Adelaide Outer Harbor Channel Widening Project: Environmental Monitoring Program

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Definitions and Abbreviations

B_1	Background (or control) water quality monitoring location
BACI	Before and After Control Impact. A method of evaluating impacts in receiving environments. Predicted monitoring sites are monitored before and after a planning activity to infer what impact have occurred as a result of the activity.
BHD	Backhoe Dredge
D_1, D_2	Water quality monitoring locations
DA	Development Assessment
DEM	Digital Elevation Model
DMP	Dredge Management Plan. A plan that details the scope, methodology and incident response processes during dredging activity.
DMPA	Dredge Material Placement Area
EMP	Environmental Monitoring Program. A plan that details monitoring to be undertaken prior to, during and post dredging.
Environmental Representative	Flinders Ports appointed Environmental Representative, responsible for monitoring and overseeing environmental performance of Dredge Contractor during dredging
EPA	Environmental Protection Authority
FP	Flinders Ports Pty Ltd
LAT	Lowest Astronomical Tide
NTU	Nephelometric Turbidity Unit. A measurement of turbidity, or the concentration of suspended particles in a water sample.
OHCW	Outer Harbour Channel Widening, the 'project'
PAR	Photosynthetically Active Radiation. A method to measure light availability for photosynthetic organisms (i.e. seagrass) facing impacts
SHB	Split Hopper Barge
THSD	Trailer Suction Hopper Dredge

TSS	Total Suspended Solids. A measurement of the dry-weight of suspended particles in a sample of water.
ZVMP	Zone Validation Monitoring Plan
WQMP	Water Quality Monitoring Plan – the method for monitoring water quality during dredging

1 Introduction

The Port of Adelaide is the primary port in South Australia, located at Outer Harbor (approximately 14km west of the Adelaide CBD) in South Australia (Figure 1-1). The port is operated by Flinders Ports and handles a diverse array of inbound and outbound cargoes, contributing significantly to the State's economic activity. A significant amount of this trade is containerized, and Outer Harbor is the location of the Flinders Adelaide Container Terminal and the Port Adelaide Passenger Terminal which contribute significantly to South Australia's import and export of goods and visitors.

Flinders Ports Pty Ltd (FP) has identified the need to widen the existing shipping channel and swing basin at Outer Harbor in Port Adelaide. This is being driven by the emergence of Post Panamax class vessels which are wider than the 36m design vessel width of the existing channel and swing basin. Outer Harbor can only currently accommodate vessels up to a maximum width of 42.2m width with operational restrictions. The Port Adelaide Outer Harbor Channel Widening Project will enable the port to accommodate vessels with a maximum width of 49m without operational restrictions.

To meet this growth the existing channel will be widened by 40m to a total width of 170m. The swing basin will be widened from 505m to 560m. The widening footprint of the channel and turning basin are illustrated by the red line in Figure 1-1. The dredged material will be transported to a designated dredge material placement area (DMPA), located approximately 30km offshore in the Gulf of St Vincent (yellow box in Figure 1-2). This area is approximately 7km by 5km in size and located in deep water (>30m), thereby avoiding major shipping routes.

A detailed Development Application (DA) Report was submitted in July 2017 in accordance with the *Development Act 1993*, as a Section 49 application given this project is defined as *public infrastructure*. Sponsorship for this application was received from the Minister for Transport and Infrastructure prior to lodgement in May 2017. Flinders Ports DA 010/V048/17 received approval on 28th May 2018.

Flinders Ports has prepared this Environmental Monitoring Program (EMP) to comply with the requirements of the Dredge Licence issued by the Environmental Protection Authority (EPA) on the 12 March 2019 (#50556). As a condition of approval, the licensee (Flinders Ports) must develop an '*Environmental Monitoring Program (EMP) which must include a Zone Validation Monitoring Program, a Water Quality Monitoring Plan and the details required by Condition 3 of the Development Approval #010/V048/17*'.

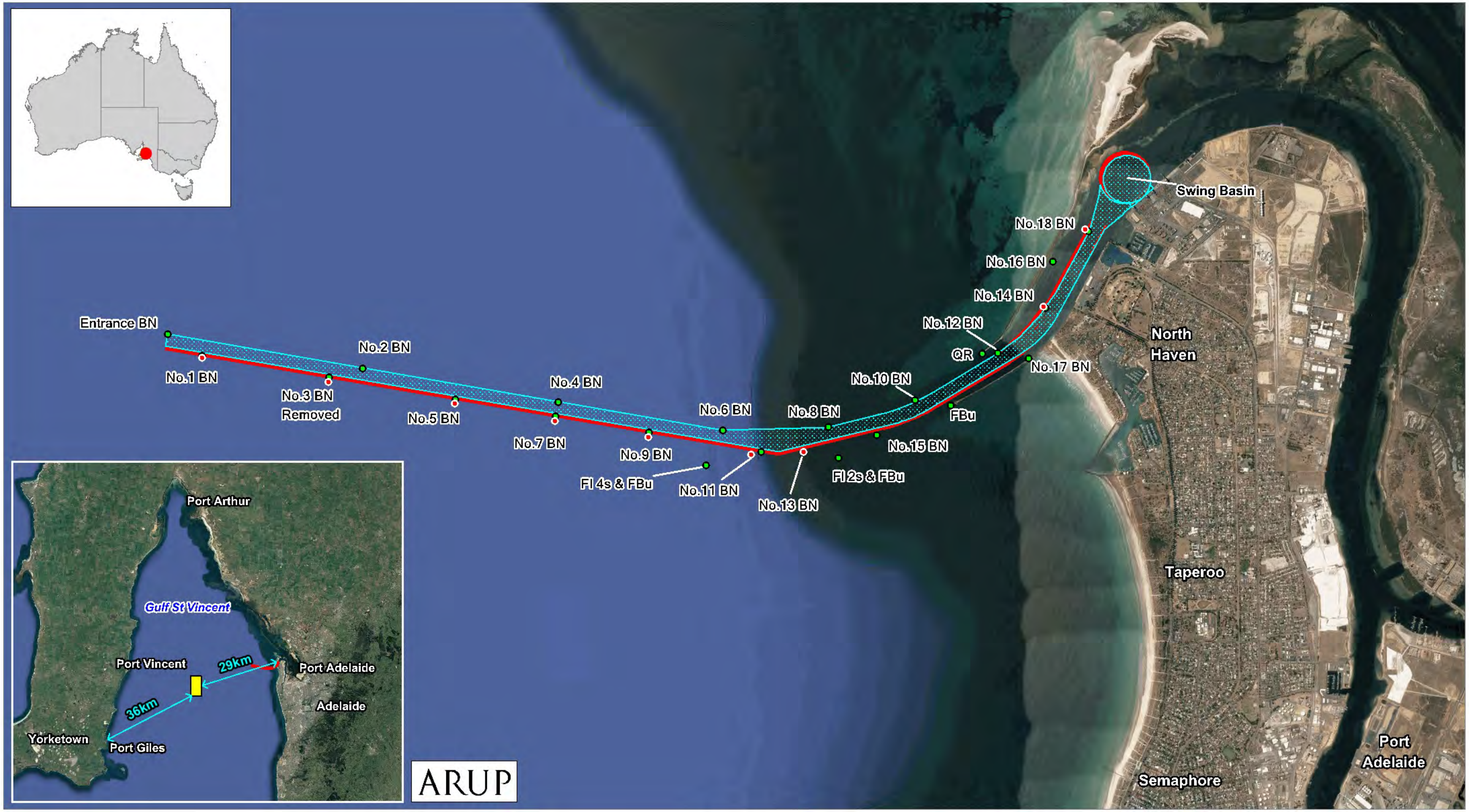
This document responds to the DA and dredge licence requirements, and documents environmental/water quality monitoring that will be undertaken pre, during and post dredge campaign.

This document should be read in conjunction with the Dredge Management Plan (DMP) prepared and approved for the project. The DMP documents all environmental management procedures and responsibilities during dredging activity.

It is anticipated that dredging activity will occur over a period of 3 months from the 1st June 2019.

Dredging will involve a combination of a Trailing Suction Hopper Dredger (TSHD) of 12,000m^3 hopper capacity and a Back-hoe Dredger (BHD) supported by 3,500m^3 hopper capacity Split Hull Barges

(SHB). The TSHD will be used to dredge the sandy/soft material. The BHD would be used to dredge mainly stiff clayey sands and cemented material unable to be handled by TSHD. Refer to the DMP for further details.



LEGEND

- New Location of existing Beacon
- Existing Beacon
- Dredge Material Placement Area
- Proposed Channel Widening Footprint
- Existing Channel Footprint

Title:

Project Location

Figure: **1-1**

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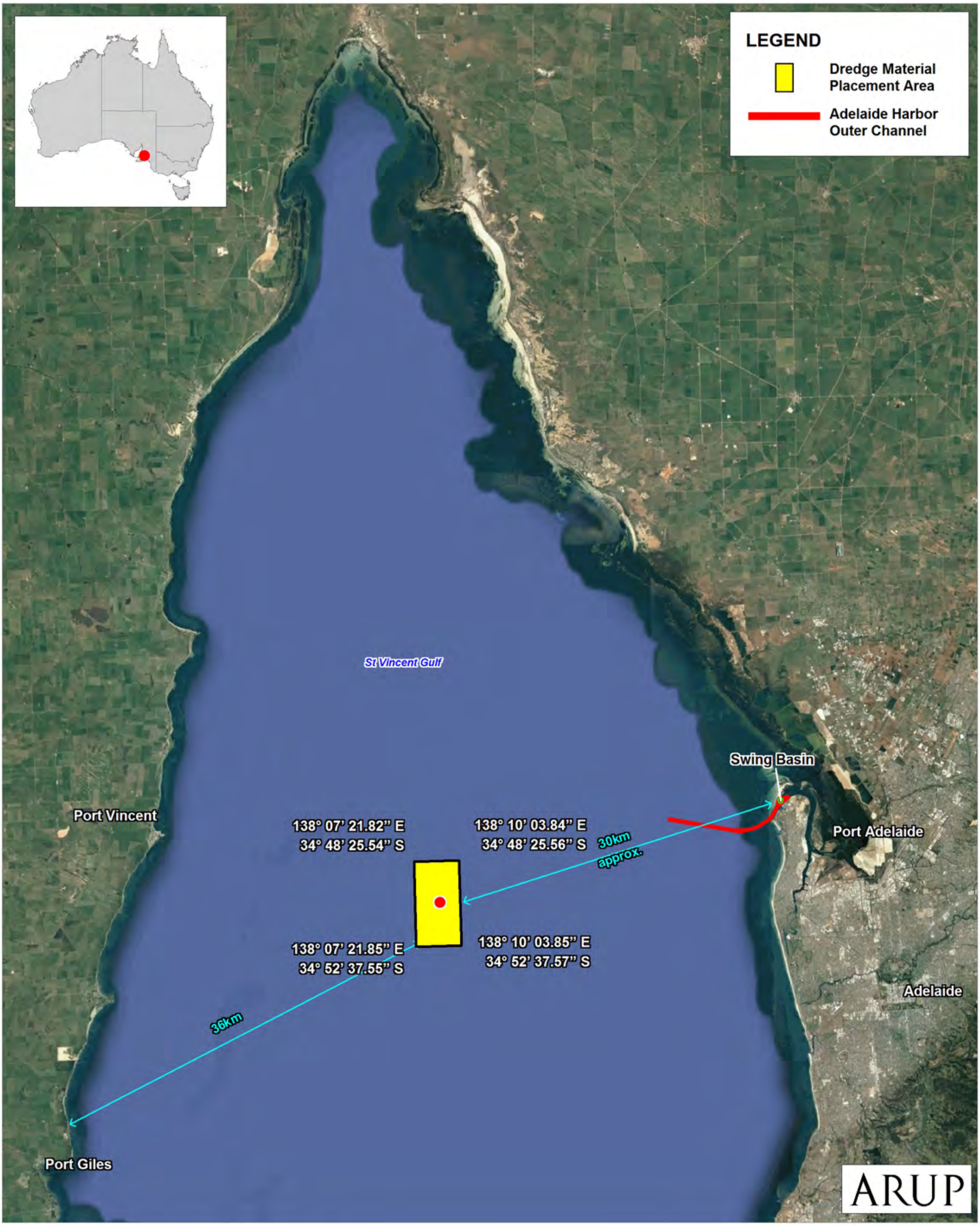

Title:
Dredge Material Placement Area

Figure: 1-2

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2 Purpose, Scope and Objectives

The purpose of the EMP is to identify the methodology for monitoring and validating modelled impacts of dredging for the OHCW Project, as

The objectives of this EMP are:

- To describe how conditions relating to environmental monitoring imposed by the DA approval and Dredging Licence will be addressed;
- To identify and outline environmental monitoring roles and responsibilities related to potential water quality and seagrass impacts; and
- To promote environmental best practice.

Day-to-day management of water quality during dredging is addressed in the DMP and will be performed by the Dredge Contractor.

2.1 Environmental Management Framework

Figure 2-1 shows the overall environmental management framework, which will be adopted during the OHCW Project.

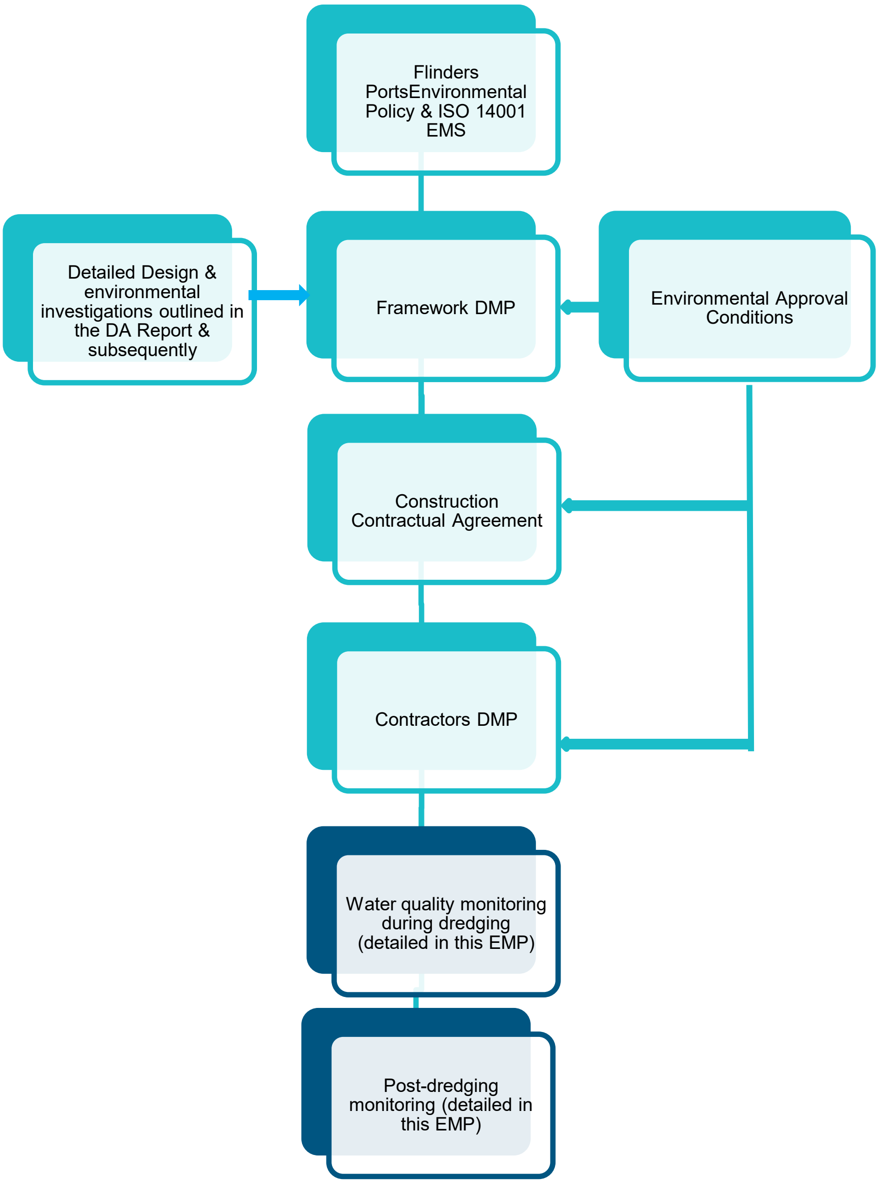


Figure 2-1 Flinders Ports Environmental Management Framework

2.1.1 Roles and Responsibilities

The principal entities and their roles and responsibilities under the EMP are as follows and detailed in Table 2-1.

Table 2-1 Roles and Responsibilities

Entity	Role
Flinders Ports	• Ensuring the dredge contractor has undertaken all necessary biosecurity inspections • Ensure all necessary plans or surveys have been approved by relevant approval agencies prior to dredging commencing (i.e. POMS Management Plan, EMP, pre-dredge seagrass survey) • Ensuring the dredge contractor has appropriate environmental management systems and reporting protocols in place • Providing a complaints hotline and responding formally to complaints received • Reporting any environmental incidences or approval non-conformances to relevant approval agencies • Complying with conditions of the issued Dredging Licence, as the licence holder.
Dredge Contractor	• Undertake all biosecurity inspections of vessels prior to them entering Australian Waters • Complying with all relevant legislation and approvals during dredging and placement operations • Undertake appropriate management actions to reduce turbidity when alerted of water quality triggers being reached • Assist FP and the Environmental Representative with reporting requirements • Assist FP and the Environmental Representative in investigating and responding to complaints received • Provide FP with a monthly dredge performance report • Notify FP and the EPA in the event of an environmental incident • Undertake and keep records of staff environmental awareness training • Prepare and comply with a detailed Dredge Management Plan that meets the objectives of the strategic DMP
FP appointed Environmental Representative	• Install, operate and maintain water quality monitoring equipment • Provide regular satellite images of dredge plumes to all relevant parties • Set up and maintain water quality data management website, including data processing and sending trigger alert alarms to the appointed dredge contractor • Undertake minimum monthly environmental performance audits (or more frequently, if required) • Prepare monthly and post-dredging reports for FP and regulators • Undertake pre/during/post biological surveys required (including seagrass and POMS surveys)

2.1.1.1 Flinders Ports

Flinders Ports Pty Ltd is the proponent and overall project administrator of the OHCW Project. They will have responsibility for appointing a representative to undertake the water quality and seagrass monitoring detailed in this EMP. Any legislative/licence breaches will be reported to the EPA (or other approval entities, as necessary) by FP.

2.1.1.2 Flinders Ports Environmental Representative

The Environmental Representative will be responsible for carrying out monitoring as detailed in this EMP and reporting findings to relevant parties within the nominated timeframes i.e. FP and Dredge Contractor.

2.1.1.3 Dredge Contractor

The Dredge Contractor is responsible for implementing management actions to reduce turbid plumes in the event that water quality monitoring exceeds licenced 'Alarm' or 'Hold' triggers.

2.1.2 Surveys, Monitoring and Reporting

A number of surveys and reports are required to be undertaken prior to, during and post-works as a condition of approvals. These are detailed in Table 2-2 below.

Table 2-2 Dredge Campaign survey and reporting requirements

Item	Content	Responsibility	Relevant Document	Relevant Approval	Approving Authority
Prior to the Commencement of Works					
Baseline water quality monitoring	12 months of monitoring to set final water quality triggers	Environmental Representative	EMP	-	EPA
Seagrass Survey	Methodology for BACI measurement of seagrass before dredging	Environmental Representative	EMP	U-988, Condition 3.3.2 (Dredge Licence)	EPA
Dredge Management Plan	Management procedures to minimise environmental impacts during dredging	Flinders Ports/Dredge Contractor	DMP	U-994 (Dredge Licence)	EPA
Survey for the presence/absence of C. taxifolia	Survey report	Environmental Representative	DMP	U-994, Condition 3.2.1b (Dredge Licence) and 4g (DA)	EPA

Item	Content	Responsibility	Relevant Document	Relevant Approval	Approving Authority
POMS Management Plan	POMS Management procedures	Flinders Ports	POMS Management Plan	U-988, Condition 2.9.1	EPA
Biosecurity Inspection Certificate	Inspection records	Dredge Contractor	DMP	U-994, Condition 3.2.4c (dredge licence)	EPA
Biofouling Management Plan	Plan consistent with IMO standards	Dredge Contractor	DMP	U-994, Condition 3.2.4a (dredge licence)	EPA
Bathymetric Survey	Survey	Dredge Contractor	-	U-998, Condition 3.3.2 (dredge licence)	EPA
During Works					
Zone Validation Monitoring Program	Satellite imagery to show the relative plume extent at a given time	Environmental Representative	EMP	U-990 (dredge licence)	EPA
Water Quality Monitoring Plan	Monitoring at three approved locations	Environmental Representative	EMP	U-991 (Dredge Licence) and Condition 4b (DA)	EPA
Water quality data processing and real-time information website	Post data collection processing and website maintenance	Environmental Representative	EMP	U-991, Condition 3.4.2e (dredge licence) and Condition 4b (DA)	EPA
Monthly Zone-validation reporting	A method for validating predicted hydrodynamic modelling and impact zones	Environmental Representative	EMP	U-990, Condition 3.5.2a (iv) (Dredge Licence)	EPA
Vessel-tracking	GPS vessel tracking to publicly document vessel locations	Dredge Contractor	DMP	U-996, Condition 2.8.1 and 2.8.2 (Dredge Licence)	EPA

Item	Content	Responsibility	Relevant Document	Relevant Approval	Approving Authority
Post-works					
Seagrass monitoring	Post (in April, 2020) and 2 years post seagrass monitoring (in April 2022)	Environmental Representative	SMP	U-998, Condition 3.3.2 (Dredge Licence	EPA

A separate Closure Plan will also be prepared, in accordance with Condition U-995. This will include a description of completion tasks, including post-dredging bathymetric surveys and seagrass monitoring (as described in the table above, and the Seagrass Monitoring Plan in Appendix A.

2.1.3 Auditing

The Environmental Representative will undertake audits at least monthly during dredging, and more frequently if required (i.e. non compliances recorded). The audit must be conducted in accordance with *International Standard 14001: Environmental Management Systems* protocols; an auditing scope and schedule will be developed for each audit and will be expected to include:

- General observations of status of environmental controls for the project;
- General environmental management measures are in place and actively managed e.g. training records, registers etc;
- Monitoring and measurement results during the audit period;
- Compliance with legislative obligations, including conditions of approval;
- Compliance with the requirements of the DMP;
- On-site environmental management controls are effective in managing environmental risk and are being maintained;
- Non-conformances are being identified and recorded;
- Appropriate corrective actions are being undertaken in the event of non-conformances;
- Relevant records are being maintained e.g. marine mammal observations; and
- Opportunities for improvement.

3 Environmental Impact Assessment

3.1 Dredge Plume Modelling

A dredge plume was modelled to predict the dredging related Total Suspended Solids (TSS) concentrations above the ambient conditions.

Above ambient plume concentrations have been presented in NTU as baseline water clarity monitoring and hence impact level limits are most commonly measured in NTU. Depth-averaged turbidity values are presented since they are most relevant to assessing ecological impacts due to the reduction in seabed Photosynthetically Active Radiation (PAR).

Dredging related above ambient sediment deposition rates have been derived from the daily rate of change in bed sediment mass and are expressed in units of $mg/cm^2/day$. Total net deposition at the end of the project has also been derived and is expressed in mg/cm^2.

3.1.1 Turbidity Percentiles

In order to represent the spatially varying exposure to dredge plume turbidity effects a statistical percentile analysis was applied to the model predictions of dredging related turbidity. The methodology for deriving the turbidity percentiles is described in BMT (WBM 2017a).

Turbidity percentiles for the selected dredging scenario are shown in Figure 3-1. The acute exceedance level 95^{th} percentile (worst case) is shown on the left and the chronic 50^{th} percentile exceedance level 50^{th} percentile on the right.

3.1.2 Sediment Deposition

In order to represent the spatially varying exposure to dredge plume deposition effects a statistical percentile analysis was applied to the model predictions of dredging related sediment deposition. The methodology for deriving the turbidity percentiles is described in BMT (WBM 2017a).

Sediment deposition rate percentiles for the dredging campaign are shown in Figure 3-2, and take account of the Dredging Contractors methodology for works. The acute exceedance level (95^{th} percentile) is shown on the left and the chronic exceedance level (50^{th} percentile) on the right. The final distribution of net sediment deposition at the end of the selected dredging scenario is shown in Figure 3-3.

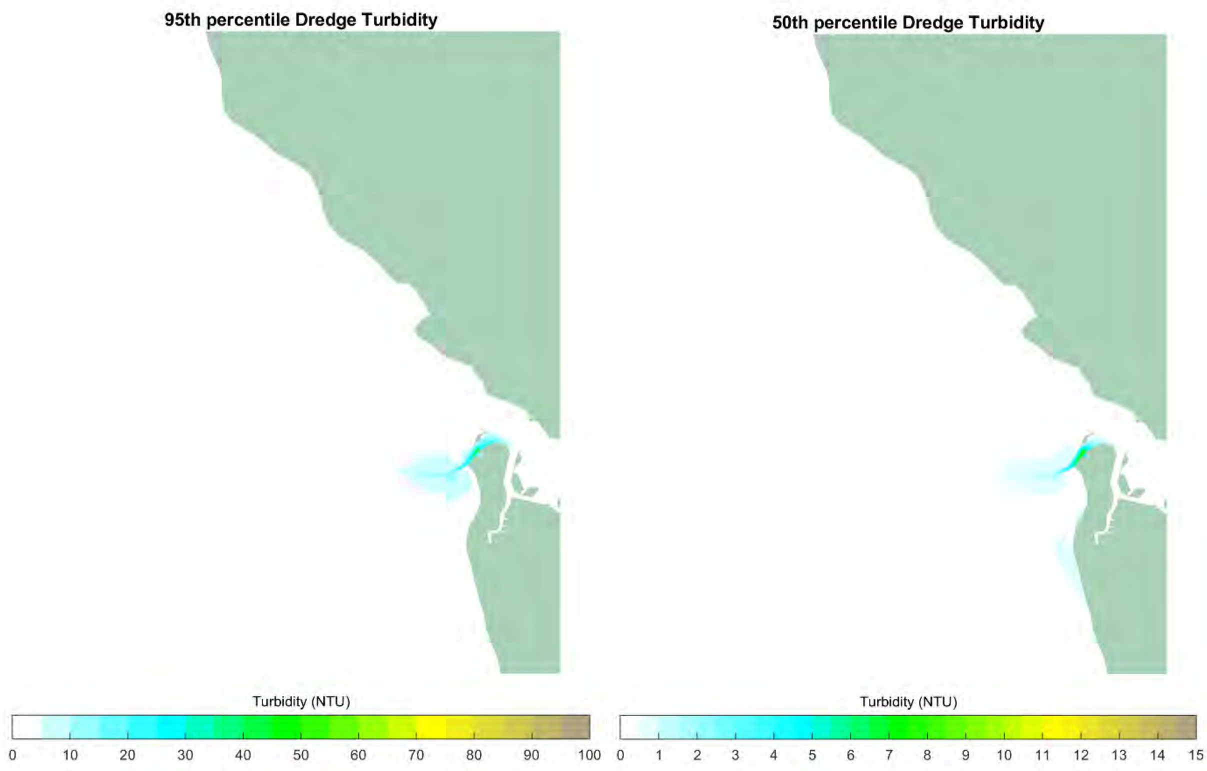


Figure 3-1 Turbidity Percentile Contours. Acute 95th Percentile (Left); Chronic 50th Percentile (right).

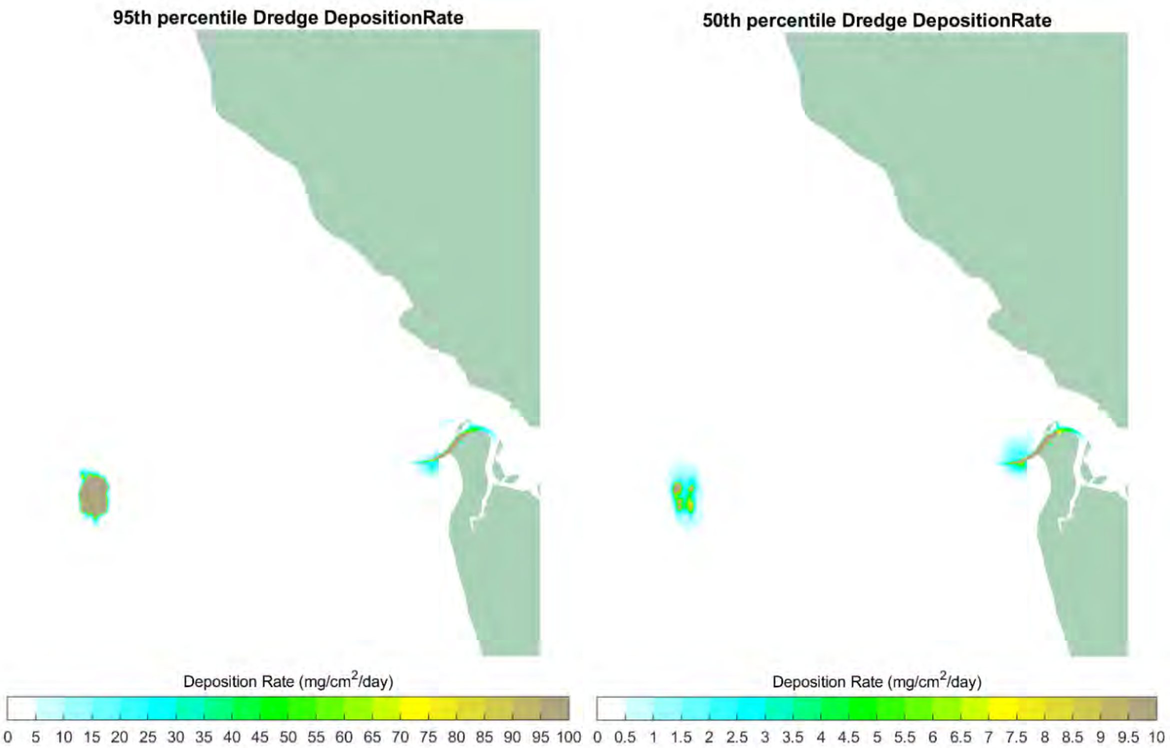


Figure 3-2 Sediment Deposition Rate Percentile Contours. Acute 95th Percentile (left); Chronic 50th Percentile (right).

Figure 3-3 Final Net Sediment Deposition Contours.

3.2 Seagrass Survey

A seagrass survey was undertaken in April 2017, using towed video transections at 30 sites both within the predicted modelled zone of impact and at control sites. At some sites where the water quality was poor or there were more cryptic species of seagrass encountered, a Van Veen grab sampler was used to collect samples of the seabed to confirm classifications made from the video imagery. Georectified remote imagery was used in combination with a high resolution digital elevation model (DEM) to calculate the benthic reflective index and map habitat classifications on a broad scale.

Classification categories in Table 3-1 were broadly based on previous classifications produced by EPA (2013a) and a visual estimate of seagrass cover in-line with EPA (2013b):

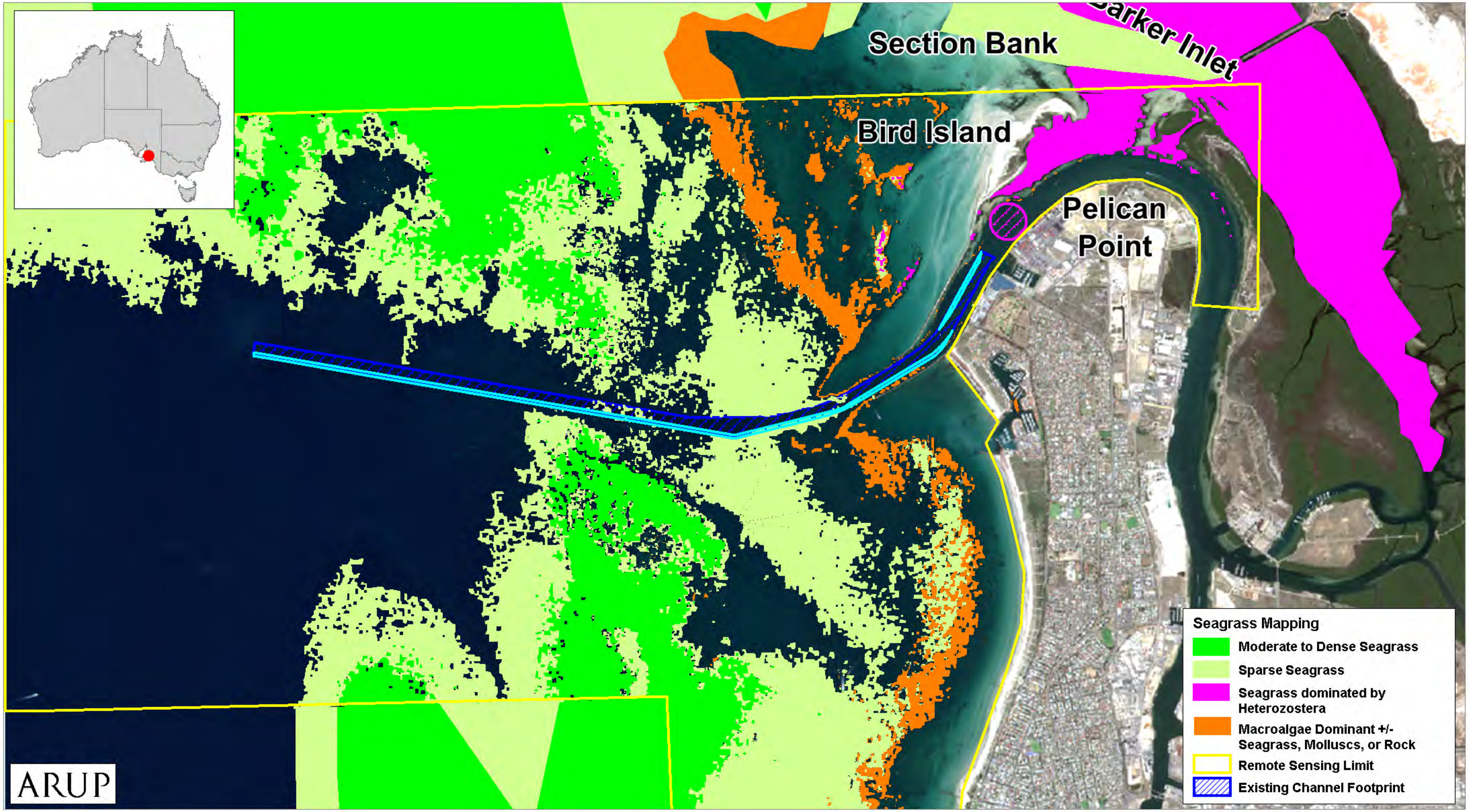
- Sparse –35% seagrass coverage.
- Moderate 35–70% seagrass coverage.
- Dense 70–100% seagrass coverage.

Table 3-1 Habitat classification categories

Classification category	Coverage	Notes
Moderate to dense seagrass	Moderate to dense (35–100%)	Amphibolis and/or Posidonia
Sparse seagrass	Sparse (1–35%)	Halophila australis and/or very sparse Posidonia
Seagrass dominated by Heterozostera	Moderate to dense (35–100%)	Based on unsupervised classification and past distribution (2011), not ground truthed during this study
Macroalgae dominant ± seagrass, molluscs or rock	n.a.	Macroalgae was generally associated with consolidated rock or razorfish Molluscs indicates razorfish cover between 10 and 50% Consolidated rock, where present, was generally low relief limestone reef covered in sparse to moderate macro or turf algae Sparse Halophila australis and/or Posidonia recorded between macroalgae habitat
Unconsolidated sand	n.a.	–

The main seagrass habitats observed in 2017 were large meadows dominated by either the perennial genera *Amphibolis* or *Posidonia*, or a mixed meadow of these genera (Seagrass sparse or Seagrass moderate to dense. Ephemeral seagrasses (e.g. *Halophila australis*) were present throughout the study area, particularly in water depths between 6 and 13 m below Lowest Astronomical Tide. Ephemeral seagrasses were difficult to map as they were only present in low densities (0–35%) and often interspersed with low density *Posidonia* spp., macroalgae, wrack or razorfish with macroalgal cover. However, areas previously mapped as unconsolidated bare substrate adjacent to the offshore shipping channel were mapped as sparse seagrass cover, mainly *Halophila australis*, in 2017. There were also small patches of parse (0–35%) seagrass cover (mainly *Halophila australis*) within the shipping channel.

A Seagrass Monitoring Plan is provided in Appendix A.



LEGEND

- Existing Channel Footprint
- Swing Basin Footprint
- Channel Widening Footprint

Title:

Seagrass Mapping April 2017

Figure: **3-4**

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3.3 Water Quality Risk Assessment

3.3.1 Methodology

A water quality risk assessment methodology was applied to the project, using the outputs from the predictive dredge plume numerical model (Refer to Section 3.1 for further detail). Impact predictions are presented as 'zones of impact', which is now recognised as 'best practice' in dredging environmental assessments and are commonly used in environmental assessments of dredging projects in Australia, building on the methodologies set out in the dredging environmental assessment guidelines produced by the Western Australia Environmental Protection Agency (WA EPA) (2016).

The zones adopted for the water quality risk assessment, include the following:

- Zone of High Impact = water quality impacts resulting in predicted mortality of ecological receptors with recovery time greater than 24 months.
- Zone of Low to Moderate Impact = water quality impacts resulting in predicted sub-lethal impacts to ecological receptors and/or mortality with recovery between 6 months (lower end of range) to 24 months (upper end of range).
- Zone of Influence = extent of detectable1 plume, but no predicted ecological impacts.

It is important to note that the recovery times outlined for the various zones should be considered as indicative only, noting that such timeframes are dependent on a range of factors that are extremely complex and difficult to accurately predict. The zones and their 'recovery timeframes' represent a means for comparing the likelihood that significant, detectable impact to sensitive receptors could occur, and are based on the assumption that recovery timeframes are dependent on the magnitude of impact.

A concept design of the zones of impact (sourced from WA EPA 2016) is shown in Figure 3-5.

In the DA report, an assumption was made that all seagrass would be lost immediately post-dredging within the zone of high and low to moderate impact, as a conservative measure. The tolerance of the seagrass species present within the study area and likely to be impacted by the dredge plume (largely *Heterozostera* sp. north of the inner channel) to light is one of the key determinants of species loss and recovery. Colonising /ephemeral species (such as *Heterozostera* spp.) are characterised by short turnover times (<months) and low physiological resistance to disturbances. However, ephemeral species can recover rapidly, in part due to high investment in sexual reproduction and the resultant ability to build up a seed bank (Erftemeijer & Robin Lewis 2006, Kilminster et al. 2015). Conversely, persistent/perennial species (such as *Amphibolis/Posidonia* spp.) have long turn-over (months–years) of growth units (i.e. rhizome, shoot and root), clonal vegetative growth and high physiological resistance to disturbance, but are slow to recover from disturbances (Kilminster et al. 2015).

Gils et al (2017) undertook a review of possible minimum light requirements for seagrass species present in South Australia on behalf of SA Water. It is suggested that Heterozostera spp. have an optimal light availability threshold of >20% Light (% of surface irradiance), over a 30 day rolling

[1] 'Detectable' plume in terms of detectable above background conditions by instrumentation deployed in the water column

average period. This is based on a literature review however and has not been field tested. Furthermore, the main area of predicted loss is in an intertidal area, which has complex light requirements in comparison to subtidal areas.

Seagrass surveys will be undertaken to identify changes to seagrass composition post-dredging, using a BACI method, as further explained in Section 4.

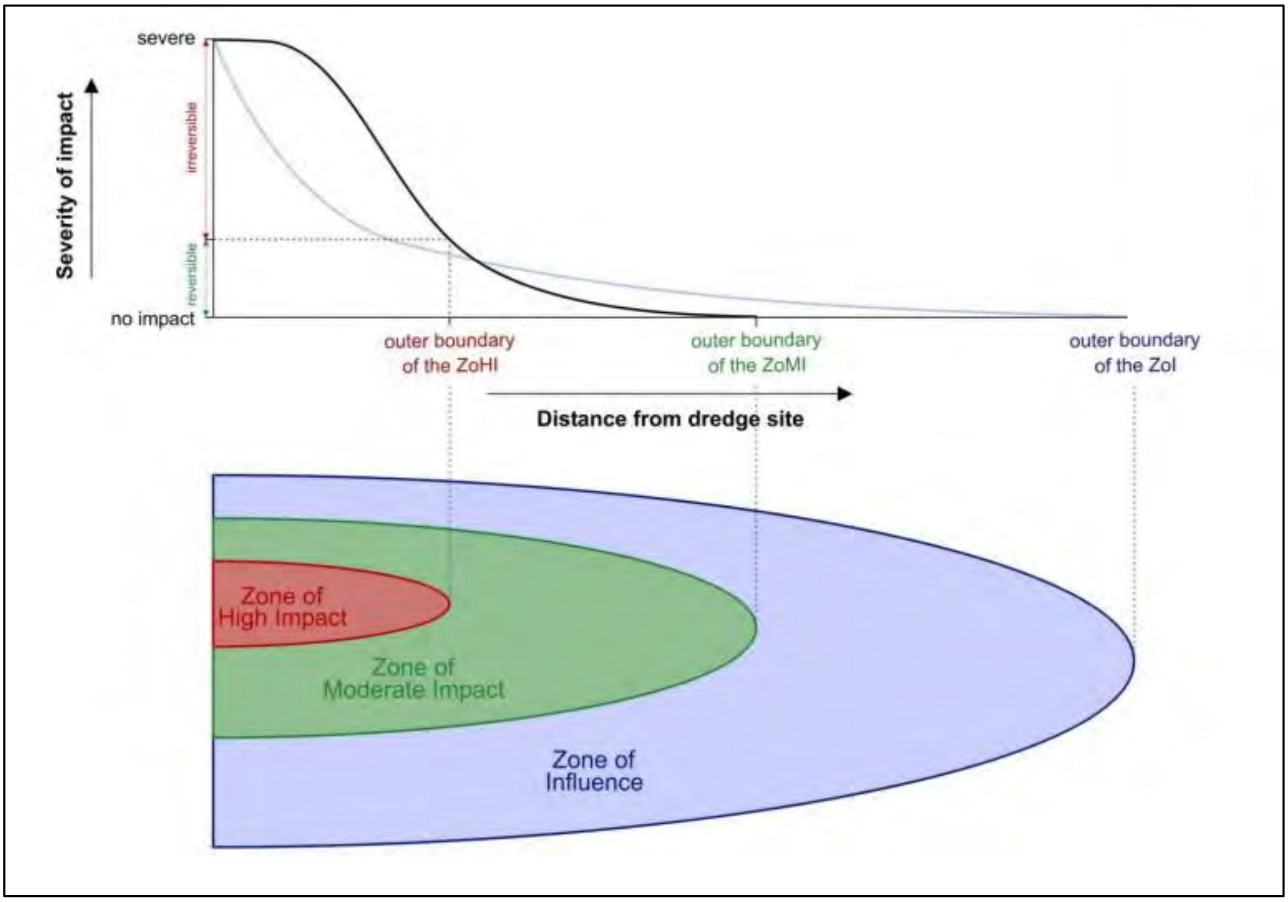


Figure 3-5 Concept design of impact zones (WA EPA 2016)

Derivation of the impact zones requires the selection of thresholds related to the excess turbidity and sediment deposition due to the dredging project (note that the 80th percentile is normally used for identifying thresholds as it is suited to identifying sensitive receptor impacts). In lieu of long-term continuous baseline data and site-specific literature values for the project area, turbidity threshold values were based on a combination of the following sources:

- DHI (2010) – thresholds based on excess suspended sediment levels (converted to turbidity) for a dredging project in low turbidity waters in Western Australia (Chevron's Wheatstone project).
- POTL (2016) – thresholds used for a dredging EIS in Queensland (Townsville Port Expansion), with different thresholds developed for turbid and low turbidity offshore waters, with the low turbidity thresholds relevant to this project (AECOM & BMT, 2016).

The adopted turbidity thresholds for this project are provided in Table 3-2.

Table 3-2 Impact thresholds for above ambient turbidity

Impact Zone	Turbidity (NTU) thresholds above background[2]			
Zone of High Impact	3	5	15	-
Zone of Low to Moderate Impact	1	2	5	-
Zone of Influence	-	0.5	2	5

The sediment deposition threshold values, also based on DHI (2010), are presented in Table 3-3.

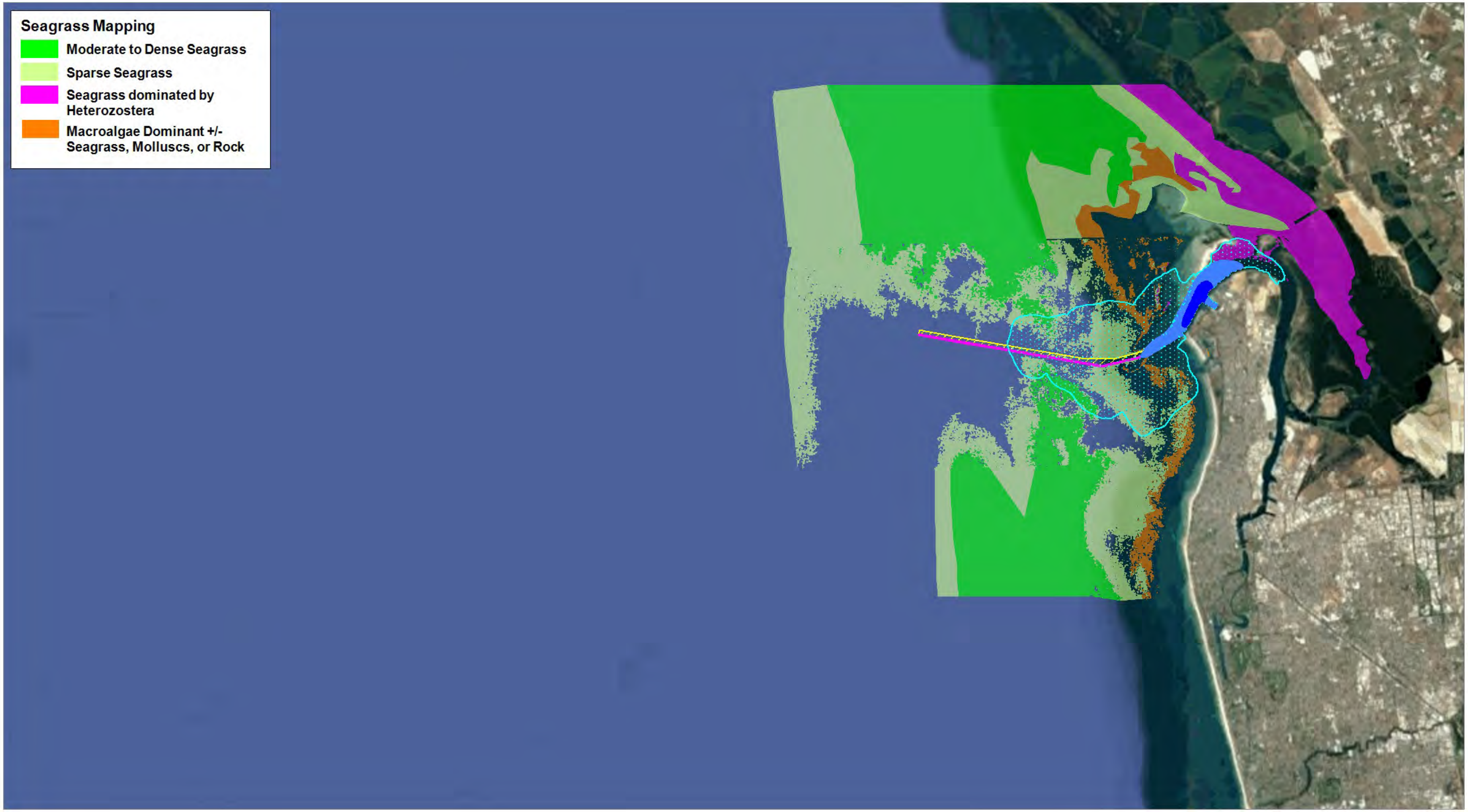
Table 3-3 Impact thresholds for sediment deposition (above background)

Impact zone	50%ile i.e. 15 days per month ($mg/cm^2/day$)	95%ile i.e. 1.5 days per month ($mg/cm^2/day$)	Final Deposition (mg/cm^2)
Zone of High Impact	>70	>700	>700
Zone of Low to Moderate Impact	20-70	200-700	200-700
Zone of Influence	3.0-20	30-200	30-200

3.3.2 Selected Case Risk Maps

The turbidity impact map for the selected case winter scenario is shown in Figure 3-6. The zone of low to moderate turbidity impact remains entirely within the Port River / Outer Harbor sheltered waters. The sediment deposition impact zone map is shown in Figure 3-7.

[2] Background is defined as turbidity measures in real-time during dredging at the background buoy (B1). Background measurements will be collected and report to provide an indication of whether turbidity is a result of dredging, or reflective of naturally occurring weather events.



Zones of Impact

- Zone of Influence (no ecological impact)
- Zone of Low to Moderate Impact
- Zone of High Impact
- Existing Channel
- Dredge Channel

Title:

Turbidity Zones of Impact - Selected Case (winter)

Figure: **3-6**

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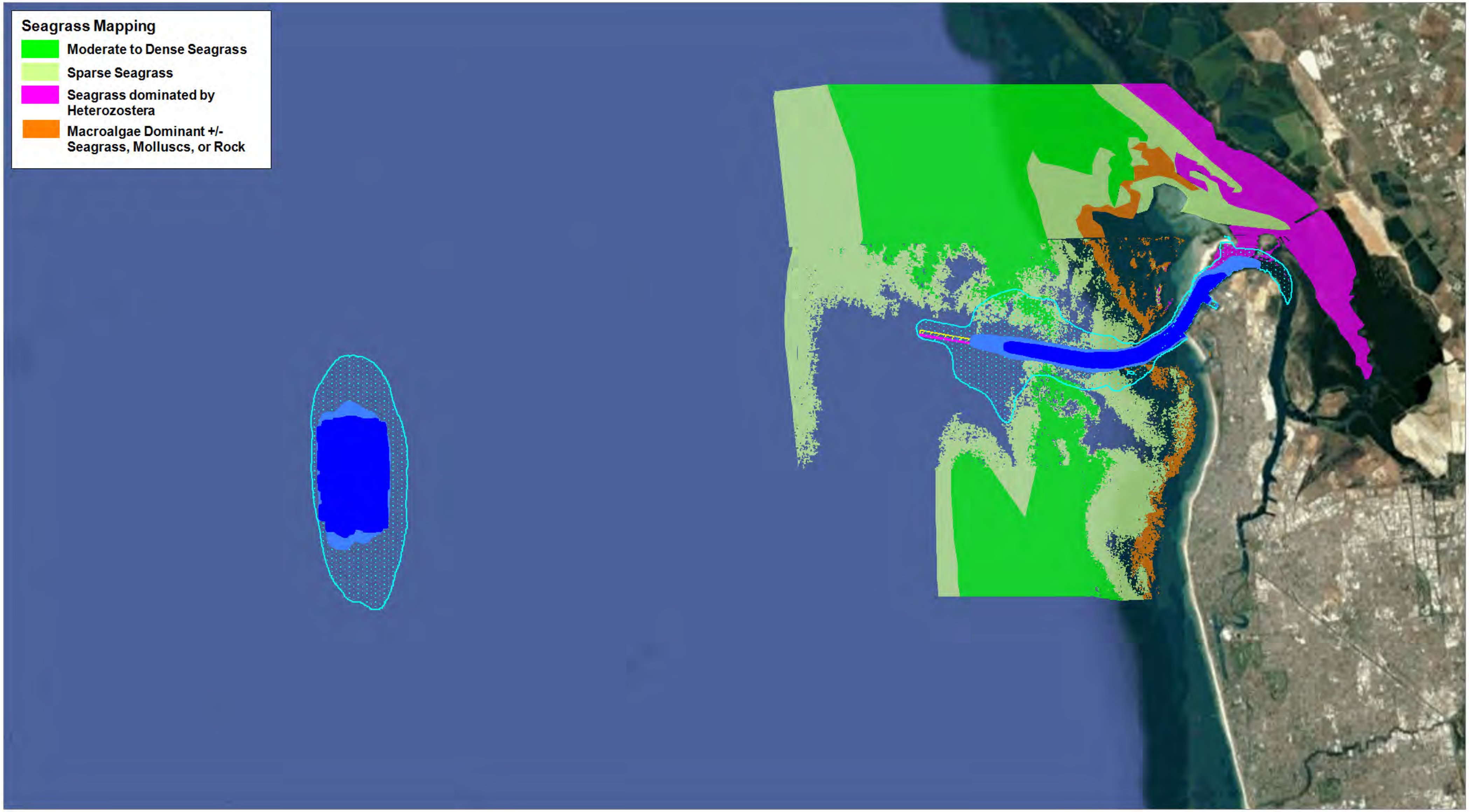

Zones of Impact

- Zone of Influence (no ecological impact)
- Zone of Low to Moderate Impact
- Zone of High Impact
- Existing Channel
- Dredge Channel

Title:

Deposition Zones of Impact - Selected Case (winter)

Figure: **3-7**

Rev: **A**

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4 Environmental Monitoring Methodologies

The following sections outline environmental monitoring methodologies, as required by the dredge licence (Refer to Table 2-2). Each strategy outlines the monitoring objective, approval requirement, methodology, timing, notifications and reporting.

4.1 Water Quality Monitoring Program

The OHCW Project team and Dredge Contractor have been evaluating the data, methodology and modelling outputs to determine an optimal management system to ensure compliance with the development approval conditions (DA 010/V048/17, 28th May 2018) and to demonstrate that this option satisfies in particular condition no: 2 "*the dredging methodology to be used must implement the 'no side-casting of the Cutter Suction Dredger (CSD)' option …..or similar method that can achieve an equivalent (or better) environmental outcome*".

Water quality testing will be undertaken by the Principal's Environmental Representative, with the key objective to measure water quality (turbidity and benthic PAR) at key sensitive receptor sites (seagrass communities) within the predicted zone of influence from dredge plumes from dredging (Refer to 4.1.1 for further information on the location of monitoring sites).

Monitoring involves a period of baseline data collection (almost 12 months) prior to dredging to assess baseline conditions and to finalise dredging limits. Monitoring will continue for the duration of the dredge campaign to ensure that dredge plumes do not adversely impact on water quality and sensitive receptors.

4.1.1 Monitoring Locations

Water quality monitoring will be undertaken at three (3) sites to collect water quality data as follows:

- Two 'dredge plume monitoring' sites – one site located to the north of the channel (D1) and one site to the south of the channel (D2). These sites would be located near to seagrass meadows and within the predicted zone of influence as indicated by dredge plume modelling.
- One 'background' site - located approximately 4.5 km from the channel dredging area, and representing background conditions.
- The proposed monitoring sites are included in Table 4-1 and shown in Figure 4-1. All three sites are located in a water depth of approximately -8 m LAT.

Table 4-1 Monitoring Sites

Site	Description	Approximate Coordinates	
		Latitude	Longitude
D1	Dredge plume monitoring site 1	34.7774°	138.4590°
D2	Dredge plume monitoring site 2	34.7997°	138.4750°
B1	Background site	34.8600°	138.4568°

Title:

Monitoring Location Sites

Figure: 4-1

Rev: A

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4.1.2 Parameters to be Monitored

The following parameters will be continuously measured (i.e. data logged every 10 minutes) during baseline and dredging phases:

- Turbidity - as measured by optical scatter via a nephelometer giving readings in Nephelometric Turbidity Units (NTU). Turbidity provides a proxy for suspended sediments within the water column.
- Photosynthetically Active Radiation (PAR) – benthic PAR measured on the seafloor to represent that part of the light spectrum that is available to benthic photosynthetic organisms (e.g. seagrass) to utilise. Terrestrial PAR will also be measured to provide an indication of light attenuation through the water column, making allowance for cloudy conditions.
- Dissolved oxygen, pH, salinity and temperature – water quality instruments at each site will be fitted with sensors to measure these parameters. To supplement the continuously logged data, and to give independent measures of turbidity, water samples will be collected at the three monitoring sites during servicing trips (approximately every three weeks) and analysed for the following parameters:
  - Total suspended solids;
  - Turbidity; and
  - Chlorophyll-a.

Water samples will be analysed at a NATA accredited laboratory, with results provided in monthly reports.

4.1.3 Monitoring Equipment

At each monitoring site, a water quality logger will be fitted with sensors designed for long-term deployments in the marine environment. These loggers will record turbidity, and be deployed using purpose-built monitoring buoys anchored to the seabed to maintain position. With the loggers installed in each monitoring buoy, the sensors will be located at a depth of approximately 1 m below the water surface. This allows telemetry and real-time access to data, and has the advantage that measurements would be available in real-time via the telemetered data feed and a web-based portal, which allows for continuous monitoring of data capture and quality.

Twin turbidity sensors will be deployed at each site during the dredging campaign, which will allow two independent data sources per site.

Benthic PAR sensors will be deployed at each monitoring site on a bottom-mounted frame. These sensors will measure light levels reaching seagrass beds. A terrestrial PAR sensor will also be deployed in a secure location at the Royal South Australian Yacht Squadron to collect surface PAR data. This sensor will be fixed to a structure (e.g. roof or post) in an unobstructed area in full sunlight, which can be accessed on a routine basis for data downloading and servicing.

Water quality loggers will provide continuous logging of data, with anti-fouling guards and sensor wiping apparatus to prevent interference to sensors from marine growth. Instruments will be programmed to log data once every ten minutes and report any exceedance of targets immediately to the Dredge Contractor for actioning.

Telemetry and other appropriate water quality monitoring equipment will also be installed to ensure dredging can be reactive within a timely manner and flag exceedances in real time. This data will be available to both the Dredge Contractor and the Principal's Site Representative, with alerts via mobile text message or email of any exceedance.

The 10 minute logged monitoring data will be downloaded and stored in a database. Monitoring data downloaded via telemetry (turbidity data) will be fed live onto a secure website for real-time viewing by key project personnel, including the Dredge Contractor, Principal's Site Representative, Flinders Ports staff and the EPA. This will allow the project team to immediately detect and where necessary respond to any water quality issues.

Real-time turbidity data (after undergoing QA/QC procedures and processed into rolling medians) will be made publicly available via Flinders Ports website.

4.1.3.1 Equipment Calibration

Water quality sensors (turbidity, pH, salinity, dissolved oxygen) will be calibrated regularly as per manufacturer's specifications. Calibration records will be kept and attached to monitoring reports.

Measurements at each buoy will also be cross-checked regularly (every 2-3 weeks during maintenance activity) using the following:

- A hand-held water quality instrument taking measurements adjacent to each buoy.
- Water samples collected adjacent to each buoy and analysed for turbidity.

4.1.4 Monitoring Timing

The duration of water quality monitoring will be as follows:

- Baseline monitoring - commenced in June 2018 and continued for a period of approximately 8 months until the end of February 2019.
- Dredge monitoring - undertaken for the duration of dredging, which will be for a period of approximately three months.

4.1.5 Turbidity

A responsive management program that utilises a series of turbidity trigger levels is to be used to achieve compliance with approval conditions. (and illustrated in Figure 4-2). Management actions that are to be undertaken sequentially as trigger levels are reached is illustrated in Figure 4-3 and further described in the DMP.

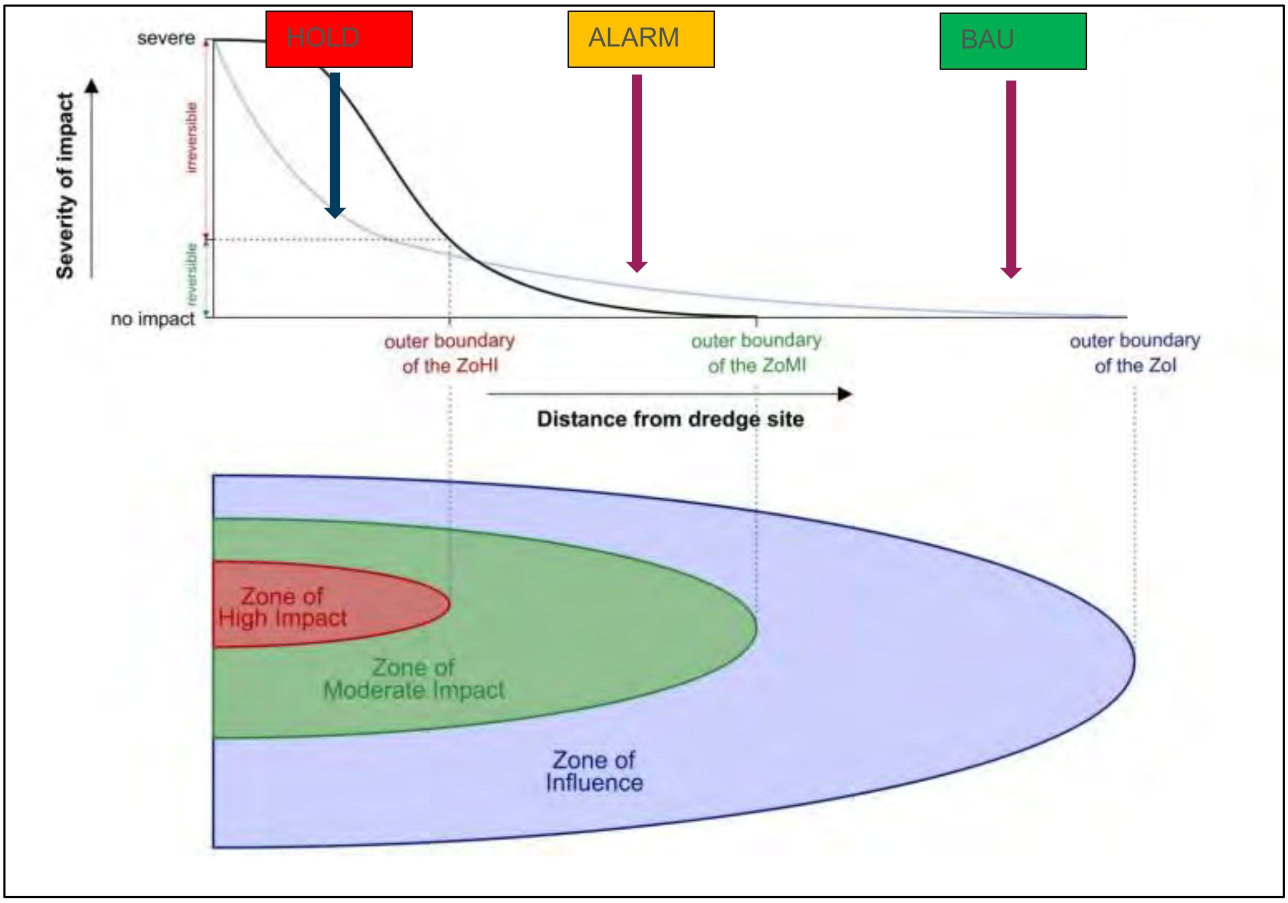


Figure 4-2 trigger levels (Alarm and Hold)

4.1.5.1 Level 1: Business as Usual

Turbidity levels remain below ALARM thresholds, dredging continues as planned with ongoing monitoring at all times.

4.1.5.2 Level 2: ALARM

Turbidity levels exceed either of the following thresholds requiring the implementation of management actions by the Dredge Contractor to reduce levels:

- 2.8 NTU based on a 15 day rolling median; or
- 5.8 NTU based on a 6 day rolling median.

Upon reaching the ALARM trigger level, the dredge contractor will implement management measures to reduce turbidity levels to return readings back down to Level 1 (Business as Usual). Specific actions are detailed in the DMP.

4.1.5.3 Level 3: HOLD

Turbidity levels exceed either of the following thresholds:

- 5.8 NTU based on a 15 day rolling median; or

- 15.8 NTU based on a 6 day median rolling median.

As mentioned in Section 6.2.3 of the DMP, BHD dredging may not be contributing to increased turbidity levels at the monitoring stations, since amount of spilled sediment is much lower than with a TSHD. If there is an exceedance of a HOLD trigger, the following will apply to the continued operation of the BHD:

- If there is no downward trend in the raw turbidity data after three hours (one quarter tidal cycle) then the BHD must cease dredging unless hand-held turbidity measurements confirm raw turbidity is below 5.8 NTU at 100 m from the BHD in each compass direction (N, S, E, W).
- Hand-held measurements will be taken every three hours to confirm turbidity is below 5.8 NTU at 100 m while HOLD trigger is exceeded if the BHD continues dredging.
- If hand-held turbidity measurements indicate that turbidity is higher than 5.8 NTU within 100 m of the BHD, then additional measurements will be taken at 500 m and 1,000 m from the BHD in each compass direction (N, S, E, W) to delineate the extent of the plume. If this monitoring indicates that the BHD is not contributing to the HOLD exceedance, then BHD dredging may continue pending approval from the EPA.

4.1.5.4 Assessment of Turbidity Data

Should the rolling median turbidity exceed the above thresholds, the rolling median turbidity (i.e. 6 day or 15 day) at the background monitoring site (B1) is to be assessed to determine if ambient turbidity is elevated and is accounting for increased turbidity at D1 or D2.

If the rolling median turbidity exceeds the ALARM level trigger at D1 or D2 and is greater than 20% above the rolling median background data at B1, then ALARM level management measures will be implemented. Otherwise, if the rolling median turbidity exceeds the ALARM level trigger at D1 or D2 but is not greater than 20% above the rolling median background data (B1), then dredging may continue, s this indicates higher background levels are occurring independent of the dredge activity (a natural weather event, for example).

If the rolling median turbidity exceeds the HOLD level trigger at D1 or D2, then dredging is to stop and not start until turbidity levels reduce below Level 3 HOLD levels or if approval is received from the EPA to continue dredging. Level 2 ALARM management measures are to be implemented for a period upon commencement.

Some worked examples are provided below.

Worked Example 1

- 15-day rolling median at site D1 increases to 2.81 NTU (exceeds ALARM level)
- 15-day rolling median at site B1 is 2.60 NTU
- D1 is only 7.5% higher than B1 (i.e. within 20%), therefore elevated turbidity is likely due to natural conditions and dredging can continue.

Worked Example 2

- 15-day rolling median at site D2 increases to 2.81 NTU (exceeds ALARM level)
- 15-day rolling median at site B1 is 3.20 NTU
- D2 is lower than B1, therefore elevated turbidity is likely due to natural conditions and dredging can continue.

Worked Example 3

- 15-day rolling median at site D1 increases to 2.81 NTU (exceeds ALARM level)
- 15-day rolling median at site B1 is 2.11 NTU
- D1 is 25% higher than B1 (i.e. greater than 20%), therefore elevated turbidity is likely due to dredging and ALARM level management measures are to be implemented.

Worked Example 4

- 6-day rolling median at site D2 increases to 15.85 NTU (exceeds HOLD level)
- Dredging is to stop until turbidity decreases below HOLD level or if approval is received from the EPA to continue dredging.

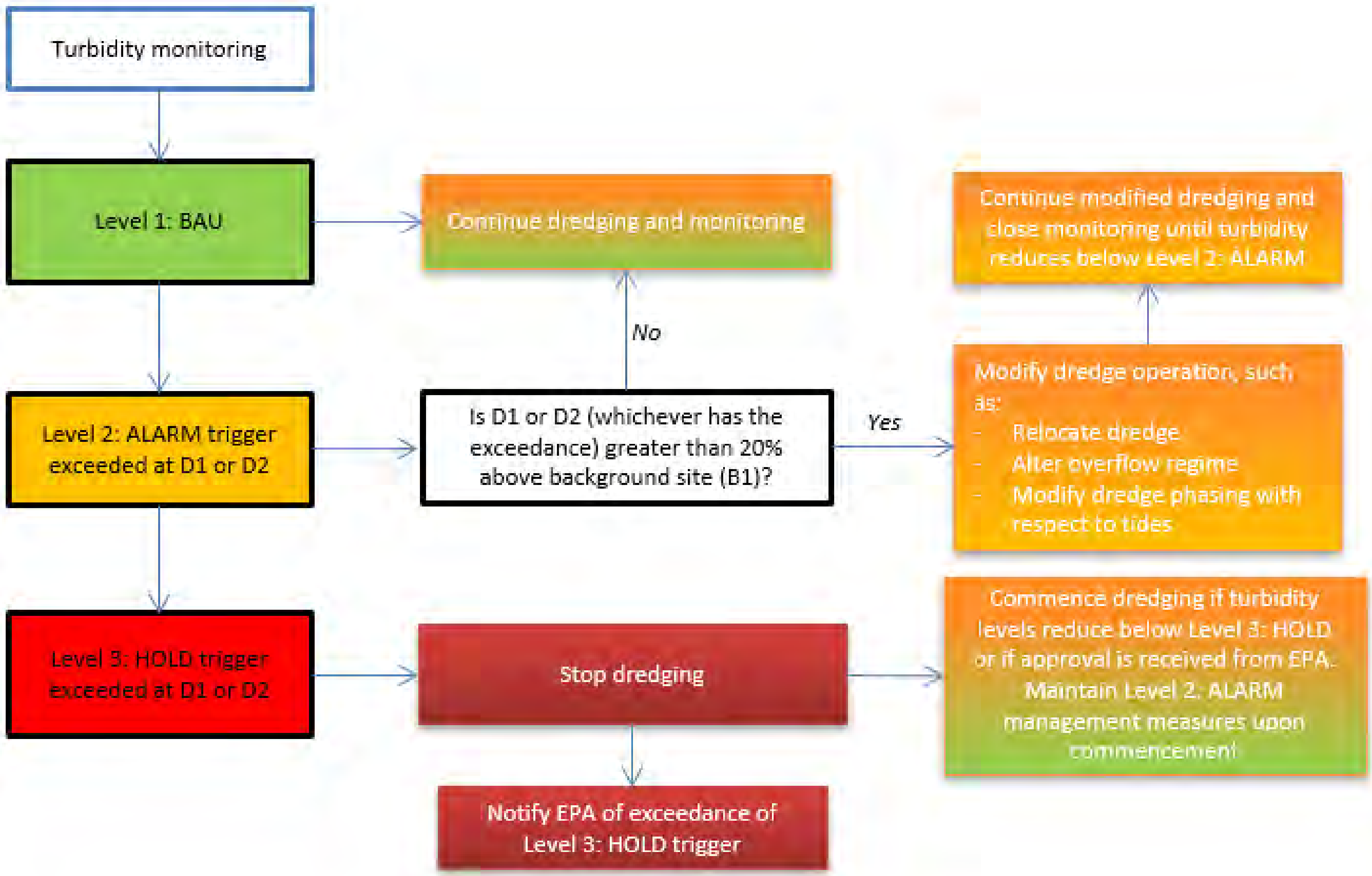


Figure 4-3 Flow Chart illustrating reactive management approach

Additional notes for proposed trigger levels:

- Applying median in lieu of average in calculations to account for extremes in data and as per ANZECC/ARMCANZ (2000).
- TSS:NTU ratio will be validated upon commencement of dredge campaign through sampling (up to 30+ quality samples) at an accredited NATA laboratory.
- Monitoring is to be undertaken using continuous loggers, which record and download turbidity, Dissolved Oxygen, pH, salinity and temperature every 10 minutes.

4.1.5.5 Equipment Failure

In the event of failure of the monitoring equipment during dredging, the following will be undertaken:

- Spare monitoring equipment (including hand-held instruments) will be available at all times for rapid deployment (within 24 hours in case of equipment failure of deployed equipment).
- Telemetered equipment is fitted with a GPS tracker, and the moment the instruments cease recording or the GPS tracker indicated a buoy has moved from the fixed location, an automatic notification will be issued to Flinders Ports, the Dredge Contractor, the Environmental Representative and the EPA. Instruments will either be recovered or spare monitoring equipment deployed, as per the timeframes above. The EPA will be notified of the remedial measures undertaken.
- A field team (Whyalla Diving) will be on stand-by during the works to ensure rapid mobilisation and ability to correct any irregularities within 24 hours.
- During the period between equipment failure and deployment of replacement equipment, vessel-based daily spot measurements will be undertaken by the Dredge Contractor using a hand-held water quality instrument at each monitoring location (weather dependent) three times daily (morning, midday, afternoon). These spot measurements will be used to assess whether there is an increasing or decreasing trend in turbidity.

If there was an exceedance of an ALARM or HOLD level that was attributable to dredging at the time of equipment failure, then the ALARM or HOLD level actions would continue to be implemented as a precautionary approach until the equipment is fixed. If rolling medians were below ALARM or HOLD levels at the time of equipment failure, then the following would apply:

- If spot measurements taken using a hand-held water quality instrument indicate that there is a decreasing trend in turbidity and measurements are below ALARM or HOLD levels, then dredging can continue.
- If spot measurements taken using a hand-held water quality instrument exceed ALARM or HOLD levels, then ALARM or HOLD level actions will be implemented.

4.1.5.6 Quality Assurance/Quality Control

The quality assurance/quality control process for turbidity data during the dredging can be summarised as follows:

- Sensors and equipment will be cleaned and calibrated regularly (approximately once every 2-3 weeks, or at a higher frequency if necessary (i.e. following equipment failure).
- An alarm will be sent to the Environmental Representative and Dredge contractor should data downloading cease. Any data gaps/erroneous data will be reviewed and fixed, where feasible.
- Any erroneous spikes in data will be flagged automatically by the monitoring website and quarantined from the data set manually.
- Twin turbidity sensors will be deployed at each site during the dredging campaign, which will allow two independent data sources per site. The two data sources will undergo automatic processing by the monitoring website as follows:
  - Data from the two concurrent turbidity sensors will be downloaded and compared.
  - If the difference in turbidity readings is within 20%, then the average value will be used.
  - If the difference is greater than 20%, then the minimum value will be used (this assumes that one sensor has failed or is biofouled).

Samples for laboratory analysis of turbidity will also be taken regularly (every 2-3 weeks, when equipment servicing is undertaken) to ensure that sensors are reading correctly. Should data not be reading correctly, an appropriate offset can be placed on the data on the monitoring website to ensure data displayed is correct. With twin sensors in place, it is unlikely that both sensors will be reading incorrectly if regularly calibrated. A sample will be taken pre-dredging to confirm sensors are reading correctly prior to commencement.

4.1.5.7 TSS/NTU ratio

Model outcomes from the plume dispersion model made prior to start of works are given in total suspended solid (TSS) concentrations in mg/l. In order to verify this to the measured turbidity values in Nephelometric Turbidity Units (NTU) a relationship has been adopted of 1 NTU = 3 mg/l based on 16 samples conducted during a trial dredge campaign in 1996. Based on this relationship expected turbidity limit exceedances are to be evaluated for Contractor's work method. To validate this relationship to actual values, the Contractor will take water samples and turbidity readings in the dredge plume to establish the relationship, which will be verified by a licenced laboratory. Turbidity measurements and water samples are collected simultaneously in the same spot to ensure a proper relation between the two. This is done by tying a Niskin bottle, or similar, to the turbidity sensor. Turbidity readings are logged at the same time that a water sample is taken. Water samples for establishment of the TSS-NTU correlation will be done from a crew or survey vessel using a turbidity sensor type (similar to YSI optical turbidity sensor – 90^0 backscatter). This sensor uses the same turbidity probe as the sensor used on the fixed monitoring stations.

TSS sampling is performed at the same time as the NTU measurement at a safe distance near the BHD and TSHD, in different areas of the dredge plume to capture a large range of turbidity readings. It should be done until a statistically strong relationship is determined between TSS and NTU. The number of samples taken for TSS depends on the hydrodynamic, soil and environmental conditions but usually requires about twenty to fifty samples to be collected representing various turbidity levels.

The aim is to collect samples in as wide a range of turbidity levels as possible, and spread out as evenly along this range as possible, to establish the strongest relationship possible.

The calibration is based on membrane filtration which involves taking a number of water samples, passing the water through a pre-weighed filter which is re-weighed after drying the sample in the oven. The difference in weight corresponds to the dry weight of the suspended particles in the water sample. Contractor will use an accredited laboratory to analyse the water samples.

On basis of the analysed samples and the turbidity readings in NTU, a correlation between the two is established and conversion factors are defined. An example of such a correlation is presented in Figure 4-4. Should the results be significantly different to those already in use, they will be communicated to the EPA as soon as available. It is not intended that this will change the existing water quality limits, but will inform dredging methods.

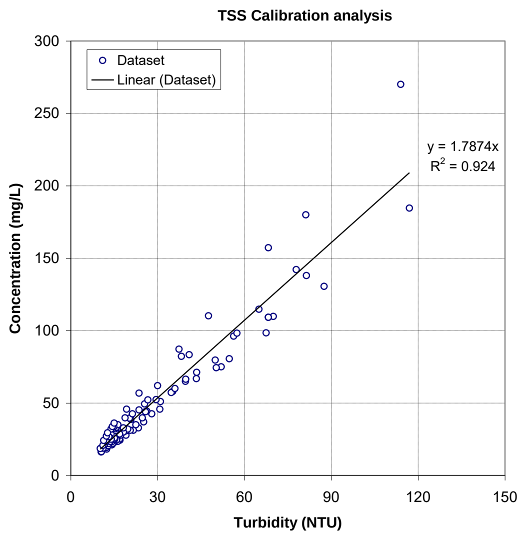


Figure 4-4 Example of a calibration graph between turbidity (NTU) and concentration of suspended sediments obtained from a Total Suspended Solids (TSS) analysis based on membrane filtration.

This will be done both for the BHD as well as the TSHD dredge, since this correlation may be different based on the differences in sediment properties of material being dredged.

4.1.6 PAR

Instruments that have the capability to record benthic photosynthetically active radiation (PAR) data will be installed on frames on the seabed at the three monitoring locations. PAR is an indicator of light available to sensitive receptors (e.g. seagrass), and sensors allow light attenuation through the water column to be calculated for a general area. The instruments installed do not allow for real-time PAR readings however as the data is only downloaded during equipment servicing trips, making them unsuitable for setting PAR limits that a dredge contractor is able to respond in real time to any exceedances. In addition, insufficient baseline data for seagrasses within the Outer Harbor and their light tolerance is available, making it difficult to set a reasonable trigger level that would be representative of the species present.

While the data will be available for long term research that may assist with future projects, it is not appropriate to use PAR as a trigger for the dredge operator.

4.1.7 Other Water Quality Parameters

pH, temperature and Dissolved Oxygen will also be recorded every ten minutes at B1, D1 and D2 by the continuous loggers. Although no limits have been set for these parameters, any exceedance of ANZECC WQ Guidelines for marine environments will be noted and a review of monitoring data will be undertaken and any potential impacts investigated.

4.1.7.1 Reporting

A water quality monitoring report will be provided to the EPA 7 days after the end of each month of dredging. This will contain the following:

- All raw data collected;
- A summary of the data in an acceptable format that may be used for reporting purposes;
- Any exceedances of water quality limits and how these were rectified; and
- General performance of dredging in accordance with this EMP.

4.2 Zone Validation Monitoring Program

As detailed in Section 3, impact assessment has been undertaken to predict zones of impact during dredging. In order to validate these predictions, the EPA require a Zone Validation Monitoring Program (ZVMP).

4.2.1 Validation of results

The predicted zones of impact will primarily be validated through the water quality monitoring program outlined above. In addition, satellite imagery will be reviewed no later than every 8 days (images will be chosen based on nearest available image and reliability of imagery i.e. least cloud cover).

The intent of the imagery is to demonstrate that:

- The plumes are similar to what was proposed via the modelling during the approval process;
- That the probes are in the right location to demonstrate risk (i.e. in the plume); and
- That the disposal of spoil does not extent outside of the approved area.

Imagery from the MODIS satellite showing the raw satellite image will be processed using algorithms to estimate turbidity plumes (an example image is provided below in Figure 4-5).

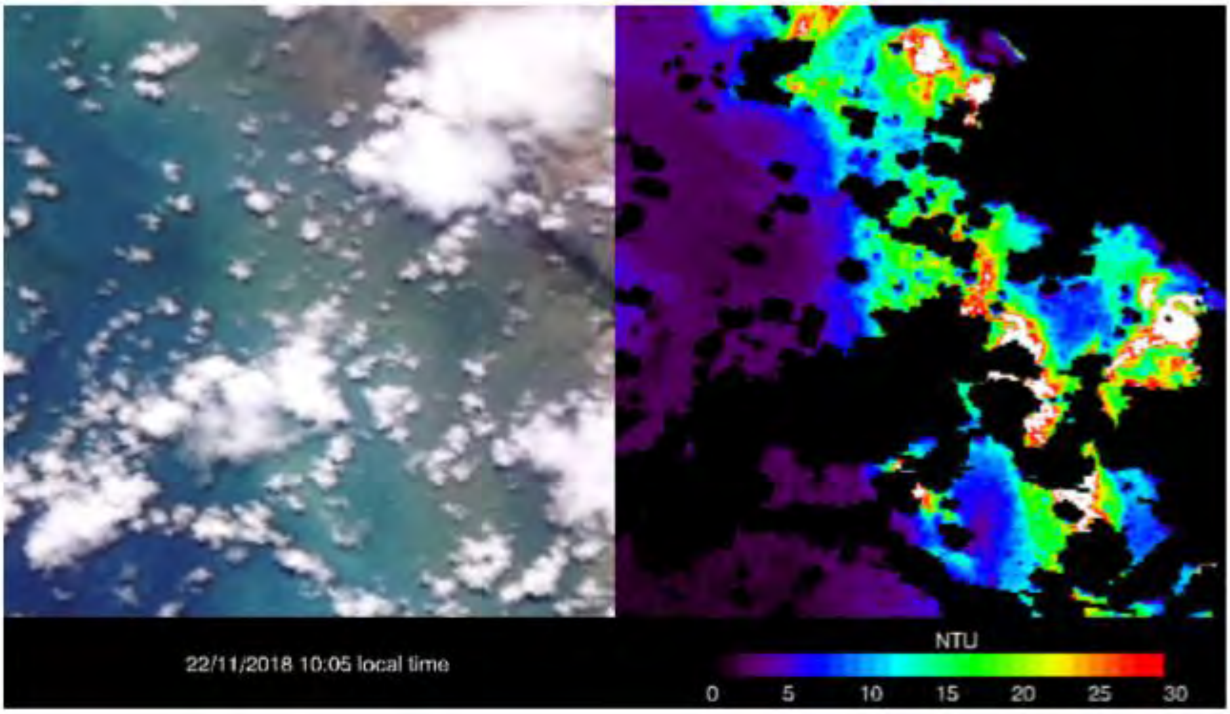
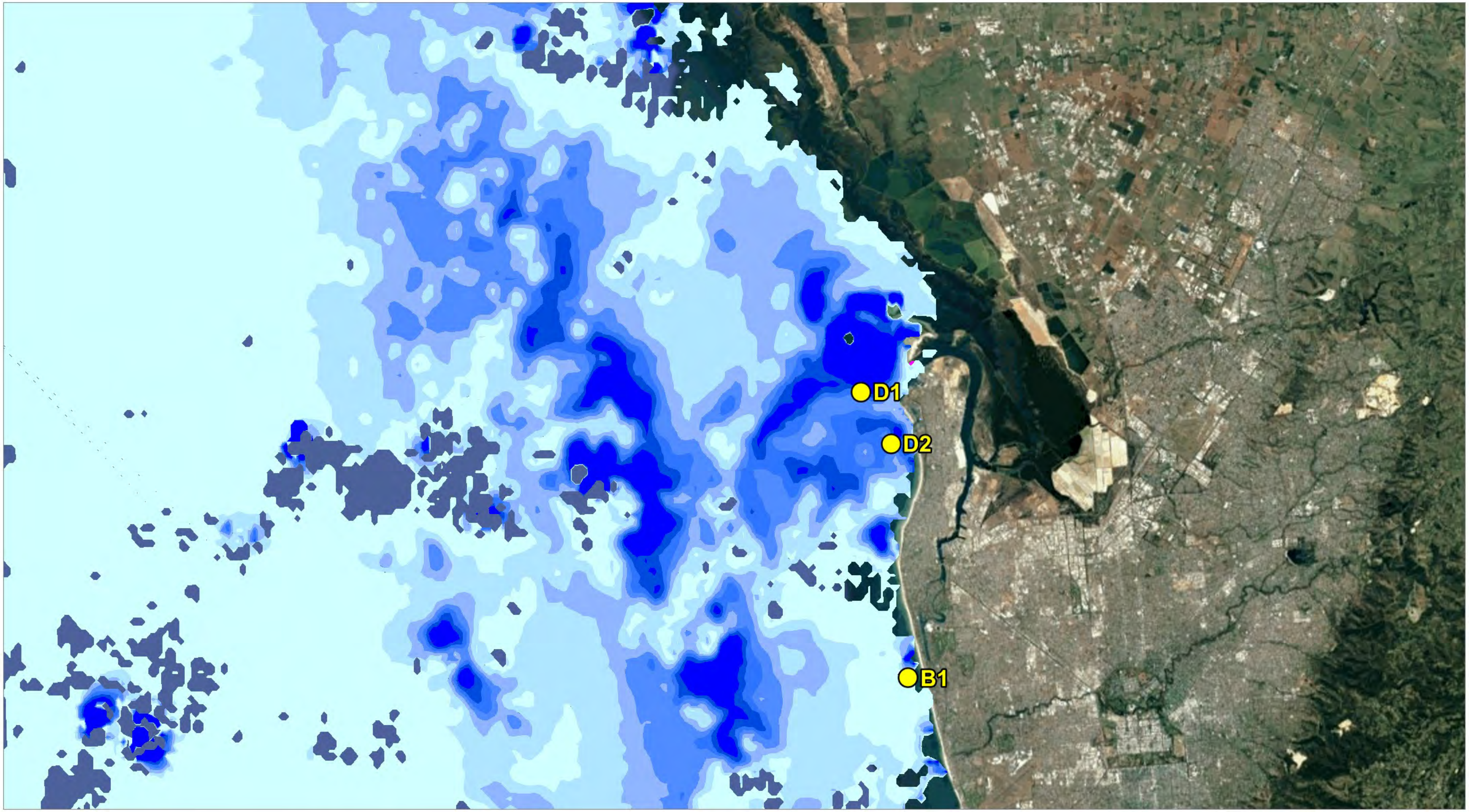


Figure 4-5 MODIS satellite raw data and post-processed turbidity imagery



Legend

- 0 - 5 NTU
- 5 - 10 NTU
- 10 - 15 NTU
- 15 - 20 NTU
- 20 - 25 NTU
- 25 - 30 NTU
- > 30 NTU

Title:

Satellite-Inferred Turbidity (22 November 2018 - 10 am)

Figure: **4-6**

Rev: **A**

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The satellite imagery is not to be used as a regulatory tool, as it can be influenced by the following:

- Cloud cover affects the turbidity figures in adverse weather conditions, as the satellite cannot see through clouds (note that heavy cloud cover has heavily impacted the ability to interpret turbidity in Figure 4-6).
- Satellite imagery may not always be available at the times required.
- It is a snapshot of a turbidity plume at the time the satellite has passed, and cannot therefore be correlated directly with modelling results, which presents data at the 50^{th} and 95^{th} percentiles only at a particular point of time and can be subject to variation depending on weather conditions.
- The algorithm to convert satellite image to turbidity is less accurate in nearshore areas adjacent to the coast – it can create some patchiness and inaccuracy in results.

It is to be used as a secondary tool to validate the plume extent, in conjunction with the primary measurement, water quality measured at the monitoring sites.

4.2.2 Management Measures

In the event that water quality monitoring does not meet water quality criteria, management actions are to be taken as per the measures outlined in Section 4.1. Should satellite imagery show a plume extent that is significantly greater than that predicted by plume modelling, water quality monitoring outputs will be reviewed. If there is no exceedance of water quality limits, no further action will be taken. In the event that an exceedance of instrument-taken water quality results occurs, the satellite imagery will be reviewed as a secondary investigation measure or ‘back-up snap shot’. It is difficult however to align the time of exceedance with the timing of satellite imagery, as it is not available instantaneously and can therefore be difficult to compare.

4.2.3 Reporting

As a component of required monthly reports, the EPA will be provided with all satellite imagery downloaded during the relevant timeframe, and a written summary and interpretation of results.

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Appendix A Seagrass Management Plan

Adelaide Outer Harbor Channel Widening Project: Seagrass Monitoring Program

Reference: R.B22346.008.02.Seagrass_Monitoring_Program.docx
Date: April 2019

Document Control Sheet

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Author:	Grace Bourke
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Definitions and Abbreviations

Term	Description
BACI	Before-After Control-Impact
BRI	Benthic Reflective Index
DA	Development Application
DEM	Digital Elevation Model
DMP	Dredge Management Plan
EMP	Environmental Monitoring Program
EPA	Environmental Protection Authority
ha	Hectares
NVC	Native Vegetation Council
SEB	Significant Environmental Benefit
SMP	Seagrass Monitoring Program

Contents

List of Figures

1 Introduction

Flinders Ports Pty Ltd (Flinders Ports) has identified the need for an upgrade of the existing infrastructure at Port Adelaide as a priority project for Flinders Ports. A detailed Development Application (DA) Report was submitted in July 2017 in accordance with the Development Act 1993, as a Section 49 application given this project is defined as public infrastructure. Sponsorship for this application was received from the Minister for Transport and Infrastructure prior to lodgement in May 2017. Flinders Ports DA 010/V048/17 received approval on 28th May 2018. A Dredge License (Licence No. 50556) was granted by the EPA on 12th March 2019.

This Seagrass Monitoring Program (SMP) has been prepared in accordance with Dredge License Condition 3.3 (U – 988) and in accordance with the Vegetation Clearance Permit issued by the Native Vegetation Council under the Native Vegetation Regulations, in 2018. This Clearance Permit allows for the clearance of up to 162 ha of seagrass.

This document should be read in conjunction with the Dredge Management Plan (DMP) and Environmental Monitoring Program (EMP) prepared and approved for the project. The DMP documents all environmental management procedures and responsibilities during dredging activity. The EMP documents all monitoring that will be undertaken prior to, during and post-dredging.

Previous investigations have found that seagrass is the dominant benthic primary producer habitat adjacent to the area proposed for dredging. Seagrasses are environmentally significant – and protected under the South Australian Native Vegetation Act 1991 – as they provide feeding, foraging and nursery habitat for marine and estuarine fauna, oxygenate the water, cycle nutrients, and stabilise marine sediments from erosion.

The purpose of the seagrass assessments for the Dredge Licence Condition and the Native Vegetation Significant Environmental Benefit (SEB) survey differ. However, this SMP has been designed to meet both condition/permit requirements. The aim of the Dredge License Condition is to determine the live seagrass extent and percent cover within the Survey Area that is consistent with a Before-After-Control-Impact (BACI) design. While the aim of the Native vegetation SEB survey is to accurately quantify the amount of permanent seagrass loss that may be attributable to the dredging program and confirm the SEB payment amount. The proposed SMP survey locations, timing and methodology to be undertaken as part of the Project has been designed to ensure compliance with both aims and is outlined herein.

2 Seagrass Monitoring Program

2.1 Seagrass Monitoring Program Sampling Design

The broad aims of the Seagrass Monitoring Program are to detect changes in seagrass meadows in the study area due to dredging. The two components of the SMP are as follows:

- Dredge Licence Condition Seagrass Assessment: Quantitative seagrass extent and percentage cover analysis both temporally (before and after dredging) and spatially (control and impact sites) to comply with the BACI approach. The sampling design allows changes in seagrass health at the potential impact sites to be evaluated against variation measured at multiple control sites.
- Native Vegetation SEB survey: Quantitative assessment of seagrass loss due to dredging activities within the channel widening footprint, and the Low to Moderate and High Impact areas.

Both components are conducted using similar field methodologies (underwater video camera and foot based transects) as outlined in section 2.4.

2.2 Survey Timing

Field surveys are to be conducted at three temporal points throughout the Project lifecycle, which includes one baseline survey (prior to dredging) and two post-dredging surveys:

- Prior to dredging commencing (in April 2019);
- After dredging ceases, in April 2020; and
- Approximately 18 months post dredging activities ceasing (in April 2021).

These have been scheduled so that surveys are conducted generally at the same time each year, to allow for direct comparison of results. This takes into account the fluctuations in seagrass extent and growth with the seasons (i.e. seagrass extent is typically greater in summer months, and contracts in winter as light availability reduces).

2.3 Survey Locations

2.3.1 Dredge Licence Condition Seagrass Assessment

The survey locations to comply with the Dredge Licence Condition and the BACI approach consist of the following:

- Control sites – sites not be impacted by dredging activities. Those sites outside of the turbidity zone of influence.
- Impact sites – sites modelled as being within the turbidity zone of influence (no ecological impact).

The survey sites and transect locations are shown in Figure 2-1 and are consistent with the location of sites surveyed in 2017 where possible, to allow comparison. Sites were broadly selected based on previous seagrass mapping to ensure all representative benthic habitat types are sampled. Sites at the water quality monitoring buoys are also included. Sites that do not have seagrass present in the 'before' assessment are sampled anyway.

Each of the control and impact sites cover an area of 16 ha, composed of a 400 m by 400 m quadrant. There are 25 control sites and 10 impact sites and within each of the sites, there are five 50 m replicate transects. The five transect replicates within each site means that the sampling is representative of the site and there is sufficient power to detect a difference between sampling events at the site level. The survey design provides a detection power (the power for detecting an effect of a given size) of 87% and therefore provides the necessary power at a critical feature cover of 15%.

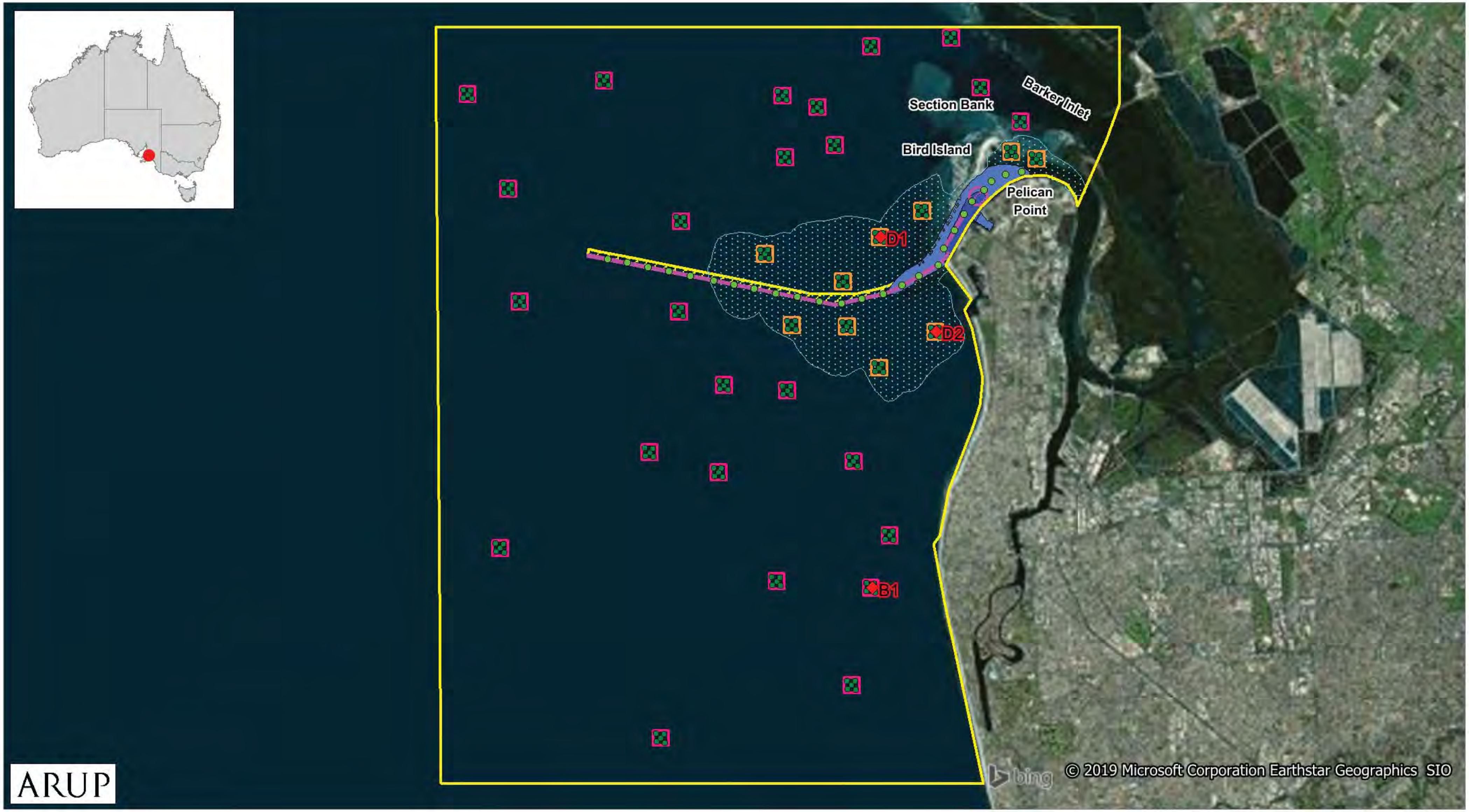
The transect points are conducted at broadly similar locations between survey campaigns. However, due to variability in prevailing weather conditions, transects within a site cannot be exactly replicated each sampling period. However, this does not impact on results due to the level of replication within sites. On arrival at each transect point and prior to any video footage collection, the direction of drift of the boat due to winds/tides is determined. The direction of the 50 m transect is decided by the Master of the vessel and BMT staff but is collected within the pre-defined site boundary.

2.3.2 Native Vegetation SEB survey

The survey locations to comply with the Native Vegetation SEB survey consists of recovery sites (as shown in Figure 2-1). The recovery sites are those directly affected by dredging activities within the Project dredge footprint and within the modelled turbidity zone of low to moderate impact and turbidity zone of high impact.

For the recovery transect sites, there is no pre-defined site boundary but consist of single points. At each of the proposed 25 recovery transect sites, a 50 m transect is surveyed. As explained in Section 2.3.1, the transect points are to be conducted at broadly similar locations between survey campaigns, due to variability in prevailing weather conditions.

Note that the recovery sites are used in addition to the control and impact sites to inform satellite mapping to determine changes in the extent and distribution of seagrass percent cover and composition. The recovery sites are not be compared against the Control or Impact sites for the Dredge Licence Condition Seagrass Assessment (BACI design).



LEGEND

- Existing Channel Footprint
- Channel Widening Footprint
- Control site
- Impact Site
- Control/Impact Transect Point
- Recovery Transect Point (Native Vegetation SEB survey)
- Turbidity Monitoring Buoy Location
- Turbidity zone of influence (no ecological impact)
- Turbidity zone of Low to Moderate Impact
- Turbidity zone of High Impact
- Survey Area (as per Dredge Licence)

Title:

Proposed Seagrass Monitoring Program Transect Locations

BMT endeavours to ensure that the information provided in this map is correct at the time of publication. BMT does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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2.4 Survey Methodology

The field survey undertaken for the SMP involves the use of:

- Towed video camera transects in sub-tidal areas;
- Foot-based transects in intertidal locations and those inaccessible by boat near Bird Island; and
- Benthic trawl techniques using a modified seagrass rake for species identification.

The towed video camera and foot-based survey techniques are used to identify seagrass species composition and percentage cover. Note that benthic trawls will only be used to collect samples of the seabed to confirm seagrass classifications through visual inspection where this is not possible from video footage. The minimum amount of seagrass will be taken to confirm species classifications (les than 0.5m2).

Towed video transects (and foot based transects in intertidal areas) are conducted along the transects within the study area. The underwater video camera system consists of a high definition camera (3840 x 2160 pixels per frame) with a wide-angle lens. The camera is flown at ~1 m above the substratum at a speed of 1–2 km/h facing downwards. All footage is recorded onto the internal camera memory, while composite standard definition footage is relayed to a screen on the vessel for real-time data analysis by a trained marine ecologist. All equipment (laptop, GPSs and the camera) is set to the same date/time to ensure that habitat data collected along each transect can be geo-referenced onto mapping (as appropriate). The length of the 50 m transects begins at the point of clear footage at the seafloor.

The percentage coverage, seagrass species/genus and other variables of interest (e.g. algae including Caulerpa, bivalves and benthic habitat types) are recorded, taking additional GPS marks at locations where the densities and/or species composition changed. Densities are estimated using seagrass percentage cover standards (McKenzie 2003, see Figure 2-2). The video footage collected is reviewed post-field to ensure a consistent approach to habitat classification and to match the survey data to the GPS tracklog (by date and time).

Specifically, for the Dredge Licence Condition Seagrass Assessment (i.e. for the transects conducted at the control and impact sites), the video camera is set to take a still image every 5 seconds (concurrent with the video footage). These images are used to inform the quantitative seagrass percentage cover and statistical assessment. The Coral Point Count software used for the image analysis, uses a random assignment of points given relatively similar distances from the sea bed. Thus, this removes the need to know the depth from the sea bed and allows transects to be completed in a more efficient manner.

Timing of the survey is planned to coincide with suitable weather and sea conditions to ensure good visibility. However, if sites are encountered where water quality is poor and/or camera visibility is hindered, the survey is postponed until suitable conditions occur.

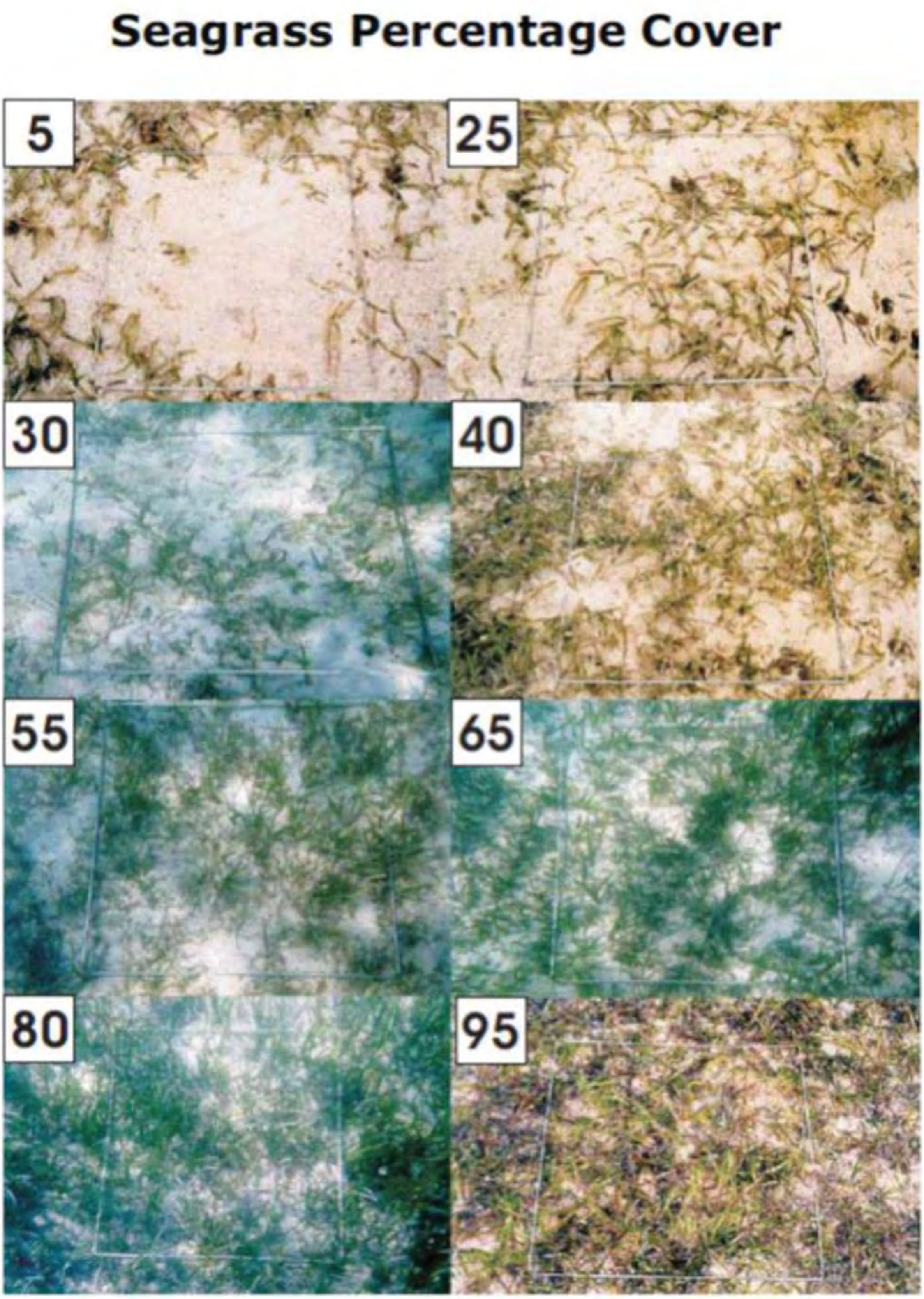

Figure 2-2 Seagrass percentage cover estimates (McKenzie 2003)

2.5 Survey Results Analysis and Reporting

2.5.1 Dredge Licence Condition Seagrass Assessment

To comply with the Dredge Licence Conditions, after each survey is undertaken, field survey data is analysed using suitable techniques and documented (including mapping).

2.5.1.1 Coral Point Count Analysis

Image analysis is undertaken using Coral Point Count software with points randomly assigned across the image. Five images for each transect are randomly selected to be analysed.

Analysis involves digitally overlying a virtual photo-quadrat containing random points on each captured video frame. The Coral Point Count software is then used to measure the percentage cover of key categories of benthic biota by scoring each random point according to the classification system. The optimum number of points per image is selected after a preliminary precision analysis conducted on a subset of representative images.

From this data, percentage cover for each seagrass species at each treatment (control and impact) is be estimated and compared through time (before and after dredging) with a statistical analysis.

2.5.1.2 Statistical Methods

Quantitative comparisons are used to examine any differences in percentage cover of seagrasses between the sampling campaigns (the one pre-dredging survey and the two post-dredging survey), and among and within treatments (control and impact). This is be done using Analysis of Variance (ANOVA) of arcsine-transformed percentage cover data, assuming normal errors and homogeneous variances exist. If the assumptions of ANOVA are not satisfied by data transformation, the data will be analysed using generalized linear modelling, with an appropriate (Poisson) error distribution to meet the requirements of the structure of the data. To assess whether there have been significant changes in the cover of seagrass between control and impact areas, a BACI analysis framework is used (Underwood 1992). A significant interaction term showing a reduction in cover at impact sites and not control is interpreted as evidence of impact.

2.5.1.3 Satellite Mapping

Satellite imagery is used to establish the full extent of seagrass coverage outside of the surveyed transects, within the survey area shown in Figure 2-1, for the three temporal seagrass monitoring surveys. These maps use data from all transects including control, impact and recovery sites. Up to date satellite imagery is combined with high resolution digital elevation model (DEM) data to calculate the benthic reflective index (BRI). Habitat classifications (including seagrass percent cover and composition) is derived using a BRI based on the blue and green visible colour spectra, as per Sagawa et al. (2010).

2.5.1.4 Reporting

After the completion of each seagrass monitoring survey, a summary report is prepared for review and approval by the EPA. The report includes an introduction, methodology and survey results and analysis, including habitat maps for each survey campaign based on the satellite habitat classifications. Dredging cannot commence until the EPA have approved the 'before' dredging seagrass report.

Upon completion of the second and third temporal point field surveys, collected data is analysed and compared with previous survey data to determine the extent of seagrass impact.

2.5.2 Native Vegetation SEB survey

To comply with the NVC Native Vegetation SEB survey, after each SMP survey is undertaken, field survey data is analysed using suitable techniques and documented (including mapping).

2.5.2.1 Satellite Mapping

As explained in Section 2.5.1.3.

2.5.2.2 Data Analysis

To determine the extent of seagrass loss within the study area (including the Channel Widening Footprint, the Turbidity High Impact areas and the Turbidity Low to Moderate Impact areas, as well as the wider study area), the area of each habitat classification based on the satellite mapping is calculated for each survey. The area calculations for the two post dredging surveys are compared to the baseline survey to determine the area of seagrass loss. The second post dredging survey (2021) is compared to the first post dredging survey (2020) to determine if there has been any seagrass recovery since the dredging campaign.

2.5.2.3 Reporting

After the completion of each seagrass monitoring survey, a summary report is prepared for the NVC to confirm the Native Vegetation Licence SEB value. The report includes an introduction, methodology and survey results and statistical analysis, including a habitat map based on the satellite habitat classifications.

3 References

McKenzie, L.J. (2003) Draft guidelines for the rapid assessment of seagrass habitats in the western Pacific (QFS, NFC, Cairns) 43pp.

Sagawa T, Boisnier E, Komatsu T, Mustapha KB, Hattour A, Kosaka N, Miyazaki S (2010) Using bottom surface reflectance to map coastal marine areas: a new application method for Lyzenga's model. International Journal of Remote Sensing, 31: 3051–3064.

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