HEPA					MEPA					
	Date	ANGL	MALI	WLIS	20th %	80th %	BRCK	CONI	KGBY	ICI	5th %	95th %	TDPL	PLBE	EII
Temp (°C)	Aug-19	21.6	21.6	20.8	20.8	21.6	21.6	21.2	21	20.6	20.8	21.7	20.9	21.0	20.5
	Nov-19	25.9	26.0	25.9	25.8	26.1	26.3	25.9	26.1	26.3	25.7	26.3	26.4	25.9	26.3
	Feb-20	28.1	27.7	28.1	27.8	28.1	27.6	28.0	27.7	27.8	27.7	28.1	28.1	28.0	27.8
	Jun-20	23.9	23.5	22.8	22.8	23.8	23.4	23.3	22.7	22.6	22.8	23.9	22.9	22.9	22.6
	Sep-20	24.4	24	24.1	24	24.4	24	24.2	24.2	24.5	24	24.4	24.2	24.3	24.5
	Dec-20	29.4	29.5	29.9	29.3	29.9	29.6	29.5	30.1	30.4	29.2	29.9	30.1	29.9	30.7
	Mar-21	29.5	29.6	29.1	29.5	30.8	29.7	30.3	30.7	29.8	29.4	31.2	30.8	30.3	29.3
	May-21	25.9	26.2	25.1	25.1	26.2	24.9	25.9	25	24.8	25.1	26.2	25.5	25.1	23.9
	Aug-21	22.6	22.6	22.6	22.27	23.7	22.3	24.1	22.7	22.2	22.21	24.56	23.1	23.1	22.3
	Nov-21	27.5	27	27.29	27.34	27.85	27.2	27.32	27.39	27.63	27.33	27.89	27.55	27.34	27.87
DO (%)	Aug-19	100.3	99.7	100.3	90	90	102.8	102.1	103.6	96.1	80	80	102.8	102.4	98.8
	Nov-19	109.3	99.2	102	90	90	104.8	106.7	105.8	101.0	80	80	106.4	105.6	102.5
	Feb-20	121.5	102	104.8	90	90	99.6	114.7	102.3	98.4	80	80	111.6	114.2	96.2
	Jun-20	100.3	100.3	99.8	90	90	101.5	102.2	104.1	99.8	80	80	103.3	101.1	102.6
	Sep-20	103.7	106	106.5	90	90	105.7	104	103.2	106.4	80	80	103.5	103.6	106.2
	Dec-20	107	105.2	106.7	90	90	106.5	106.6	106.7	111.8	80	80	107.1	103.9	111.5
	Mar-21	104.6	110.3	86	90	90	102.2	95.9	96.8	111.3	80	80	87.0	97.5	100.5
	May-21	96.85	97.35	95.35	90	90	98.4	98.7	98.3	96.6	80	80	97.75	98.35	93.3
	Aug-21	85.1	83.4	84.5	90	90	84.5	81.5	82.7	82.3	80	80	83.4	84.4	84.3
	Nov-21	106.3	91.42	92.1	90	90	94.2	97.4	98.4	93.44	80	80	98.03	95.53	92.1
Salinity (ppt)	Aug-19	36.94	36.92	37.20	36.92	37.20	36.96	37.14	37.28	37.20	36.91	37.20	37.21	37.18	37.24
	Nov-19	38.05	38.82	38.94	38.69	38.99	38.98	38.26	38.67	39.30	38.05	39.26	38.88	38.54	39.17
	Feb-20	35.28	36.06	37.43	35.29	37.45	35.77	35.43	35.41	36.67	35.24	37.53	35.57	35.35	36.28
	Jun-20	36.17	36.23	36.40	36.19	36.40	36.27	36.40	36.47	36.46	36.16	36.4	36.45	36.41	36.53
	Sep-20	39.08	39.14	39.48	39.1	39.5	39.27	39.19	39.39	39.47	39.1	39.5	39.4	39.28	39.58
	Dec-20	33.70	34.00	34.40	33.7	34.4	34.20	33.80	34.00	34.40	33.7	34.4	34.30	33.90	34.30
	Mar-21	35.90	35.90	36.20	35.9	36.1	36.20	35.90	35.50	36.10	35.8	36.3	35.31	35.7	36.10
	May-21	36.14	36.13	36.61	36.1	36.6	36.61	36.22	36.61	36.65	36.1	36.6	36.39	36.62	36.77

	Aug-21	35.1	35.2	27.1	**34.81**	**35.66**	35.4	34.9	35.5	35.8	**33.37**	**35.84**	35.2	35.2	35.5
	Nov-21	35.8	36.08	36.88	**36.16**	**36.89**	36.07	**35.87**	36.28	36.85	**36.15**	**36.90**	36.72	36.16	36.9
pH	Aug-19	8.31	8.30	8.43	**8.30**	**8.43**	8.40	8.31	8.44	8.42	**8.30**	**8.44**	**8.46**	8.41	8.33
	Nov-19	7.99	7.95	7.96	**7.95**	**7.98**	7.98	**7.99**	7.98	**7.93**	**7.94**	**7.99**	7.98	7.97	**7.91**
	Feb-20	8.27	8.17	8.17	**8.08**	**8.14**	**8.04**	**8.24**	**8.20**	**8.17**	**8.15**	**8.27**	8.23	8.24	**8.14**
	Jun-20	8.09	8.09	8.13	**8.08**	**8.13**	8.09	**8.03**	8.09	8.13	**8.08**	**8.14**	**8.02**	8.09	**8.06**
	Sep-20	8.04	8.05	8.04	**8**	**8.1**	8.05	8.05	8.02	8.03	**8**	**8.1**	8.01	8.05	8.02
	Dec-20	7.89	7.96	8.00	**7.9**	**8**	7.97	**7.87**	7.95	7.98	**7.9**	**8**	**7.79**	7.96	7.93
	Mar-21	8.10	7.90	8.20	**7.9**	**8.2**	8.00	8.20	7.90	**8.40**	**7.5**	**8.3**	7.71	**7.14**	8.10
	May-21	8.27	8.28	8.24	**8.2**	**8.3**	8.29	8.28	8.28	8.27	**8.2**	**8.3**	8.25	8.28	8.25
	Aug-21	8.4	8.3	8.3	**8.39**	**8.52**	8.4	8.5	8.4	8.3	**8.37**	**8.6**	8.3	8.4	**8.2**
	Nov-21	8.36	8.37	8.35	**8.35**	**8.43**	8.35	8.35	8.39	8.35	**8.34**	**8.43**	8.43	8.38	8.34
Turbidity (NTU)	Aug-19	0.4	0.4	0.3	**0.3**	**0.5**	**1.1**	**0.7**	**1**	**1.3**	**0.1**	**0.6**	**1.9**	**2.2**	**1.7**
	Nov-19	0	0	0	**0**	**0**	0	0	**0.1**	0	**0**	**0.7**	0	0	0.4
	Feb-20	1	1.4	0	**0**	**1.4**	**2**	**3.3**	**2.8**	**6.1**	**0**	**3.8**	**5.4**	0	**4.7**
	Jun-20	1	0.7	0.9	**0.6**	**1**	**1.7**	0.6	**2**	**1.2**	**0.5**	**1.3**	1.2	**1.5**	**2.6**
	Sep-20	1.7	0.4	0.9	**0.4**	**1.4**	1.3	**1.5**	**2.6**	1.1	**0.3**	**2**	1.4	1.4	1.65
	Dec-20	0.5	0.5	1	**0.4**	**0.9**	0.9	0.9	**1.3**	**1.3**	**0.3**	**1.1**	**1.2**	1	**1.5**
	Mar-21	1.1	1.2	1.2	**0.9**	**1.6**	1	0.9	**1.8**	**3**	**0.7**	**2.3**	**2.7**	1.6	1.6
	May-21	0	0.35	0.5	**0.1**	**0.5**	0.6	**0**	0.3	**0.6**	**0**	**13.9**	0.9	1.3	1.05
	Aug-21	0.1	0.5	0.3	**0.19**	**0.93**	0.6	0.4	0.4	0.4	**0.08**	**1.98**	0.6	0.09	0.7
	Nov-21	0.84	0.61	1.33	**1.49**	**3.40**	2.05	1.58	1.84	**1.46**	**1.35**	**4.07**	2.66	1.49	3.51

Note: orange font indicates values outside of the EQG percentiles thresholds calculated for each LEP.

Water Temperature

Median water temperature over the course of the reporting period was mostly consistent between all sites and across the LEP boundaries (Table 16, Figure 5a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for temperature over the 2019-2021 sampling period). A typical trend reflected seasonal variability with the wet season having the greatest temperature in comparison to the dry season, with peaks in March 2020, December 2020 and March 2021, and lower values recorded in September 2020 and August 2021. The highest recorded median temperature was during March 2021 at site TDPL (30.8°C), whilst the lowest occurred at EII (22.2°C) during August 2021. Site CONI in the HEPA and PLBE in the MEPA were the only sites consistently within the EQG percentile thresholds described in

Table 6. Site ICI in the HEPA had the highest median value across the ten (10) quarterly sampling events (Table 15)

All recorded median values are comparable to the interim EQGs presented in Table 7 which identifies median temperature values for summer (32.1°C), winter (23°C) and spring (27.3°C).

Table 15 Summary Water Temperature Statistics recorded during Port of Dampier MEQSAP sampling (2019-2021).

	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Minimum	21.6	21.4	20.8	21.3	21.1	20.9	20.5	20.9	20.9	20.5
Maximum	31.3	29.7	29.6	30.0	30.5	31.1	30.4	31.7	30.9	30.7
Median	24.5	24.0	24.1	24.4	24.9	23.4	28.5	25.6	25.1	23.7
Average	26.4	24.9	24.9	25.6	26.0	25.3	27.0	26.4	26.0	24.9
Standard deviation	3.1	2.8	2.8	-3.1	-3.0	-3.4	-3.4	3.8	3.4	3.2

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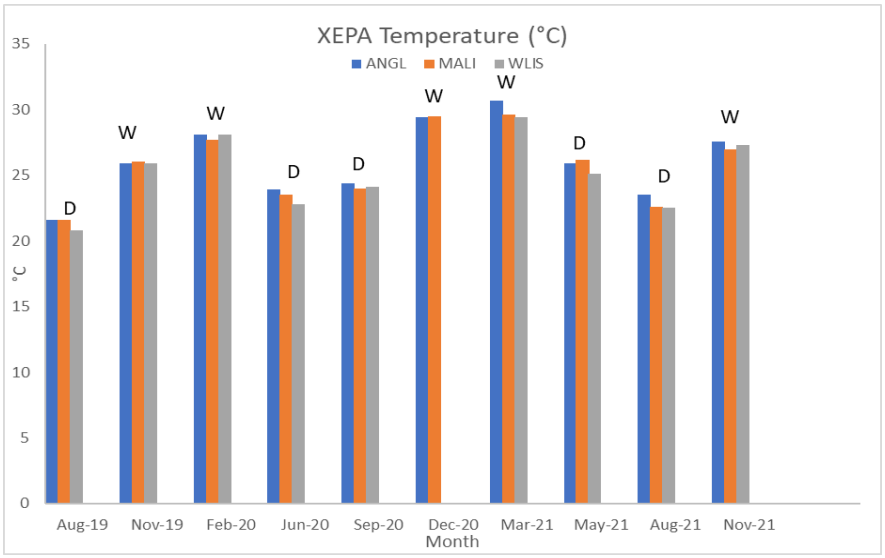

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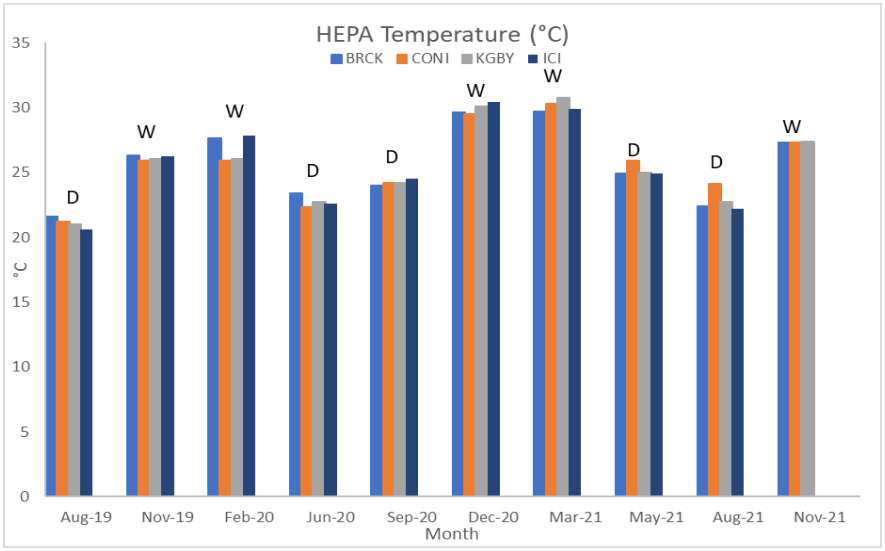

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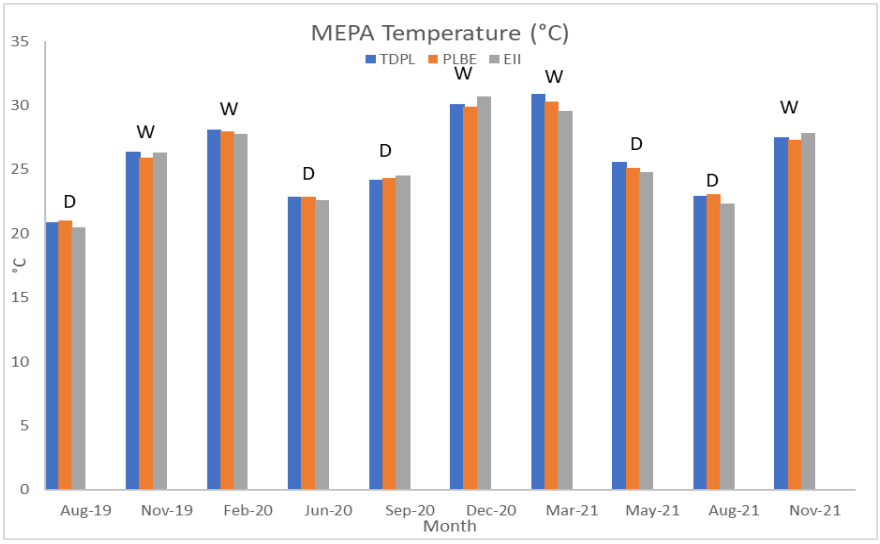

Figure 5a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for temperature over the 2019-2021 sampling period. D = dry season, W = wet season.

Dissolved Oxygen

Median dissolved oxygen levels across the reporting period were comparable between all sites and across the LEP boundaries (Figure 8a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for pH over the 2019-2021 sampling period). There were no distinct trends observed aside from marginally lower DO values during March and August 2021. The highest recorded median DO level during any sampling occasion was 121.5% at site ANGL within the XEPA (reference sites) during Feb 2020 (wet season), and a lowest median concentration of 81.5% at site CONI within the HEPA during August 2021 (dry season). All months were relatively stable, with a maximum variation occurring in March 2021 (wet season). Site ICI in the HEPA had the highest median value across the ten (10) quarterly sampling events (Table 16). There were no results over the wet or dry season that were below the EQG thresholds described in

Table 6.

Table 16 Summary Dissolved Oxygen Statistics recorded during Port of Dampier MEQSAP sampling (2019-2021).

	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Minimum	84.3	81.8	84.0	83.6	81.2	80.9	80.3	83.2	83.3	80.3
Maximum	121.8	108.6	108.0	107.3	120.0	110.0	112.4	114.5	128.5	112.4
Median	100.3	97.5	96.1	98.4	100.1	96.5	101.0	87.7	98.0	93.4
Average	97.6	94.0	95.3	95.9	96.8	93.9	97.9	93.8	96.2	92.9
Standard Deviation	11.1	9.0	8.0	-9.1	-10.5	-10.0	-9.2	9.8	10.0	9.3

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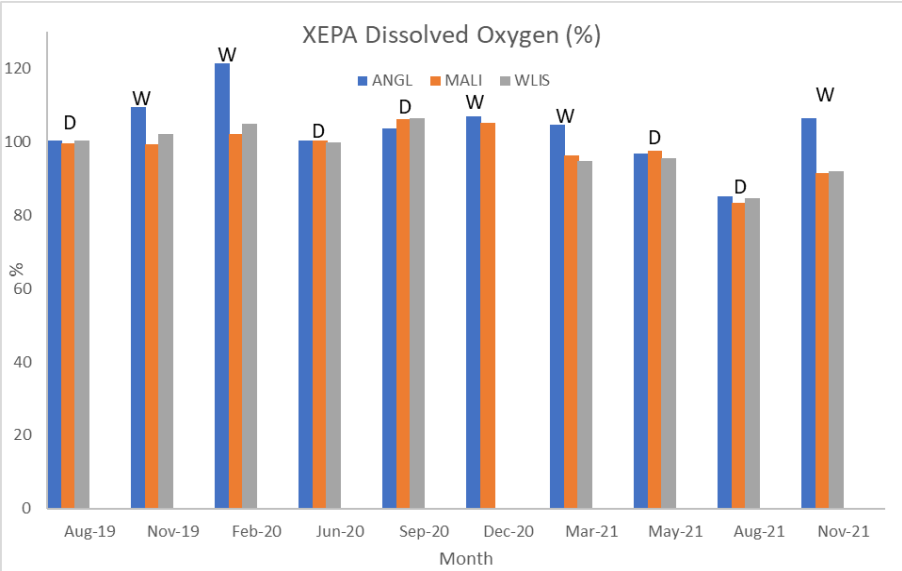

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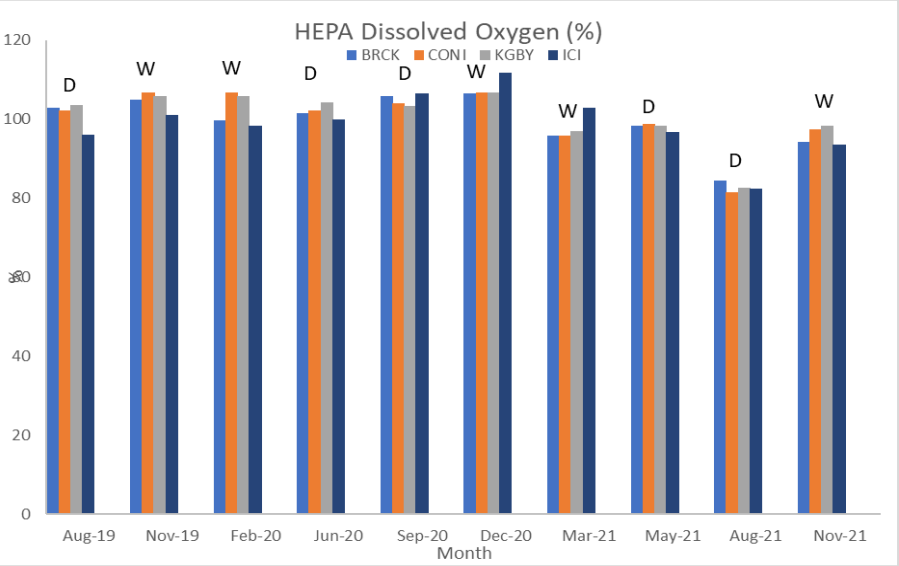

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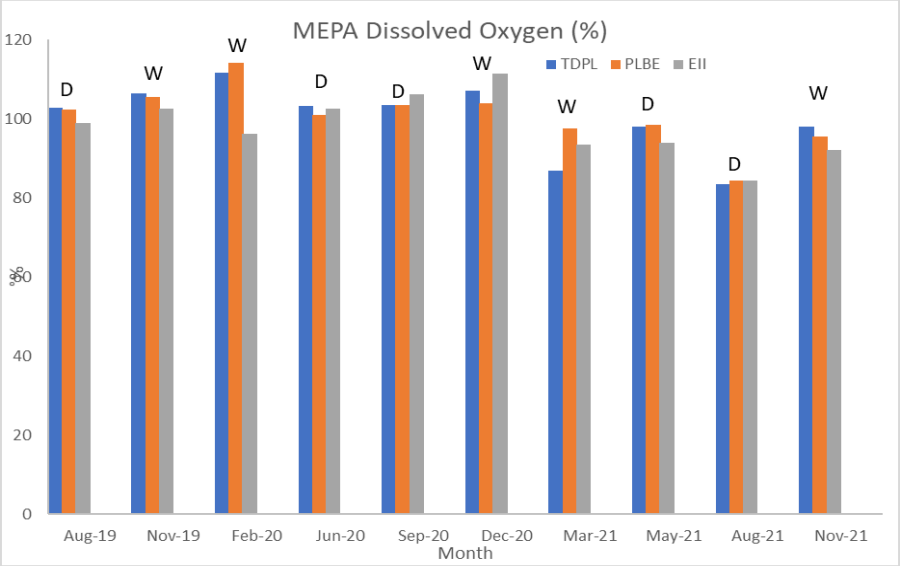

Figure 6a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for median dissolved oxygen over the 2019-2021 sampling period. D = dry season, W = wet season.

Salinity

Median salinity levels within the Port of Dampier and surrounding waters varied seasonally, however recorded consistent values among sites within each LEPs (Figure 7a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for salinity over the 2019-2021 sampling period). Concentrations were notably higher during September 2020 when compared to the other events. The maximum median for salinity was recorded at EII during September 2020 (39.58 ppt), whilst the minimum occurred at WLIS (in the XEPA) during August 2021 (27.1 ppt). All sites in the HEPA and MEPA were within the EQG percentile thresholds described in

Table 6 most of the time but also slightly above or below at some point. Site ICI in the HEPA had the highest median value across the ten (10) quarterly sampling events (Table 17). Aside from high values in September 2020 and low values in August 2021, the results are comparable to the interim EQG value which stipulate values of 35.4, 35.6 and 35.7ppt for winter, spring and summer months, respectively.

Table 17 Summary statistics for salinity (psu) recorded at all sites during Port of Dampier MEQSAP sampling (2019-2021).

	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Minimum	32.1	0.1	20.5	34.0	32.2	34.0	8.1	32.1	33.9	28.7
Maximum	39.1	39.2	39.5	39.3	39.2	39.4	39.6	39.5	39.3	39.6
Median	35.3	35.9	36.4	35.9	35.9	35.6	33.6	35.5	35.6	36.0
Average	35.6	36.0	33.9	36.2	36.0	36.0	24.1	35.8	35.9	36.2
Standard deviation	1.4	2.5	5.3	-1.5	-1.6	-1.3	-13.9	1.5	1.3	1.5

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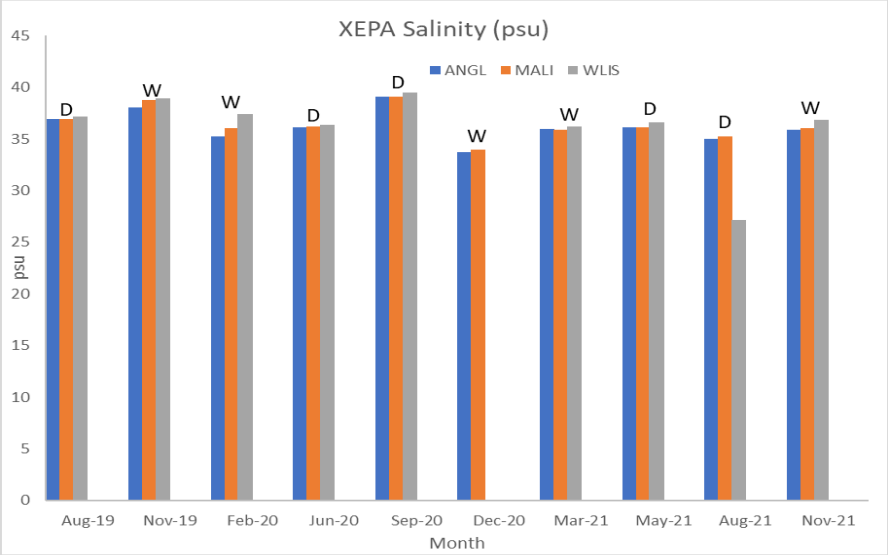

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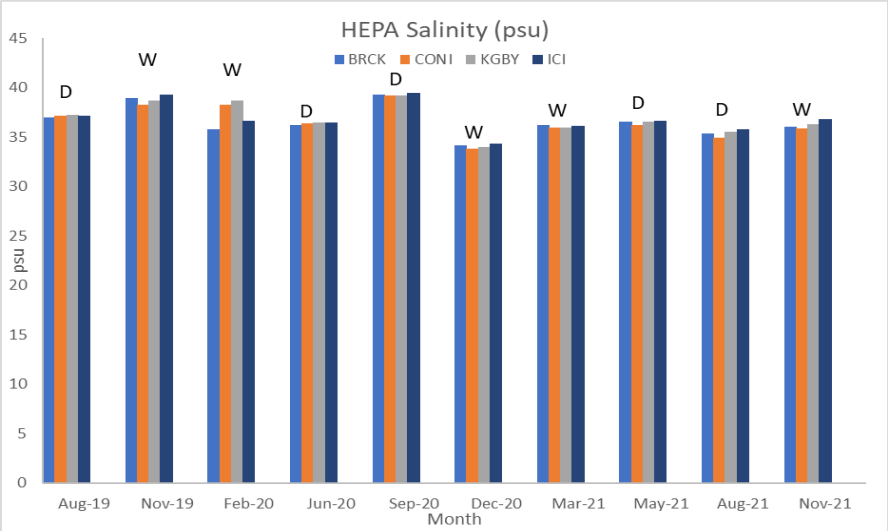

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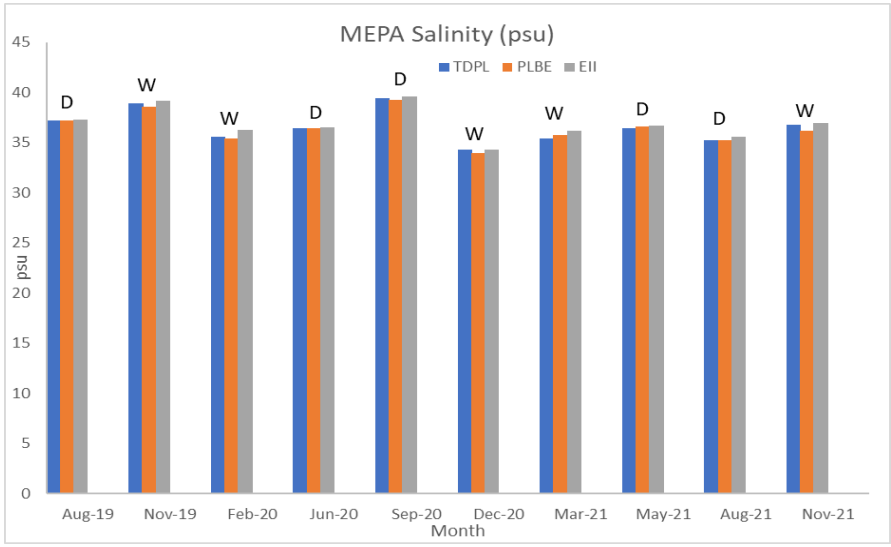

Figure 7a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for salinity over the 2019-2021 sampling period. D = dry season, W = wet season.

pH

Median pH results were consistent among sites throughout September 2020 and May 2021, variation among sites was recorded during the December 2020, March 2021 and November 2021 monitoring events (Figure 8a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for pH over the 2019-2021 sampling period). No clear seasonal trends were observed across the monitoring period. The biggest pH range in all three LEPs was recorded during the same monitoring event (March 2021). TDPL (in the MEPA) recorded a maximum of 8.46, with the minimum (7.14) recorded at PLBE. All sites in the HEPA and MEPA were within the EQG percentile thresholds described in

Table 6 most of the time but also slightly above or below at some point. pH values were generally comparable to the interim EQGs presented in Table 7 which identifies a median pH value of 8.00.

Table 18 Summary statistics for pH at all sites during Port of Dampier MEQSAP sampling (2019-2021).

	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Minimum	6.4	7.8	7.9	7.9	7.3	7.7	7.9	8.0	8.1	8.1
Maximum	8.5	8.2	8.4	8.5	8.6	8.5	38.2	8.5	8.5	8.4
Median	8.3	8.0	8.3	8.1	8.2	8.3	8.4	8.4	8.4	8.3
Average	8.2	8.0	8.2	8.2	8.2	8.2	20.4	8.3	8.4	8.2
Standard deviation	0.3	0.1	0.1	-0.2	-0.3	-0.2	-14.0	0.2	0.1	0.1

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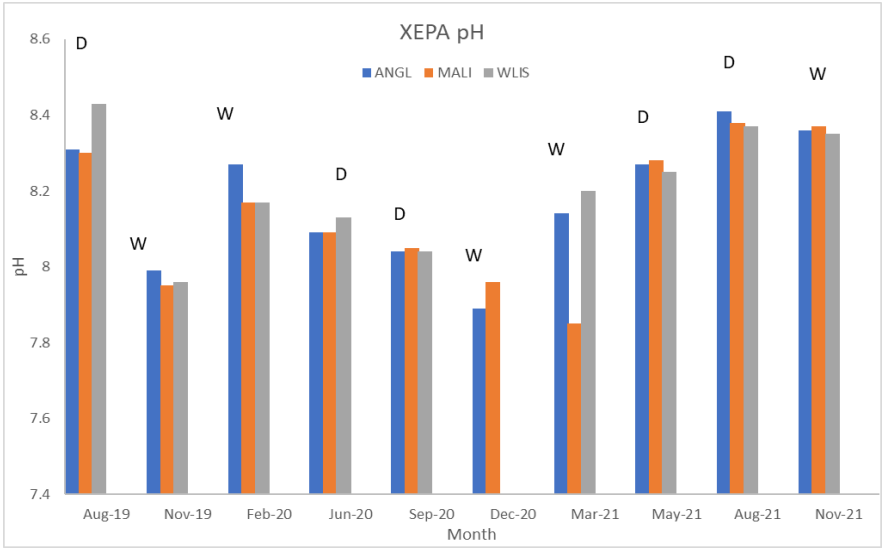

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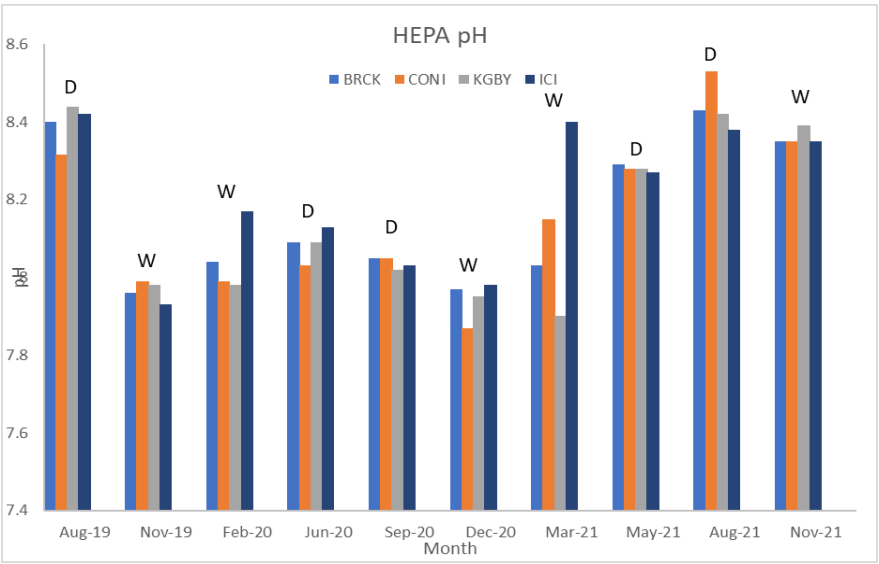

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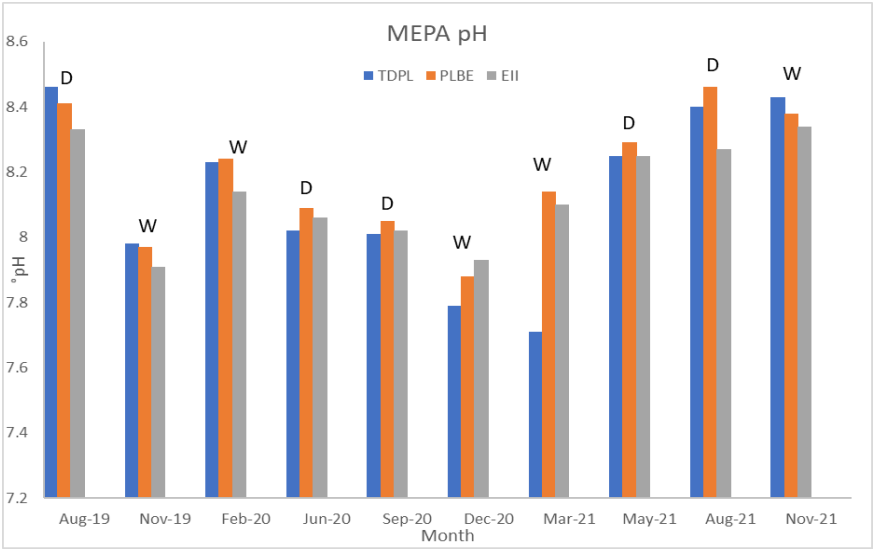

Figure 8a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for pH over the 2019-2021 sampling period. D = dry season, W = wet season.

Turbidity

Median turbidity values for the Port and surrounding waters varied seasonally but were typically consistent, with peaks in February 2020, March 2021 and November 2021 (all wet season) and lower values occurring in May 2021 (dry season). The highest median value occurred at ICI (in the HEPA) in February 2021 (6.1 NTU), whilst the minimum value occurred within sites ANGL and CONI during May 2021 (0 NTU).

Turbidity values for the XEPA were relatively low in comparison to other LEP areas. A maximum value was recorded at ANGL during September 2020 (1.7 NTU), whilst a minimum was also recorded at ANGL during May 2021 (0 NTU). There are no EQGs applicable for turbidity within the XEPA.

The HEPA ranged from 0 NTU at CONI in May 2021 to 2.6 NTU at KGBY in September 2020. Site KGBY was elevated above the 80th percentile EQG (described in

Table 6) for all months aside from May, August and November 2021 sampling events. Only November 2019, September 2020 and August 2021 were within the 80th percentile at site ICI (in the HEPA) with the rest exceeding the EQG. Conversely, at PLBE (in the MEPA) only August 2019 and June 2020 with BRCK recording no elevations.

Median turbidity values recorded within the MEPA ranged from 0 NTU during November 2019 to 5.4 NTU at TDPL during February 2021. All values from the last three sampling events (May, August and November 2021) are within the 5th and 95th percentile EQG values.

Table 19 Summary statistics for turbidity (NTU) recorded at all sites during Port of Dampier MEQSAP sampling (2019-2021).

	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Minimum	0.5	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	6.7	30.3	8.7	27.7	9.1	40.9	10.2	16.0	19.9	9.0
Median	0.5	0.5	0.5	0.9	0.7	1.5	2.2	1.6	1.2	1.3
Average	0.8	0.9	0.6	1.3	1.0	1.6	2.3	2.0	1.4	1.5
Standard deviation	0.9	2.4	0.7	-2.4	-1.2	-2.7	-1.9	1.9	2.1	1.3

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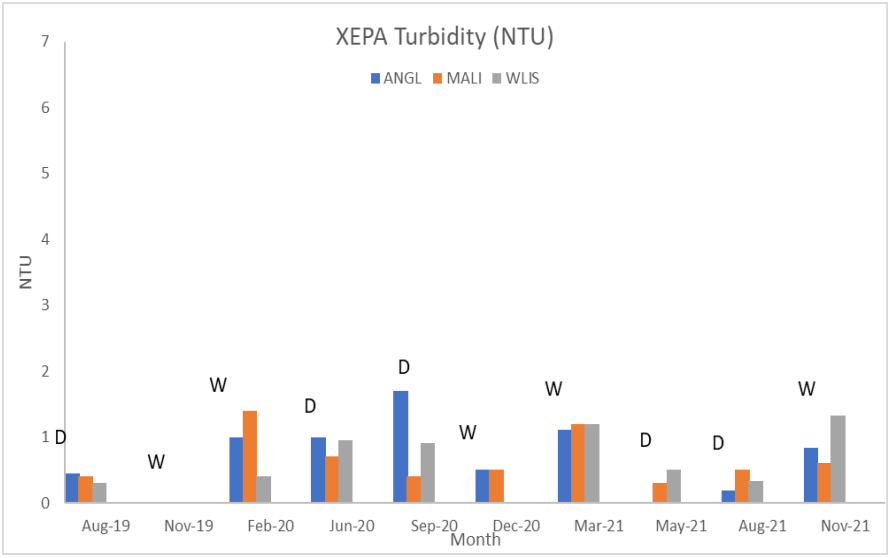

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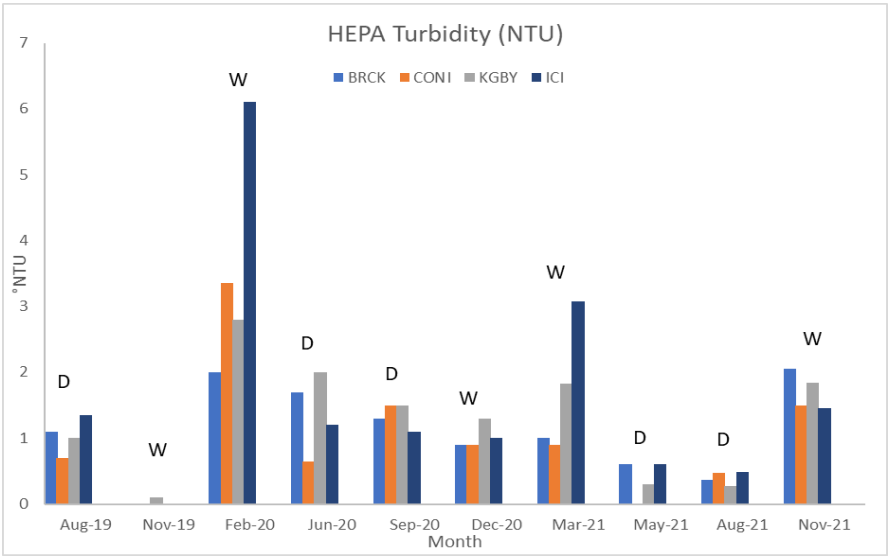

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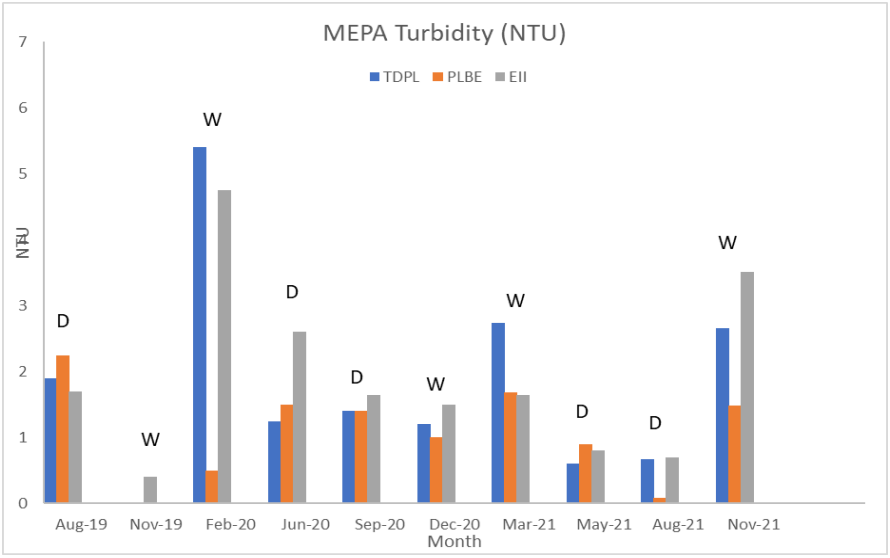

Figure 9a, b & c XEPA (top), HEPA (middle) and MEPA (bottom) for turbidity over the 2019-2021 sampling period. D = dry season, W = wet season.

Chlorophyll α

The chlorophyll-a levels within the Port and surrounding waters are all below PQL levels for all months (except February 2020, March 2021 and November 2021). Chlorophyll-a levels are greatly elevated across all LEPs in the February 2020 sampling event, indicating natural environmental elevation. This elevation may have been caused by excess organic matter within the sample or increased rainfall as a result of TC Damien, with Karratha airport recording a daily maximum rainfall of 235.2mm in the 48 hours before TC Damien made landfall (BOM 2020).

Table 20 Chlorophyll α levels within the Port and surrounding waters. Note: values denoted < indicate values reported below the laboratory PQL.

			XEPA			HEPA				MEPA		
	Units	PQL	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Aug-19	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nov-19	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Feb-20	µg/L	1	8	3	1	4	8	7	2	7	6	5
Jun-20	µg/L	1	<1	<1	<1	<1	<1	<2	<1	<1	<1	<1
Sep-20	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Dec-20	µg/L	1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
Mar-21	µg/L	1	1	<1	<1	<1	<1	2	<1	2	2	1
May-21	µg/L	1	<1	<1	1	<1	<1	<1	<1	<1	<1	<1
Aug-21	µg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Nov-21	µg/L	1	1	<1	<1	<1	<1	2	<1	2	3	3

Nutrients

Laboratory results for all nutrients (nitrogen, phosphorus, ammonia, and NOx) are presented in Table 21**.** These results indicate that nutrients levels are low with the majority of results below laboratory PQLs. Note there are currently no interim EQGs defined for nutrients.

Table 21 Nutrient levels within the Port and surrounding waters. Note: values denoted < indicate values reported below the laboratory PQL.

					XEPA			HEPA					MEPA	
			Units	PQL	ANGL	MALI	WLIS	BRCK	CONI	KGBY	ICI	TDPL	PLBE	EII
Nitrogen		Aug-19	mg/L	0.1	1	1.2	1.4	1.3	1.8	1.8	1.6	1.2	1.5	1
		Nov-19	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Feb-20	mg/L	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		June-20	mg/L	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
		Sep-20	mg/L	0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
		Dec-20	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
		Mar-21	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
		May-21	mg/L	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
		Aug-21	mg/L	0.1	0.4	0.5	0.4	0.5	0.4	0.3	0.5	0.5	0.4	0.4
		Nov-21	mg/L	0.1	1.1	1.5	0.9	1.1	0.9	1	1.1	1	1.2	1.2
Phosphorus		Aug-19	mg/L	0.005	0.006	<0.005	0.005	0.006	0.005	0.005	0.005	0.005	0.006	0.005
		Nov-19	mg/L	0.005	0.008	0.009	0.009	0.008	0.014	0.01	0.009	0.01	0.007	0.008
		Feb-20	mg/L	0.005	0.015	0.013	0.008	0.008	0.015	0.005	0.023	0.015	0.013	0.023
		June-20	mg/L	0.005	0.011	0.01	0.008	0.014	0.014	0.013	0.012	0.012	0.017	0.012
		Sep-20	mg/L	0.005	0.011	0.01	0.008	0.014	0.014	0.013	0.012	0.012	0.017	0.012
		Dec-20	mg/L	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01
		Mar-21	mg/L	0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	0.03	<0.01	<0.01	<0.01
		May-21	mg/L	0.01	0.04	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02
		Aug-21	mg/L	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
		Nov-21	mg/L	0.005	0.022	0.018	0.026	0.019	0.019	0.011	0.019	0.0.19	0.017	0.02
Ammonia		Aug-19	mg/L	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
		Nov-19	mg/L	0.003	0.005	0.004	0.004	0.003	0.004	0.003	0.007	<0.003	0.004	0.01
		Feb-20	mg/L	0.003	<0.003	<0.003	<0.003	0.041	0.11	0.05	0.02	0.006	0.041	0.049

		June-20	mg/L	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.002
		Sep-20	mg/L	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	<0.003
		Dec-20	mg/L	0.02	<0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03	<0.02
		Mar-21	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
		May-21	mg/L	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
		Aug-21	mg/L	0.003	0.008	0.009	0.012	0.01	0.008	0.01	0.01	0.015	0.011	0.011
		Nov-21	mg/L	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003
NOx		Aug-19	mg/L	0.002	0.005	0.004	0.005	0.004	<0.002	0.002	0.007	<0.002	0.005	0.003
		Nov-19	mg/L	0.002	0.011	0.004	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
		Feb-20	mg/L	0.002	0.002	0.014	0.014	0.01	0.003	0.015	0.021	0.003	0.002	0.021
		June-20	mg/L	0.002	0.007	0.004	0.002	<0.002	0.002	<0.002	0.007	<0.002	0.003	<0.002
		Sep-20	mg/L	0.002	0.007	0.004	0.002	<0.002	0.002	<0.002	0.007	<0.002	0.003	<0.002
		Dec-20	mg/L	0.01	<0.01	<0.01	0.04	0.03	0.04	0.01	<0.01	<0.01	<0.01	<0.01
		Mar-21	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		May-21	mg/L	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
		Aug-21	mg/L	0.002	0.048	0.048	0.047	0.037	0.014	0.025	0.03	0.042	0.037	0.04
		Nov-21	mg/L	0.002	0.006	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002

6.2. Recreation and Aesthetics

6.2.1. Aesthetic Observations

Aesthetic observations were typically consistent through the sampling period. When compared with the interim EQGs descriptions no results are considered to represent a decline. There was minor *Trichodesmium* coverage at EII in September 2020, CONI and TDPL in December 2020, and at TDPL in March 2021. No observed incidences of large-scale marine deaths, noticeable visible film or debris on the surface, odour or natural reflectance were recorded above the criteria described within the MEQSAP.

6.2.2. Primary and Secondary Contact

All levels for bacteriological samples are below the respective PQLs, and below the EQGs identified in the MEQSAP.

No phytoplankton concentrations exceed DOHWA watchlist species trigger values, aside from a small trigger of *Trichodesmium* during March 2021 at TDPL. All other results indicate the Port of Dampier and surrounding waters are safe for primary and secondary contact for humans. No interim EQGs were exceeded during the sampling period.

7. Summary

The EPA encourages Port Authorities to apply the EQMF to all marine waters within their boundaries and to ongoing environmental management. PPA has implemented the Port of Dampier MEQSAP which applies the EQMF to provide context for the marine environmental data being collected in the Port and to align the monitoring program with current EPA Technical Guidance. The MEQSAP also provides a framework to use when considering and assessing the potential impacts of this Project and other new proposals against the environmental factors 'Marine Environmental Quality'.

The Port is a multiple use environment that is associated with construction of Port infrastructure and heavy industrial activities. Nevertheless, the results across the ten (10) quarterly MEQSAP sampling events (2.5 years) demonstrate that marine water quality in outer Port areas (i.e. distant industrial or urban contaminant sources) is still at near background levels. Only a relatively small proportion of the broader Port area is heavily utilised and this inner Port area continues to maintain an acceptable level of environmental quality for the protection of all EVs and EQOs.

The MEQSAP results summarised in this report inform the 'Phase 1 - initial baseline monitoring period' (i.e. Years 1-3). This report therefore establishes baseline water quality conditions for the environmental impact assessment of the Project.

Laboratory results of water samples for hydrocarbons (TRH, PAH and BTEXN), heavy metals (dissolved), nutrients and bacteriological parameters identified that most parameters were below the PQLs and most were below their respective EQGs. No high levels of contaminants outside the range of short term natural variation were recorded at any sites. Elevations of chlorophyl-a levels in February 2020 was likely attributed to increased rainfall and excess organic matter in samples as a result of TC Damien.

Salinity, temperature, pH and dissolved oxygen depth profiles recorded levels that were generally within the expected limits of natural and seasonal variability and displayed well mixed water columns.

Turbidity was slightly higher at the MEPA and HEPA sites than at the XEPA sites. This difference is likely due to the natural difference in suspended sediment concentrations with an overall smaller particle size between inshore areas of Murujuga (Dampier Archipelago), compared with those sites located further offshore within the XEPA.

Phytoplankton results were below Primary and Secondary contact guidelines, and no DoHWA potentially toxic watch list species were identified within the water samples. Aesthetic observations showed no large-scale fish deaths, no oil/film on the surface, normal reflectance, no odour or seagrass wrack at any site. Small coverage of *Trichodesmium* were occasionally observed which were determined to be 'low risk'. *Trichodesmium* ('Red Tides') pose a threat to the condition of EVs within the Port and surrounding waters. The Port is planning to integrate further *Trichodesmium* monitoring into the MEQSAP to better understand the life cycle, what triggers its production and its effects on the surrounding environment.

A 'Traffic Light Assessment' approach is used in the MEQSAP to evaluate and present the monitoring results with respect to the EQIs and associated EQOs. As site specific EQGs and EQS have not yet been finalised, the baseline Traffic Light Assessment results have been compared to DVGs from sources such as Australian and New Zealand Guidelines (ANZG) (2018), Commonwealth Scientific and Industrial Research Organisation

(CSIRO) (2006) and Department of Environmental and Conservation (DEC) (2006). Where guidelines are not readily available percentiles are calculated in accordance with ANZG (2018) for the respective LEP area. The 'Traffic Light Assessment' results from across the ten (10) quarterly MEQSAP sampling events (2.5 years) are presented in Table 22.

Table 22 Water quality parameters compared to Environmental Quality Criteria (EQC) Numerical Values defined in the Port of Dampier MEQSAP (O2 Marine 2019).

Levels of Ecological Protection	***XEPA***			***HEPA***				***MEPA***		
Environmental Quality Indicator	**ANGL**	**MALI**	**WLIS**	**BRCK**	**CONI**	**KGBY**	**ICI**	**TDPL**	**PLBE**	**EII**
EQO1: Maintenance of Ecosystem Integrity										
Dissolved Oxygen	●	●	●	●	●	●	●	●	●	●
Water Temperature	These physico-chemical parameters will be assessed against EQG's following completion of Phase 1 baseline data collection.									
Salinity										
pH										
Turbidity										
Chlorophyll-α										
Hydrocarbons	●	●	●	●	●	●	●	●	●	●
Metals	●	●	●	●	●	●	●	●	●	●
Nutrients	●	●	●	●	●	●	●	●	●	●
EQO4: Water quality is safe for primary contact recreation (e.g. swimming and diving).										
EQO5: Water quality is safe for secondary contact recreation (e.g. fishing and boating).										
Pathogenic Bacteria	●	-	-	-	-	●	-	●	-	-
Toxic & Nuisance Phytoplankton	●	-	-	-	-	●	-	●	-	-
pH	●	●	●	●	●	●	●	●	●	●
EQO6: Aesthetic values of the marine environment are protected.										
Visual Clarity & Colour	●	●	●	●	●	●	●	●	●	●
Fauna deaths	●	●	●	●	●	●	●	●	●	●
Oil/debris	●	●	●	●	●	●	●	●	●	●

Levels of Ecological Protection	XEPA			HEPA				MEPA		
Odour	●	●	●	●	●	●	●	●	●	●

In summary the MEQSAP results to date support the findings of previous water quality studies undertaken in the Port (detailed in Table 2) and indicate that recommended DGVs provided in ANZG (2018) provide appropriate levels for protecting the environmental values of the Port waters and Mermaid Sound. However, following completion of the MEQSAP 'Phase 1 - initial baseline monitoring period' these EQC will be refined and site specific EQG and EQS will be finalised for the Phase 2 (Post-year 3) – Monitor & Investigate period.

8. Information for Dredge Plume Modelling

While monitoring of turbidity within the MEQSAP is undertaken by nephelometers recording nephelometric turbidity units (NTU), dredge plume modelling deals with particles expressed as suspended sediment concentration (SSC) in mg/L and so a conversion factor is necessary. A strong positive linear relationship (SSC = 0.75 NTU) was observed from monitoring during a Pilbara Iron maintenance dredging project (MScience 2016) just south of this Project. This relationship is suitable for converting NTU to SSC for this assessment as it is based on dredging of sediment adjacent to the Project and therefore the plume characteristics and dissipation rates are likely to be similar.

MEQSAP turbidity values for the Port and surrounding waters were typically consistent across the ten (10) quarterly MEQSAP sampling events (2.5 years). However, offshore (XEPA) turbidity values were relatively low in comparison to nearshore (HEPA and MEPA). Elevated turbidity within the nearshore zone may be related to shallower water depth and greater shear stresses at the seabed, along with a higher concentration of fine sediments more susceptible to re-suspension (SKM 2012).

As the dredge plume model only accounts for sediment from dredging, mean background SSC concentrations (ambient SSC) for offshore and nearshore have been determined using the above relationship and will be added to model estimates to provide an absolute SSC experienced by benthos.

Mean background SSC concentrations to inform dredge plume modelling are as follows:

Offshore: mean NTU = 0.8; mean SSC = 0.75*0.8 = 0.6 mg/L

Nearshore: mean NTU = 1.6; mean SSC = 0.75*1.6 = 1.2 mg/L

Modelling Input	Parameter	Background concentration
Dredge plume	TSS	0.6 mg/L (offshore >10m water depth) 1.2 mg/L (nearshore <10m water depth)

In addition many of the EPA's dredging thresholds are stated in DLI – Daily Light Integral (the sum of moles of photons from within the PAR spectrum per square metre per day). The MEQSAP does not include monitoring of light, therefore, there is a requirement for another conversion factor that relates SSC to light attenuation.

There is an existing NTU~PAR relationship collected during a recent monitoring program conducted for a maintenance dredging program adjacent to the Karratha Gas Plant (MScience 2019).

Regressing DLI against depth (actual measured depth which included tidal variation) and turbidity produced the equation: DLI (mol.m-2.d -1) = 35.5 – 2.95 Depth(m) – 3.58 NTU. Converted into SSC (0.75*NTU) the equation becomes: DLI (mol.m-2.d -1) = 35.5 – 2.95 Depth(m) – 4.65 SSC (mg/L).

It is recommended that this locally acquired relationship be investigated and possibly modified for converting absolute SSC (background + dredging) into DLI for the purposes of dredge plume modelling and impact assessment of this Project. This information is presented in the Dredge Plume Modelling Report (O2 Marine 2022c).

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