Mardie Project

Marine Environmental Quality Monitoring & Management Plan

CLIENT: Mardie Minerals

STATUS: Rev 3 **REPORT No.:** 190108

ISSUE DATE: 20th October 2020

O2 MARINE

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WA Marine Pty Ltd t/as O2 Marine
ACN 168 014 819
Originating Office – Southwest
29 Albert Street, Busselton WA 6280
T 08 93351232 | info@o2marine.com.au

Version Register

Version	Status	Author	Reviewer	Change from Previous Version	Authorised for Release (signed and dated)	
Rev 0	Draft	C Lane	T Hurley N Dixon	Address client review comments	C Lane	24/5/2019
Rev 1	Final	R Stevens	N Dixon	Inclusion of Monitoring & Management Sections	C Lane	9/12/2019
Rev 2	Final	R Stevens	Office of the EPA	Update Project Description, revised LEPs and incorporate comments from client	C Lane	25/03/2020
Rev 3	Final	R Stevens		Include several updates from EPA Review	C Lane	20/10/2020

Transmission Register

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Name	Email Address
Neil Dixon	Neil.Dixon@bciminerals.com.au
Michael Klvac	Michael.Klvac@bciminerals.com.au

Acronyms and Abbreviations

Acronyms/Abbreviation	Description
ANZG	Australian and New Zealand Guidelines
BCH	Benthic Communities and Habitat
EPA	Environmental Protection Authority
EQC	Environmental Quality Criteria
EQIs	Environmental Quality Indicators
EQMF	Environmental Quality Management Framework
EQOs	Environmental Quality Objectives
ESD	Environmental Scoping Document
EVs	Environmental Values
GLpa	Gigalitre per annum
ktpa	kilo tonnes per annum
LEPs	Levels of Ecological Protection
MEQ	Marine Environmental Quality
MEQMMP	Marine Environmental Quality Monitoring & Management Plan
MEQP	Marine Environmental Quality Plan
MS	Ministerial Statement
MTs	Management Targets
Mtpa	Million tonnes per annum
NaCl	Sodium chloride, commonly known as salt.
SOP	Sulphate of potash
SWQMS	State Water Quality Management Strategy

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1. Introduction

1.1. Project Description

1.1.1. Proposal Summary

Table 1-1 Proposal Summary

Proposal Title	Mardie Project
Proponent Name	Mardie Minerals Pty Ltd
Short Description	Mardie Minerals Pty Ltd is seeking to develop a greenfields high quality salt and sulphate of potash (SOP) project and associated export facility at Mardie, approximately 80 km south west of Karratha, in the Pilbara region of WA. The Proposal will utilise seawater to produce a high purity salt product, SOP and other products derived from sea water. The Proposal includes the development of a seawater intake, concentrator and crystalliser ponds, processing facilities and stockpile areas, bitterns disposal pipeline and diffuser, trestle jetty export facility, transhipment channel, drainage channels, access / haul roads, causeway, desalination (reverse osmosis) plant, borrow pits, pipelines, and associated infrastructure (power supply, communications equipment, offices, workshops, accommodation village, laydown areas, sewage treatment plant, landfill facility, etc.).

1.1.2. Proposal Description

Mardie Minerals Pty Ltd (Mardie Minerals) seeks to develop the Mardie Project (the Proposal), a greenfields high-quality salt project in the Pilbara region of Western Australia (**Figure 1-1**). Mardie Minerals is a wholly-owned subsidiary of BCI Minerals Limited.

The Proposal is a solar salt project that utilises seawater and evaporation to produce raw salts as a feedstock for dedicated processing facilities that will produce a high purity salt, industrial grade fertiliser products, and other commercial by-products. Production rates of 4.0 Million tonnes per annum (Mtpa) of salt (NaCl), 100 kilotonnes per annum (ktpa) of Sulphate of Potash (SoP), and up to 300 ktpa of other salt products are being targeted, sourced from a 150 Gigalitre per annum (GLpa) seawater intake. To meet this production, the following infrastructure will be developed:

- Primary seawater intake pump station;
- Concentrator ponds;
- Crystalliser ponds;
- Processing facilities and stockpiles;
- Causeway, trestle jetty and transhipment berth/channel;
- Bitterns disposal pipeline, seawater intake (for dilution) and diffuser;
- Drainage channels and flood protection levees;
- Administration buildings;
- Accommodation village;
- Access / haul roads;
- Desalination plant for freshwater production;

- Boat launching facility and port stockyard; and
- Associated infrastructure including power supply, communications, workshop, laydown, landfill facility, sewage treatment plant.

Seawater for the process will be pumped from a large tidal creek into the concentrator ponds. All pumps will be screened and operated accordingly to minimise entrapment of marine fauna and any reductions in water levels in the tidal creek.

Concentrator and crystalliser ponds will be developed behind low permeability walls engineered from local clays and soils and rock armoured to protect against erosion. The height of the walls varies across the project and is matched to the storm risk for the area.

Potable water will be required for the production plants and the village. The water supply will be sourced from desalination plants across the Proposal. The high salinity brine output from the plants will be directed to concentrator ponds or a lined process pond.

A trestle jetty will be constructed to convey salt (NaCl) from the salt production stockpile to the transhipment berth pocket, approximately 2.2 km offshore. The jetty will not impede coastal water or sediment movement, thus ensuring coastal processes are maintained.

Dredging of up to 850,000 m^3 will be required to ensure sufficient depth for the transhipper berth pocket at the end of the trestle jetty, as well as along a 4.5 km long channel out to deeper water. The average depth of dredging is approximately 1 m below the current sea floor. The dredge spoil is inert and will be transported to shore for use within the development.

The production process will produce a high-salinity bittern that, prior to its discharge through a diffuser at the far end of the trestle jetty, will be diluted with seawater to bring its salinity closer to that of the receiving environment.

Access to the project from North West Coastal Highway will be based on an existing public road alignment that services the Mardie Station homestead and will require upgrading..

The majority of the power required for the project (i.e. approximately 95%) is provided by the sun and the wind, which drives the evaporation and crystallisation processes. In addition, the Proposal will require diesel and gas to provide additional energy for infrastructure, support services and processing plant requirements.

The Proposal will be developed within three development envelopes. The boundaries of these development envelopes are shown in **Figure 1-2** and described in **Table 1-2**.

Table 1-2 Location and proposed extent of physical and operational elements

Element	Ref.	Proposed Extent
Physical Elements		
1. Ponds & Terrestrial Infrastructure Development Envelope – concentrator and crystalliser ponds, processing plant, access / haul road, desalination plant, causeway, administration, accommodation village, laydown, other infrastructure.	Fig. 2	Disturbance of no more than 11,212 ha within the 16,005 ha Ponds & Terrestrial Infrastructure Development Envelope.
2. Marine Development Envelope – trestle jetty, seawater intake and pipelines.	Fig. 2	Disturbance of no more than 7 ha within the 50 ha Marine Development Envelope.
3. Dredge Channel Development Envelope – berth pocket, channel to allow access for transhipment vessels, bitterns outfall diffuser.	Fig. 2	Disturbance of no more than 115 ha within the 304 ha Dredge Channel Development Envelope.
4. Mangrove Disturbance	Fig. 2	Disturbance of mangrove communities limited to 20 ha of Scattered Canopy mangroves and 1.0 ha of Closed Canopy mangroves
Operational Elements		
Desalination Plant discharge	Fig. 2	Discharge to ponds or bitterns stream
Dredge volume	Fig. 2	Dredging is only to occur within the Dredge Channel Development Envelope. Dredging of no more than 850,000 m3 of material from the berth pocket and high points within the dredge channel, with the material to be deposited within the Ponds & Terrestrial Infrastructure Development Envelope.
Bitterns discharge	Fig. 2	Discharge of up to 3.6 gigalitres per annum (GLpa) of bitterns with a specific gravity of no more than 1.25 via a diffuser within a Low Ecological Protection Area. Bitterns will be diluted prior to discharge.
Pond seawater intake		Up to 150 GL per annum, from a screened intake with a maximum average intake flow rate at the screen of less than 0.15 m/s. Seawater abstraction will only occur when water levels are at mean sea level or higher.

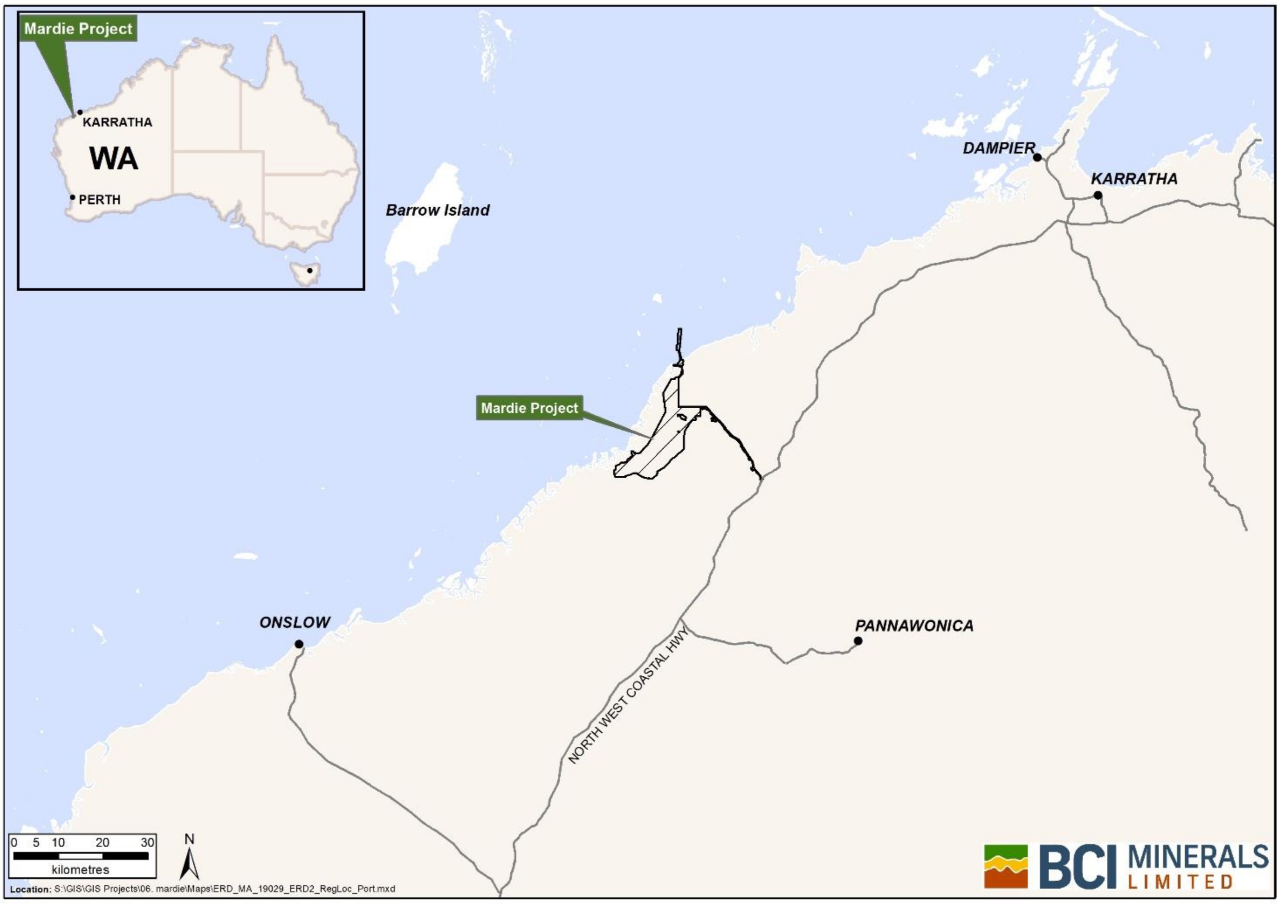

Figure 1-1 Mardie Project Regional Location

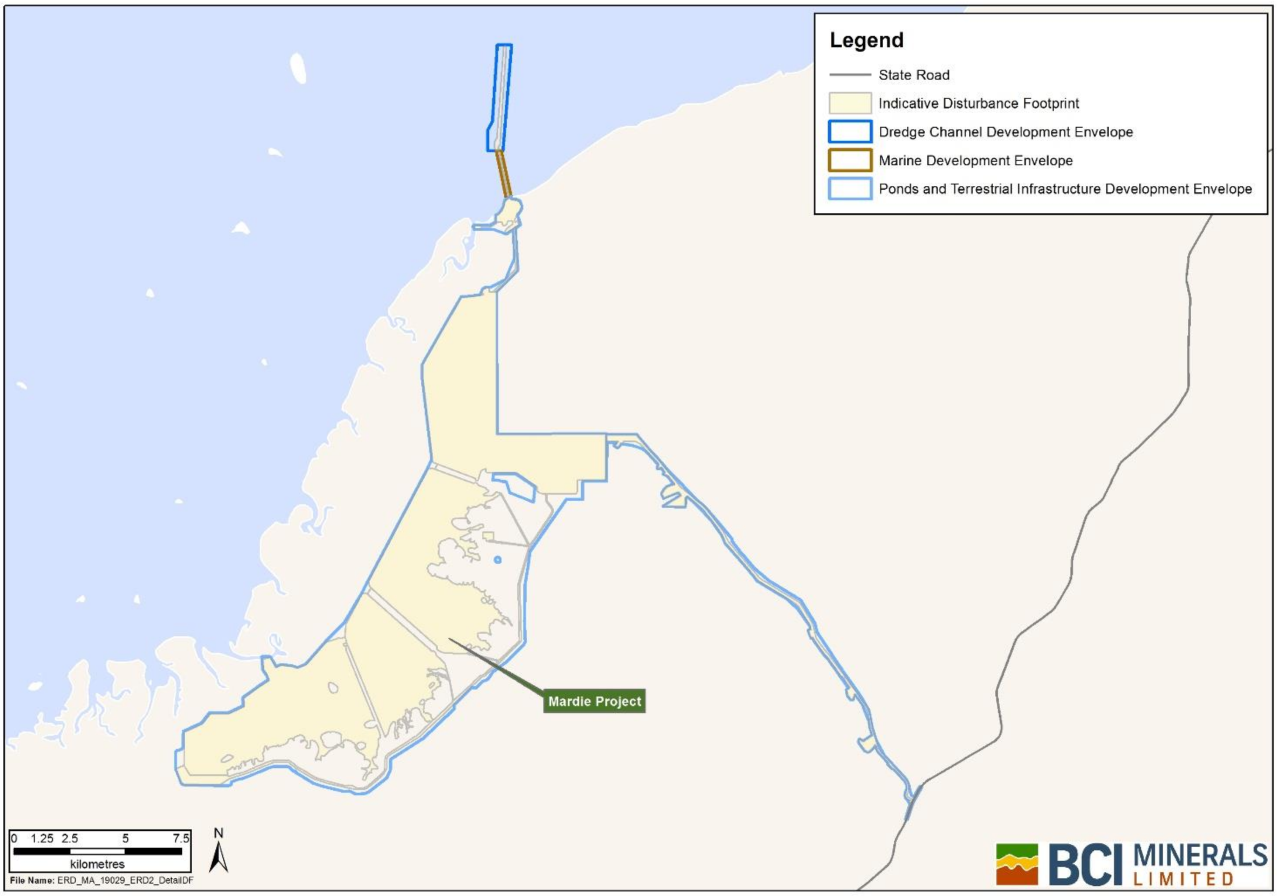

Figure 1-2 Mardie Project Development Envelopes

1.2. Scope

The purpose of this Marine Environmental Quality Monitoring and Management Plan (MEQMMP) is to establish a framework to ensure that the implementation of the Project does not compromise the Environmental Values (EVs) and Environmental Quality Objectives (EQOs) of the Mardie coastal area. The framework relies on establishing EVs and EQOs, spatially defining the Levels of Ecological Protection (LEPs) for the Project area, and applying a risk-based, adaptive approach to monitoring and management.

The MEQMMP applies to the following project activities that have the potential to impact on the environmental quality of the marine environment at Mardie:

- the discharge of waste bitterns;
- day-to-day port operations; and
- the storage and handling of potentially contaminating materials.

Project activities associated with off-shore dredging and on-shore construction are managed through their respective, specialised environmental management plans.

The MEQMMP sets out a process for monitoring and reporting to allow residual impacts to be assessed against acceptable limits of ecological change during the lifecycle of the Proposal. Where results outside the limits of acceptable change are reported, a pre-determined risk-based response is triggered to ensure the EVs and EQOs are not compromised.

Specifically, the objectives of this MEQMMP are to:

- Identify EVs and clearly define EQOs relevant to the Proposal area;
- Spatially define LEPs relevant to the Proposal area;
- Establish Environmental Quality Criteria (EQC) to provide measurable levels of acceptable change to Environmental Quality Indicators (EQIs) for each EV;
- Establish protocols and procedures for the monitoring, management and reporting regarding the achievement of EQOs and protection of EVs;
- Provide a framework to guide management response and required actions in the event established EQC are exceeded; and
- Ensure the collection, analysis and reporting of marine environmental quality (MEQ) data occur in a consistent and robust manner.

This MEQMMP applies to each of the key project phases. The Plan also details the process for routine review and continual improvement of the Plan as the Proposal progresses, or at any time key processes alter and new risks are identified.

To ensure the objectives of the MEQMMP are achieved the following key processes have been defined:

1. Pre-Project Baseline Data Collection;
    - Derive locally relevant EQC from baseline data to inform ongoing monitoring and management.
2. Commissioning and Validation;
    - Undertake further whole of effluent toxicity (WET) of the final bitterns during the commissioning phase to ensure the species protection levels (SPL) within the outfall mixing zone and the designated LEPs are appropriate;

- Validate the accuracy of numerical modelling in predicting the extent of the mixing zone; and
- Validate performance of the bitterns outfall diffuser during both commissioning and operational phases of the Proposal.

3. Ongoing MEQ Monitoring;
    - Monitor and mitigate potential impacts to MEQ throughout the life of the Proposal.

2. Existing Environment

This section describes the existing environment at the site of the proposal and surrounding waters. The description of the existing environment is based on a desktop review of historical information and investigations currently conducted as part of the environmental impact assessment process.

2.1. Coastal Setting

The Pilbara coast is noted to be a region of extremes (Elliot et al 2013), an arid environment where sediment is delivered periodically to the coast through networks of rivers and streams and where significant events such as tropical cyclones bring episodic flooding and inundation impacts that drive geomorphic changes along its coastal landforms. Semeniuk (1993) describes the dominant drivers for coastal processes and ecology within the study area as typically wave dominated, with a lesser dominant driver associated with meso-tides experienced in the region with a range exceeding 3.5 m.

The coastal area of the Pilbara is composed of an ancient hard-rock terrain over which the deposition of sediment from sources including coral reefs, flood plains and river deltas has occurred for 2 million years. The shoreline at the Proposal site is generally northwest facing with the inter-tidal region around the Proposal site generally described as quaternary mudflat deposits, clay, salt and sand (Elliot et al 2013).

The inner shelf region is very wide along this section of the coast, and consequently the near shore bathymetry is very shallow, with water depth of approximately 5 m (below LAT) at a distance of 10km offshore. A series of offshore islands and reefs are located immediately offshore which provide natural protection for the coastline during extreme events (e.g. Tropical Cyclones). Further offshore the Montebello Islands, Barrow Island and the Barrow shoals provide significant protection against extreme waves associated with the passage of a tropical cyclone.

A series of major tidal creeks lined by mangroves and salt marsh extend from the shoreline through the intertidal area, with branches that convey tidal flows across the tidal flats. Beyond the mangrove areas, large areas of clay pan are present across expansive tidal flat areas which extend 10km or more inland from the coast. During neap tides the high tide water level is generally contained within the creeks through the intertidal areas and there is little to no inundation of the tidal flats. During spring tides, a large proportion of the intertidal area becomes completely inundated and based on aerial imagery and anecdotal reports the surface water can remain on the surface for days after. The Fortescue river mouth is located approximately 20 km east of the Proposal site and under extreme flooding scenarios breakout flows have the potential to extend across the Proposal site (RPS 2018).

Analysis of satellite images from the Mardie site over the period 2004 - 2017 reported in RPS 2018 note the dynamic nature of the mangroves and tidal creek areas. The flat terrain of the intertidal areas results in the tidal watersheds being highly sensitive to small changes in the landform. The analysis examined the tidal branches over time noting evidence of increased colonisation of many of the creeks by mangroves along with increased branching of the creeks over the approximately 13-year period, which is likely indicative of either sea-level rise or erosion of sediment from the intertidal zone. Behind the mangrove zone the analysis indicated a clay pan area which is colonised by algae and cyanobacteria that form extensive crusting mats. The tidal creek systems through the intertidal area provide the mechanism by which seawater is moved in and out of this area under the general tidal regime.

2.2. Climatology and Oceanography

The southern Pilbara region has a tropical monsoon climate with distinct wet and dry seasons. The dry season extends from May to October, and is characterised by warm to hot temperatures, easterly to southeasterly winds from the continental landmass, clear and stable conditions as the subtropical high-pressure ridge migrates over this area. In the afternoon, the wind direction shifts to north-westerly, particularly later in the dry season, associated with the onset of the land sea breeze as the temperature difference between the continent and the ocean increases throughout the day. In the wet season the wind climate is dominated by westerly and north-westerly winds. Wind rose plots for the Dry Season months (May to October) and Wet Season months (November to April) are presented in **Figure 2-1** based on analysis of the measured wind records from Mardie Airport over the period 2011 - 2018.

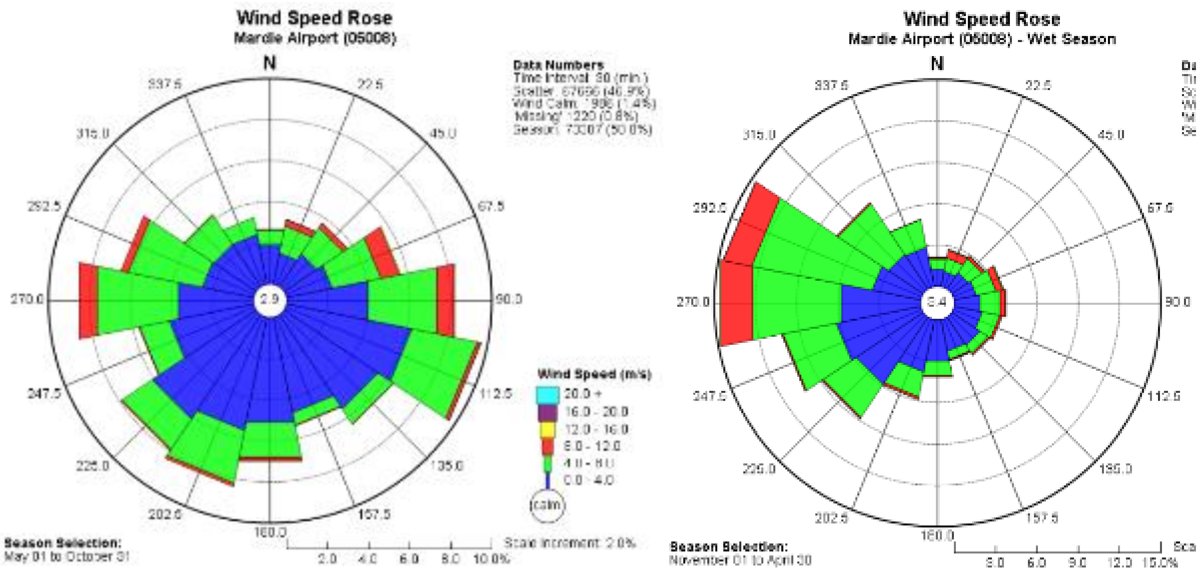

Figure 2-1 Wind Rose plots for Dry Season (left) and Wet Season Months (right) based on analysis of the measured data from Mardie airport

Climate statistics for the town of Mardie are presented in Figure 2-2 from the Bureau of Meteorology (BoM) site which is approximately 16km inland. Maximum daily temperatures at Mardie average 33.9 °C throughout the year, peaking at 38.0 °C in January and falling to 27.7 °C in July. The Pilbara is influenced by northern rainfall systems of tropical origin. These systems are responsible for heavy falls during the summer months, while the southern low-pressure systems sometimes bring limited winter rains. The annual average rainfall is only 128 mm, and the mean monthly rainfall has a bimodal distribution, peaking in January to March and also May to June, with very little rainfall from July to December (**Figure 2-2**). Daily rainfall can reach over 300 mm during extreme events that may occur one to two times per decade. Evaporation rates in the region are high, estimated to exceed by ten times the annual rainfall.

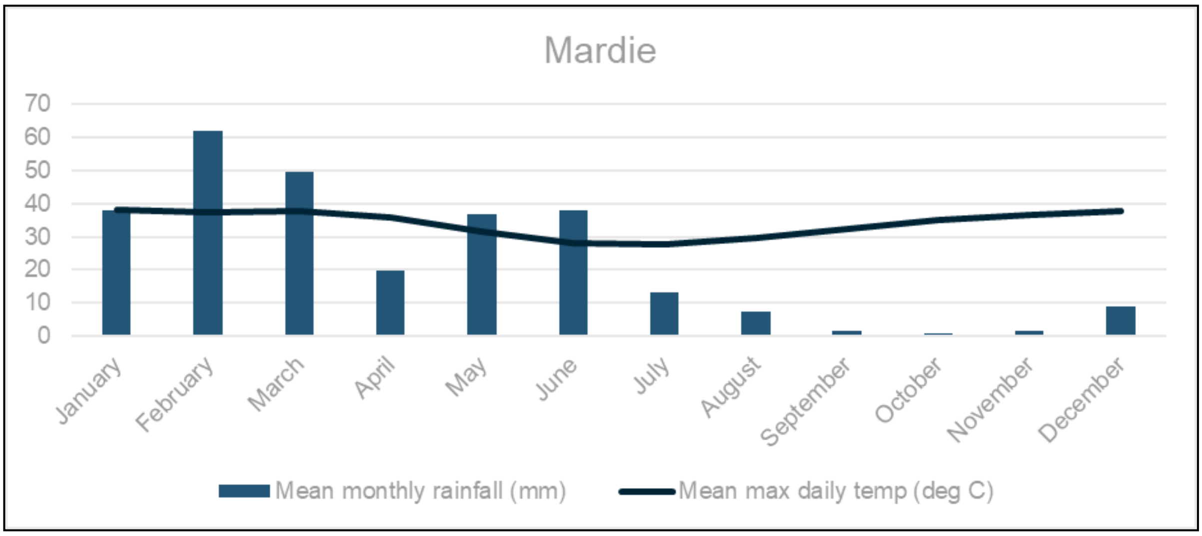

Figure 2-2 Climate Statistics for Mardie (BOM).

The Australian cyclone season extends from November through to April with an average of 10 cyclones per year, although not all make landfall. Tropical cyclone winds can generate extreme coastal water levels through storm surge and these systems are frequently associated with heavy rainfall that can cause significant flooding. The Pilbara region of Western Australia has a high exposure to tropical cyclone events, with a typical cyclone track recurving and making landfall on the coastline between Broome and Exmouth. The season typically runs from mid-December to April, peaking in February and March. The Karratha to Onslow coastline is the most-cyclone prone section of the Australian coast, typically experiencing one landfalling event every two years. The northwestern coastline of Western Australia is highly vulnerable to the occurrence of storm surge. This is due to the frequency of tropical cyclones, the wide continental shelf and relatively shallow ocean floor over the North West Shelf, as well as the low-lying nature of much of the coastline. In addition, tropical cyclone events are strongly associated with flooding due to widespread heavy rainfall.

Historical events of significance impacting between Karratha and Onslow include: Trixie 1975, Chloe 1984, Orson 1989, Olivia 1996, John 1999, Monty 2004, Clare 2006 and Glenda 2006 (**Figure 2-3**). In late March 2019 the passage of TC Veronica tracked west over the region from offshore of Karratha losing intensity as it continued west offshore of Mardie as a tropical low system.

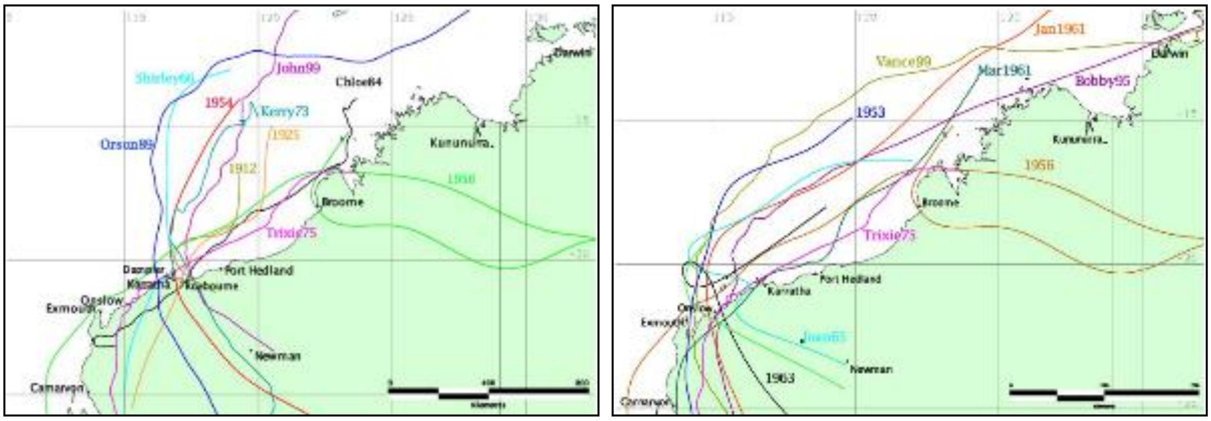

Figure 2-3 Tracks of notable cyclones impacting Karratha (left) and Onslow (right)

The astronomical tide is the periodic rise and fall of the sea surface caused by the combination of the gravitational force exerted by the moon and the Sun upon the Earth and the centrifugal force due to rotations of the Earth and moon, and the Earth and the Sun around their common centre of gravity. Tides are subject to spatial variability due to hydrodynamic, hydrographic and topographic influences. At the study area, the tides are characterised by amplification of tidal range due to the shallow bathymetry over the North West Shelf and complex hydrographic and topographic features. The tide levels recently analysed from data near the Proposal site indicates that the mean spring tide range exceeds 3.5 m and the maximum tide range is ≈ 5.1 m.

The northwest shelf of Western Australia experiences waves generated from three primary sources: Indian Ocean swell, locally generated wind-waves and tropical cyclone waves. Along the shoreline the ambient (non-cyclonic) wave climate is generally mild. In dry season months low amplitude swell originating in the Indian Ocean propagates to the site and occurs in conjunction with locally generated sea waves of short period (<5 s). In the wet season the wave climate is locally generated sea waves from the southwest. In general, the significant wave height is dominated by locally generated sea conditions within the range of 0.5 m to 1 m at short wave periods (Tp< 5 s). Measured data from an ADCP instrument deployed approximately 15 km offshore for the Proposal has been analysed to characterise the wave conditions in the wet and dry seasons as shown in **Figure 2-4**.

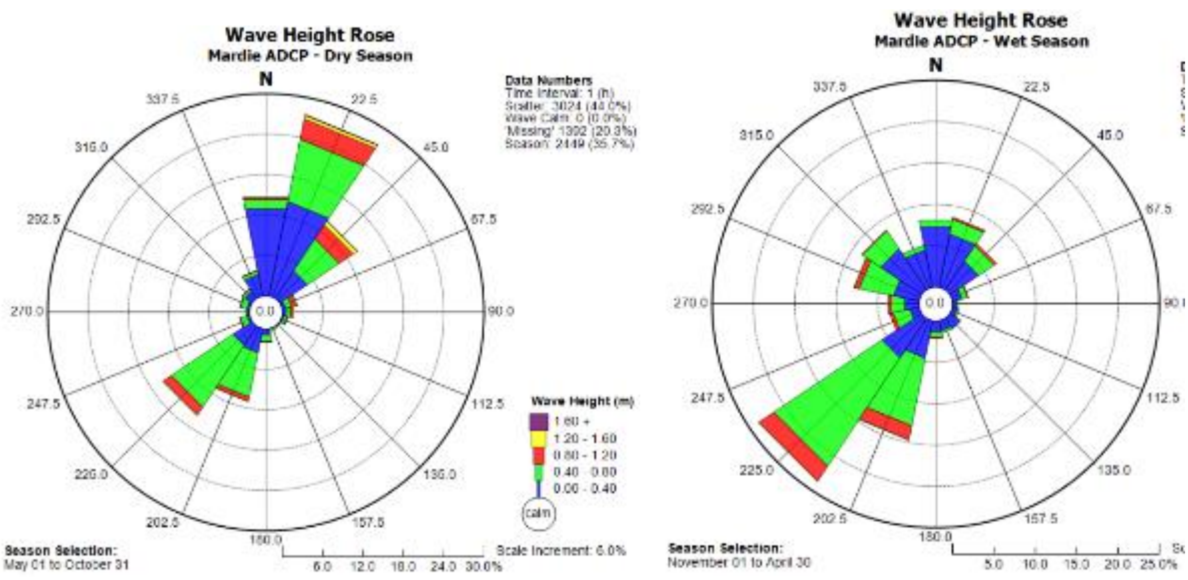

Figure 2-4 Wave conditions offshore of the Mardie Proposal location for Dry Season months (left) and Wet Season Months (right) based on measured data April 2018 – January 2019.

Whilst the non-cyclonic ambient wave conditions are generally mild, in contrast the strong winds in a tropical cyclone can generate extreme wave conditions. It is noted that the offshore island features would provide some natural protection from extreme wave conditions depending on the direction of propagation. Extreme cyclonic waves contribute to the total water level through wave run-up which is the maximum vertical extent of wave uprush on a beach and is comprised of both wave set-up and swash. The impact of cyclonic waves on the study site is dependent on the prevailing water level conditions and direction of cyclone approach. If coincident with a spring tide and storm surge, waves could propagate beyond the typical position of the beach and induce erosion of the shoreline as well as sediment transport.

Tropical cyclones are typically associated with heavy rainfall prior to, during and after the landfall of the system, which can lead to catchment flooding. The elevation in coastal water levels caused by the storm tide and wave processes can also propagate into estuarine waterways. The peak flood levels within the waterways will be influenced by the combination of fluvial and ocean, and coastal based processes, the interaction of which is highly dependent on the timing of peak of each process and the specific bathymetry and topography of the catchment and the inlet.

2.2.1. Geomorphology

The geomorphology of the site is characterised by tidal creeks which have generally evolved in response to the ongoing tidal current forcing. Rainfall in this environment is highly intermittent and it is likely that rainfall runoff occurs as sheet flow over the local drainage catchments that have relatively small catchment areas towards the tidal creek drainage network. Sediment is delivered periodically to the coast through networks of rivers and streams. Extreme water levels and waves and associated rainfall and runoff under cyclonic conditions would be a significant driver of geomorphic changes along the coast, leading to erosion and enhanced sediment transport processes (Elliot et al 2013).

The primary mechanism for sediment transport in nearshore areas appears to be the tidal flows. The measured data from inshore shows a marginally stronger flood magnitude compared with the ebb, likely due to the shallow water and complex bathymetry which funnels water in on the flood tide between the reefs and islands. Based on measured data from inshore, the depth averaged velocity in spring tides is in the range of 0.3 m/s to 0.5 m/s, whilst on the neaps the current speed is 0.2 m/s to 0.3 m/s. Whilst the site is generally protected from swells, the sea waves and swell will contribute to nearshore and shoreline sediment transport processes

Sediment samples from the nearshore areas around the Proposal site collected by O2 Marine in 2018 and 2019 confirm the seabed composition is made up of predominantly sand fractions with varying degrees of fines. The samples collected from the seabed through the region of the proposed berth pocket and entrance channel showed fine fractions (silt and clay) of 20 % to 30 %. Further offshore (approximately 5 km) the sediment sampling indicated the fine fractions reduced to less than 5 % of the sample with the composition of the seabed sediment dominated by sand fractions.

2.2.2. Tide and Water Levels

The Mardie Proposal location experiences a dominant semi-diurnal tide (two highs and two lows a day) and the tidal planes have been defined by the National Tide Centre (NTC) based on field measurements completed for the Proposal in late 2018 (O2 Marine 2019c). The Mardi Gauge (MardiLAT18) datum definition completed by the NTC shows that the offset between LAT and Mean Sea Level (MSL) is 2.75 m and the total tidal range is 5.185 m with tidal planes shown in **Table 2-1**. The mean tide range is 3.6 m in springs and 1 m in neaps.

It is noted that the calculated tidal planes for Mardie are larger than for the nearest stations at Steamboat Island, Barrow Island Tanker Mooring and North Sandy Island likely as a result of the closer inshore location (O2 Marine 2019c).

Table 2-1 Mardie Tidal Planes (location 21.03572 S, 115.92766 E, National Tide Centre)

Tidal Planes	Elevation (m LAT)
HAT	5.185
MHWS	4.557
MHWN	3.226
MSL	2.75
MLWN	2.275
MLWS	0.943
ISLW	0.528
LAT	0

Measured data from an inshore Aquadopp in November 2018 is shown in **Figure 2-5** illustrating the water level time series through the spring and neap cycles. It is noted that the instrument could not measure tide levels below -2 m MSL.

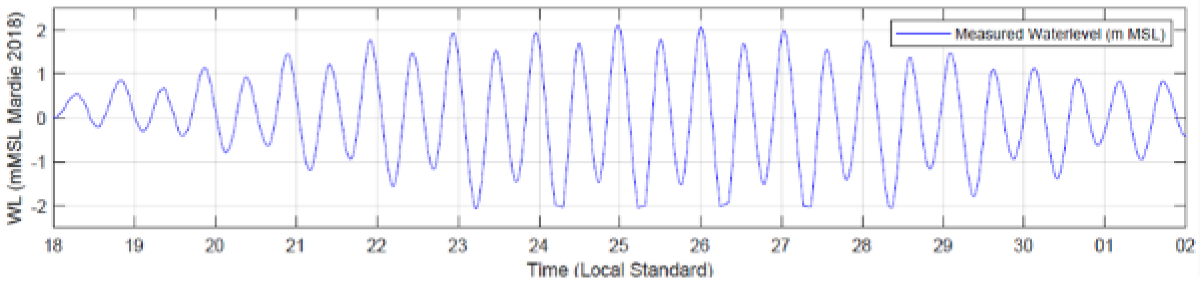

Figure 2-5 Measured water level data from inshore Aquadopp location November 2018

Modelling of coastal inundation completed by RPS for the Proposal in 2018 described the following key processes over the typical spring-neap cycle for the tides propagating across the tidal flat areas:

Water floods onto the land within the Proposal area when tidal levels offshore are approaching high tide at tide levels of 1.2 m MSL or higher.

Flooding onto the land occurs via multiple pathways:

1. Water floods onto the coastal margin through the mangrove zone and lower sections of the coast and floods onto the land surrounding the creeks.
2. Water floods out of the creeks from multiple low points that occur along the full length of the creeks and floods out onto the surrounding land via erosion channels.
3. Water floods from the terminal ends of the creeks and flows directly to the claypans beyond.

Water delivered from multiple pathways by high spring tides tends to merge over the land surrounding the creeks and then flood out to form a shallow lake over the clay pan area. The water floods out over the clay pan as a surge. The extent of the flooded area varies with the tidal level offshore, which generates the head of water to force the surge, and the time required for water to flood out over the surrounding land.

Different wetting periods were observed in the simulation during different stages of the spring-neap cycle. During the highest spring-tides that were simulated, the claypan areas were overtopped by water for periods of 4 to 6 hours every 12 hours. Hence, the period over which the ground could dry was limited to less than 6 hours on each tidal cycle. In contrast, the simulations indicated increased time between wetting as the tidal levels decreased towards neap tides and that no flooding of the clay pan areas will occur when high tide levels fall below approximately 1.1 to 1.2 m MSL. These conditions occur over periods spanning 7 to 10 days. Consequently, the claypans will not be overtopped for 7-10 days over neap-tide periods. Hence, in addition to the fluctuations in water depth over the clay pans, fluctuations in tidal levels will have consequence for the retention of moisture in the soil within the algal mat areas. Review of the time-lapse imagery also indicates that salt precipitates over the ground surface when the ground does not wet after 2 to 3 days, with potential consequence for the osmotic pressure exerted on the algal mats and organisms that predate on the algae.

To analyse the storm surge and extreme water levels for the site, RPS completed a study in 2017 for the Proposal. The outcomes from that study indicated the following return period guidance:

- 100-year still water sea level is 4.2 to 4.3 m above MSL, which is about 2m higher than HAT.
- 10-year sea level is in the range 3.5 - 3.7 m above MSL, which is about 1.3m higher than the HAT.

These levels incorporate an allowance of 0.2 m for sea level rise to 2050 and based on the terrain would flood the coastline for several km (RPS 2017).

2.3. Water Quality

Marine water quality baseline monitoring was conducted from March 2018 - September 2019 at two locations (inshore and offshore) (O2 Marine 2020). In-situ physicochemical monitoring and water sampling for laboratory analysis was conducted over this period. The below is a summary of the results presented within O2 Marine (2020a).

2.3.1. Water Temperature

Lowest temperatures at the inshore location were recorded during the dry season (18 - 26°C), with the highest recorded during the wet season (22 - 33°C). Temperature variability at the offshore location was lower than at the inshore location, however the sampling period for temperature at the offshore location was limited to approximately three months, compared to the inshore location which sampled a full annual cycle. Lower variability in temperature at the offshore location in comparison to the inshore location is likely explained by the greater influence of oceanic water at the offshore site and greater depth of the instrument. Deeper oceanic waters are generally less influenced by diurnal temperature variation than shallower inshore waters.

2.3.2. Salinity

Salinity was comparable between the dry season (36.9 – 38.0 ppt) and the wet season (36.6 – 38.31 ppt). Median salinity remained at 37.5 ppt across both the wet and dry seasons, but was highest during March (38.3 ppt) and lowest during April (36.6 ppt). The salinity conditions recorded at the inshore monitoring location for the dry and wet seasons is slightly higher than the median salinity range (35.1 - 37.1 ppt) previously reported by CALM (2005) for the nearshore Pilbara region. The values are lower than the nearshore salinity range reported by Oceanica (2004) for the eastern side of Exmouth Gulf (35.9 - 42.7 ppt). Therefore, the metahaline salinity conditions reported at Mardie appear to be more characteristic of a sheltered bay or estuary, which has limited vertical mixing and limited exchange with lower salinity oceanic currents. Hydrodynamic modelling undertaken by Baird (2020b) found that due to the alignment of the island and reef features of the Passage Islands, the majority of incoming tidal flow on the flood tide is directed through the gap between Scholl Island and Mardie Island, approximately 10 km to the north of the inshore monitoring location. Seawater exchange from the open ocean to the inshore region in the vicinity of the Proposal export facilities is therefore influenced by this constraint of flows around the Passage Islands, which is likely to affect the rate of mixing with the open ocean (Baird, 2020b). It is therefore possible that restricted mixing with lower salinity oceanic currents, combined with high evaporation rates and very little freshwater runoff to the nearshore waters has contributed to creation of a higher salinity environment in the vicinity of the inshore monitoring location (O2 Marine, 2020).

2.3.3. Light

Light data was collected between 19 December 2018 and 3 August 2019 at an offshore and inshore location. Variable levels of underwater light were recorded reaching the substrate throughout the sampling period. Data recorded for Daily Light Integral (DLI) typically identified highest DLI recordings during neap tides and lowest during spring tides when compared with the results from the pressure / depth data. Light levels are significantly affected by water depth due to absorption, refraction and diffraction through the water column (Jones et al., 2019). Despite the greater depth of the offshore site (11 m) than the inshore site (6 m), higher light levels were recorded on the seabed offshore for most of the monitoring period. This is supported by general field observations of higher water clarity offshore than inshore.

The offshore DLI recorded ranges between 0 – 16.5 (mol/m2)/day, with the maximum recorded on 16 January 2019 and the minimums recorded on 28 January, 21 March, 11 April, 17 May, 3 June and 28 July 2019. The maximum DLI for the inshore sites was recorded on 9 July 2019 and the timing of several of the extended light minimum events corresponded with those listed for the offshore site. One period of low light coincided with Tropical Cyclone Veronica approaching the coast on 21 March and the other coincided with the low pressure system on the 3 June 2019. Light levels are influenced by the amount of suspended sediment / turbidity present through the water column, as well as the depth of the water column. The lowest light levels at the end of January corresponded with turbidity maximums. It is noted that, thus far, light data for Mardie is only available for the wet season, which also corresponds with strong seasonal onshore winds, both of which may have contributed to lower levels of light through increased suspended sediment concentrations (SSC).

2.3.4. Turbidity / Suspended Sediment Concentration

Turbidity data was recorded between 7 November 2018 and 9 September 2019. A notable difference in turbidity was observed between the inshore and offshore monitoring locations. In general turbidity was found to be much higher at the inshore location [mean of 14.03 Nephelometric Turbidity Units (NTU)] than at the offshore location (mean of 1.45 NTU), which is consistent with regional surveys which also found turbidity and SSC declined with distance from shore (O2 Marine, 2020f). At the inshore location the 14-day rolling mean of natural baseline NTU and SSC frequently exceeded the Jones et al. (2019) thresholds for possible and probable effects on corals. Conversely, the 14-day rolling mean for NTU and SSC at the offshore location did not exceed either of the Jones et al. (2019) coral thresholds. Therefore, whilst these thresholds may be appropriate criteria for dredge monitoring in the offshore areas, they are unlikely to be suitable for dredge monitoring in the inshore areas.

2.3.5. Laboratory Results

All results were below the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) 99% species protection guidelines for all analytes with stated guideline values. These results indicate that the current allocation of maximum and high LEPs are appropriate for Mardie marine waters.

2.4. Sediment Quality

O2 Marine (2019a) undertook a Sediment Quality Investigation to determine the characteristics and quality of the material to be dredged and disposed of onshore. The assessment included both preliminary and detailed site investigations in accordance with DWER (2014) guidelines for the Assessment and Management of Contaminated Sites.

2.4.1. Preliminary Site Investigation

The preliminary site investigation reviewed historical sediment investigations (i.e. DEC, 2006) and sources of contaminants and identified that there are no known contaminants of potential concern within the proposed dredging area. Therefore, all areas were classified as being “uncontaminated”. Outcomes of the preliminary site investigation provided a basis for determining the scope of the detailed site investigation, including defining the contaminants of potential concern (CoPC) and identifying the number, depth and location of required sampling (O2 Marine, 2019a).

2.4.2. Detailed Site Investigation

A detailed site investigation was undertaken by O2 Marine in December 2018, January 2019 and February 2019 (O2 Marine, 2019a). Collected sediment samples were sent to a NATA-accredited laboratory for testing of:

- Physical Sediment Characteristics: particle size analysis (PSA), total organic carbon (TOC), moisture content;
- Inorganic Compounds: Total metals and metalloids (Al, Ag, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Sb, V and Zn);
- Organic Compounds: Total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene, xylenes and Naphthalene (BTEXN), polycyclic aromatic hydrocarbons (PAH) and tributyltin (TBT);
- Phenoxyacetic acid herbicides;
- Organochlorine (OCP) and organophosphate pesticides (OPP);
- Nutrients (total nitrogen, total kjeldahl nitrogen, ammonia, nitrate and nitrite, total phosphorous and filterable reactive phosphorous); and
- Acid sulfate soils (ASS) screening test.

Samples from seven locations were also analysed to provide an assessment of the benthic infauna communities present in the sampling area. The following key findings were noted:

- There was no significant difference in species richness or diversity indices across all the sites;
- All sites had high evenness suggesting that the abundances are distributed evenly among the different morphological species present Composition of taxa varied at each site. However, there was no significant difference in community composition between sites;

> Surface feeding was the most common source of food for all sites and omnivores dominated across all sites; and
> Quinqueloculina spp. was present in high numbers across most sites. Previous studies suggest that the presence of this particular genus of Foraminifera in relatively high abundance may be an indication of low environmental stress and that this genus may be considered a good bioindicator of marine environmental quality.

The following key findings were made during the detailed site investigation (O2 Marine, 2019a):

> The 95% Upper confidence limit (UCL) of metal concentrations were below the ANZECC DGV-low level screening guidelines for all contaminants of concern with exception of Nickel and Arsenic. However, these were deemed to be lithographically occurring exceedances supported by previous marine sediment sampling in the Pilbara (DEC, 2006) and normalisation to Aluminium;
> Organics including organotins (TBT etc.), Total Recoverable Hydrocarbons (TRH), TPH, and BTEXN contaminant concentrations were all below ANZECC DGVs (if available) and the vast majority of organic analytes were non-detections below the laboratory Limit of Reporting;
> All analytes in OC/OP Pesticides and Phenoxyacetic Acid Herbicides suites were at nondetection levels below the Limits of Reporting. Herbicides were identified early as a CoPC due to their extensive use on Mardie Station. This investigation found no evidence of herbicides in the marine sediments sampled; and
> None of the samples failed the ASS screening test and, as such, the sediments within the dredging area are considered to pose a low ASS / PASS risk.

O2 Marine (2019a) concluded that the sediment within the dredge corridor is uncontaminated and is considered suitable for onshore disposal. Additionally, the background sediment quality in the vicinity of the proposed outfall is also uncontaminated and is similar to other unimpacted areas of the Pilbara, WA.

2.5. Benthic Communities and Habitat

O2 Marine undertook extensive Benthic Communities and Habitat (BCH) surveys within both the intertidal and subtidal environments. The assessment was undertaken across the study area by dividing the region into seven discreet Local Assessment Units (LAUs). These detailed assessments are presented in the following technical reports:

> O2 Marine (2020b) Mardie Project – Intertidal Benthic Communities and Habitat. Report prepared for Mardie Minerals Ltd; and
> O2 Marine (2020c) Mardie Project – Subtidal Benthic Communities and Habitat. Report prepared for Mardie Minerals Ltd.

The following sections summarise the data presented in detail within these two reports.

2.5.1. Intertidal Benthic Communities and Habitat

The study area is predominantly comprised of barren Mudflats/Saltflats, Samphires/Samphire Mudflats and Foreshore Mudflats/Tidal Creeks, comprising ~73% of mapped intertidal BCH and ~58% of the total mapped area (i.e. including terrestrial habitats such as Sand Dune & Spinifex Sandplain islands occurring between intertidal BCH within the study area). This is consistent with the URS (2010) who identified similar community types comprising over 60% of the mapped study area nearby the Ashburton Delta between Secret Creek and Four Mile Creek South of Onslow. Rocky Shore and Sandy Beach communities were found to occupy the lowest land area, encompassing ~0.2% of the BCH area. Terrestrial habitats occurring within the study area represent ~21% of the total mapped area, which is similar to habitat mapping undertaken by URS (2010) along the Ashburton Delta Coast.

Broadscale regional characteristics within the study area identifies decreasing trends in the percentage abundance of Algal Mats and Mudflat/Saltflats from North to South (LAU1 to LAU6), whilst the opposite is true for Mangroves and Samphires/Samphire Mudflats. This transition of BCH composition represents a change across the study area from the ‘Regionally Significant’ mangrove area of the Robe River delta in the south (LAU6), through the broad intertidal zones dominated by Samphire/Samphire Mudflats, Mudflats/Saltflats and Algal Mats (LAUs 2, 3, 4 and 5) whereby terrestrial dunal vegetations become present in LAU1. The distribution of these habitats reflect the frequency of tidal creeks which become increasingly sparse within the North of the study area with Sandy Beaches and a coastal sand dune system forming a larger proportion through LAU2 into LAU1.

Regional characteristics from the seaward to landward zones of the intertidal area are typified by Foreshore Mudflats/Tidal Creeks extending to the high-water mark whereby Mangrove communities have established as the dominant intertidal BCH type. Mangroves occur in bands of varying width along the coastline and banks of Tidal Creeks, with more structurally complex, taller and denser CC communities occurring on the seaward extent and making way for the sparser, lower and less structurally complex SC communities on the landward extent. CC communities are particularly dominant within the southern coastal LAUs where they occur over a wider range of habitats and form larger forests extending out over tidal flats. Samphire communities occur on the landward extent of mangrove communities, typically Am3, where they often form overlapping boundaries (these shared habitats are classified to the dominant BCH type and mapped as Mangroves). Samphires typically form extensive communities, characterised by highly variable densities, between mangrove fringed creeks and seaward from where Algal Mats and bare Mudflats/Saltflats dominate. The exception is the zonation observed in LAU6 where samphires occur immediately seaward of mapped terrestrial flora communities, intermixed with some bare Mudflat/Saltflats. Algal Mats typically occur landward of Samphire/Samphire Mudflats throughout the central region, and behind Sand Dune communities in LAU1. Mudflats/Saltflats dominate in LAU5 in the south-east through LAUs and into LAU1 in the north, with a comparatively small pocket occurring in LAU6.

Intertidal BCH distributions are presented within **Figure 2-6**.

Algal Mats

Algal mats are typically green to grey or black, and either contiguous or fragmented. 11 species were identified with filamentous cyanobacteria *Microcoleus sp*. and *Lyngbya sp*. the dominant species.

Algal mat communities extend over 3,400 ha and comprise 10% of the total mapped intertidal BCH area. They predominantly occur in two major communities within the central and northern sections of the Study Area. They occur within a relatively nominal elevation of 1.1 – 1.3 m AHD which is lower than the adjacent seaward BCH where they form vast shallow lakes at high tides (>1.2m).

Foreshore Mudflat/Tidal Creeks

A variety of benthic habitat types from flat fine to coarse sands, flat mud, sparse to high macroalgae, and low to moderate seagrasses were identified occurring within Foreshore Mudflats/Tidal Creeks.

Foreshore Mudflats/Tidal Creeks occur over 5,000 ha and comprise 14% of the total mapped intertidal BCH area. Tidal creeks are typically well established within the southern LAUs (Robe River Delta) and become sparser in the northern LAUs. Foreshore mudflats extend over a wider area through the central LAUs with subtidal area much closer to the coastline in the northern and southern LAUs.

Mangroves

Closed Canopy Mangroves

Closed Canopy (CC) mangroves comprise the greater structural complexity, typically higher seaward mangrove associations. *Avicennia marina* dominate the species with *Rhizophora stylosa* the sub dominant species.

CC mangrove communities extend over 1,280 ha and comprise 4% of the total mapped intertidal BCH area. They are very well established within LAU 6, with over 46% of their total area represented. CC mangroves occur as ribbons along the coastline and fringing tidal creeks, with more vast forest occurring within the southern LAU, particularly LAU 6 within the boundary of the Robe River Delta

Scattered Canopy Mangroves

Scattered Canopy (SC) mangroves comprise the least structural complexity, typically lower landward mangrove associations. Avicennia marina dominate the species with *Ceriops australis* also observed.

SC mangrove communities occur over 2,300 ha and comprise 7% of the total mapped BCH area. SC mangroves are the most extensive mangrove functional groups representing over 64%. They are typically located on the landward extents extending over wide intertidal mudflat areas with the largest areas occurring in LAU 2, LAU 4 and LAU 6.

Rocky Shorelines and Sandy Beaches

Rocky shorelines within the Study Area were typically low relief rock platforms generally with little to low associated flora and fauna. Macroalgae were identified as the dominant communities with minimal juvenile hard corals, oyster stacks and some soft corals also present.

Rocky shorelines occur over 59 ha comprising <1% of the total mapped BCH area. They are only located within LAU 2 and LAU 6.

Sandy beaches are typically flat, low energy, low profile beaches backed by gently rising dunes. Sandy beaches are only located within LAU1 and LAU 2 representing 32 ha in total and comprising <1% of mapped BCH. They are found extending from the northern extent of LAU 1 into the northern LAU 2 they continue along the coast for approximately 2.5 km west of the northernmost creek mouth.

Samphire/Samphire Mudflat

Samphire/Samphire Mudflats are distributed over more than 5,900 ha, comprising approximately 17% of the mapped intertidal BCH. They are typically located on the landward extent of mangroves, whilst through the centre of the Study Area are on the seaward extent of algal mats, with a smaller communities in LAU 1 and LAU 3 seaward of terrestrial vegetation. By area they are the greatest in LAU 2 and lowest in LAU 1.

Mudflats/Saltflats

Mudflat/Saltflats are extremely low in biodiversity and support little to no associated fauna or flora due to their characteristic high salinities. Mudflat/Saltflats are the dominant intertidal BCH extending over 10,500 ha and comprising 29% of the total mapped BCH area. They are most dominant through the supratidal LAUs (3 & 5) representing over 83% of their total distribution. They typically occur on the higher intertidal gradients on the landward extent of Samphire's or Algal Mats.

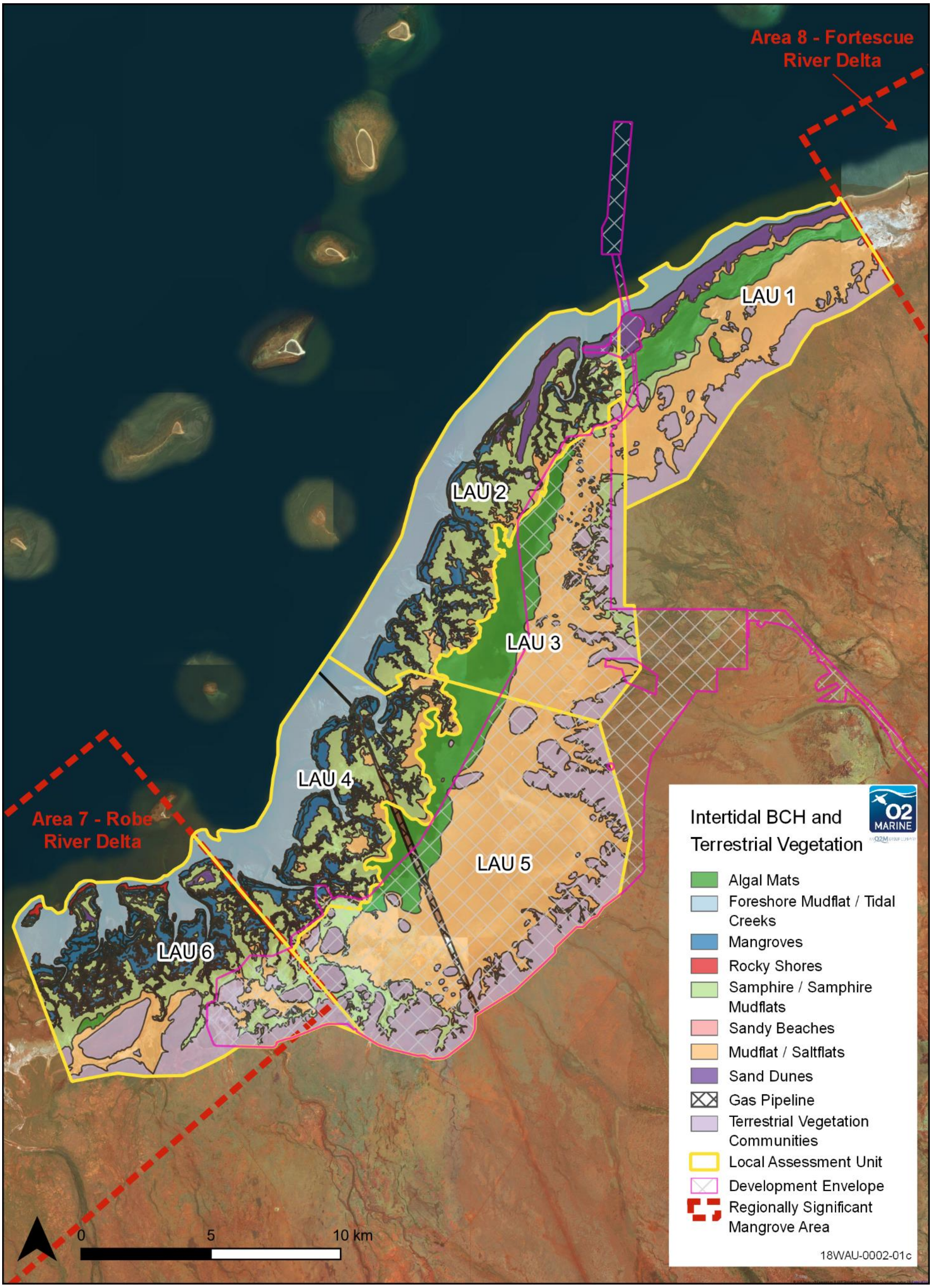

Figure 2-6 Intertidal Benthic Communities and Habitat and Local Assessment Units

2.5.2. Subtidal Benthic Communities and Habitat

Subtidal BCH surveys identified three broad habitat classes present within LAU 7 (the only subtidal BCH LAU) including Bare sand, filter feeder/macroalgae/seagrasses and coral/macroalgae with eight BCH subclasses distinguished based on varying levels of benthic cover and dominant taxa.

LAU 7 is a shallow, naturally turbid environment that is characterised by bare sand / silt with patchy distribution of predominantly macroalgal (*Phaeophyceae: Sporochnus, Hormophysa, Sargassum & Dictyota; Rhodophyceae: Asparagopsis; Chlorophyceae: Caulerpa, Halimeda*) and filter feeder communities (e.g. sponges, octocorals, hydroids, ascidians). These inshore sand, macroalgal and filter feeder habitats are known to be widespread throughout turbid nearshore environments of the Pilbara region and, as such, are not considered to be of any regional significance (O2 Marine, 2020c).

Halophila seagrass species are also present in LAU 7, however, targeted multi-season surveys failed to identify any locations within LAU 7 that recorded benthic cover of seagrass that was more than 1%. It is well documented that seagrass habitats in the Pilbara vary greatly between seasons and years. However, unrelated surveys by O2 Marine at nearby Cape Preston (50 km north of Mardie) in March 2018 identified extensive Halophila sp. seagrass meadows, indicating that seasonal local conditions were appropriate to support meadow formation at Mardie at the time of surveys undertaken. Therefore, it is unlikely that LAU 7 constitutes ideal habitat to support the quality of the regionally significant seagrass meadows that are regularly observed at Cape Preston to the north and Coolgra Point to the South.

Coral species are also present in low to moderate densities within LAU 7. However, the majority of corals in the vicinity of LAU 7 are confined to biogenic reefs and rocks fringing the nearby islands. The diversity and abundance of corals in LAU 7 was relatively low and confined to sediment tolerant species (e.g. *Faviidae, Dendrophyllidae, Mussidae* and *Poritidae*). However, a marked increase in diversity and abundance of coral species was observed at the fringing reefs surrounding the nearby islands, indicating that these areas represent the most regionally significant coral habitats. Although LAU 7 supports complex BCH, including coral and seagrass species, extensive surveys did not identify any subtidal BCH areas that are considered to be locally or regionally significant coral habitats.

Although LAU 7 supports complex BCH, including coral and seagrass species, extensive surveys did not identify any subtidal BCH areas that are considered to be locally or regionally significant.

Subtidal BCH distributions are presented within **Figure 2-7**.

Filter Feeder/Sparse Macroalgae/Seagrass

Sand/Sparse (<5%) Filter Feeders

Sparse filter feeder habitat occurs where the relief is flat and is associated with fine to coarse sands. Although only present in sparse densities (<5% cover), hydroids are most common where there is no bedform, whilst sponges occur where there is some bioturbation.

This habitat comprises 2% of the subtidal BCH within LAU 7 and is widely dispersed throughout the region.

Low (5-10%) Cover Macroalgae/Filter Feeders

Flat to low relief constituting either fine to coarse sands, including shell grit on occasions. Macroalgae, hydrozoan and sponge species are equally dispersed throughout this habitat although benthic cover is low (3-10%). Occasional very sparse (<1%) cover of Halophila sp. seagrass was also observed at some locations.

This habitat comprises 6% of the subtidal BCH within LAU 7 and follows a patchy distribution throughout the region.

Outside of LAU 7, this habitat was also observed in small patches fringing the shallow waters of Long Island, Mardie Island and close to the mainland.

Coral/Macroalgae

Low (5-10%) Coral Cover

Flat to low relief rock and rubble with coarse sand. Low (3 - 10%) cover of soft and hard corals, including *Faviidae, Dendrophyllidae, Mussidae* and *Octocorals*. Sparse macroalgae was also present.

This habitat comprises 1% of the subtidal BCH within LAU 5. Outside of LAU 7 this habitat was also found fringing Mardie Island and in small isolated patches between Angle Island and the mainland. It was generally recorded in waters between 1-3 m depth.

Moderate (10-25%) Cover Coral/Macroalgae

Low to moderate relief rock and rubble/coarse sand. Low to moderate cover (3 – 25%) of soft and hard corals with macroalgae. Corals largely consisted of *Faviidae, Poritidae*, and *Octocorals*, while *Phaeophyceae* dominated the macroalgae communities.

This habitat class comprises only 1% of the subtidal BCH within LAU 7. However, outside of LAU 7, it was recorded in larger areas in fringing shallow waters south of Mardie Island and adjacent to the mainland coast.

Dense (>25%) Cover (Macroalgae Dominated)

This habitat class occurs on low relief substrate with fine to coarse sands and areas of exposed limestone reef. Dense assemblages (>75%) of macroalgae and hydrozoan species predominately in waters at depths of 2.2m-4.0m. This habitat also supported sparse juvenile corals (*Faviidae, Dendrophyllidae, Mussidae)* with occasional larger coral (*Poritidae*) bommies (1-2m diameter).

This habitat class comprised <1% of the subtidal BCH in LAU7. It was also identified outside of LAU7 in the waters fringing the eastern outer edge of Long Island, Round Island and Sholl Island.

Dense (>25%) Cover (Coral Dominated)

Low relief limestone reef and rubble substrate which supports high coral cover (25%-75%) of diverse coral species, including *Faviidae, Dendrophyllidae, Mussidae, Portitidae*, and *Octocoral* species.

This habitat class was only recorded at one location in LAU7 and, as such, comprises only <1% of the subtidal BCH within LAU7. However, it was also recorded outside of LAU7, in a much larger area, fringing the Northern edge of Mardie Island.

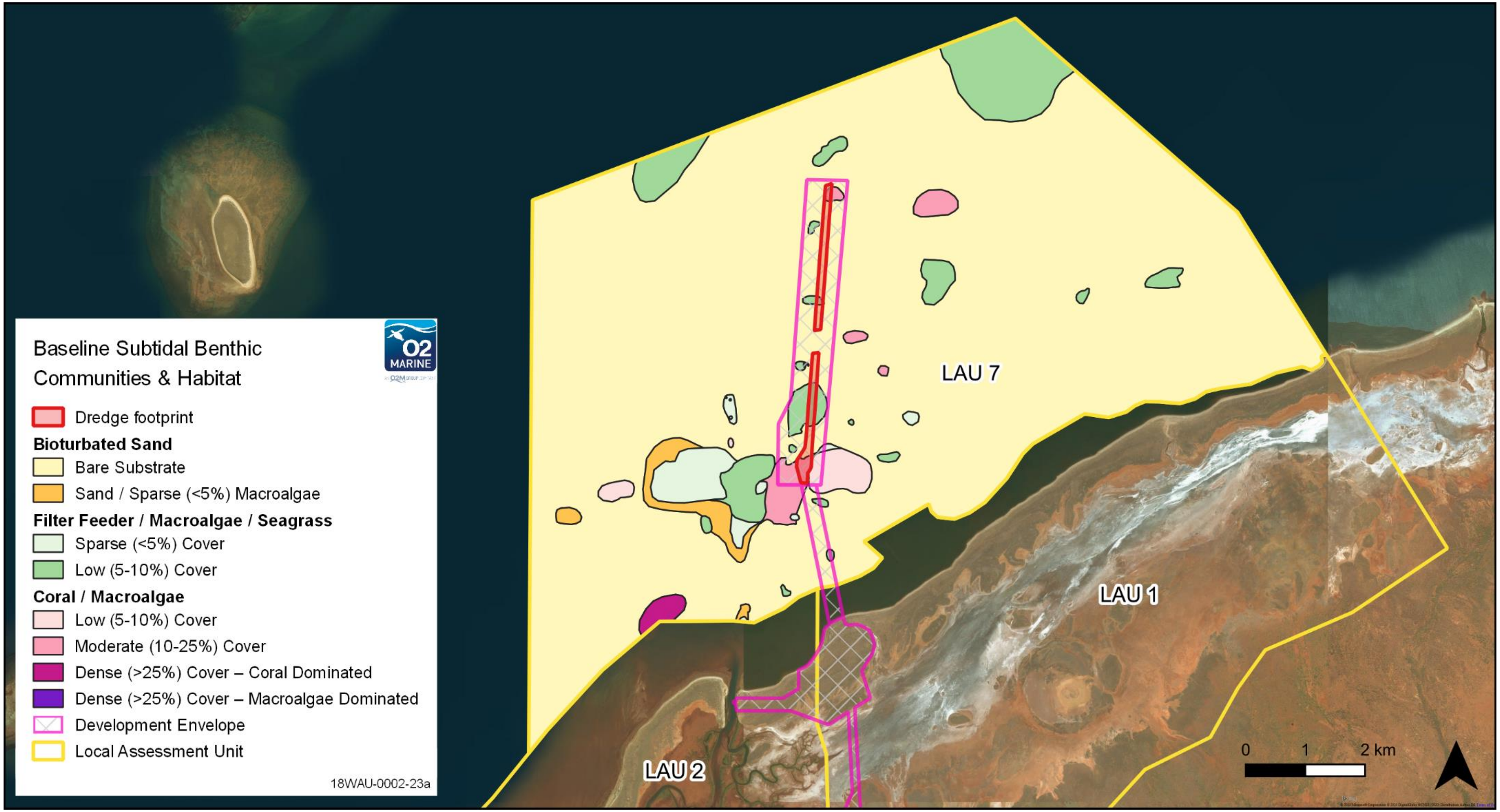

Figure 2-7 Subtidal Benthic Communities and Habitat and Local Assessment Unit

2.6. Marine Fauna

O2 Marine (2020d) undertook an assessment of the likelihood of occurrence for threatened marine mammal species identified through the desktop review, based on the list of species provided in the ESD (Preston, 2018).

Listed threatened marine mammals with high potential to occur or are known to occur off the Mardie coast (on occasion) include:

- Marine Mammals:
  - Humpback whale (*Megaptera novaeangliae*);
  - Dugong (*Dugong dugong*); and
  - Australian humpback dolphin (*Sousa sahulensis*).
- Marine Turtles:
  - Loggerhead turtle (*Caretta caretta);*
  - Green turtle (*Chelonia mydas*); and
  - Flatback turtle (*Eretmochelys imbricate*)
- Elasmobranch:
  - Green sawfish (*Pristis zijsron)*

2.6.1. Marine Mammals

Humpback Whale

Humpback whales migrate annually from Antarctic feeding grounds to the Kimberley coast for calving during the winter. Humpback whales predominantly occur offshore in open oceanic environments. However, they are known to stopover in the lee of the offshore islands and have been observed on several occasions during the humpback southerly migration, within 5 km of the Mardie Project Marine Development Envelope, by O2M staff in 2018. The southern migration is the period when they are closest to shore at an average of 36 km although are often recorded in waters less than 10 m deep during the latter part of the migration (September to November). The Project area is a shallow embayment (i.e. generally <5m deep) and could not be considered critical habitat for any whale species.

Dugong

Dugong (Dugong dugong) are found throughout the Pilbara region, particularly close to the coast or in the lee of reef-fringed islands and often in areas where seagrass has previously been recorded. Although Dugong have been previously recorded in the nearshore waters of the Mardie coastline, the nearest known Dugong aggregations have been recorded near Cape Preston in the North and Coolgra Point in the South, generally in areas that consistently support extensive seagrass meadows (O2 Marine, 2020d).

No Dugong were observed in the waters around Mardie during over 700 hours of vessel-based observations. O2 Marine (2020d) concluded that this was most likely due to the lower value of the subtidal BCH in the area as suitable feeding or foraging habitat for Dugong.

Australian Humpback Dolphin

The Australian humpback dolphin was the only conservation significant species known to occur in the Project area, with records of Australian humpback dolphins (*Sousa sahulensis)* reported throughout the year at the Montebello Islands (Raudino *et al* 2018) and in the Mardie Project area. They are likely to be one of the most common dolphin species occurring in the Project area. This species together with the Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*) are likely to be the most abundant dolphin species in the Mardie Project area inside the 20 m isobath.

2.6.2. Marine Turtles

Only a small part of potential marine turtle nesting beach lies within the development envelopes, a narrow section of the beach labelled as ‘Mardie Creek East’ in Figure 92. The Pendoley (2019) survey identified only very minor nesting effort by Flatback turtles and a single hawksbill turtle, along the 15 km stretch of coastline to the east of the creek. These results indicated that the mainland beaches are not currently a regionally important rookery. The results of the temperature loggers also confirmed that mainland beaches were significantly warmer than the offshore islands, impacting the success rate of any marine turtle nests on these beaches.

With the exception of the single hawksbill nest recorded on the mainland in December, turtles nested most successfully on the offshore islands; 34 – 42 % of Flatback and 36 – 50 % of hawksbill nesting attempts on the islands resulted in a nest. None of the three Flatback nesting attempts on the mainland resulted in a nest. This variation in nesting success may be related to the varying nesting habitat characteristics between the island and mainland monitoring sites. For example, the island sites featured a wide supratidal zone, a well-defined primary dune, and fine-medium grained sand size that may have facilitated the successful deposition of a clutch, whereas the mainland sites featured a narrow supratidal zone, little or no primary dune development, and medium-coarse grained sand size that may have hindered successful clutch deposition.

The main species recorded on the offshore islands was Flatback turtles, with relatively less nesting effort seen for hawksbill and green turtles at the same locations. The snapshot monitoring data from Round, Middle, and Angle Islands confirmed similar species composition and abundance at these sites. These results are consistent with turtle activity throughout the Pilbara where Flatback and Hawksbill nesting is dominant on nearshore island habitat, and Flatback turtles are the most common mainland nesting species (Pendoley et al., 2016).

Baseline artificial light results found the overhead skies at the Proposal are typically very dark and representative of pristine, natural dark skies unaffected by artificial light. The only light source visible from all mainland and offshore light monitoring sites was the Sino Iron facilities located over 30 km away on the easterly horizon.

2.6.3. Elasmobranchs

Sawfish

The Northwest Marine Region is considered a particularly important area for sawfish species because the region and adjacent inshore coastal waters and riverine environments contain nationally and globally significant populations of sawfish species (DSEWPaC 2012). However, relatively little is known about the distribution and abundance of sawfish species in north-western Australia (Morgan 2012).

In the Pilbara, green sawfish are known to utilise the mouths of major river systems (i.e. Ashburton River) as pupping grounds and nursery areas, before juveniles migrate into adjacent creeks at approximately 3 to 6 months old, and then further offshore to mature at a length of about 3 m (Morgan 2012). Acoustic tracking of green sawfish from the Ashburton shows that the species does not travel more than 700m upstream from the mouth of the river. In the Western Pilbara they are assumed to be present in all tidal creeks. In the Project area larger systems are represented by the Robe River and Fortescue River. Green sawfish are currently known from Exmouth Gulf, Whim Creek, Beagle Bay, Pender Bay, King Sound in Western Australia. Tidal mangrove systems, river estuaries, and rivers of the King Sound provide ideal nursery habitat for juveniles <0.5m (Whitty et al, 2011 and Whitty, 2017, Elhassan 2018). Studies also indicate movement of the species away from turbid areas and low-salinity areas i.e. when rainfall flushes estuaries etc. mangrove and inshore areas used as nurseries where they spend their first few years of life and then move to deeper waters (Elhassan 2018).

Green sawfish are expected to be present in the creeks and rivers of the Mardie coastline. The habitats present within the intake creek are well represented in the region with as many as a dozen smaller size creeks within 100km.

3. Environmental Quality Management Framework

3.1. Background

The Environmental Quality Management Framework (EQMF) was developed to implement the National Water Quality Management Strategy Guidelines No. 4 and 7 (ANZG 2018). In Western Australia the EQMF process has been utilised as a guide to implement water quality monitoring and management after being incorporated into the State Water Quality Management Strategy No.6 (SWQMS 2004). The Environmental Protection Authority (EPA) provides further guidance for the development and application of the EQMF as a consistent and standardised approach for measuring and reporting on marine environmental quality (MEQ) across other areas of Western Australia's marine environment (EPA 2016). The key structural elements of the EQMF are shown in **Figure 3-1**.

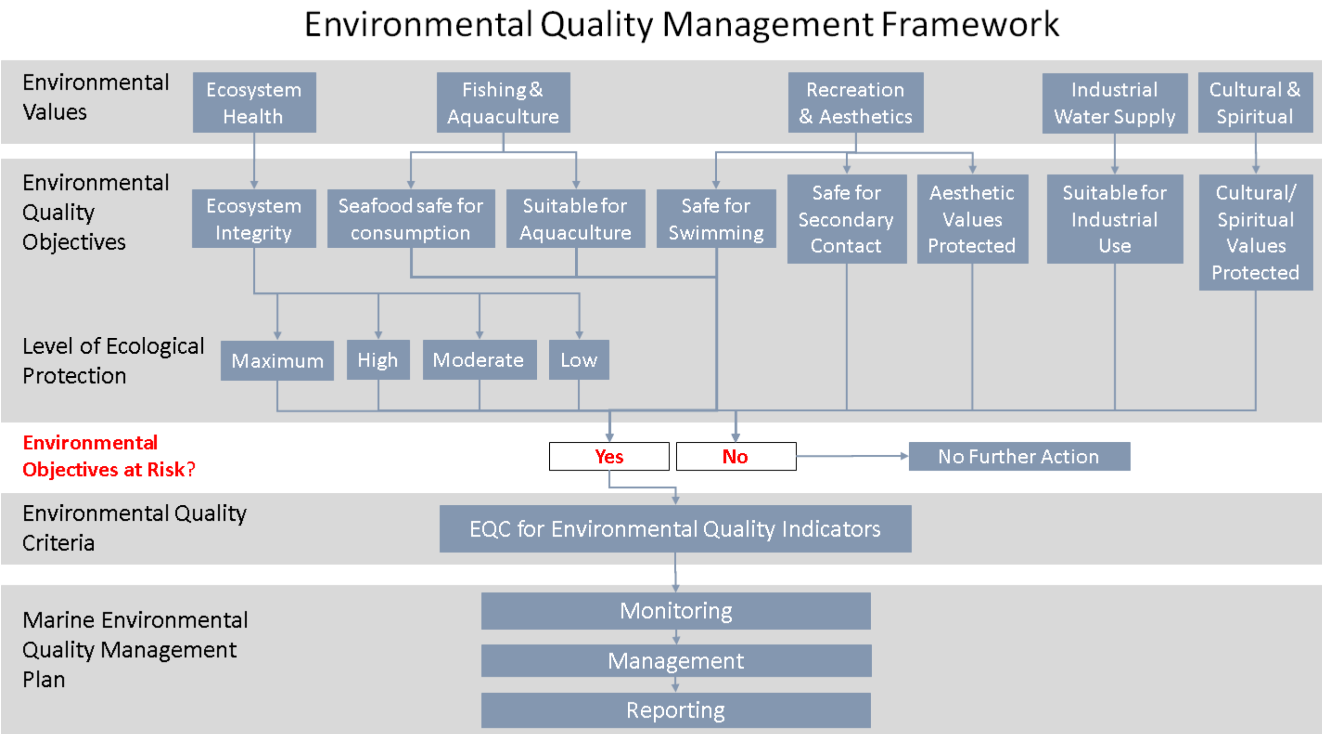

Figure 3-1 Environmental Quality Management Framework

The following sections outline how the EQMF framework has been applied to define the Environmental Values (EVs), Environmental Quality Objectives (EQOs) and spatial Levels of Ecological Protection (LEPs) for the Mardie Project area.

3.2. Environmental Values & Environmental Quality Objectives

Environmental Values (EVs) are defined as "P*articular 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 Pilbara marine environment are already well established in Pilbara Coastal Waters Consultation Outcome (DoE 2006). Five EVs and eight corresponding EQOs apply to the Mardie Project area. These EVs and corresponding EQOs are presented in **Table 3-1**.

Table 3-1 Environmental Values and Environmental Quality Objectives applicable to the Mardie Project area

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 2.3 below).
Fishing and 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.

Site-specific features of the EVs identified through various investigations undertaken for the Mardie Project are summarised in **Table 3-2**.

Table 3-2 Specific features of EVs identified through Mardie Environmental Investigations

Ecosystem Health	Fishing & Aquaculture	Recreation & Aesthetics	Cultural & Spiritual	Industrial Water Supply
> Water quality (O2 Marine 2020a) > Sediment quality (O2 Marine 2019a) > Ecological processes > Benthic Communities and Habitat (O2 Marine 2020b/2020c): o Corals o Macroalgae o Filter feeders o Seagrass) o Mangroves o Samphires o Algal mats > Marine Fauna (O2 Marine 2020d): o Turtles o Fish o Shore birds o Sea birds o Sea Snakes o Whales o Dolphins o Dugong	> Shore-based fishing > Boat-based fishing > Crabbing is popular in the tidal creeks > Onslow Prawn Managed Fishery – Fortescue Nursery Area > No aquaculture operations undertaken at present	> Recreational fishing > Free diving > Scuba diving > 4WD Vehicles / Quad bikes > Access to the Project area	> Hunting > Mud crabbing > Fishing > Maceys Shipwreck > Recognition of traditional owner rights to access & usage of country	> Proposed Mardie Project seawater intakes

3.3. Levels of Ecological Protection

In accordance with EPA (2016), the objective for 'Ecosystem Health' is spatially allocated into four Levels of Ecological Protection (LEPs): Maximum, High, Moderate and Low. Each LEP area is assigned an acceptable limit of change as shown in **Table 3-3**. The spatial distribution of the LEPs enables measurable EQOs to be allocated for areas in accordance with expectations for ecosystem health condition. For example, important areas for conservation are assigned a Maximum LEP and maintained within the limits of natural variation, whereas large changes from natural variation may be allowed in small areas assigned a Low LEP around a bitterns discharge where EVs may not be protected.

Table 3-3 Limits of acceptable change in the key elements of ecosystem integrity for the four levels of ecological protection (Source: EPA, 2016).

Key elements of ecosystem integrity and their limits of acceptable change		Level of protection for maintenance of ecosystem integrity			
Key elements	**Limits of acceptable change**	**Maximum**	**High**	**Moderate**	**Low**
Ecosystem processes (e.g. primary production, nutrient cycles, food chains)	Ecosystem processes are maintained within the limits of natural variation (no detectable change)	✓	✓		
	Small changes in rates, but not types of ecosystem processes			✓	
	Large changes in rates, but not types of ecosystem processes				✓
Biodiversity (e.g. variety and types of naturally occurring marine life)	Biodiversity as measured on both local and regional scales remains at natural levels (no detectable change)	✓	✓	✓	
	Biodiversity measured on a regional scale remains at natural levels although possible change in variety of biota at a local scale				✓
Abundance and biomass of marine life (e.g. number or density of individual animals, the total weight of plants)	Abundances and biomasses of marine life vary within natural limits (no detectable change)	✓	✓		
	Small changes in abundances and/or biomasses of marine life			✓	
	Large changes in abundances and/or biomasses of marine life				✓
The quality of water, biota and sediment (e.g. types and levels of contaminants such as heavy metals, dissolved oxygen content, water clarity)	Levels of contaminants and other measures of quality remain within limits of natural variation (no detectable changes)	✓			
	Small detectable changes beyond limits of natural variation but no resultant effect on biota 99% Species Protection Limits (SPL) Applies		✓		
	Moderate changes beyond limits of natural variation but not to exceed specified criteria 90% SPL Applies			✓	
	Large changes from natural variation 80% SPL Applies				✓

LEP boundaries have been previously described for the Mardie Project area in the *Pilbara Coastal Water Quality Consultation Outcomes* (DoE 2006). These existing LEP boundaries were reviewed and updated in the context of the proposed Mardie waste bitterns outfall and Port facility, to spatially define proposed LEPs around the project infrastructure.

The LEP boundaries were defined and mapped in consideration of the following key elements:

- A Low LEP area (LEPA) was designated based on modelled predictions of the bitterns plume which determined that a 90% SPL would be achieved at the LEPA/MEPA boundary (Baird 2020). Whole of effluent toxicity (WET) testing results presented in O2 Marine (2019b) were used to inform the number of dilutions required to meet the 90% SPL used by Baird (2020a);
- A Moderate LEP area (MEPA) was designated for all waters (excluding the LEPA areas) based on providing a 250 m buffer surrounding ship turning basin and berthing pocket and modelled predictions of the bitterns plume which determined that a 99% SPL would be achieved at the MEPA/HEPA boundary (Baird 2020). WET testing results presented in O2 Marine (2019b) were used to inform the number of dilutions required to meet the 99% SPL used by Baird (2020a);
- Two small HEPAs were designated within adjacent to proposed small vessel launching and retrieval ramp and the seawater abstraction pipeline in the northern and southern creeks respectively. These were both based upon a 250 m buffer around proposed infrastructure; and
- Existing LEPs as presented in the Pilbara Coastal Water Quality Consultation Outcomes (DoE 2006) were retained for all other areas which includes a High LEP area (HEPA) and a Maximum LEP area (XEPA). Based on WET testing results presented in O2 Marine (2019b), Baird (2020a) determined that a 99% SPL would be achieved at the MEPA/HEPA boundary.

The proposed spatial designation of LEPs for the Mardie Proposal area is presented in **Figure 3-2**.

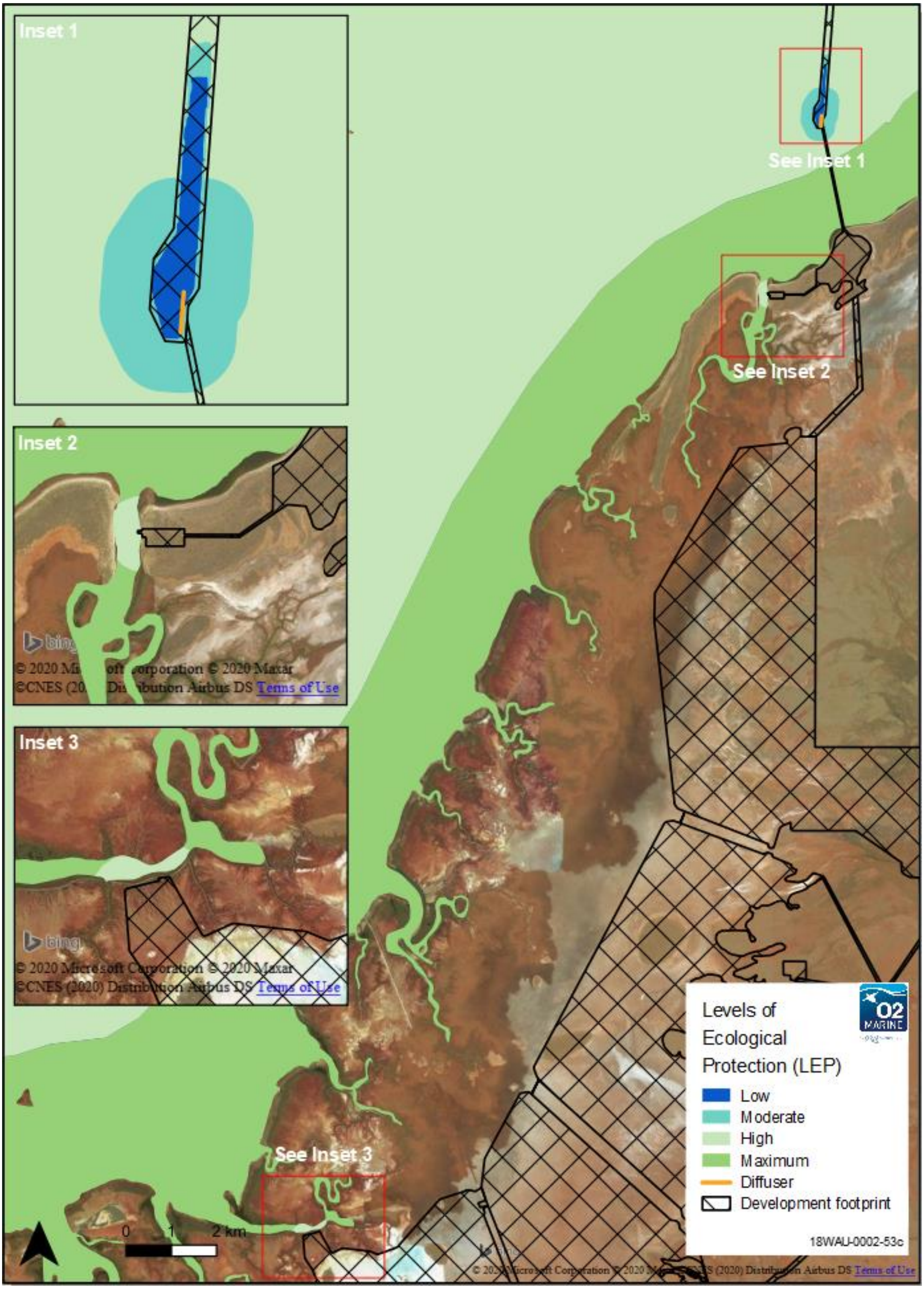

Figure 3-2 Levels of Ecological Protection for the Mardie Proposal

4. Environmental Pressures and Key Threats to Marine Environmental Quality

4.1. Relevant Operational Activities

The following three key operational elements of the Mardie Proposal have been identified as posing a potential risk to MEQ:

- Waste bitterns discharge operations;
- Port operations; and
- Product processing and storage.

The key aspects of these operational elements are discussed below in the context of risks to MEQ.

4.1.1. Waste Bitterns Discharge Operations

The production process will produce a high-salinity bittern (i.e. salinity ~325 ppt) that will be discharged into the marine environment through a diffuser at the end of the trestle jetty.

Whole of Effluent Toxicity (WET) testing results (O2 Marine 2019b) determined that the following dilutions of the waste bitterns would need to be achieved in order to meet the required Species Protection Levels (SPL) for each of the designated LEPs:

- 90% SPL requires 263 dilutions (LEPA/MEPA Boundary); and
- 99% SPL requires 417 dilutions (MEPA/HEPA Boundary).

In order to reach the required levels of dilution within each of the zones, the raw bitterns will be prediluted five-fold with seawater prior to being discharged through the diffuser (Baird 2020).

Prior to commencing full discharge operations, a diffuser commissioning phase will occur to allow initial validation of the outfall modelling and make final adjustments to the diffuser configuration (e.g. port spacing, port angle, etc.) and discharge operations (e.g. discharge rate, discharge velocity, pre-dilution rate, etc.) to ensure that the required number of dilutions are met at the LEP boundaries specified above. Key elements of the preliminary diffuser design and configuration are provided in **Table 4-1**.

Table 4-1 Preliminary Diffuser Design and Configuration (Source Baird 2020)

Design Parameters	Details
Location:	Outfall is attached to the trestle jetty and discharges into the dredged berth pocket
Discharge Regime:	Constant
Water Depth:	6.45m MSL
No. of Ports:	Maximum 8 Ports
Port Spacing:	10.5 m apart
Port Diameter:	0.13 m
Port Angle:	90° to dominant current, 45° up towards surface
Total Diffuser Length	200 m
Discharge Velocity:	2.5 m/s
Discharge Flow Rate:	0.69 m^3/s
Discharge Volume:	3.6 GLpa
Raw Bitterns Salinity:	325 ppt
Diluted 1:5 Outfall Effluent Salinity	85.4 ppt
Whole Effluent Toxicity Results	99% SPL requires 417 dilutions – target bitterns concentration 0.24%
	90% SPL requires 263 dilutions – target bitterns concentration 0.38%
	80% SPL requires 227 dilutions – target bitterns concentration 0.44%

4.1.2. Port Operations

The Proposal includes the export of bulk salt. The salt will be loaded onto a transhipper barge using typical conveyors and ship-loading infrastructure, then the barge will travel offshore and re-load the salt onto an ocean-going vessel anchored offshore.

Some product spills may occur during the loading of vessels, however these volumes will be relatively low and intermittent. A risk area for Port Operations would be maintenance activities along the conveyor system where product has built up over time and requires removal, resulting in hypersaline runoff water to the receiving environment.

Vessel bunkering of the transhipper and support vessels is likely to be undertaken alongside the trestle jetty, within the berth pocket and the proposed LEPA/MEPA zones. Therefore, whilst hydrocarbon spills to the marine environment are possible in this area, they will be managed in accordance with leading industry operating procedures and as such represent a relatively low risk.

Vessel movements within the Port area are also likely to continually mobilise and redistribute fine sediments in the vicinity of the berth pocket.

4.1.3. Storage and Processing Facilities

Concentrator and crystalliser ponds will be developed behind low permeability walls engineered from local clays and soils and rock armoured to protect against erosion. The height of the walls varies across the project and is matched to the flood risk for the area.

A spill or leak of brine from the ponds or pipelines could result in impacts to MEQ within adjacent tidal creeks. However, brine is the resource for the Proposal, and as such the evaporation ponds and brine pipelines have been designed to minimise the risk of leaks, overflows and wall breaches. Pipelines will utilise industry-standard materials to minimise the chance of leaks, and mitigation will be implemented to reduce this risk further. Ponds have been designed with adequate freeboard and overflow features to minimise the risk of unplanned overflows and wall breaches.

5. Conceptual Model of Pressures/Threats and Selection of Environmental Quality Indicators

5.1. Conceptual Model for the Mardie Project

In accordance with EPA (2016) a conceptual model has been developed which presents the key threats and their assciated pressures summarised from the operation desriptions presented above. These are then contextualised into the presure/reponse pathways through identification of the enviornmental indicators though which the presures and threats act to reduce MEQ if not appropriately managed.

The conceptual model and subsequent EQIs selected for the Project are presented within **Figure 5-1**.

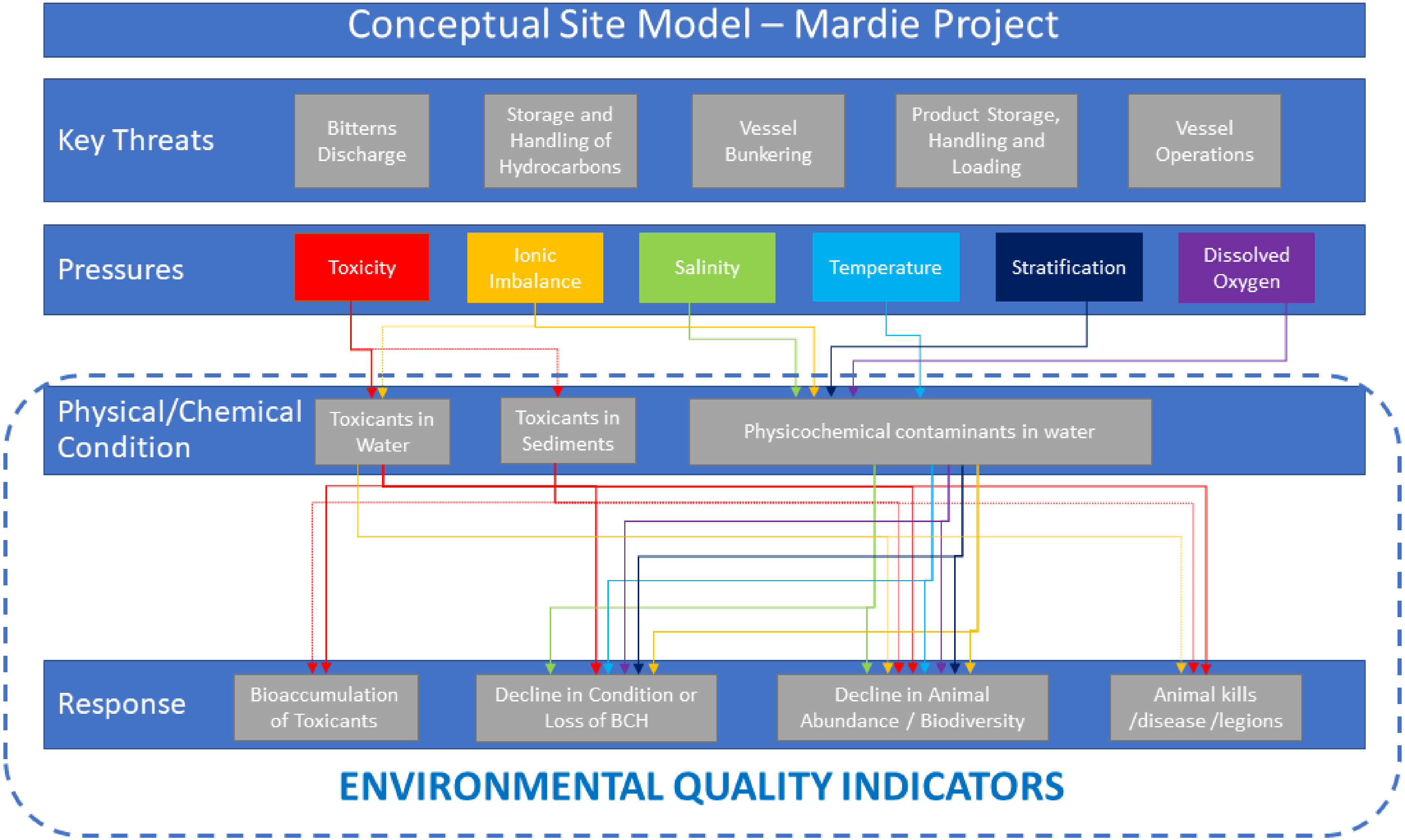

Figure 5-1 Mardie Project Conceptual Site Model

5.2. Environmental Quality Criteria

EQIs are measurable parameters selected to monitor changes in each EQO. The EQIs for the Mardie Project are listed in **Table 5-1**.

EQCs are generally quantitative and are usually described numerically. They are comprised of Environmental Quality Guidelines (EQG) and more robust Environmental Quality Standards (EQS) and allow changes within adopted EQIs to be quantitatively assessed over time.

> ***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.

As identified within the Monitoring and Management Section (**Section 6**) prior to establishing specific numerical criteria for the EQGs and EQSs, it is proposed that:

- a minimum of two years baseline data will be collected prior to commissioning to determine site specific EQCs (**Section 6.2**);
- Whole of Effluent Toxicity (WET) testing be undertaken on bitterns at the completion of the commissioning process to determine the number of dilutions required at each LEP boundary (**Section 6.4.5**); and
- Laboratory analysis be conducted on the bitterns to determine which toxicants are concentrated and therefore selected to represent EQSs for bitterns dilution assessment at the LEP boundaries (**Section 6.4.6**).

The adopted approach to derive preliminary EQC constituents for the EQIs is presented within **Table 5-1** and preliminary EQGs outlined within **Figure 5-2**.

Table 5-1 Environmental Quality Indicators and Criteria selected for the Mardie Project

Environmental Quality Indicators	Environmental Quality Criteria					
	Environmental Quality Guidelines					Environmental Quality Standards
	Constituents[1]	Low LEP	Moderate LEP	High LEP	Maximum LEP	
Physicochemical Constituents in Water	Salinity[2]	No EQG Apply	95th percentile of natural background salinity concentration is achieved	80th percentile of natural background salinity concentration is achieved	No detectable change from natural background levels for Physicochemical parameters or toxicants within water and sediments	< No loss or decline within BCH communities outside of acceptable levels of change for MEPA (i.e. 95th percentile of natural background) and no change from natural within HEPA and XEPA) < No loss or decline within animal communities outside of acceptable levels of change for MEPA (i.e. 95th percentile of natural background) and no (no change from natural within HEPA and XEPA) < No reports of animal disease or deaths attributable to the Project < Salinity concentrations below the maximum calculated from WET testing and bitterns sampling for each LEP boundary
	Dissolved oxygen[2]		5th percentile of natural background DO concentration is achieved	80th percentile of natural background DO concentration is achieved		
	pH		5th or 95th percentile of natural background pH conditions are achieved	20th or 80th percentile of natural background pH conditions are achieved		
	Temperature		5th or 95th percentile of natural background temperatures are achieved	20th or 80th percentile of natural background temperatures are achieved		
	Dissolved major anions and cations Ionic balance		5th or 95th percentile of natural background ionic balance conditions are achieved	20th or 80th percentile of natural background ionic balance conditions are achieved		
	Total Alkalinity as CaCO3 Total Hardness as CaCO3		5th or 95th percentile of natural background conditions are achieved	20th or 80th percentile of natural background conditions are achieved		
Toxicants in Water[3]	Metals Hydrocarbons Chloride Fluoride	80% species protection trigger values for potentially bioaccumulating/ bioconcentrating chemicals	90% species protection trigger values	99% species protection trigger values[4]		< No loss or decline within BCH communities outside of acceptable levels of change for LEP (no change from natural within HEPA and XEPA) (EPA 2016) < No loss or decline within animal communities outside of acceptable levels of change for LEP (no change from
		The required number of dilutions as determined through WET testing is achieved at LEP boundaries				

Environmental Quality Indicators		Environmental Quality Criteria				
	Environmental Quality Guidelines					Environmental Quality Standards
	Constituents[1]	Low LEP	Moderate LEP	High LEP	Maximum LEP	
Toxicants in Sediment	Metals Antifoulants Hydrocarbons	ISQG-low trigger values but only for potentially bioaccumulating/ bioconcentrating chemicals	ISQG-low trigger values			natural within HEPA and XEPA) (EPA 2016) < 80th percentile of tissue concentrations in filter or deposit feeder at suitable reference site (HEPA) and no detectable change from natural background (XEPA). < No reports of animal disease or deaths attributable to the Project < Selected toxicant concentrations below the maximum calculated from WET testing and bitterns sampling for each LEP boundary

Notes:

[1]: This list of consituents for EQGs is considered preliminary based upon identified potential risks. These will be revised at the completion of the MEQ Validation Phase (Refer **Section 6.4**)

[2]: EQGs will apply for surface and bottom waters

[3]:Where no guidelines trigger values are available, or the toxicants are naturally occuring at high levels the EQG will be derived from the 95th percentile of natural background concentrations and applied within the HEPA and XEPA only.

[4]: Except cobalt which where the 95% species protection trigger value applies

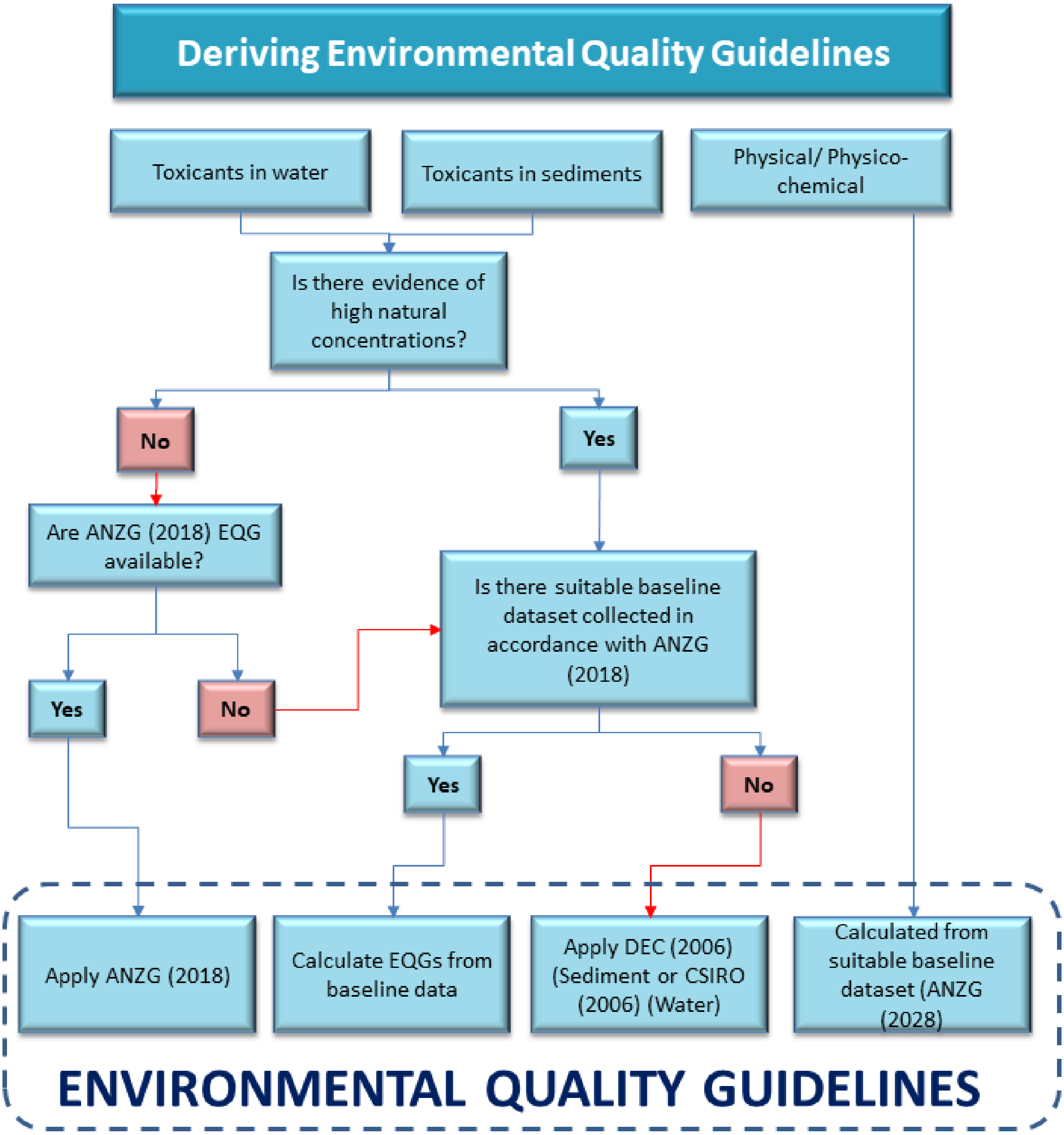

Figure 5-2 Summary of the approach used to derive preliminary Environmental Quality Guidelines

6. Monitoring and Management

Monitoring and management actions proposed to mitigate potential operational impacts of the Mardie Project on MEQ are described in **Table 6-1**.

Table 6-1 Management Targets and Proposed Actions to Mitigate Operational Impacts on Marine Environmental Quality

Management Target	Management Actions		Environmental Performance		
	Item	Actions	Reporting / Evidence	Timing	Contingency
General: Maintenance of ecosystem integrity within each of the LEP areas.	1.1	Implement the Marine Environmental Quality Monitoring Program (Refer **Section 6.5.6**) to confirm the required EQOs and spatial LEPs are being achieved.	> Monitoring Program Implementation Reports	> Annually for the life of the Project.	> Implement reactive monitoring / management in the event that EQOs are determined to be at risk.
Manage waste bitterns discharge to achieve: > **A Low LEP within the nearfield mixing zone** > **A Moderate LEP within 70 m of the outfall diffuser; and** > **A High LEP within 250 m of the Port facility (i.e. Trestle Jetty, Berth Pocket and Turning Basin)**	2.1	Outfall diffuser to be designed and operated to achieve the required dilutions and associated SPLs: > At the LEPA/MEPA boundary (263 Dilutions; 90% SPL); and > At the MEPA/HEPA boundary (417 Dilutions; 99% SPL). *Note. Number of dilutions may require update to meet revised SPLs following completion of WET testing on actual bitterns sample as per Item 2.2.*	> Diffuser Basis of Design Report > Bitterns Outfall Management Plan (item 2.1) > Model Validation Study Report	> Ongoing for the life of Project.	> Revise outfall diffuser design to meet requirements.
	2.2	Undertake WET testing on the actual waste bitterns sample (refer to **Section 6.4.5**) and update modelling if appropriate to ensure that SPLs are achieved at each of the specified LEP boundaries.	> Bitterns Ecotoxicity Report > Updated Modelling Report (If required)	> During bitterns outfall commissioning phase, prior to commencement of operations. > Again during operations phase to evaluate the final discharge configuration. > Whenever changes to the product or bitterns occur during the life of the Project	> Update modelling and management plans as appropriate.

Management Target	Management Actions		Environmental Performance		
	Item	Actions	Reporting / Evidence	Timing	Contingency
	2.3	Implement the bitterns outfall model validation study as described in the MEQMMP (**Section 6.4.6**).	> Bitterns Outfall Model Validation Study Report	> During bitterns outfall commissioning phase, prior to commencement of operations. > Again during initial operations phase to evaluate the final discharge configuration. > Biannually (i.e. during winter & summer) for first 5 years > Whenever changes to the product or bitterns occur during the life of the Project	> Revise outfall diffuser design to meet requirements as appropriate.
Manage vessel bunkering, chemical storage and spill response to avoid release of contaminants to the marine environment	3.1	Develop and implement project specific management procedures: 1. Chemical Storage and Handling Procedure. 2. Bunkering Procedure. 3. Port Facility Oil Spill Response Plan. 3. Shipboard Oil Pollution Emergency Plan (SOPEP).	> Management Procedures > Audit records providing evidence of effective controls.	> Prior to commencement of any works onsite.	> Corrective actions should be applied where there is evidence that procedures have not been followed. > Update procedures as appropriate.
	3.2	All vessel equipment to be designed and operated to prevent spills and leaks through the provision of in-built safeguards including, but not limited to, relief valves, overflow protection, and automatic and manual shut-down systems.	> Inspection reports > Vessel management procedure	> Inspection reports required at least quarterly for the life of the Project.	> Rectify any equipment that is damaged or missing as soon as practicable. > Port operations not to commence prior to development and approval of vessel management procedures.
	3.3	In accordance with the Port Facility Oil Spill Response Plan (Item 3.1), Hydrocarbon spills will be reported to the Relevant Decision-making Authority (DMA). An incident report will be submitted for each spill to the marine environment.	> Verbal communication > Incident Report	> Immediate verbal communication. > Incident report submitted with 24 hrs of incident.	> Implement reactive sampling as appropriate.

Management Target	Management Actions		Environmental Performance		
	Item	Actions	Reporting / Evidence	Timing	Contingency
Manage operations to avoid release of any brine or product from the processing, storage or vessel loading facilities to the marine environment	4.1	Intake and outfall pipelines will utilise industry-standard materials to minimise the chance of leaks, and mitigation will be implemented to reduce this risk further.	> Pipeline Basis of Design Report	> Prior to pipeline installation	> Review pipeline design as required.
	4.2	Ponds will be designed with adequate freeboard and overflow features to minimise the risk of unplanned overflows and wall breaches.	> Pond Basis of Design Report	> Prior to pond construction	> Review pond design as required.
	4.3	Regular inspections to be undertaken on facilities to ensure: > Bund wall condition / integrity; and > Pipeline condition / integrity.	> Inspections reports	> At least quarterly for the life of the Project.	> Implement routine or reactive maintenance as required to rectify any observed defects.
	4.4	Routine maintenance procedures to be developed and implemented for all product storage and processing infrastructure.	> Maintenance Procedures	> Procedures to be developed prior to construction and updated as required for the life of the Project	> Corrective actions should be applied where there is evidence that procedures have not been followed. > Update procedures as appropriate
	4.5	Relevant Decision-making Authority (DMA) is to be notified immediately in the event of a critical asset failure to the marine environment. An incident report will be submitted for each spill.	> Verbal communication > Incident Report	> Immediate verbal communication. > Incident report submitted with 24 hrs of incident.	> Implement reactive sampling as appropriate.

6.1. Monitoring and Management Programs

To ensure that defined EVs and EQOs are not compromised through construction, commissioning and routine operation of the Mardie Project a comprehensive monitoring and management program is proposed. The elements of the monitoring and management program as they relate to potential MEQ impacts from the Project are defined in **Table 6-2**, whilst an overview of the monitoring requirements are presented in **Table 6-3**.

Table 6-2 Elements of the Marine Environmental Quality Monitoring and Management

Element	Sub-Elements	Rationale
Pre-Commissioning Baseline Monitoring	Water Quality Monitoring Sediment Monitoring Benthic Infauna Physical Observation	To collect sufficient spatial and temporal data with a high level of replication from which site specific EQGs and EQS will be derived. Potential Project impacts have been identified to water and sediment quality, so monitoring has been designed in accordance with ANZG (2018) protocols for monitoring and assessment of these values.
Bitterns Diffuser Outfall Commissioning	Bitterns Discharge Quality Bitterns Discharge Flowrate	To implement a monitoring and management program for bitterns outfall diffuser commissioning that meets MEQ expectations. This program targets the actual water quality being discharged to ensure that the design specifications are being achieved. If water quality of the discharge is achieved, then it is assumed through bitterns outfall modeling that the EQC within each LEP will be achieved (Note: the below program will validate this assumption)
Marine Environmental Quality Validation	Bitterns Whole Effluent Toxicity and Contaminant Testing	To identify the actual toxicity of the bitterns discharge on local native species WET Testing will be undertaken. Laboratory assessment of continents of potential concern will also be undertaken to ascertain which toxicants are highly concentrated in the bitterns. These results will be used with other monitoring results to validate modelled impact predictions and verify the LEPs and EQCs.
	Bitterns Diffuser Outfall Validation Testing	To ensure that the specified bitterns discharge criteria are met once routine operations are established. These results will be used with other monitoring results to validate modelled impact predictions and verify the LEPs and EQCs.
	Model and EQC Validation	To provide an assessment of whether the defined EQCs are being met at their respective LEPs and determine if the discharged bitterns conform with WET testing and modelled predictions and required dilutions are being achieved at the LEPA/MEPA and MEPA/HEPA boundaries during routine operations. These results will be used with other monitoring results to validate modelled impact predictions and verify the LEPs and EQCs
Routine Operational Performance Assessment	Bitterns Diffuser Outfall Water Quality	To ensure that design specifications for bitterns discharge constituents, as defined by modelling and WET testing, are being achieved through the lifecycle of the Project.
	Ongoing Marine Environmental Quality	To verify that impacts from operational activities associated with the Mardie Project, such as ocean outfall, vessel operations stormwater runoff or groundwater flows, do not impact MEQ outside the limits of acceptable ecological change associated with the defined LEPs.

Table 6-3 Monitoring Program Overview

Element	Sub-Element	Sample Requirement	Parameters	Frequency	Duration	No. of Sites	No. Samples per site*
Pre-Commissioning Baseline Monitoring	Water Quality Monitoring	Physico-chemical water column profiling	Electrical conductivity Salinity Temperature pH Dissolved oxygen Turbidity	Six weekly	2 years	4	NA
		Water sampling	Hydrocarbons Ionic balance Metals and metalloids	Six weekly	2 years	4	1
	Sediment Quality Monitoring	Sediment sampling	Particle size distribution Total organic carbon and moisture Metals and metalloids Hydrocarbons	Once only**	NA	10	1
	Benthic infauna	Sediment grab sample	Lowest taxonomic level	Annual	2 years	10	3
	Aesthetic Observation	Physical observations	Nuisance organisms Large-scale deaths Oil/Film Natural reflectance Objectionable odour Floating debris, rubbish, surface slicks	Six weekly	2 years	14	NA
Bitterns Diffuser Outfall Commissioning	Bitterns discharge quality	Water grab sample	Salinity	Weekly	TBD	2	2

Element	Sub-Element	Sample Requirement	Parameters	Frequency	Duration	No. of Sites	No. Samples per site*
	Bitterns discharge flowrate	Flow rate measurement	Instantaneous flow rate – 0.69 m^3/s	Weekly	TBD	NA	NA
Marine Environmental Quality Validation	Whole Effluent Toxicity Testing	Actual bitterns sample	48-hour larval development test: *Saccostrea echinate* (Milky Oyster). 96-hr toxicity test: *Melita plumulosa* (Amphipod). 8-day Sea anemone *pedal lacerate* development test: *Aiptasia pulchella* 72-hr sea urchin larval development test: *Heliocidaris tuberculata*. 96-hr Fish Imbalance toxicity test: *Lates calcarifer* (Barramundi). 7-hr Fish Imbalance and biomass toxicity test: *Lates calcarifer*. 72-hr marine algal growth test: *Nitzschia closterium*.	Once only***	NA	NA	1
	Bitterns Diffuser Outfall Validation Testing	Grab Sample	Salinity Toxicants	Weekly	6 Weeks	2	2
		Flow rate measurement	Instantaneous flow rate – 0.69 m^3/s	Continuous	6 Weeks	NA	NA
	Model and EQC Validation	Physico-chemical water column profiling	Electrical conductivity Salinity Temperature pH Dissolved oxygen Turbidity	Weekly	6 Weeks	19	NA
		Physico-chemical in-situ data logging	Electrical conductivity Salinity Temperature pH Dissolved oxygen Turbidity	Continuous	6 Weeks	2	NA

Element	Sub-Element	Sample Requirement	Parameters	Frequency	Duration	No. of Sites	No. Samples per site*
		Water Sampling	Hydrocarbons Ionic balance Metals and metalloids	Weekly	6 Weeks	19	1
		Physical observations	Nuisance organisms Large-scale deaths Oil/Film Natural reflectance Objectionable odour Floating debris, rubbish, surface slicks	Weekly	6 Weeks	19	NA
Routine Operational Performance Assessment	Bitterns Diffuser Outfall Water Quality	Grab Sample	Salinity	Biannually	2 Years	2	2
		Flow rate measurement	Instantaneous flow rate – 0.69 m^3/s	Continuous	2 Years	NA	NA
	Ongoing Marine Environmental Quality	Physico-chemical water column profiling	Electrical conductivity Salinity Temperature pH Dissolved oxygen Turbidity	Quarterly	Ongoing	21	NA
		Water Sampling	To be Determined through MEQ Validation Phase and consultation with EPA	Quarterly	Ongoing	21	1
		Sediment Sampling	Particle size distribution Total organic carbon and moisture Metals and metalloids Hydrocarbons	Annually	Ongoing	21	1
		Benthic Infauna	Lowest taxonomic level	Annual	Ongoing	10	3
		Physical observations	Nuisance organisms Large-scale deaths Oil/Film Natural reflectance	Quarterly	Ongoing	21	NA

Element	Sub-Element	Sample Requirement	Parameters	Frequency	Duration	No. of Sites	No. Samples per site*
			Objectionable odour Floating debris, rubbish, surface slicks				

Notes:

** Excludes field QA/QC sample requirements*

*** Excludes previously undertaken investigation reported in O2 Marine 2019a*

**** WET testing and bitterns contamination analysis are also required at any time during which the Project process is altered in any way, thus potentially altering the levels of constituents and therefore possibly the toxicity within the discharge stream*

6.2. Pre-Commissioning Baseline Monitoring Program

6.2.1. Context

In order to be able to determine impacts upon MEQ from the Mardie Project a comprehensive set of EQCs needs to be defined that are specific to the local area within which the Project will be situated. The pre-commissioning baseline monitoring program aims to collect data from the local marine environment with which to derive site specific EQCs for which actual Project impacts can be measured against during commissioning and ongoing routine operations. This program is typically comprised of the following sub-monitoring elements:

- Marine water quality monitoring;
- Physical observations;
- Sediment monitoring; and
- Benthic infauna.

6.2.2. Purpose

The purpose of this element is to collect sufficient spatial and temporal data with a high level of replication from which site specific EQGs and EQS will be derived in accordance with ANZG (2018). Site specific EQGs and EQS will be used to define marine environmental performance during both the commissioning and routine operational phases of the Project lifecycle. In accordance with ANZG (2018) a two-year baseline monitoring period is proposed to provide a suitable data set for the intended purpose.

This phase will also allow the fine tuning of sampling methodology to ensure the described practices are effective when applied under field situations. Any lessons learnt, or alterations to the defined methodologies will be included into a revised version of this MEQMMP.

6.2.3. Environmental Quality Criteria

As the purpose of this phase is to collect baseline data from which to derive site specific EQC, there are no applicable EQGs or EQSs for assessment of data.

At the completion of this phase EQC will be calculated in accordance with **Figure 5-2** which will apply to MEQ monitoring programs outlined within **Section 6.4.7** and **Section 6.5.6**.

6.2.4. Sampling Design

Table 6-4 provides a summary of the proposed sampling frequency. Where practical, sampling should be undertaken on or near to the same date each month/year to allow for consistent comparison of seasonal trends. Sampling frequency has been determined based on the recommended number of samples and sample collection frequency specified in ANZG (2018).

Sediment and water quality investigation have previously been undertaken to assists with the environmental assess met for the proposed project. Data has been analysed and reported in the following project specific technical documents:

> Mardie Project Baseline Sediment Characterisation. Report prepared by O2 Marine for Mardie Minerals Ltd (O2 Marine 2019a); and
> Mardie Project Baseline Water Quality Monitoring. Report prepared by O2 Marine for Mardie Minerals Ltd (O2 Marine 2020a).

Whilst these studies were developed to specifically inform project environmental impact assessment, data collected will be pooled with data to be collected during the baseline water and sediment quality program to derive EQCs in accordance the process specified in **Section 5.2**.

Additional sediment and water quality data will be collected in accordance with this MEQMMP.

Table 6-4 Monitoring Frequency for the Proposed Phase I Baseline data collection

Monitoring Event	Frequency	Period	No. of Sampling Rounds*	No. of Sites	No. of Samples Collected*
Physico-chemical Water Quality Profiling	Six weekly	2 years	17	4	68
Benthic Infauna Sampling	Annual	2 years	2	10	60
Sediment Sampling	Annual	2 years	2	10	20
Physical Observation	Six weekly	2 years	17	14	88
Water Sampling	Six weekly	2 years	17	4	68

Notes:
** Excludes sampling previously undertaken as reported in O2 Marine 2019a or O2 Marine 2020a.*

The water quality monitoring program includes four (4) locations. These are presented in **Figure 6-1** and described in **Table 6-5**.

Sediment quality and infauna monitoring programs include 10 locations. These are presented in **Figure 6-3** and described in **Table 6-5**

Table 6-5 Baseline Water Quality Monitoring Locations and Routine Tasks

Site Name	Site Reference	Level of Ecological Protection	Easting (GDA94 MGA50)	Northing (GDA94 MGA50)	Routine Sampling Tasks				
					Physical Observations	Physico-chemical Water Column	Water Sample Collection	Sediment Monitoring	Benthic infauna
MB1	This site is located offshore within the HEPA allowing an assessment of the pre-project baseline conditions.	High	388382.2	7673404.0	X	X	X		
MB2	This site is located nearshore within the XEPA allowing an assessment of the pre-project baseline conditions.	Maximum	388485.8	7670738.7	X	X	X		
NC1	This site is located adjacent to the small vessel support infrastructure area within Mardie Creek allowing assessment of impacts associated with related activities.	High	388401.7	7668638.8	X	X	X		
MIC1	This site is located adjacent to the sweater abstraction intake within Peter's Creek allowing assessment of potential impacts related to this activity.	High	379199.1	7649389.6	X	X	X		

Site Name	Site Reference	Level of Ecological Protection	Easting (GDA94 MGA50)	Northing (GDA94 MGA50)	Routine Sampling Tasks				
					Physical Observations	Physico-chemical Water Column	Water Sample Collection	Sediment Monitoring	Benthic infauna
MLB1 MLB3 MLB4 MLB6	These sites have been selected to represent baseline conditions at the LEPA/MEPA Boundary.	Moderate	389583.4 389693.6 389595.6 389454.1	7673064.5 7673081.6 7672206.6 7672198.1	X			X	X
MMB1 MMB3 MMB7 MMB5	These sites have been selected to represent baseline conditions at the MEPA/HEPA Boundary.	High	389612.5 389719.4 389893.2 389174.2	7673446.5 7673454.8 7672216.9 7672168.4	X			X	X
MH1 MH3	These sites have been selected to represent reference sites located away from the influence of operations and construction which can be used for ongoing MEQ sampling programs.	High	388640.0 390650.1	7672814.3 7672847.0	X			X	X

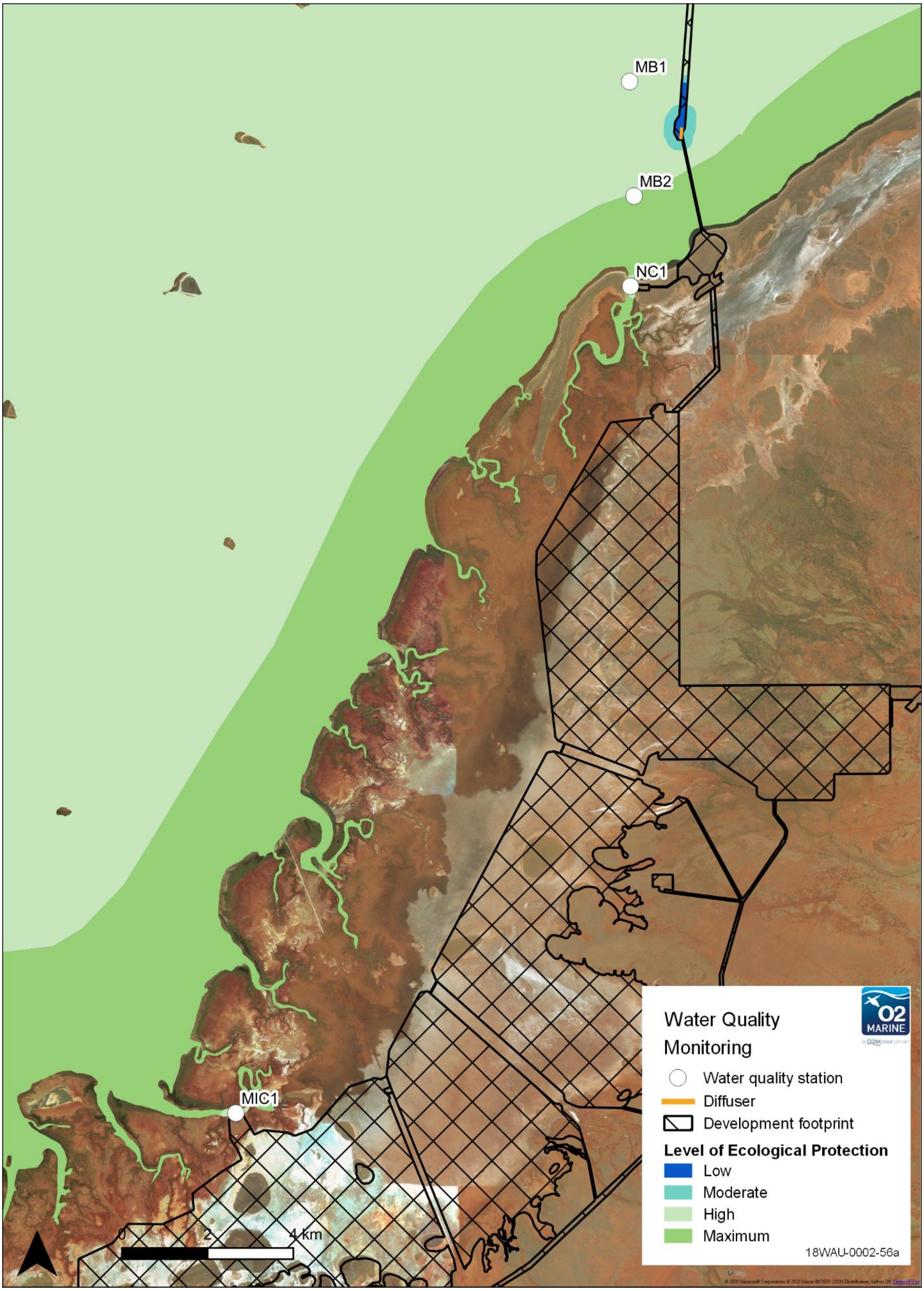

Figure 6-1 Baseline Water Quality Monitoring Locations

6.2.5. Sampling Methodology

Physical Observations

General Observations

The following field observations are to be recorded at each site during each sampling event:

> Date and time of sampling at each location;
> Person conducting sampling;
> Site reference;
> GPS coordinates of sampling location;
> Tides and water depth at the time of sampling;
> Wind speed (km/hr) and direction;
> Sea state (i.e. wave and swell heights); and
> General weather conditions (rain, storms, cloud cover, etc).

Digital photographs should also be taken throughout the monitoring event as weather conditions change and as required to document any notable site observations. Field logs are to be scanned and saved in BCI's records management system and attached as an appendix in the quarterly and annual reports.

Aesthetic Observations

At each sampling location, observations of aesthetic water quality parameters should be recorded for each of the quick reference guide categories provided in **Table 6-6**. Aesthetic observations are to consider waters within an approximate 50 metre radius of the survey vessel.

Table 6-6 Aesthetic observations quick reference guide

Parameter	REF	1	2	3	4	5
Nuisance organisms (Surface coverage %)	**A**	Nil	1-10	11-50	51-80	100+
Large-scale deaths (Marine fauna)	**B**	Nil	1-10	11-51	51-81	100+
Oil/Film (Surface coverage)	**C**	Nil	1-10%	11-50%	51-80%	81-100%
Natural reflectance (Diminished)	**E**	81-100%	51-80%	11-50%	1-10%	Nil
Objectionable odour	**F**	Nil	Slight	Moderate	Strong	Offensive
Floating debris, rubbish, surface slicks (Surface coverage %)	**G**	Nil	1-10	11-50	51-80	100+

Physico-chemical Water Quality Monitoring

A pre-calibrated, Water Quality Sonde will be used to collect physico-chemical water quality profiles at all four (4) sampling locations identified within **Table 6-5**. As a minimum, the following parameters will be measured at 0.5 metre (m) intervals throughout the water column from the seabed to the surface:

> Depth (m);
> Water temperature (°C);
> pH;
> Salinity (ppt);
> Electrical Conductivity (mS/cm);
> Turbidity (NTU); and
> Dissolved oxygen (% saturation & mg/L).

All recorded measurements are to be stored on the sonde hand-held unit and downloaded to a secure server within 24 hours. The data should be immediately assessed to ensure validity and, any erroneous data should be removed from the analysis as appropriate.

Water Sample Collection

Water samples will be collected at all four (4) sampling locations as identified within **Table 6-5**. Water samples will be collected using a depth-integrated water sampler[1] to pump the required volume of water commencing at the seabed up to the surface.

The water sampler will be rinsed with Decon solution (or equivalent) between samples. Water samples will be collected in suitable (laboratory supplied) bottles and immediately stored on ice for transport to a National Association of Testing Authorities (NATA) accredited laboratory for analysis.

All sample containers will be marked with a unique identifier, the date/time and the sampler's name and clarification that the samples are *marine water* using a waterproof permanent maker. All samples will then be listed on a Chain of Custody (CoC) form to be included with the samples sent to the laboratories.

Laboratory Analysis

General water sample analysis will be performed on samples collected from all four (4) sampling locations**.** These samples are required to be analysed by a NATA-accredited laboratory for the following;

> Ionic balance:
    - Alkalinity and Hardness;
    - Calcium, Magnesium, sodium, potassium cations;
    - Chloride, fluoride and sulphate anions
> Hydrocarbons (TRH, TPH and BTEXN); and

[1] If a depth-integrated water sampler is not available, a pole sampler or niskin bottle (or equivalent) may be used to sample at a depth of 0.5m below the surface. Near-surface sampling is generally considered to be representative of water quality at the sample sites as waters in Mardie Coastline experience a high degree of mixing.

- Dissolved Metals and Metalloids (Al, As, Bo, Cd, Cu, Hg, Pb, Zn, V).

Field Quality Assurance & Quality Control

All water quality meters are to be in calibration. If monitoring equipment is hired, calibration certificates are to be provided from the supplier. Calibration records are to be saved and attached as an appendix to compliance reports.

The following Quality Assurance & Quality Control (QA/QC) Samples should be collected as described below:

- A ***duplicate sample*** is to be collected at the same site as two (2) of the primary monitoring samples. The purpose of the sample is to confirm that the primary laboratory is able to produce consistent results when analysing the same sample. The site where it was taken is to be recorded but not reported to the laboratory. Ideally it should be collected at a site that is expected to have higher levels of contamination (based on historic data and potential sources of contamination) as this will confirm a wider range of analytes and reduce the level of instrument error when comparing larger concentrations.
- A ***field split sample*** is collected at the same site as the duplicates and sent to a secondary laboratory for analysis. The purpose of this sample is to confirm that intra-laboratory analysis of the sample produces consistent results.
- A ***rinsate sample*** is collected to confirm that cross contamination doesn’t occur during the sampling processes in the field. The rinsate sample should be taken after the decontamination process of the sample collection container by running deionised water over the container and collecting it in laboratory provided bottles.

Laboratory Quality Assurance & Quality Control

Laboratories used for water sample analysis must be NATA accredited. Comprehensive QA/QC testing of water samples should be undertaken in accordance with NATA accreditation and include testing of laboratory control samples, method blanks, matrix spikes, laboratory duplicates and surrogate recovery outliers (where applicable).

Sediment Sampling

Sample Collection

Sediment samples will be collected at all ten (10) sampling locations described in **Table 6-5**. Sampling will involve the collection of sediment using a combination of vibro-coring, surface grab sampling and diver-coring. The grab, plastic tray and other equipment in contact with the sediment will be rinsed with Decon solution and seawater prior to sampling each site to reduce potential for contamination. Where insufficient sediment is collected (i.e. less than 1/3rd of grab volume), the grab will be required to be redeployed. Estimate and record the volume of sediment collected and empty the grab into a plastic tray to mix and homogenise the sediment. Photograph each sample once emptied into the plastic tray. Place sample into appropriate sample jars/ containers provided by laboratory. Containers should be refrigerated or placed into an esky with ice bricks before frozen at the completion of each sampling day and sent to a NATA approved laboratory.

All sample containers will be marked with a unique identifier, the date/time and the sampler's name and clarification that the samples are *marine water* using a 'Wet-write' permanent maker. All samples will then be listed on a CoC form which will accompany the samples sent to the laboratories.

Laboratory Analysis

Sediment quality sample analysis will be performed on samples collected from all 10 monitoring locations**.** These samples will be analysed by a NATA-accredited laboratory for the following analytical suite:

> Particle size distribution (PSD);
> Total organic carbon (TOC);
> Moisture;
> Metals and metalloids (Al, As, Bo, Cd, Cu, Hg, Pb, Zn, V);
> Hydrocarbons (TRH, TPH and BTEXN);
> Antifoulant Compounds (Diuron, Chlorothalonil).

Field Quality Assurance & Quality Control

Disposable nitrile gloves should be used during handling of the sediment sample and all equipment in contact with the sediment should be washed down with Decon solution prior to each sample being taken. The following QA/QC Samples should be collected as described below:

> ***Triplicate samples*** (i.e. three separate samples taken with the sediment grab at the same location) should be taken at one (1) site to determine the variability of the sediment physical and chemical characteristics.
> A ***field split sample*** (i.e. one sediment grab sample thoroughly mixed and then split into three sub-samples) should be collected at collected at one (1) site to assess inter and intra-laboratory variation, with one of the three samples sent to a second laboratory.
> A ***transport blank*** (acid-washed silica sand) in a sealed jar should be provided by the laboratory and taken to site but not opened. The transport blank is sent back to the laboratory with the other samples and analysed. This blank is used to assess if any contamination is already present in the acid-washed sand or container.
> A ***method blank*** (acid-washed silica sand) should be used to assess the potential for contamination during the sampling process. The method blank should be placed into the 'van Veen' grab and processed identically to the usual sediment samples. The method blank should be sent to the laboratory and analysed with the other samples to assess presence of contamination during the processing procedures.

Laboratory Quality Assurance & Quality Control

Laboratories used for sediment toxicity sample analysis must be NATA accredited. Comprehensive QA/QC testing of sediment samples should be undertaken in accordance with NATA accreditation and include testing of laboratory control samples, method blanks, matrix spikes, laboratory duplicates and surrogate recovery outliers (where applicable).

Benthic Infauna

Sample Collection

Sediment samples for benthic infauna analysis will be collected at all 10 locations as identified within **Table 6-5**. Benthic infauna samples will be collected from a vessel using a sediment grab sampler such as a van-veen grab or similar. Three (3) replicate samples will be collected at each location to provide statistical replication required for adequate analysis of benthic infauna.

The following sample process/collection steps will occur:

> Once the sample has been recovered it will be released from the grab sampler into a suitable collection tray
> Weigh the sediment sample and record for post sampling data analysis purposes;
> Sieve the sediment through a 500 μm sieve using either the saltwater deck wash to remove fine sediment; and
> All material retained on the sieve, such as coarse sediment and benthic infauna, will be carefully rinsed into suitable pre-labelled containers and preserved with 95-100% ethanol solution.

This process will be replicated to ensure three (3) individual sediment samples are collected from each location to provide sufficient statistical data to allow assessment of variability within each sample location.

Equipment required for the benthic infauna sediment sampling includes the following:

> Suitable sediment grab sampler;
> Deck winch;
> Deck wash hose;
> Sample collection tray;
> Funnel (x2)
> 500 μm sieve box;
> Suitable sample containers;
> Washing bottles;
> Waterproof labelling pens;
> Decon 90; and
> 95-100% Ethanol solution.

Laboratory Analysis

Laboratory picking is conducted under a dissecting-microscope, with all benthic infauna being removed from the sediment. Picking quality assurance checks are done on 10% of the total samples, with a 5% picking error rate. If the picking error is above 5% then previous samples are checked, until a satisfactory error rate is met. All picked benthic infauna will be stored in separate sample vials with 70% ethanol. Macroinvertebrates will be identified to Family taxonomic level using a compound microscope.

6.2.6. Data Assessment and Reporting

Data Validation

All data is required to be validated prior to the release of any monitoring reports to confirm that data has been entered correctly. Data entry is to be checked and verified against raw data logs and laboratory reports by an independent person.

Quality Control

An assessment of quality control data needs to be undertaken and included in all reports including:

- Assessment of field contamination (rinsate, transport blank and method blank);
- Assessment of field variability (duplicate, triplicate or replicate);
- Assessment of lab variability (intra and inter-laboratory duplicates, picking error); and
- Laboratory QA/QC results.

Data Assessment

During this phase no, commissioning or project related operational activities will occur. Therefore, data collected will not be required to be assessed against the EQCs identified within **Section 5.2** to interpret if EVs and EQOs are being compromised. However, for the purposes of providing context to sample results, a review of the similarity of reference sites to LEPA/MEPA and MEPA/HEPA boundary sites will be undertaken to confirm suitability.

At the completion of the two year baseline data collection period a review of the baseline data will be undertaken to derive and determine site specific EQG and EQS for the LEPA, MEPA and HEPA LEP Boundary areas in accordance with the process outlined in the EQMF (**Section 5.2**). Site specific EQS will be incorporated into a revised version of this MEQMMP once defined.

Reporting

At the completion of each sampling round a brief summary report will be submitted outlining the results obtained.

A comprehensive report will be compiled at the completion of the two-year data collection period which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- Timeseries graphs of physicochemical water column profiles;
- A table summarising laboratory analysis results;
- Timeseries graphs of laboratory analysis results;
- Statistical summary of infauna (as per collection frequency)
- An assessment of all data collected against the EQCs;
- Presentation of the calculated site specific EQG and EQS in accordance with ANZG (2018); and
- Any actions or recommendations required as a result of field implementation of the Sampling and Analysis Plan (SAP) and assessment of monitoring data.

6.3. Bitterns Diffuser Outfall Commissioning

6.3.1. Context

In order to discharge bitterns, a diffuser commissioning period will be required. During commissioning it is possible that the bitterns being discharged will not meet the design criteria which was initially used to model the dilutions and recirculation in order to establish an appropriate mixing zone. The end of the commissioning period will be determined when engineering confirms typical operating conditions have been achieved for all facilities and associated infrastructure and monitoring confirms the SPLs for each LEP are achieved.

Management during the initial commissioning process is focused on achieving the desired level of dilution required to ensure the discharged bitterns meets the accepted level of brine discharge. Where desired levels are not being achieved contingency actions will be implemented to ensure the permanent bitterns outfall discharge process and design are optimised prior to completion of commissioning. These actions that are implemented during commissioning will ensure that the end point for routine operations is a discharge process that meets or exceeds the expected targets.

6.3.2. Purpose

The purpose of commissioning monitoring and management is to design a process that meets MEQ expectations, whilst providing flexibility during the initial stages of the bitterns discharge process to allow a staggered start up and optimisation process. Management triggers have been designed which provide assurance around protecting EVs, but also to ensure appropriate contingency management actions, such as alterations to the process or design, are implemented during this period, thus reducing the potential for long-term issues.

6.3.3. Environmental Quality Criteria

As the purpose of this phase is to determine the number of dilutions between the raw bitterns and the diffuser during commissioning no EQC apply. Rather, two Management Triggers presented below guide this phase of the Project.

6.3.4. Management Triggers

In order to achieve the purpose, two levels of management triggers have been established which will inform Management when contingency measures need to be put into place to ensure the required SPLs are met at the LEP boundaries. Contingency measures are identified in **Section 6.3.6** and are typically based upon conducting an investigation into the reason why a management trigger was exceeded and putting appropriate corrective actions in place to reduce re-occurrence and where possible rectify the situation to ensure optimisation of the process prior to completion of commissioning.

The two levels of management triggers are based upon the maximum instantaneous flow rate and the maximum predicted design concentration for constituents within the bitterns discharge.

Additional management trigger levels are applicable to the MEPA / LEPA boundary, however these are detailed within **Section 6.4**.

Management Trigger 1

Management trigger 1 is based upon the maximum instantaneous flow rate of:

> *0.69 m^3/s constant discharge regime.*

The management trigger level will be exceeded if the maximum instantaneous flow rate is exceeded, thus enacting contingency management as described in **Section 6.3.6.**

Management Trigger 2

Management trigger 2 is based upon maximum discharge concentrations of:

- *325 ppt salinity of the pre-diluted bitterns waste; and*
- *85.4 ppt salinity of the 5 times diluted bitterns waste at the outfall.*

Adjusted management trigger levels will be revised accordingly prior to commissioning to ensure they are appropriately set. If any management triggers are breached contingency management as described in **Section 6.3.6** will be required.

6.3.5. Bitterns Diffuser Outfall Commissioning Monitoring Program

Bitterns diffuser outfall commissioning monitoring will require continuous flow rate monitoring during discharge and water samples to be collected from the raw bitterns wastewater sump and at the diffuser outfall.

Two duplicate water samples will be collected weekly from the following two locations:

- Direct grab sampling from the raw bitterns wastewater sump directly prior to discharge; and
- Direct grab sampling from the pipeline at the closest point to final discharge and where five dilutions with seawater has occurred.

Samples will be collected directly into laboratory supplied sample bottles at each location. Sampling will be undertaken in accordance ANZG (2018) for water quality sampling with QA/QC samples requiring a transport blank.

Water samples will be sent to a NATA accredited laboratory for analysis of salinity. Laboratory QA/QC requirements will be undertaken in accordance with the NATA accreditation and reported with the sample results.

Data Assessment and Reporting

Data Validation and Quality Control

All data is required to be validated prior to the release of any monitoring reports to confirm that data has been entered correctly. Data entry is to be checked and verified against raw data logs and laboratory reports by an independent person.

An assessment of quality control data needs to be undertaken and included in all reports including:

- Assessment of field contamination (transport blank);

- Assessment of variability (duplicate);
- Laboratory QA/QC results.

Data Assessment

Laboratory analysed samples, physicochemical results and recorded flow rates will be compared with defined management triggers as soon as practicable. Any elevation will require contingency actions as described in **Section 6.3.6** to be implemented**.**

Reporting

At the completion of each sampling round a validated laboratory report and interpreted tabulated data will be submitted to BCI Minerals.

An investigation report will be compiled in accordance with BCI Minerals Management System for any elevated results which requires investigation. Submission to the regulator will be subject to project approval conditions.

A comprehensive report will be developed at the completion of the commissioning phase which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- Timeseries graphs of physicochemical parameters In-situ;
- A table summarising laboratory analysis results;
- Timeseries graphs of laboratory analysis results;
- An assessment of all data collected against management triggers;
- A review of management trigger exceedances investigations and remedial actions implemented; and
- Any actions or recommendations required as a result of field implementation of the SAP and assessment of monitoring data.

6.3.6. Contingency Management during Commissioning

In the event that the bitterns discharge is not meeting the defined management triggers operational and design solutions will be investigated. Firstly, depending upon the exceedance, an investigation needs to be undertaken to determine the cause(s). Once the cause(s) is determined then appropriate corrective or preventative actions need to be put into place to ensure re-occurrence does not occur. This system of investigation and implementation of remedial actions will ensure that during the commissioning phase all possible design modifications are put into place to ensure optimal performance of the process at the completion of commissioning.

There are several potential operational and design solutions which may be used as contingency measures in response to management trigger exceedances. **Figure 6-2** provides an overview of the contingency response and management framework to be applied during commissioning of the diffuser.

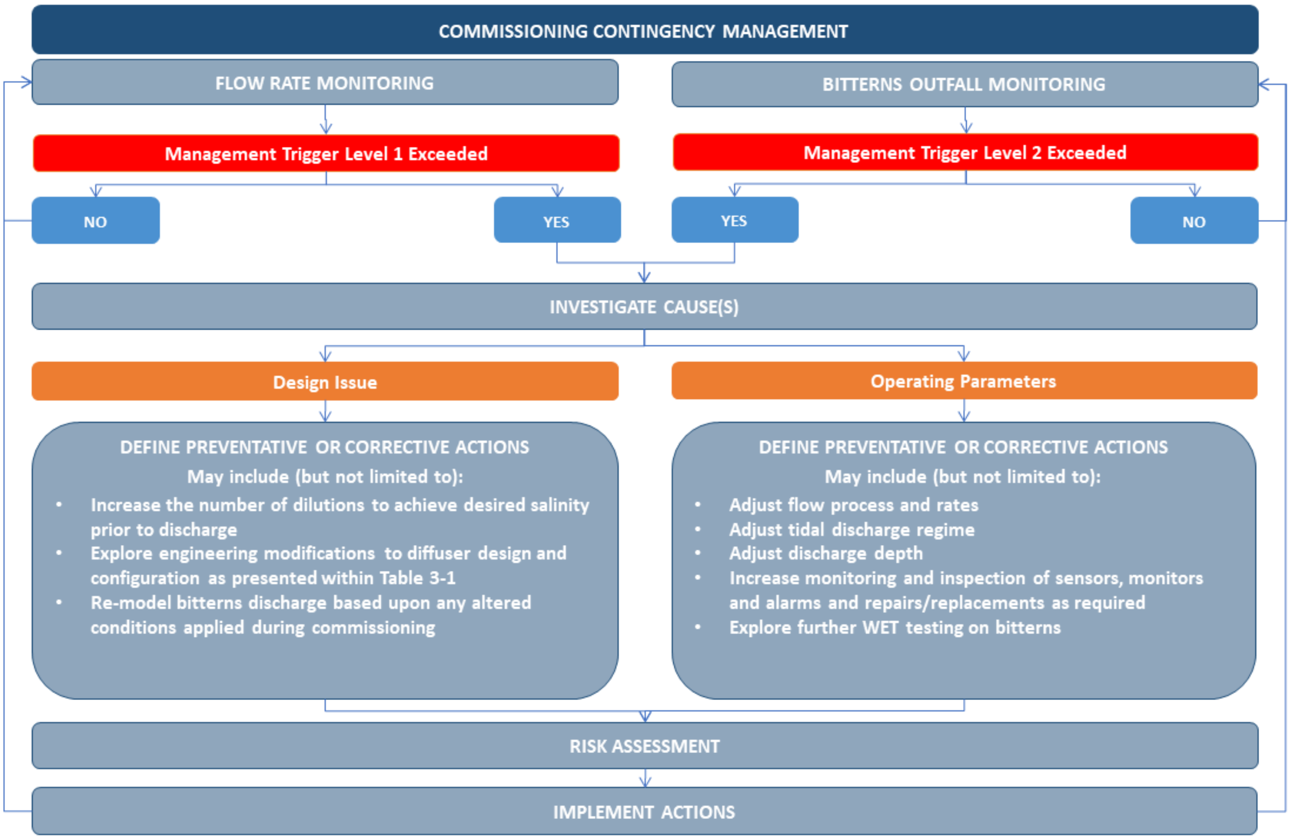

Figure 6-2 Contingency management framework during bitterns discharge commissioning

6.4. Bitterns Diffuser Outfall Validation

6.4.1. Context

To determine the actual impacts from project related activities to the MEQ a comprehensive MEQ validation monitoring and management program has been designed. This program is broken into several smaller components which each have different objectives, methodologies and contingency actions. These components are:

- Whole Effluent Toxicity (WET) testing to determine actual bitterns discharge toxicity and the number of dilutions required to achieve ecological protection at LEP boundaries;
- Bitterns discharge validation testing to characterise the discharge from the outfall diffuser against design and determine final concentrations of toxicants; and
- EQC and modelling validation monitoring at strategically positioned impact and reference locations surrounding the outfall to allow an assessment against defined site specific EQC.

Management during validation is focused on ensuring that predicted impacts are commensurate with actual impacts within the respective spatial LEPs, therefore protecting the associated EVs and EQOs. Where desired levels are not being achieved contingency actions will be implemented to ensure the permanent discharge of bitterns and associated engineering design are optimised for routine operations, and Project related activities either meet or exceeds the predicted impacts within the defined LEPs.

6.4.2. Purpose

The purpose of MEQ validation monitoring and management is to ensure that the predicted and modelled impacts are accurate (model validation) and that actual Project impacts are within the limits of acceptable change as defined for each LEP. This will ensure that the defined EVs and EQOs are not compromised by operational activities associated with the Mardie Project once typical conditions have been reached (i.e. completion of the commissioning phase).

6.4.3. Environmental Quality Criteria

As the purpose of this phase is to validate predictive modelling, determining final toxicity and dilution factors required to protect MEQ at LEP boundaries, only EQGs are applicable to this Phase. The preliminary EQGs are presented in **Table 6-7**. These are based upon the ANZG (2018) species protection levels for toxicants in water at protection levels commensurate with **Table 5-1**. These are intended, within this version of the MEQMMP, as a guide only and are subject to review at the completion of the Phase I baseline data collection program.

Table 6-7 Preliminary EQGs for Marine Environmental Quality Validation – Phase III

EQI	Units	EQG			
		Low	Moderate	High	Maximum
Temperature pH Salinity Electrical Conductivity Turbidity Dissolved Oxygen	Various	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1.** Where appropriate EQGs will be determined for surface and seafloor.			
Aluminium	(µg/L)	Impact < Reference 99th percentile	Impact < reference 95th percentile	Impact < reference 80th percentile	
Arsenic (III/V)	(µg/L)	Impact < Reference 99th percentile	Impact < reference 95th percentile	Impact < reference 80th percentile	
Boron	(µg/L)	Impact < Reference 99th percentile	Impact < reference 95th percentile		
Cadmium[1]	(µg/L)	36	14	0.7	
Copper[1]	(µg/L)	8	3	0.3	
Lead[1]	(µg/L)	12	6.6	2.2	
Mercury[1]	(µg/L)	1.4	0.7	0.1	
Vanadium[1]	(µg/L)	280	160	50	No detectable change from natural background
Zinc[1]	(µg/L)	43	23	7	
TRH C6-C14	(µg/L)	25	25	25	Impact < reference 95th percentile
TRH C15-C36	(µg/L)	100	100	100	Impact < reference 95th percentile
BTEXN[1] - Benzene - Toluene - Ethylbenzene - Xylene[2] - Napthalene	(µg/L)	 1300 330 160 150 120	 900 230 110 100 90	 500 110 50 50 50	
Hydroxide Alkalinity as $CaCO_3$ Carbonate Alkalinity as $CaCO_3$ Bicarbonate Alkalinity as $CaCO_3$ Total Alkalinity as $CaCO_3$ Total Hardness as $CaCO_3$	(mg/L)	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			
Total Anions Total Cations Ionic Balance	(meq/L) (meq/L) (%)	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			
Cations: Calcium Magnesium	(mg/L)	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			

EQI	Units	EQG			
		Low	Moderate	High	Maximum
Sodium potassium					
Anions: Chloride Fluoride Sulphate	(mg/L)	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			

Notes:
[1] Derived from ANZG (2018) DGVs for 99%, 90% and 80% SPL
[2] Xylene based upon m-Xylene from ANZG (2018)

6.4.4. Management Triggers

In order to achieve the purpose, three levels of management triggers have been established which will inform Management when contingency measures need to be put into place to ensure Project related impacts are within the acceptable levels. Contingency measures specific to each validation program are identified below and are typically based upon conducting an investigation to determine the cause of any management trigger exceedances and implementing appropriate corrective actions to reduce re-occurrence and where possible rectify the situation to ensure optimisation of Project related processes.

The three levels of management triggers are based upon the maximum instantaneous flow rate, the maximum predicted design concentration for constituents within the bitterns discharge and the EQC defined within **Table 6-7** for the constituents being monitored. The management trigger levels are detailed below.

Management Trigger 1

Management trigger 1 is based upon the maximum instantaneous flow rate of:

> *0.69 m3/s constant discharge regime.*

The management trigger level will be exceeded if the maximum instantaneous flow rate is exceeded, thus enacting contingency management as described below.

Management Trigger 2

Management trigger 2 is based upon maximum discharge concentrations of:

> *325 ppt salinity of the pre-diluted bitterns waste; and*
> *85.4 ppt salinity of the 5 times diluted bitterns waste at the outfall.*

Adjusted management trigger levels may be revised accordingly to ensure they are appropriately set. If any management triggers are breached contingency management as described below will be required.

Management Trigger 3

Management Trigger 3 are defined as the EQCs and are based upon assessment against MEQ samples collected at the LEPA/MEPA or MEPA/HEPA boundaries or within the LEPs.

MEQ samples collected from designated sample locations are to be assessed against the EQCs presented within **Table 6-7**, noting these are preliminary and subject to review at the completion of Phase I. The validation monitoring will ensure that the required level of species protection is being met at each of the LEP boundaries.

Where an exceedance of any of the EQCs occur contingency management as described in the following sections will be required.

6.4.5. Whole Effluent Toxicity Testing

Purpose

The purpose of WET testing is to identify the specific toxicity of the bitterns wastewater under accredited laboratory conditions, using indigenous selected species. WET testing results will provide an assessment of the dilution factors required to be achieved on bitterns outfall wastewater to achieve the species protection levels defined within **Table 3-3**.

Results from the WET testing will also be used along with results from the toxicant concentration assessment (**Section 6.4.6**) to further define and revise the EQCs for ongoing operational performance assessment **(Section 6.5)**.

Sampling Design

WET testing has been undertaken of the prototype bitterns discharge effluent by ESA. Once the commissioning phase of the Project nears completion WET testing will be undertaken when water quality of the discharge is considered to be within design specifications and therefore representative of actual conditions experienced during routine operations. WET testing will be conducted twice on samples taken directly from the raw bitterns namely:

1. towards the finalisation of Project commissioning to identify the toxicity of the bitterns under normal operating conditions; and
2. within 12 months of commission to validate routine operational discharge.

Additional WET testing will also be required at any time during which the Project process is altered in any way, thus potentially altering the levels of constituents and therefore possibly the toxicity within the discharge stream.

The proposed WET testing sampling program will involve two processes namely:

1. Range finding test for toxicity to determine if the effluent is toxic and if so, determine the appropriate concentration range for subsequent tests, and
2. Definitive toxicity testing to determine the 50% Effect Concentration (EC50), 50% Inhibitory Concentration (IC50), 50% Lethal Concentration (LC50) and No Observed Effect Concentration (NOEC) values of effluent for selected species.

WET testing is proposed to be undertaken on a minimum of five (5) locally relevant species from four (4) taxonomic groups. Testing will be in accordance with laboratory NATA accredited methodologies and in accordance with ANZG (2018) toxicity sampling and testing protocols. The proposed tests and locally relevant species identified for WET testing are listed below:

1. 48-hour larval development test: *Saccostrea echinate* (Milky Oyster).
2. 96-hr toxicity test: *Melita plumulosa* (Amphipod).
3. 8-day Sea anemone pedal lacerate development test: *Aiptasia pulchella*
4. 72-hr sea urchin larval development test: *Heliocidaris tuberculata*.
5. 96-hr Fish Imbalance toxicity test: *Lates calcarifer* (Barramundi).
6. 7-hr Fish Imbalance and biomass toxicity test: *Lates calcarifer*.
7. 72-hr marine algal growth test: *Nitzschia closterium*.

The above tests will be validated closer to the time in collaboration with the preferred laboratory to ensure appropriateness of the selected tests and to determine availability of the selected species. If new tests or other species are identified in collaboration with the laboratory then the above WET tests may be revised accordingly.

Sampling Methodology

Samples for WET testing will be collected directly from the raw bitterns prior to any dilutions at the point directly before it enters the discharge pipe. Samples will be collected in laboratory supplied sample containers and in accordance with sampling instructions and ANZG (2018) protocols. Typically, this involves filling plastic sample bottles (~2.5 L) from the bitterns sump once normal operational processes are established and normal discharges are occurring. Samples are typically required to be chilled and transported to the laboratory within stipulated timeframes. Diluent water will be collected from a source within the HEPA that has been determined to have no impacts from the outfall discharge (i.e. through interpreting modelling results) from a depth equal to the outfall diffuser. Samples will be transported directly to the laboratory to ensure ecotoxicity testing can occur as soon as practicable after sample collection.

Data Assessment and Reporting

WET testing results may be used to re-run the predictive modelling and refine the spatial application of the mixing zone and designation of the LEPs.

Data Validation and Quality Control

All data is required to be validated prior to the release of any monitoring reports to confirm that data has been entered correctly. Data entry is to be checked and verified against raw data logs and laboratory reports by an independent person.

An assessment of quality control data needs to be undertaken and included in all reports including:

- Laboratory QA/QC results.

Data Assessment

Ecotoxicity testing results will be entered into a software program (e.g. BurrilOZ) to calculate the value required to achieve a 90% SPL at the boundary of the LEPA/MEPA and a 99% SPL at the boundary of the MEPA/HEPA. These results will be used to validate, or as a basis for review, of the defined spatial LEPs as presented within this Plan. They will also be used to further define and review EQCs. This process is defined in the following section (**Section 6.4.6**).

Reporting

At the completion of each WET Testing round a validated laboratory report and interpreted tabulated results will be submitted to BCI.

A summary report will be compiled at the completion of any WET testing requirements which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- A table summarising laboratory analysis results;
- An interpretation of the raw date from the software program used (i.e. BurrilOZ);
- Analysis of results against predictive modelling with respect to dilution contour modelling and spatial allocation of LEPs with the mixing zone boundary required to meet the 99% SPL; and
- Any actions or recommendations required as a result of field implementation of the SAP and assessment of monitoring data.

6.4.6. Bitterns Discharge Validation Testing

Purpose

The purpose of the bitterns discharge validation testing is to ensure that:

- the optimal design targets for bitterns constituents are being achieved once the Project has completed commissioning; and
- actual toxicant concentrations are determined within the bitterns to adequately inform the determination of the final EQCs.

Bitterns discharge validation testing will also provide an indication of the level of variability of salinity and toxicant concentrations likely to be present within the bitterns discharge, thus allowing a definitive prediction of the levels of impacts from routine discharges to be predicted.

Results from the salinity and toxicant concentration assessment will be used along with WET testing (**Section 6.4.5**) to further define and revise the EQCs for ongoing operational performance assessment **(Section 6.5)**.

Sampling Design

Bitterns discharge validation monitoring will require continuous flow rate monitoring during discharge and water samples to be collected from the bitterns discharge at two locations prior to discharge weekly for a period of six weeks post commissioning. Samples will be collected concurrently with the MEQ monitoring surveys so that the actual discharge waters can be compared against the water quality results obtained at sampling location around the outfall.

Sampling Methodology

Bitterns diffuser outfall commissioning monitoring will require continuous flow rate monitoring during discharge and water samples to be collected from the raw bitterns wastewater sump and at the diffuser outfall weekly for a period of six weeks post commissioning. Samples will be collected concurrently with the MEQ monitoring surveys so that the actual discharge waters can be compared against the water quality results obtained at sampling location around the outfall.

Two duplicate water samples will be collected weekly from the following two locations:

- Direct grab sampling from the raw bitterns wastewater sump directly prior to discharge; and
- Direct grab sampling from the pipeline at the closest point to final discharge and where five dilutions with seawater has occurred.

Samples will be collected directly into laboratory supplied sample bottles at each location. Sampling will be undertaken in accordance ANZG (2018) for water quality sampling with QA/QC samples requiring a transport blank.

Water samples will be sent to a NATA accredited laboratory for analysis of salinity and a broad suite of toxicants which be used to further refine and define the final EQCs for ongoing monitoring programmes. Laboratory QA/QC requirements will be undertaken in accordance with the NATA accreditation and reported with the sample results.

Laboratory analysis of water samples will include:

- Ionic balance:
    - Alkalinity and Hardness;
    - Calcium, Magnesium, sodium, potassium cations;
    - Chloride, fluoride and sulphate anions
- Hydrocarbons (TRH, TPH and BTEXN); and
- Dissolved Metals and Metalloids (Al, As, Ba, Bo, Br, Cd, Cu, Hg, Li, Mo, Pb, Sr, Zn, V).

Data Assessment and Reporting

Data Validation and Quality Control

All data is required to be validated prior to the release of any monitoring reports to confirm that data has been entered correctly. Data entry is to be checked and verified against raw data logs and laboratory reports by an independent person.

An assessment of quality control data needs to be undertaken and included in all reports including:

- Assessment of field contamination (transport blank);
- Assessment of variability (duplicate);
- Laboratory QA/QC results.

Data Assessment

Laboratory analysed results will be compared with the previously defined management triggers as soon as practicable. Any elevation will require contingency actions as described below to be implemented**.**

At the completion of the six-week period and in combination with WET testing results define and calculate the values which will become represent salinity and toxicant in water EQSs for ongoing bitterns outfall performance assessment. These will be derived according to the following process:

- WET testing results will be used to determine species protection values using a species sensitivity distribution using Burrlioz 2.0 software in accordance with ANZECC/ARMCANZ 2000 guidelines to determine the number of dilutions required at each LEP boundary.
- Interrogate concentrations of salinity and toxicant data from bitterns wastewater samples to:
  - Identify toxicants which are concentrated above ANZG (2018) guidelines and select toxicants suitable to act as EQCs for assessment of EQIs at LEP boundaries;
  - Determine the 80^{th} percentile for salinity and each toxicant within the sampling dataset;
  - Using dilution factors as determined from WET testing, calculate toxicant and salinity concentrations for each LEP boundary; and
- Revise the MEQMMP to incorporate these values as the defined final EQSs for operational performance assessment of the bitterns outfall.

Reporting

At the completion of each sampling round a validated laboratory report and interpreted tabulated data will be submitted to BCI.

An investigation report will be compiled in accordance with BCI Environmental Management System for any elevated results which requires investigation. Submission to the regulator will be subject to project approval conditions.

A comprehensive report will be developed at the completion of the validation monitoring which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- Timeseries graphs of physicochemical water column profiles;
- A table summarising laboratory analysis results;
- Timeseries graphs of laboratory analysis results;
- An assessment of all data collected against management triggers;
- A review of management trigger exceedances investigations and remedial actions implemented;
- Any actions or recommendations required as a result of field implementation of the MEQMMP and assessment of monitoring data; and
- Calculation and presentation of final EQCs (along with WET testing results) which will be used for Ongoing Operational Performance Monitoring as per **Section 6.5.**

6.4.7. Marine Environmental Quality Validation Monitoring

Purpose

The purpose of the MEQ validation is to provide an assessment of environmental performance to identify if the defined EQCs are being met within their respective LEPs. Results will also be used to determine if the modelled bitterns constituent concentrations and predicted dilution factors are being achieved at the LEPA/MEPA and MEPA/HEPA boundaries.

Sampling Design

Table 6-8 provides a summary of the proposed sampling frequency.

Table 6-8 Monitoring Frequency for EQC Validation Monitoring

Monitoring Event	Frequency	Commencement	Completion
Water Quality Sampling	Weekly	End of Commissioning	6 weeks post commissioning
Physico-chemical Water Quality Profiling	Weekly	End of Commissioning	6 weeks post commissioning
In-Situ Physico-chemical Monitoring	Continuous	End of Commissioning	6 weeks post commissioning
Physical Observations	Weekly	End of Commissioning	6 weeks post commissioning

The program includes a total of 19 MEQ monitoring locations, including:

- Six (6) sites at the LEPA/MEPA boundary;
- Eight (8) sites at the MEPA/HEPA boundary; and
- Five (5) sites within the HEPA.

Details of the 19 monitoring locations and associated routine sampling tasks to be completed at each location are presented in **Table 6-9** and displayed in **Figure 6-3**.

Table 6-9 Marine Environmental Quality Monitoring Locations and Associated Routine Sampling Tasks for MEQ Validation

Site Name	Site Reference	Level of Ecological Protection	Easting (GDA94 MGA50)	Northing (GDA94 MGA50)	Routine Sampling Tasks			
					Physical Observations	Physico-chemical Water Column	General Water Sample Analysis	In-situ Physicochemical
MLB1-6	These sites are located on the LEPA/MEPA boundary. They are positioned within the predicted bitterns outfall plume as modelled by Baird (2020a) to ensure impacts are within the predictions and the LEP. They also represent potential impact boundaries from the Offshore Shipping Facility	Moderate	389583.4 389661.9 389693.6 389595.6 389534.3 389454.1	7673064.5 7673378.3 7673081.6 7672206.6 7672059.9 7672198.1	X	X	X	X[1]
MMB1-8	These sites are located on the MEPA/HEPA boundary. They are positioned within the predicted bitterns outfall plume as modelled by Baird (2020a) to ensure impacts are within the predictions and the LEP.	High	389612.5 389684.9 389719.4 389895.9 389893.2 389529.4 389174.2 389298.4	7673446.5 7673542.6 7673454.8 7672749.8 7672216.9 7671801.9 7672168.4 7672704.6	X	X	X	
MH1-4	Sites MH1-4 are outside of the predicted bitterns outfall plume as modelled by Baird (2020a) to ensure impacts are within the predictions and the LEP. They also collectively provide an assessment of any measured change within the High LEP from the Offshore Shipping Facility.	High Maximum (MH4)	388640.0 389076.1 390650.1 389338.8	7672814.3 7674293.2 7672847.0 7670946.0	X	X	X	

Site Name	Site Reference	Level of Ecological Protection	Easting (GDA94 MGA50)	Northing (GDA94 MGA50)	Routine Sampling Tasks			
					Physical Observations	Physico-chemical Water Column	General Water Sample Analysis	In-situ Physicochemical
MIS1	This site is located within the dredge channel where the bathymetry is naturally deeper than the proposed channel depth and there is the potential for the plume to disperse out of the channel.	High	389736.0	7674275.2	X	X	X	

1: In-situ physicochemical monitoring undertaken at MLB4 and MLB6 only

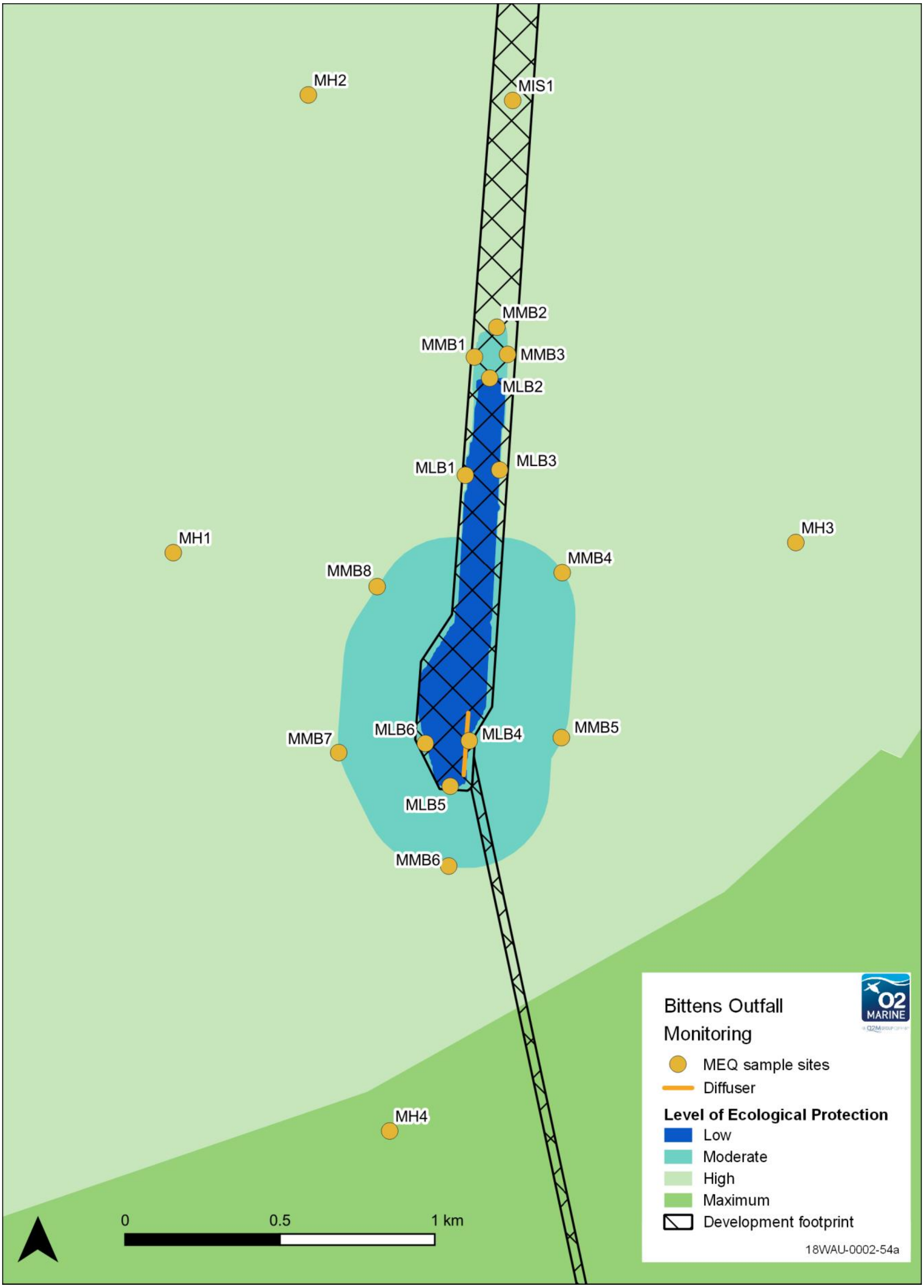

Figure 6-3 Bitterns Outfall and Offshore Marine Facilities Sites for Validation Sampling

Sampling Methodology

Sampling methodologies for the following activities will be conducted in accordance with the protocols outlined within **Section 6.2.5:**

- Physical Observations; and
- Physico-chemical water column profiles.

In-situ physicochemical sampling and water quality sampling activities will be undertaken in accordance with the protocol described below.

Sampling dates and times will be scheduled to ensure that a range of tidal conditions, including coverage of neap and spring tides, incorporating incoming and outgoing tidal regimes, are assessed.

In-situ Water Quality Sampling and Analysis

A range of instruments will be deployed at two (2) monitoring locations as identified within **Table 6-9** to record in-situ physiochemical parameters, each attached to purpose-designed seabed frames. The in-situ loggers will record the following parameters:

- Electrical Conductivity
- Salinity
- Temperature
- Depth/Pressure
- Photosynthetically Active Radiation (PAR)
- Temperature
- Turbidity (NTU)

The seabed frames are designed to stand upright on the seabed, while maintaining the instruments at approximately 0.3 m above the seafloor and to reduce the likelihood of interaction of sensors with sediment, large rocks and rubble on the seafloor.

Water quality instrument maintenance & calibration is typically conducted regularly (i.e. typically every 6 weeks), however as this will be a six weekly deployment maintenance and calibration will be conducted prior to deployment. Maintenance, calibration checks and data download/backup are carried out in line with manufacturer specifications and QA/QC protocols. Where calibration checks are not satisfactory, a new calibration is performed as per manufacturer specification.

Water Sample Collection

Water samples will be collected at all 19 sampling locations identified within **Table 6-9**. Water samples will be collected from three separate depths, as required to validate and identify modelled stratification (Baird 2020). The following samples will be collected:

- 0.5m below surface;
- Middle of water column; and
- 0.5m above seafloor.

Samples will be collected using an electronic water sample pump or niskin bottle to collect the required volume of water from each of the depths identified above.

The water sampler will be rinsed with Decon solution (or equivalent) between samples. Water samples will be collected in suitable (laboratory supplied) bottles and immediately stored on ice for transport to a National Association of Testing Authorities (NATA) accredited laboratory for analysis.

All sample containers will be marked with a unique identifier, the date/time and the sampler's name and clarification that the samples are *marine water* using a waterproof permanent maker. All samples will then be listed on a Chain of Custody (CoC) form to be included with the samples sent to the laboratories.

Laboratory Analysis

General water sample analysis will be performed on samples collected**.** These samples are required to be analysed by a NATA-accredited laboratory for the following parameters;

- Ionic balance:
  - Alkalinity and Hardness;
  - Calcium, Magnesium, sodium, potassium cations;
  - Chloride, fluoride and sulphate anions
- Total Recoverable Hydrocarbons (TRH);
- Total Petroleum Hydrocarbons (TPH);
- BTEXN; and
- Dissolved Metals and Metalloids.

Field Quality Assurance & Quality Control

All water quality meters are to be in calibration. If monitoring equipment is hired, calibration certificates are to be provided from the supplier. Calibration records are to be saved and attached as an appendix to compliance reports.

The following Quality Assurance & Quality Control (QA/QC) Samples should be collected as described below:

- A ***duplicate sample*** is to be collected at the same site as two (2) of the primary monitoring samples. The purpose of the sample is to confirm that the primary laboratory is able to produce consistent results when analysing the same sample. The site where it was taken is to be recorded but not reported to the laboratory. Ideally it should be collected at a site that is expected to have higher levels of contamination (based on historic data and potential sources of contamination) as this will confirm a wider range of analytes and reduce the level of instrument error when comparing larger concentrations.
- A ***field split sample*** is collected at the same site as the duplicates and sent to a secondary laboratory for analysis. The purpose of this sample is to confirm that intra-laboratory analysis of the sample produces consistent results.
- A ***rinsate sample*** is collected to confirm that cross contamination doesn't occur during the sampling processes in the field. The rinsate sample should be taken after the decontamination process of the sample collection container by running deionised water over the container and collecting it in laboratory provided bottles.

Laboratory Quality Assurance & Quality Control

Laboratories used for water sample analysis must be NATA accredited. Comprehensive QA/QC testing of water samples should be undertaken in accordance with NATA accreditation and include testing of laboratory control samples, method blanks, matrix spikes, laboratory duplicates and surrogate recovery outliers (where applicable).

Data Assessment and Reporting

Data Validation

All data is required to be validated prior to the release of any monitoring reports to confirm that data has been entered correctly. Data entry is to be checked and verified against raw data logs and laboratory reports by an independent person.

Quality Control

An assessment of quality control data needs to be undertaken and included in all reports including:

- Assessment of field contamination (rinsate, transport blank and method blank);
- Assessment of field variability (duplicate and triplicate);
- Assessment of lab variability (triplicate);
- Laboratory QA/QC results.

Data Assessment

Compliance with the preliminary EQGs (**Table 6-7**) for the respective LEP at each sample location will be assessed through a comparison of the median results for each parameter from the commissioning and six-week post-commissioning phases. Data from the commissioning phase and medians for each parameter calculated from the six-week dataset for each site from the post commissioning phase will be compared directly to the EQCs. Results for each individual site will be compared to the relevant guideline value or the relevant Reference percentile. Reference percentiles will be calculated from the six-week median for each individual Reference site.

Reporting

At the completion of each sampling round a validated laboratory report and interpreted tabulated data will be submitted to BCI Minerals.

An investigation report will be compiled in accordance with BCI Minerals Environmental Management System for any elevated results which require investigation. Submission to the regulator will be subject to project approval conditions.

A comprehensive report will be compiled at the completion of the validation phase which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- Timeseries graphs of physicochemical water column profiles;
- A table summarising laboratory analysis results;
- Timeseries graphs of laboratory analysis results;

- An assessment of all data collected against management triggers;
- A review of management trigger exceedances investigations and remedial actions implemented; and
- Any actions or recommendations required as a result of field implementation of the SAP and assessment of monitoring data.

Sample Preservation, Storage and Holding Times

Analytical Limits of Reporting (LoRs) should be appropriate to provide suitable detection levels as appropriate to allow comparison with ANZG (2018) or DEC (2006) guidelines for baseline monitoring and for the purposes of establishing site specific EQC at the completion of baseline monitoring.

Storage and holding times need to be confirmed with the laboratory prior to sampling to ensure the sampling program is compliant with specified standards

Contingency Management

In the event that the Project related impacts exceed the desired management trigger levels a range of operational and design solutions will be investigated. Firstly, depending upon the exceedance, an investigation needs to be undertaken to determine the cause(s). Once the cause(s) is determined then appropriate corrective or preventative actions need to be implemented to ensure re-occurrence does not occur. This system of investigation and implementation of remedial actions will ensure that during the post-commissioning phase all possible design or process modifications are established to ensure optimal performance of the process for ongoing operations.

There are several potential operational and design solutions which may be used as contingency measures in response to management trigger exceedances. **Figure 6-4** provides an overview of the contingency response and management framework to be applied during MEQ validation for the Mardie Project.

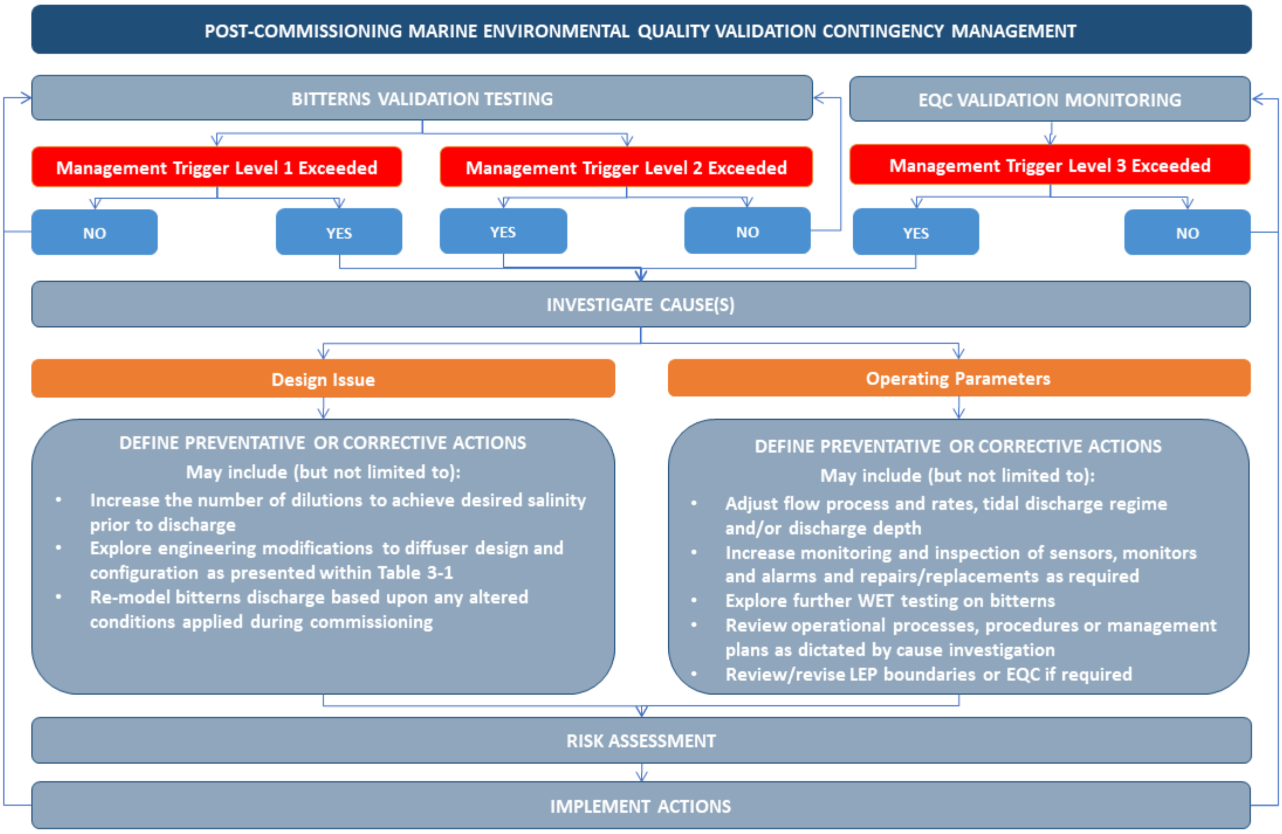

Figure 6-4 Post-commissioning brine discharge quality validation contingency management.

6.5. Routine Operational Performance Assessment

6.5.1. Context

To determine any actual impacts from routine operational activities associated with the Mardie Project, a comprehensive MEQ monitoring and management program has been designed. This program comprises two smaller components which each have a different purpose, methodologies and contingency actions. These components include:

- Ongoing assessment of bitterns discharge quality against design specifications; and
- Ongoing MEQ monitoring to ensure that potential impacts from operational activities are occurring within the limits of acceptable change allocated within each spatial LEP.

Management during ongoing operations will be focused on ensuring that the predicted levels of impact within the defined spatial LEPs are achieved, therefore protecting the associated EVs and EQOs. Where desired levels are not being achieved contingency actions will be implemented to ensure the impacts are restricted, investigated and remediated through implementing a course of actions. At this stage compliance reporting requirements will also be stipulated, with outcomes from these monitoring programs reported against their objectives and criteria and submitted, as required, to the regulator.

6.5.2. Purpose

The purpose of the routine operational performance assessment is to determine if typical operational activities associated with the Mardie Project are compliant with defined management triggers and that no temporal impacts are being observed. To determine if operations are impacting MEQ the following two monitoring and assessment programs will be implemented:

1. Bitterns Discharge Quality; and
2. Ongoing MEQ Monitoring.

6.5.3. Environmental Quality Criteria

Environmental Quality Guidelines

EQGs for routine MEQ monitoring are currently preliminary and subject to review at the completion of Phase I and Phase III data collection. The EQGs presented below are therefore considered a guide at this early stage of the program.

The final EQGs will be based upon baseline data collected through Phase I and WET testing and toxicant analysis of the bitterns undertaken during Phase III. Also review of this MEQSAP at the completion of Phase will ensure that all risks from operational activities associated with the project are included within the final EQGs presented below.

Water Quality

The preliminary EQGs are presented within **Table 6-7**. At the completion of Phase I and Phase III these will be reviewed accordingly and the final set of EQGs will be determined and presented below.

Sediment Quality

The preliminary EQGs for sediment quality are presented within **Table 6-10**. Where levels are elevated additional testing for bioavailability is required. EQGs for bioavailability testing are presented in **Table 6-11**.

Table 6-10 Preliminary EQGs for routine Marine Environmental Quality Monitoring – Sediment Sampling

EQI	Units	EQG			
		Low	Moderate	High	Maximum
Aluminium[1]	mg/kg	6150	4100	4100	No detectable change from natural background
Arsenic[1]	mg/kg	20	20	20	
Boron	mg/kg	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			
Cadmium[1]	mg/kg	1.5	1.5	1.5	
Copper[1]	mg/kg	65	65	65	
Lead[1]	mg/kg	50	50	50	
Mercury[1]	mg/kg	0.15	0.15	0.15	
Vanadium[1]	mg/kg	54	36	36	
Zinc[1]	mg/kg	200	200	200	
TRH[2] Total C6-C14 C15-C36	mg/kg	 250 25 100	 250 25 100	 250 25 100	
TPH[3]	mg/kg	280	280	280	
BTEXN[1] - Benzene - Toluene - Ethylbenzene - Xylene[2] - Napthalene	mg/kg	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			
Diuron	mg/kg	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			
Chlorothalonil	mg/kg	To be calculated upon completion of Phase I in accordance with **Figure 5-2** and as outlined within **Table 5-1**			

[1] Derived from ANZG (2018) Default Guideline Values
[2] Derived using the lowest limits of reporting available
[3] Sum of TPHs derived from Simpson et al. (2013) as presented within ANZG (2018) Default Guideline Values

Table 6-11 Preliminary EQGs for routine Marine Environmental Quality Monitoring – Sediment Toxicity Bioavailability Assessment

EQI	Units	EQG	
		Moderate	High
Arsenic[1]	mg/kg	20	20
Cadmium[1]	mg/kg	1.5	1.5
Copper[1]	mg/kg	65	65
Boron	mg/kg	Median within 80th percentile of reference range	
Lead[1]	mg/kg	50	50
Mercury[1]	mg/kg	0.15	0.15
Vanadium[1]	mg/kg	Median within 80th percentile of reference range	
Zinc[1]	mg/kg	200	200
TRH[2]	mg/kg	C6-C9: 25 C10-C14: 25 C15-C28: 100 C29-C36: 100 TRH: 250	C6-C9: 25 C10-C14: 25 C15-C28: 100 C29-C36: 100 TRH: 250
Diuron	mg/kg	Median within 80th percentile of reference range	
Chlorothalonil	mg/kg	Median within 80th percentile of reference range	

Environmental Quality Standards

The establishment of EQS typically require a robust understanding of the spatial and temporal variation of the indicators selected through which EQOs can be measured against to ensure the protection of EVs. This information is currently limited upon which to derive scientifically robust values. In accordance with ANZG (2018) the intention is to develop site specific EQS where currently no values exist, or where default guideline values have been applied through assessment of baseline data collected in accordance with this Plan or other Mardie Project monitoring programs (e.g. Mardie Operational Environmental Management Plan).

EQS established in this Plan have been derived for EQI constituents identifies in **Section 5.2** within the following groups:

Toxicants and Stressors:

> Salinity
> Key toxicants (as determined by Phase III program)

Biological Condition:

> Toxicants in biota;
> Condition of Benthic Communities and Habitat (BCH);
> Condition of Benthic Infauna; and

> Animal kills/ disease/ lesions;

Upon completion of baseline sampling programs EQS for the following extent categories will also be defined:

> Localised extent of physicochemical or toxicant stressors;
> Extent/distribution of key habitat types; and
> Distribution of marine infauna.

Table 6-12 Preliminary EQSs for routine Marine Environmental Quality Monitoring

EQI	EQS		
	Moderate	High	Maximum
Salinity in bitterns Key toxicants in bitterns	Dilutions meet 90% SPL as determined through WET testing	Dilutions meet 99% SPL as determined through WET testing	No change from natural background concentrations
Toxicants in Sediment Toxicants in Water	No loss or decline within BCH greater than 95% percentile of natural conditions	No change in BCH communities from natural conditions	
	No loss or decline within benthic fauna communities greater than 95% percentile of natural conditions	No change in benthic fauna community composition as compared to natural conditions	
	No EQS Apply	80th percentile of tissue toxicant concentrations in filter feeders compared with suitable reference site	No detectable change from natural background levels
	No reports of animal disease or deaths attributable to the Project		
Physicochemical stressors in water	No loss or decline within BCH greater than 95% percentile of natural conditions	No change in BCH communities from natural conditions	No loss or decline within BCH greater than 95% percentile of natural conditions
	No loss or decline within benthic fauna communities greater than 95% percentile of natural conditions	No change in benthic fauna communities from natural conditions	No loss or decline within benthic fauna communities greater than 95% percentile of natural conditions
	No reports of animal disease or deaths attributable to the Project		

6.5.4. Management Triggers

In order to achieve the purpose, three levels of management triggers have been established which will inform Management when contingency measures need to be put into place to ensure that Project related impacts are within the acceptable levels so that the EVs and EQOs defined for the Project area are not compromised. Contingency measures specific to each assessment program are identified in **Sections 6.5.5** and **6.5.6** and are typically based upon conducting an investigation into the reason why a management trigger was exceeded and putting appropriate corrective actions in place to reduce re-occurrence.

The three levels of management triggers are based upon the maximum instantaneous flow rate, the maximum predicted design concentration for constituents within the bitterns discharge and the final EQC for the constituents being monitored. The management trigger levels are detailed below.

Management Trigger 1

Management trigger 1 is based upon the maximum instantaneous flow rate of:

- *0.69 m3/s constant discharge regime.*

The management trigger level will be exceeded if the maximum instantaneous flow rate is exceeded, thus enacting contingency management as described in **Section 6.5.5.**

Management Trigger 2

Management trigger 2 is based upon maximum discharge concentrations of:

- *325 ppt salinity of the pre-diluted bitterns waste; and*
- *85.4 ppt salinity of the 5 times diluted bitterns waste at the outfall.*

Adjusted management trigger levels may be adjusted accordingly to ensure they are appropriately set. If any management triggers are breached contingency management as described in **Section 6.5.5** will be required.

Management Trigger 3

Management Trigger 3 are defined as the EQCs and are based upon assessment against MEQ samples collected at the LEPA/MEPA or MEPA/HEPA boundaries or within the LEPs.

MEQ samples collected from designated sample locations are to be assessed against the defined EQCs as identified in **Section 6.5.3**. MEQ monitoring will ensure that the defined LEPs have been accurately modelled and spatially set, whilst the derived EQCs are effective to achieve the EQOs and protect the EVs.

Where an exceedance of any of the EQCs occur contingency management as described in **Section 6.5.5** will be required along with further assessment against EQSs.

6.5.5. Bitterns Discharge Quality

Purpose

The purpose of bitterns discharge quality testing is to ensure that design specifications for bitterns discharge constituents, as verified through Bitterns Discharge Validation Testing, are achieved through the lifecycle of the Project.

Sampling Design and Methodology

Bitterns discharge quality monitoring will be conducted in accordance with **Section 6.4.6** with the following deviation:

- Samples are to be collected biannually for a period of two years, or as applicable in accordance with specific Project approval conditions; and
- During any time which the wastewater treatment plant alters the bitterns discharge in any way.

Data Assessment and Reporting

Data collected will require immediate comparison with management triggers identified above. Any elevation will require contingency actions as described below**.**

Data Validation and Quality Control

All data is required to be validated prior to the release of any monitoring reports to confirm that data has been entered correctly. Data entry is to be checked and verified against raw data logs and laboratory reports by an independent person.

An assessment of quality control data needs to be undertaken and included in all reports including:

- Assessment of field contamination (transport blank);
- Assessment of variability (replicate);
- Laboratory QA/QC results.

Data Assessment

Laboratory analysed samples and physico-chemical results will be compared with the previously defined management triggers as soon as practicable. Any elevation will require contingency actions as described below to be implemented.

Reporting

At the completion of each sampling round a validated laboratory report and interpreted tabulated data will be submitted to BCI Minerals.

An investigation report will be compiled in accordance with BCI Minerals Environmental Management System for any elevated results which requires investigation. Submission to the regulator will be subject to project approval conditions.

A comprehensive report will be developed at the completion of the monitoring program which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- Timeseries graphs of physicochemical water column profiles;
- A table summarising laboratory analysis results;
- Timeseries graphs of laboratory analysis results;
- An assessment of all data collected against management triggers;

- A review of management trigger exceedances investigations and remedial actions implemented; and
- Any actions or recommendations required as a result of field implementation of the MEQMMP and assessment of monitoring data.

Contingency Management

In the event that the treatment process is not meeting the desired management trigger levels a range of operational and design solutions will be investigated. Firstly, depending upon the exceedance, an investigation needs to be undertaken to determine the cause(s). Once the cause(s) is determined then appropriate corrective or preventative actions need to be put into place to ensure re-occurrence does not occur. This system of investigation and implementation of remedial actions will ensure that optimal performance of the process continues through the lifecycle of the project.

There are several potential operational and design solutions which may be used as contingency measures in response to management trigger exceedances. **Figure 6-5** provides an overview of the contingency response and management framework to be applied during routine operation of the Mardie Project.

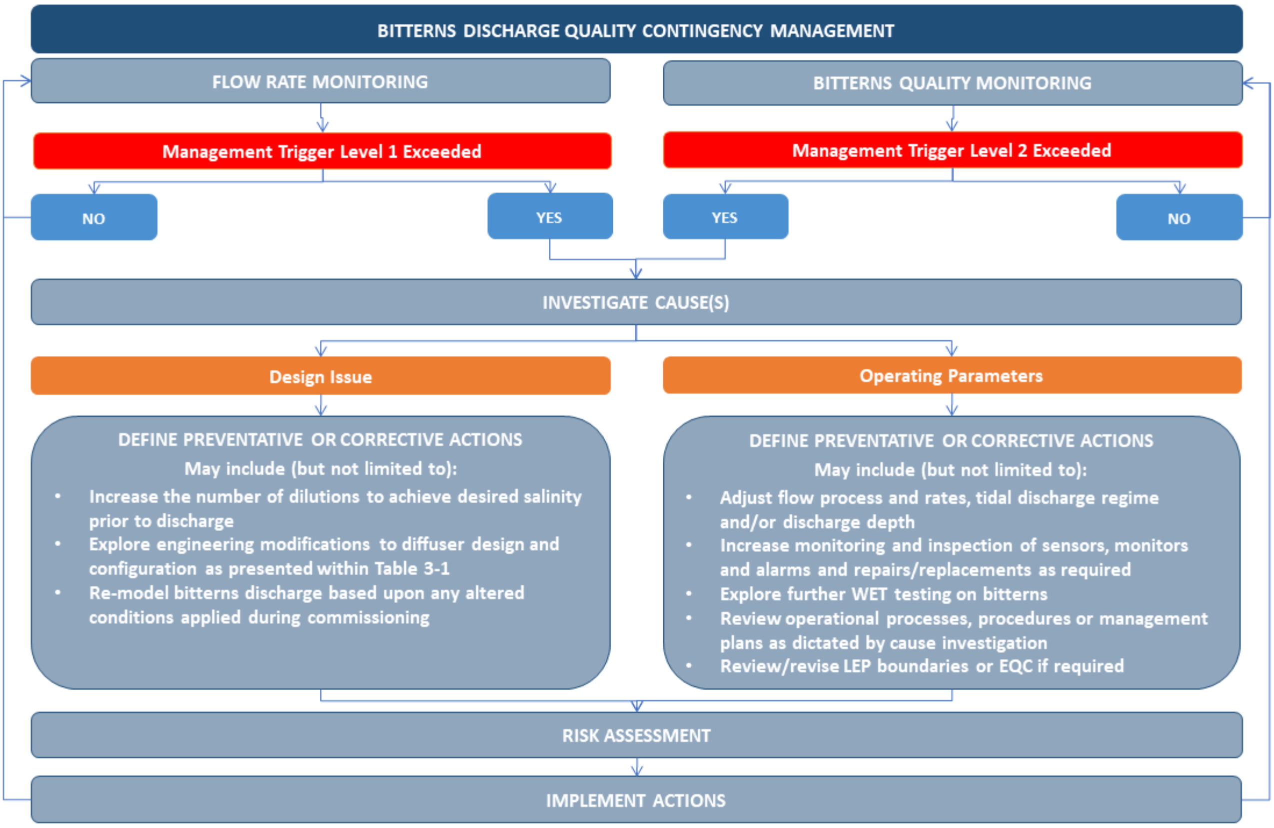

Figure 6-5 Contingency management framework for routine bitterns discharge quality

6.5.6. Ongoing Marine Environmental Quality Monitoring

Purpose

The purpose of the ongoing MEQ monitoring program is to collect quantitative data to assess against management triggers and ensure that impacts from operational activities do not impact MEQ outside the limits of acceptable ecological change for each LEP.

Environmental Quality Guidelines

Sampling Design

Table 6-13 shows the MEQ monitoring events and sampling frequencies, which are based on the lower level of risk presented to MEQ by ongoing operational activities than those associated with the commissioning and validation phases.

Table 6-13 Monitoring Frequency for Ongoing Marine Environmental Quality Monitoring

Monitoring Event	Frequency	No. Sample Sites	Commencement
Water Sampling	Quarterly	21	Post six-week validation period
Physico-chemical Water Quality Profiling	Quarterly	21	Post six-week validation period
Sediment Sampling	Annually	21	Post six-week validation period
Physical Observations	Quarterly	21	Post six-week validation period

The program includes a total of 21 MEQ monitoring locations, which are:

- Bitterns outfall:
  - Six (6) sites at the LEPA/MEPA boundary;
  - Nine (9) sites at the MEPA/HEPA boundary; and
  - Four (4) sites within the HEPA.
- Mardie Creek:
  - One (1) adjacent to the Mardie Creek small vessel launch facility within the HEPA.
- Intake Creek:
  - One potential impact site positioned adjacent to the seawater abstraction intake within the HEPA.

Locations of the 21 monitoring locations are presented in **Table 6-5** and **Table 6-9** and displayed in **Figure 6-3** and **Figure 6-6**.

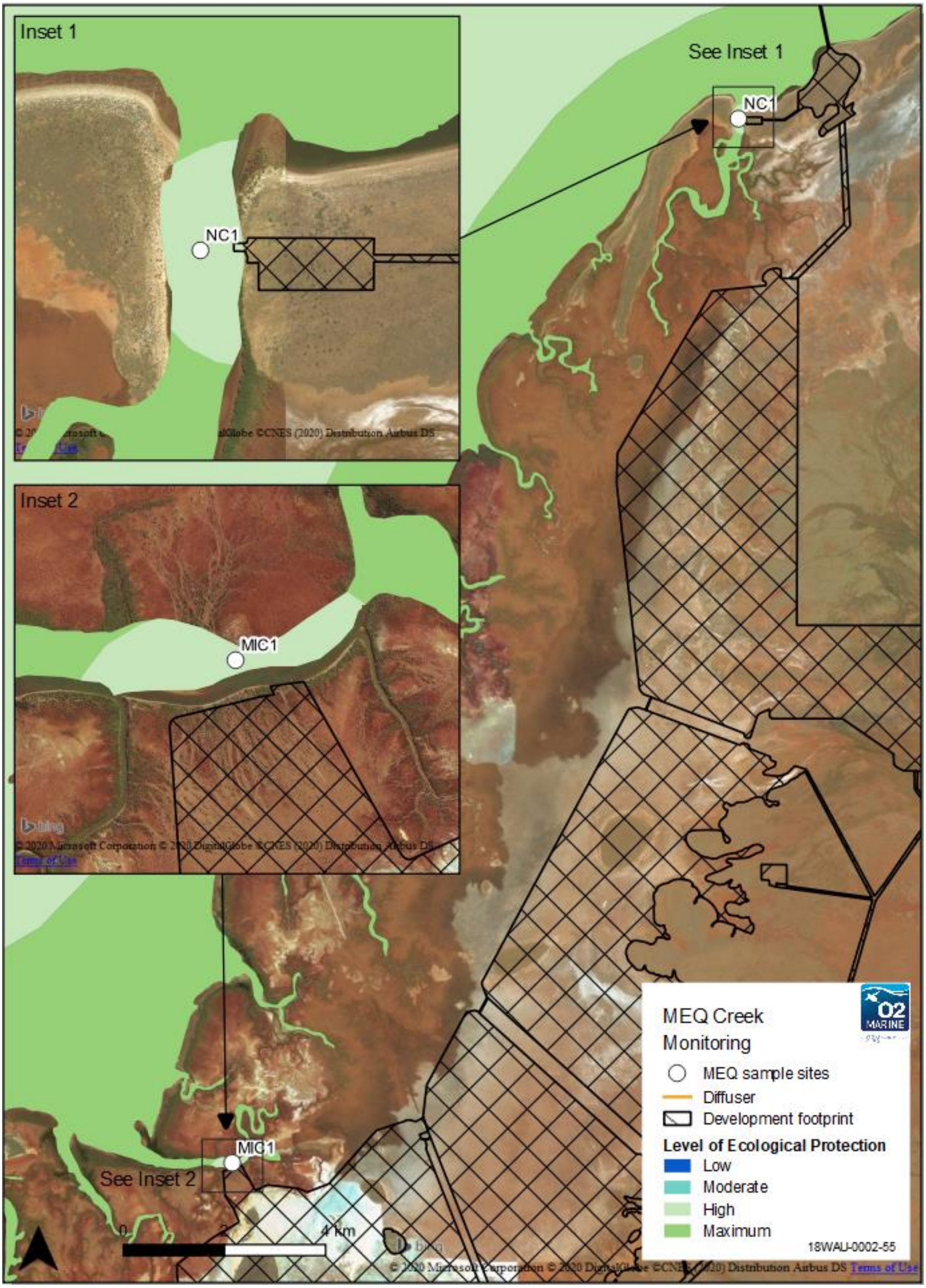

Figure 6-6 Seawater abstraction and small vessel facility MEQ monitoring locations

Sampling Methodology

Sampling methodologies for the sampling programs below will be conducted in accordance with the protocols outlined in **Section 6.2.5,** with the exception for water sampling which will occur in accordance the protocols outlined within **Section 6.4.7.** Sampling locations are described within **Table 6-5** and **Table 6-9.** The ongoing MEQ monitoring program comprise the following sampling programs:

> General Observations;
> Aesthetic Observations;
> Physico-chemical Water Column Profiling;
> Water Sample Collection; and
> Sediment Sample Collection.

In addition, the following variations for water and sediment sample collection will apply.

Water Quality Sampling

Field Quality Assurance & Quality Control

The following Quality Assurance & Quality Control (QA/QC) Samples should be collected as described below:

> A ***duplicate sample*** is to be collected at the same site as two (2) of the primary monitoring samples. The purpose of the sample is to confirm that the primary laboratory is able to produce consistent results when analysing the same sample. The site where it was taken is to be recorded but not reported to the laboratory. Ideally it should be collected at a site that is expected to have higher levels of contamination (based on historic data and potential sources of contamination) as this will confirm a wider range of analytes and reduce the level of instrument error when comparing larger concentrations.
> A ***field split sample*** is collected at the same site as the duplicates and sent to a secondary laboratory for analysis. The purpose of this sample is to confirm that intra-laboratory analysis of the sample produces consistent results.
> A ***rinsate sample*** is collected to confirm that cross contamination doesn’t occur during the sampling processes in the field. The rinsate sample should be taken after the decontamination process of the sample collection container by running deionised water over the container and collecting it in laboratory provided bottles.

Sediment Quality Sampling

Field Quality Assurance & Quality Control

The following QA/QC Samples should be collected as described below:

> ***Triplicate samples*** (i.e. three separate samples taken with the sediment grab at the same location) should be taken at three (3) site to determine the variability of the sediment physical and chemical characteristics.
> A ***field split sample*** (i.e. one sediment grab sample thoroughly mixed and then split into three sub-samples) should be collected at collected at two (2) site to assess inter and intra-laboratory variation, with one of the three samples sent to a second laboratory.

- A ***transport blank*** (acid-washed silica sand) in a sealed jar should be provided by the laboratory and taken to site but not opened. The transport blank is sent back to the laboratory with the other samples and analysed. This blank is used to assess if any contamination is already present in the acid-washed sand or container.
- A ***method blank*** (acid-washed silica sand) should be used to assess the potential for contamination during the sampling process. The method blank should be placed into the 'van Veen' grab and processed identically to the usual sediment samples. The method blank should be sent to the laboratory and analysed with the other samples to assess presence of contamination during the processing procedures.

Toxicant Bioavailability Assessment

Elevated toxicants in sediment may be present in a variety of forms, however, only the bioavailable fraction will impact organisms. Bioavailability testing assesses the availability of elevated toxicants present within sediments for the uptake of organisms. Where total toxicants from routine sediment analysis identify exceedances of the EQGs outlined within **Table 6-10,** a bioavailability analysis is required for assessment against EQGs presented in **Table 6-11**.

Bioavailability tests comprise dilute acid extraction of toxicants under laboratory conditions. Therefore, additional samples should be collected during routine sediment sampling to facilitate any additional testing that may be required. If toxicant concentrations from bioavailability tests exceed the EQGs (**Table 6-11)** further ecotoxicity or bioaccumulation testing will be required for comparison against established EQS.

Environmental Quality Standards

Sampling Design

Sampling for assessment against EQSs is reactive program required at any time that the routine monitoring program identifies exceedances above the final EQGs. **Figure 6-7** presents the relationship between EQG exceedances and reactive sampling programs which are required to be implemented. Reactive sampling programs are required to determine the extent and severity of any impacts and provide an assessment of whether the EQOs are compromised and if the EVs are at risk.

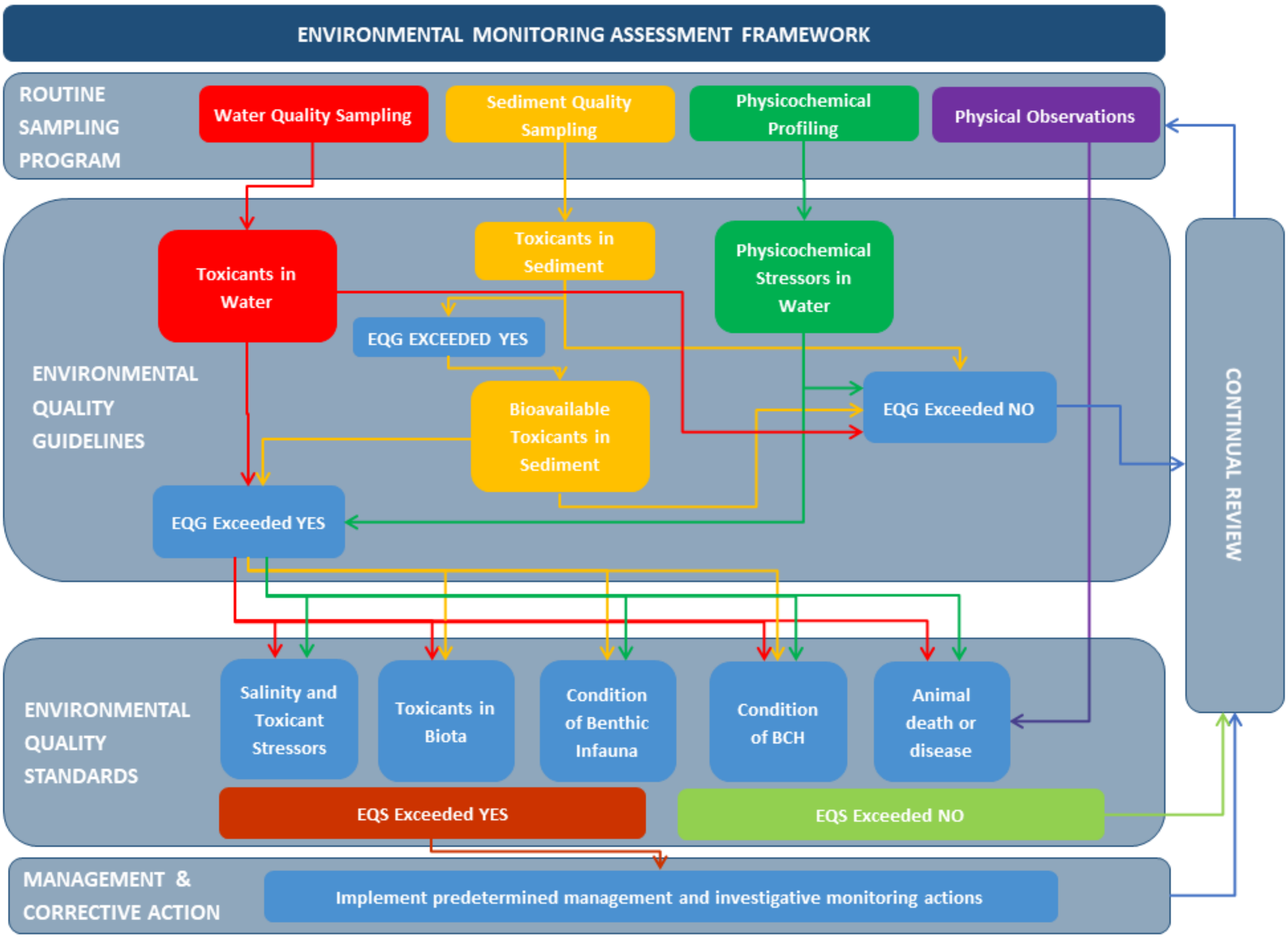

Figure 6-7 Routine Marine Environmental Quality Monitoring and Assessment Framework

Sampling Methodology

Toxicants in Biota

Bioaccumulation is a late stage testing and monitoring methodology within the phased approach described in **Figure 6-7**. The objective of monitoring is to determine if toxicants are bioaccumulating at a rate that could affect marine life and/or result in seafood being not safe for human consumption.

Initially, a desktop study will be to determine the likelihood/risk of contaminant bioaccumulation across the Project study area. The desktop study will review the concentrations of any contaminant that has exceeded the bioavailable EQSs and whether or not the contaminant is likely to bioaccumulate in locally relevant species. Guidance procedures and assessment for bioaccumulation testing will follow Simpson *et al*. (2005) and Simpson *et al*. (2008), and in the ASTM International guide E1688 (2016), *Standard Guide for Determination of the Bioaccumulation of Sediment-Associated Contaminants by Benthic Invertebrates*.

One or both of the following methods will be used for monitoring toxicants in biota, as appropriate:

> Field collected and caged/transplanted organisms; and
> Laboratory bioaccumulation test sampling.

Direct field collected and caged/transplanted organisms involve measuring any toxicants accumulating in tissues of organisms at the affected site and comparing with the same species in one or more suitable reference sites. Field collected samples rely on existing information on the concentrations of contaminants that have exceeded the relevant EQSs prior to the detection of elevated levels, whereas caged/transplanted organisms involves the deployment of relevant species (usually filter-feeding bivalves) at the affected and reference sites to measure the change in the contaminants that have exceeded the relevant EQC over time. An appropriate gut depuration interval is generally required (typically 24 hours) prior to analysis although the specific requirements should be discussed with the laboratory.

Laboratory bioaccumulation tests generally run for 28 days and use several test species. At least two bioaccumulation tests should occur, preferably on a bivalve mollusc and burrowing polychaete (Simpson *et al*., 2005). The requirements for these species are similar to toxicity testing in that each species should provide adequate biomass for analysis, ingest water/sediments and be efficient metabolisers of contaminants. However, the organisms do not need to be sensitive to the contaminants that are under investigation for bioaccumulation potential.

The location, nature and frequency of reactive monitoring required will be tailored on advice from appropriate specialists for the collection of the appropriate information required to inform any management responses to specific exceedance events. Monitoring sites will target areas of concern, with the inclusion of extra reference sites and the duration of reactive monitoring is likely to be acute. Consideration will be given to the utilisation of historical data as well as physical and chemical sediment data.

For any contaminant where bioaccumulated concentrations are statistically greater than that measured in the controls, an investigation into the source of the contaminant will be conducted. Where environmental and public health risks are identified as a possibility, the appropriate government agencies will be notified accordingly.

Benthic Communities and Habitat

BCH monitoring is a requirement of ongoing monitoring associated with the Mardie Project. BCH monitoring is described within the Mardie Operational Environmental Management Plan currently under development) (MOEMP).

Please refer to this document for further details and specific information related to monitoring BCH.

Where relevant EQGs are exceeded BCH monitoring data captured under the MOEMP will be evaluated against the EQSs presented in **Table 6-12**. If required, additional sampling may be implemented in circumstance where routine BCH monitoring results are not adequate to allow assessment against the EQS. Additional monitoring will be conducted in accordance with the methods detailed within the MOEMP, however additional sites or other variations as required for assessment against the EQS will be considered prior to the sampling occurring.

Benthic Infauna

Benthic infauna sampling will be conducted in accordance with the methods and at the sample locations presented within **Section 6.2**.

Data obtained during the sampling will be assessed against the EQS presented in **Table 6-12.**

Salinity and Key Toxicants in Bitterns

Water sample collection will be conducted in accordance with the methods outlined within **Section 6.2** at the MEPA/HEPA boundary (MMB1-8) and HEPA (MH1-4) sampling sites. Laboratory analysis will be undertaken by a NATA accredited laboratory with the analytical suite sufficient to address each of the final toxicant and salinity EQSs (as determined during Phase III).

Animal Deaths and Disease

Records of animal deaths or disease will occur primarily from the following sources:

- Physical observations undertaken during routine sampling programs; and
- Any reported incidents from operation or Project related personnel.

Any animal deaths or disease will require investigation in accordance with the contingency management procedure outlined below.

Data Assessment and Reporting

Data Validation

All data will be validated prior to the release of any monitoring and assessment reports. Data used or otherwise presented in the reports is to be checked and verified against raw data logs and laboratory reports.

Quality Control

An assessment of quality control data needs to be undertaken and included in all reports including:

- Assessment of field contamination (rinsate, transport blank and method blank);
- Assessment of field variability (duplicate and triplicate);
- Assessment of lab variability (triplicate); and
- Laboratory QA/QC results.

Data Assessment

Laboratory samples and in-situ results will be compared with the management triggers as soon as practicable to ensure that the appropriate reactive monitoring programs are implemented as soon as practicable if any EQGs are exceeded.

Elevated results will be assessed in accordance with **Figure 6-8** to determine the level of management actions or investigative monitoring required.

Reporting

An investigation report will be compiled in accordance with BCI Minerals Environmental Management System for any elevated results which requires management response in accordance with **Figure 6-9**. Submission to the regulator will be subject to project approval conditions.

A comprehensive report will be developed at the completion of each monitoring round which will include, but not be limited to:

- Summary of the methods applied and any deviations from this MEQMMP;
- Timeseries graphs of physicochemical water column profiles;
- A table summarising laboratory analysis results;
- Timeseries graphs of laboratory analysis results;
- An assessment of all data collected against management triggers;
- A review of management trigger exceedances investigations and remedial actions implemented; and
- Any actions or recommendations required as a result of field implementation of the SAP and assessment of monitoring data.

Contingency Management

In the event that Project related operational activities result in an exceedance of the defined management triggers, a tiered risk-based investigative monitoring program will be required as defined within **Figure 6-8. Figure 6-9** provides the management contingency actions required.

Firstly, depending upon the exceedance, an investigation needs to be undertaken to determine the cause(s). Due to the nature of the monitoring program potential causes can be isolated from the following four point sources:

1. Bitterns discharge water quality;
2. Offshore Port and shipping related activities;
3. Onshore vessel related activities (Mardie Creek HEPA); and
4. Seawater abstraction and related activities (Peters Creek HEPA)

Once the cause(s) is determined then appropriate corrective or preventative actions need to be put into place to ensure re-occurrence does not occur. This system of investigation and implementation of remedial actions will ensure that optimal environmental performance continues through the lifecycle of the Project.

In the event of an EQS exceedance, the CEO of DWER will be notified and a report provided to the CEO within 3 months describing any subsequent investigations, management actions put into place and success of the actions in returning marine environmental quality to within requirements.

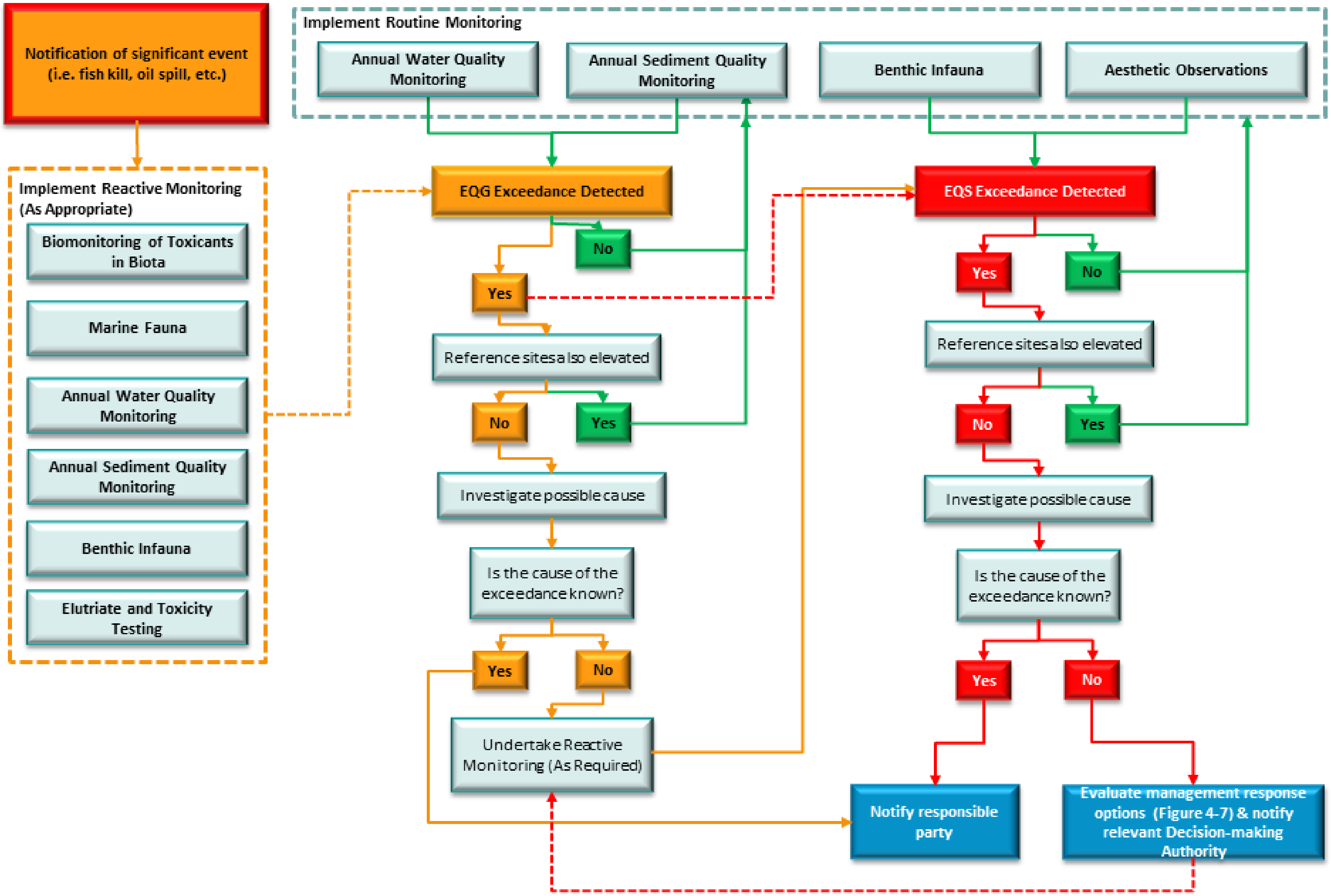

Figure 6-8 Management Response Framework for assessment of required action from routine and investigative monitoring programs

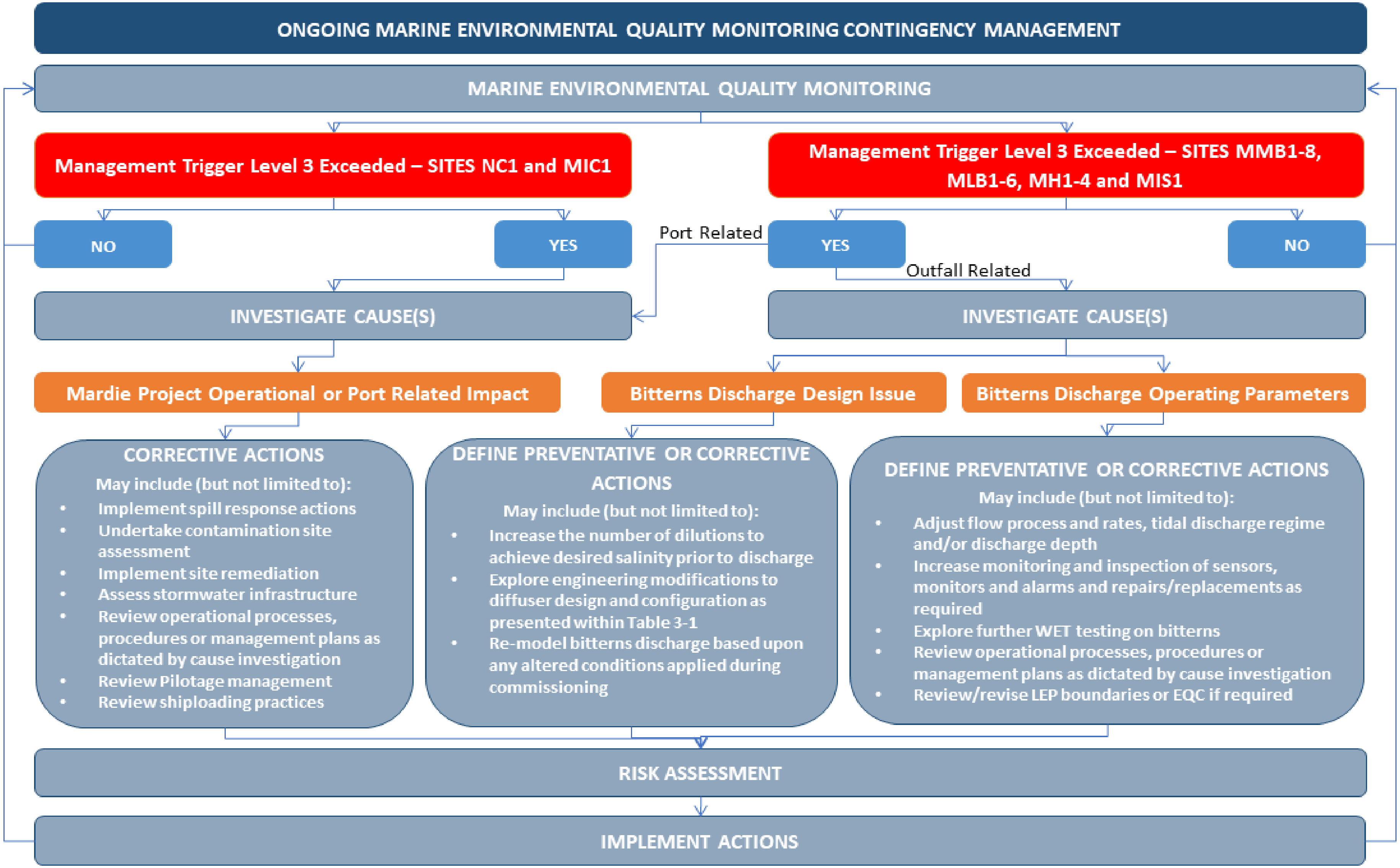

Figure 6-9 Ongoing Marine Environmental Quality Monitoring Contingency Management Actions

7. Review

This MEQMMP is a living document and will be regularly reviewed in accordance with **Table 7-1** to ensure it remains relevant to the Project and aligns with industry best practice.

Table 7-1 MEQMMP review timeframes for the Project lifecycle

Timing	Rationale
Scheduled Review	
Upon receipt of Approval Conditions	Ministerial Statement approval conditions obtained will necessitate a comprehensive review of this MEQMMP to ensure all relevant aspects are covered within this Plan to ensure compliance.
Upon completion of Baseline Data Assessment	This review is required to derive the site specific EQCs for the ongoing assessment of Project impacts, along with any other findings that require update upon completion of the baseline data collection phase.
Upon Completion of Commissioning	This will typically be required to update management triggers associated with the discharge design for the bitterns wastewater.
Upon Completion of Validation assessment	A comprehensive review of the LEPs and EQC will be required based upon data obtained during this phase. A comprehensive review of the entire MEQMMP will be required to ensure adequacy for management of the ongoing MEQ with respect to the final operational Processing Facility.
Annually during routine operations	At the completion of annual reporting requirements any recommendations for alteration of the MEQMMP will need to be incorporated into a revised version suitable for the next 12 months of operations.
Ad-Hoc Review	
Any time operational activities significantly alter	Operational changes to the project may result in an altered risk profile. Therefore, the MEQMMP will require a review to ensure that it remains fit-for-purpose for altered operational conditions.
Any time Bitterns discharge quality or regime alters	Process or design alterations changes to the bitterns discharge may result in an altered risk profile. Therefore, the MEQMMP will require a review to ensure that it remains fit-for-purpose for altered operational conditions.

During review of the MEQMMP consideration should be given to (but not limited to):

- Overall effectiveness of the Plan;
- Appropriateness of EVs, EQO and LEPs;
- To refine EQC with compiled baseline data set;
- New threats to MEQ that may be identified;
- Lessons learned during sampling or analysis;
- Changes in industry best practice;
- Changes in environmental risk; and
- Any changes in methodology or equipment used.

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