Shark Bay Resources: Dredging Environmental Impact Assessment

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BMT Commercial Australia Pty Ltd has prepared this report in accordance with our Integrated Management System, certified to OHSAS18001, ISO14001 and ISO9001

Status

This report is 'Draft' until approved for final release by the Project Director (or their authorised delegate) as indicated below by signature. A Draft report may be issued for review with intent to generate a 'Final' version but must not be used for any other purpose.

Approved for final release:

Environment Team Lead
Date: 18/06/2021

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List of Terms and Abbreviations

ABWMAC	Australian Ballast Water Management Advisory Council
AQIS	Australian Quarantine and Inspection Service
BWMP	Ballast Water Management Plan
BCH	Benthic communities and habitats
CALM	Department of Conservation and Land Management
cm	Centimetres
CPL	Carnarvon Peron Line
DAWE	Department of Agriculture, Water and the Environment
DBCA	Department of Biodiversity, Conservations and Attractions
DEC	Department of Environment and Conservation
DEIA	Dredging Environmental Impact Assessment
DEMP	Dredging Environmental Management Plan
DJTSI	Department of Jobs, Tourism, Science and Innovation
DoEE	Department of the Environment and Energy
DPIRD	Department of Primary Industries and Regional Development
DPLH	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Regulation
EIA	Environmental Impact Assessment
EP Act	Environmental Protection Act 1986
EPA	Environmental Protection Agency
EPBC Act	Environmental Protection and Biodiversity Conservation Act (1999)
EPSD Act	Environment Protection (Sea Dumping) Act 1981
g/m^2	Grams per metre squared
Hz	Hertz
IMPMP	Introduced Marine Pest Management Plan
IMS	Introduced marine species
km	Kilometre
km2	Kilometre squared
LAC	Light attenuation coefficient

LAT	Lowest astronomical tide
LAU	Local assessment units
m	Metre
m^3	Metre cubed
MAC	Malgana Aboriginal Corporation
mg/L	Milligrams per litre
MLR	Minimum light requirements
mm	Millimetre
MNES	Matters of National Environmental Significance
mol photons m^{-2} d^{-1}	Mol of photons per metre squared per day
NAGD	National Assessment Guidelines for Dredging
NSW	New South Wales
NT	Northern Territory
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically active radiation
ppt	Parts per thousand
PSD	Particle size distribution
QLD	Queensland
SAP	Sampling and Analysis Plan
SAPIR	Sampling and Analysis Plan Implementation Report
SBMP	Shark Bay Marine Park
SBPMP	Shark Bay Prawn Managed Fishery
SBR	Shark Bay Resources
SBWHA	Shark Bay World Heritage Area
SPL	Species protection level
SPV	Species protection value
t	Tonnes
TBT	Tributyltin
TOC	Total organic carbon
TSHD	Trailing suction hopper dredge

TSS	Total suspended solids
µm	Micrometres
µmol photons m^{-2} s^{-1}	Micro mol photons per metre squared per second
WA	Western Australia
YMAC	Yamatji Marlpa Aboriginal Corporation
ZoHI	Zone of high impact
ZoI	Zone of influence
ZoMI	Zone of moderate impact

Executive Summary

Shark Bay Resources Pty Ltd (SBR) operates a solar salt field at the southern end of Useless Inlet and Useless Loop, Western Australia (WA). The infrastructure supporting the salt field includes port facility (hereafter, the Port) consisting of a stockpile, jetty and loader, for export of salt products. The Port is accessed via the Denham entrance channel, accessed via the northern entrance of Shark Bay. The salt field and Port facility is surrounded by, but excised from, the Shark Bay World Heritage Area (SBWHA) and Shark Bay Marine Park (SBMP).

Recent hydrographic survey results estimated that 3770 m^3 and 38 010 m^3 of material from the berth pocket and entrance channel lies above original design depths and is required to be removed (the Project). With inclusion for over-dredge, the current proposed design requires the removal of an estimated volume of 10 000 m^3 from the berth pocket and 68 200 m^3 from entrance channel areas, respectively. SBR wish to complete works to return the berth pocket and entrance channel to historical depths.

The Project was originally referred under the following State and Federal legislation (*Environmental Protection Act 1986*, *Environment Protection and Biodiversity Conservation Act 1999* and *Environment Protection (Sea Dumping) Act 1981* [EPSD Act]) on 24 June 2020. The Environmental Protection Authority (EPA) determined that the Project be formally assessed with additional information and targeted stakeholder engagement required for the EPA to complete the assessment. As a result of the ongoing consultation with State and Commonwealth regulators, it was agreed that the proposed Project be redefined to replace dredging and offshore disposal of the berth pocket material with seabed levelling, effectively removing the potential to introduce any contaminants of concern to the existing offshore disposal area. This decision is a very conservative mitigation of potential impacts that recognises the environmental significance of the region in which SBR continues to operate.

This revised dredging environmental impact assessment (DEIA) has been prepared in support of the updates required from the regulators for the purpose of formal environmental assessment and approval under State and Commonwealth legislation. The DEIA evaluates potential impacts of dredging on environmental receptors with reference to the specific dredging and disposal methods, as well as relevant environmental legislation and guidelines. The following potential effects of the proposed Project on different environmental receptors have been assessed:

- Benthic communities and habitat
  - direct and indirect loss of benthic primary producer habitat
- Marine environmental quality
  - increase in water column turbidity
  - release of contaminants
  - hydrocarbons and waste generation
  - hypoxia
  - introduced marine species
- Marine fauna
  - impacts to threatened and migratory species
  - impacts to threatened and migratory avifauna
- Social surroundings
  - commercial and recreational fisheries
  - public safety, visual amenity and access
  - navigational hazards
  - indigenous and non-indigenous heritage.

To support this DEIA, three technical studies were undertaken: an assessment of the material to be dredged; hydrodynamic and plume modelling; and benthic habitat mapping (provided as appendices to this document). The outcomes of these technical studies were as follows:

- Entrance channel material is considered suitable for ocean disposal under the EPSD Act and will be disposed of offshore.
- Sediment sampling and analysis of berth pocket material did not contain contaminants at levels of concern, except for tributyltin (TBT), which was elevated at six sites. The weighted 95th percentile concentrations of elutriate tributyltin prior to dilution (a measure of bioavailability) met the 90% species protection guideline suggesting potential impacts to benthic and pelagic flora and fauna within the berth pocket from the release of TBT during seabed levelling of the contaminated area is negligible. It is expected that the 99% species protection levels for TBT will be met and a high level of ecological protection maintained after dilution between the release of contaminates and the boundary of the area of high ecological protection. To ensure contaminants meet the 90% species protection guidelines within the berth area excised from the SBMP and the 99% species protection guidelines outside the area, receiving waters will be monitored before, during and after seabed levelling activities.
- Plume modelling indicated that dredge and disposal activities will generate a turbid plume that is of minor extent and duration.
- Habitat mapping studies indicate the dominant benthic communities and habitat adjacent to the dredge and disposal areas were sparse seagrass meadows dominated by *Halophila spinulosa*. A cumulative loss assessment of benthic habitats and communities from the local assessment units (LAUs) included historical loss attributed to historical construction activities. As a result, cumulative loss of seagrass for the offshore LAU was estimated at 0.29 km^2, with only 0.02 km^2 of this attributed to permanent loss of sparse *H. spinulosa* due to the proposed Project. There were historical losses of seagrass habitat within the berth pocket LAU as a result of historical project works (1.88 km^2), however, no additional losses are expected as a result of the proposed project.

Based on the results of these technical studies and this DEIA, it has been concluded that the EPA's relevant objectives will be met while implementing this Project. Further, the proposed action will not significantly impact relevant World Heritage criteria and Marine Park values.

SBR will implement several monitoring and mitigation measures to manage the potential environmental impacts associated with the Project, including:

- turbidity monitoring
- introduced marine species risk assessment and identification procedures
- release of contaminants
- waste and hydrocarbon management
- marine fauna monitoring and management
- noise reduction measures.

Stakeholders will be consulted prior to the commencement of dredging and throughout the Project. If any unforeseen environmental issues arise, contingency plans (with specific indicators, action criteria and management responses) will be implemented, as detailed in the Dredging Environmental Management Plan (DEMP, provided as appendices to this document).

1 Introduction

1.1 Background

Shark Bay Resources Pty Ltd (SBR) operates two solar salt fields within Western Australia. The Shark Bay salt field was constructed in 1960, with first shipment in 1967. The field occupies 130 km^2 and was constructed by enclosing natural inlets at the southern end of Useless Inlet and Useless Loop (Figure 1-1 and Figure 1-2). The port facility that supports the salt field operations consists of a stockpile, jetty and loader for export of salt products (hereafter, the Port). The Port is accessed via the Denham entrance channel that extends through to the northern entrance of Shark Bay. The salt field and Port facility is surrounded by, but excised from, the Shark Bay World Heritage Area (SBWHA) and Shark Bay Marine Park (SBMP) (Figure 1-1 and Figure 1-2).

Recent hydrographic survey results indicate that accretion of material in the berth pocket and entrance channel will begin to impede on optimal vessel loading in the near-term. With inclusion for over-dredge, the current proposed design requires the removal of an estimated volume of 10 000 m^3 from the berth pocket and 68 200 m^3 from entrance channel areas, respectively. SBR wish to complete works to return the berth pocket and entrance channel to historical depths.

The Project was originally referred under the following State and Federal legislation: *Environmental Protection Act 1986* (EP Act), *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) *and Environment Protection (Sea Dumping) Act 1981* (EPSD Act) on 24 June 2020. The Environmental Protection Authority (EPA) determined that the Project be formally assessed with additional information and targeted stakeholder engagement required for the EPA to complete the assessment. As a result of the ongoing consultation with State and Commonwealth regulators, it was agreed that the proposed Project be redefined to replace dredging and offshore disposal of the berth pocket material with seabed levelling, effectively removing the potential to introduce any contaminants of concern to the existing offshore disposal area. This decision is a very conservative mitigation of potential impacts that recognises the environmental significance of the region in which SBR continues to operate.

1.2 Purpose of this document

This document presents a revised Dredging Environmental Impact Assessment (DEIA) that evaluates the potential environmental risks associated with the Project. Potential effects of dredging, disposal and seabed levelling on different environmental receptors were assessed, based on the specific nature of the works and results of sediment sampling and analysis of the material above design. This DEIA supports the referral/application requirements for formal environmental assessment and approval under the EP Act, EPBC Act and EPSD Act. The DEIA includes proposed environmental monitoring and management measures to control the impact of the dredging; details of which are provided in the Dredging Environmental Management Plan (DEMP; Appendix A).

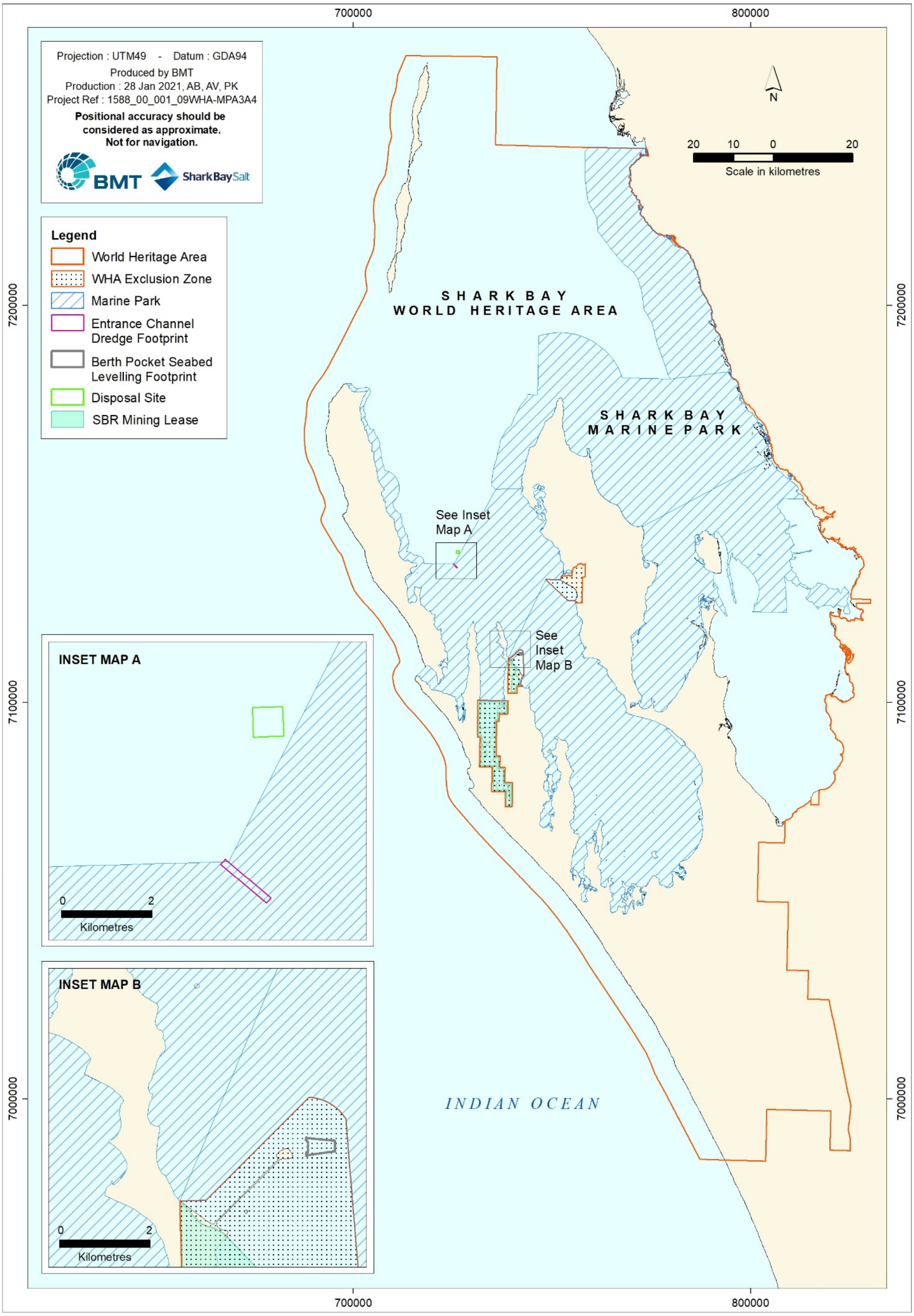

Figure 1-1 Shark Bay Resources entrance channel and Port facility location within the wider Shark Bay World Heritage Area

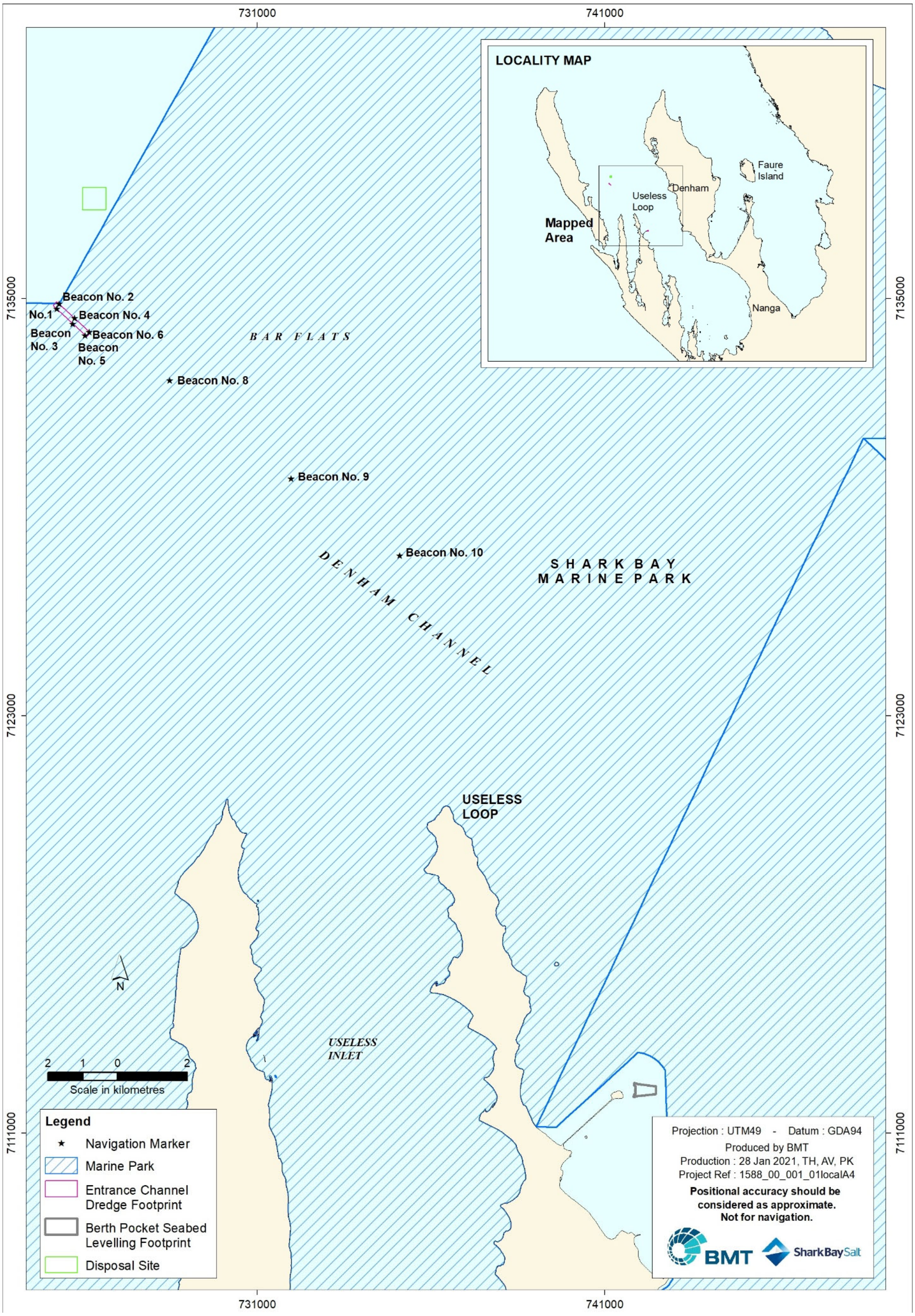

Figure 1-2 Shark Bay Resources entrance channel and Port facility location

2 Removal of High Spots

2.1 Historical high spot removal

It is unclear where dredged material from the original construction of the Port facility in the 1960s was placed. The most recent maintenance dredging occurred in 1982, when 98 260 m^3 of material was removed from the entrance channel (-10 m Chart Datum) and placed at the offshore disposal site in Figure 1-1 and Figure 1-2 (SBR 1999). Maintenance dredging of the berth pocket has not occurred since its original construction.

Approval was granted for the disposal of 722 000 m^3 of material to two offshore disposal areas by the Department of Agriculture, Water and the Environment[1] (DAWE) in 2001, and extended in 2004 (SKM 2008). Previously approved dredging and disposal works were not progressed due to internal company strategy decisions. Instead, SBR nominated to undertake smaller seabed levelling works to maintain navigable waters in the entrance channel and berth pocket.

High spot levelling via underwater sweeping or ploughing has been undertaken at regular intervals, starting from at least 2011 in the berth area. SBR managed a small levelling campaign in 2014/15, with the most recent sweeping program completed in 2018. The 2018 seabed levelling activities occurred within the entrance channel and at the Useless Loop berth pocket (hereafter, berth pocket). Seabed levelling activities commenced on 9 September 2018, working on a 24-hour basis until authorisation to demobilise was given on 30 October 2018. Based on a comparison of the pre-survey (10 September 2018) and the final clearance survey (31 October 2018), it was determined that 10 160 m^3 of material was moved at the entrance channel (BMT 2019a). These works provided some improvement in available water depth but were not successful in restoring channel design levels and widths to the original constructed state.

2.2 Summary of proposed Project

Based on a 2018 hydrographic survey, the volume of material shallower than design within the berth pocket and channel is 3770 m^3 and 38 010 m^3, respectfully. With inclusion for over-dredge, the current proposed design requires the removal of an estimated volume of 10 000 m^3 from the berth pocket and 68 200 m^3 from entrance channel areas, respectively (Table 2-2; Appendix B). Dredging and seabed levelling operations are expected to occur 24 hours a day, 7 days a week (24/7; in-line with Port activities).

The Project is conservatively expected to take place over a ~1–2-month period of consecutive days dredging (dredging 1–2 weeks, seabed levelling up to ~4 weeks), subject to potential delays due to inclement weather, unfavourable sea state and/or unforeseen equipment malfunction.

[1] DAWE was previously the Department of the Environment and Energy (DoEE)

Table 2-1 Summary of the proposal

Proposal title	**Shark Bay Dredging**
Proponent name	Shark Bay Resources Pty Ltd
Short description	The Proposal is for up to 80 000 m^3 of maintenance/capital dredging and seabed levelling of up to 10 000 m^3 in a Development Envelope of up to 106.6 ha. The Development Envelope is comprised of an entrance channel dredge footprint, offshore disposal area for dredged channel material, and seabed levelling in the berth pocket footprint.

Table 2-2 Location and proposed extent

Element	Location	Proposed extent[1]
Physical elements		
Not applicable	Not applicable	No new physical elements as a result of the Proposal.
Operational elements		
Maintenance and capital dredging – entrance channel	Refer to Figure 1-1, Figure 1-2 and coordinates in Appendix D	Up to 80 000 m^3 of material will be removed from the 35.3 ha channel entrance footprint to a maximum depth of -10.5 m lowest astronomical tide (LAT).
Seabed levelling – berth pocket	Refer to Figure 1-1, Figure 1-2 and coordinates in Appendix D	Up to 10 000 m^3 of material will be moved/levelled within the 28.1 ha berth pocket footprint to a maximum depth of -10 m LAT.
Disposal area	Refer to Figure 1-1, Figure 1-2 and coordinates in Appendix D	Up to 80 000 m^3 of material disposed within the 43.2 ha offshore disposal area.

Note:
1. The proposed extent of operational elements associated with the berth pocket and channel areas includes a 50 m buffer to allow for GPS and positioning just beyond the Project design.

2.2.1 Proposed dredging and disposal

It is anticipated that material from the entrance channel will be dredged utilising a trailing suction hopper dredger (TSHD) over a period of 1–2 weeks. Material will be dredged from the channel with a target dredge depth of 10 m below lowest astronomical tide (LAT). Sand trenches (-0.5 m deep) on both sides of the channel will be dredged to limit sediment accretion on the channel edges over time and reduce the requirements for maintenance into the future (Appendix B). For the purpose of the Sea Dumping Permit application for ocean disposal of dredged material, a Project limit of 80 000 m^3 of material from the entrance channel will adequately provide for potential changes to the dredge design volumes following the pre-mobilisation hydrographic survey and over-dredge.

2.2.2 Proposed seabed levelling

It is proposed to complete seabed levelling of the high spots adjacent to the berth, redistributing up to 10 000 m^3 of material to deeper areas within the berth pocket over an ~4-week period. There is ~20 000 m^3 fill capacity available within the berth area (Appendix B).

2.3 Alternative disposal sites

SBR has previously nominated to undertake smaller seabed levelling works in lieu of maintenance dredging to maintain navigable waters in the entrance channel and berth pocket (Section 2.1). However, recent survey results indicate that additional measures are required to restore design levels and widths to the original constructed state. SBR considered in detail the environmental costs and benefits of several alternatives for the disposal of material dredged from the channel (and the berth, under previous iterations of Project scope), including land and ocean disposal options. This section provides an overview of the various disposal options that were considered since Project pre-feasibility planning, and the advantages and disadvantages of each option provided in Table 2-3.

Onshore disposal options are limited as the site is restricted both geographically and in terms of land allocation within SBR's lease area (area excised from the SBWHA, Mining Lease 260SA; Figure 1-1). All onshore disposal options were considered in the context of the following required minimum land disturbance activities to stockpile and dewater material prior to re-use and/or trucking offsite to a resource recycling/landfill facility, given there were no on-site re-use options available at the time of assessment:

- Construction of a reclamation area.
- Material borrow site to win material to construct reclamation bund wall.
- Construction of a pipeline corridor (marine and terrestrial).
- Mobilisation of earth moving plant and equipment, plus equipment (trucks etc.) to move stockpiled material offsite to a resource recycling/landfill facility.
- Management and discharge of the tailwater back to the marine environment.

The disposal of all material onshore would require a reclamation site of ~60 000 m^2, with conservative area for settlement of fines within any supernatant water, to limit return water with elevated concentrations of suspended solids. During preliminary Project scoping, SBR identified three sites for potential onshore disposal of dredged material that would limit additional land/vegetation clearing (A–C; Figure 2-1). Not all material will fit within any one of the indicative onshore placement areas, so duplication of onshore disposal areas or staging of stockpiling material would be required to effectively place all material onshore.

Subsequent removal of onshore stockpiled material via landfill disposal (or resource recycling) does not align with the objectives of the *Waste Avoidance and Resource Recovery Act 2007*, and to discourage waste the *Waste Avoidance and Resource Recovery Levy Act 2007* imposes the landfill levy. The fees/environmental licencing associated with onshore stockpiling and/or trucking large volumes of material offsite are prohibitive, as intended, and include trucking costs, landfill/resource recovery fees, soil testing prior to receipt at the landfill/recovery centre (DWER 2019) etc. Notwithstanding, there are very few landfill/resource recovery facilities in the region capable of accepting large volumes of fill; clean or otherwise. Therefore, material would need to be trucked to near-Perth facilities, with prohibitive costs, logistics and environmental issues associated with regional waste being delivered to metropolitan areas.

With these limitations for onshore disposal, SBR initially proposed to place material at either of the two previously approved offshore dredge placement areas – inner and outer disposal areas within the SBWHA and/or SBMP – which was discussed with EPA Services during a pre-referral meeting on the 6 August 2019. The habitats at these disposal grounds were found to comprise primarily bare sand, however, historical habitat mapping (1996–2002) completed by the Western Australian Department of Biodiversity, Conservation and Attractions[2] (DBCA) indicated the inner disposal ground was covered by ~26 ha of perennial seagrass, since reaffirmed by recent (2019/2020) benthic habitat mapping (Appendix C). SBR subsequently removed the inner disposal site from the Project in recognition of the broader environmental issues faced by Shark Bay (Heron et al. 2020), but also with consideration of disturbance to a greenfield site, particularly one within the SBMP that would result in the direct loss of perennial seagrass.

Through consultation with stakeholders, SBR recognises the concerns regarding elevated concentrations of tributyltin (TBT) within berth pocket sediments, even though the assessment of risk presents a low likelihood for ecological effects (Section 5.2.2). As such, ocean disposal is proposed for dredged channel sediments only, with seabed levelling of the high spots within the berth pocket (which is excised from the SBWHA and SBMP), minimising potential risks to the marine environment and effectively leaving potentially contaminated material in situ.

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[2] DBCA was previously the Department of Environment and Conservation (DEC), and prior to that was the Department of Conservation and Land Management (CALM)

The placement of dredged channel material at the proposed offshore disposal site was ultimately selected due to the following key points:

- The offshore disposal site has been approved previously (in 2001, extended in 2004) and also represents a disturbed ‘brownfield’ site that was used for the disposal of dredged material during the 1982 dredging campaign (Section 2.1). SBR sought to avoid creation of a new ‘greenfield’ site of disturbance, onshore or offshore.
- Not all material will fit within any one of the proposed onshore placement areas and stockpiling on SBR's lease area is not a long-term solution given the limited space within their existing lease area (Mining Lease 260SA; Figure 1-1).
- Avoid the potential for secondary environmental impacts due to dust/return water turbidity to the nearby SBWHA/SBMP from onshore disposal.
- The salt operations, including dredging of the Denham channel and disposal of dredge material within the World Heritage Property were ‘not deemed to be a threat to the heritage values or integrity’ (Heron et al. 2020).
- Useless Loop is geographically restricted, with only a single dirt road access point by land. Offshore disposal heavily reduces the logistical restraints involved in onshore placement in terms of equipment mobilisation/demobilisation and travel time.
- Beneficial reuse options were not available and would incorporate the same secondary impact and logistical constraints as detailed above.

Table 2-3 Alternative disposal site options for Shark Bay Resources dredging

Disposal option		Advantages	Disadvantages	Decision
1	Offshore – all material to either the inner or outer previously approved disposal areas within the Shark Bay World Heritage Area (SBWHA) and/or Shark Bay Marine Park (SBMP).	**Engineering** • Less time to complete disposal run due to closer alignment of disposal sites relative to the berth pocket and entrance channel dredge areas. • Less equipment required compared to onshore disposal options (Options 3–7) **Environment** • Previously approved disposal site in 2001, approval extended in 2004. • Previously used outer area (brown-field site) for disposal of entrance channel dredge material in 1982.	**Environment** • Potential loss of 26 ha of perennial seagrass from the inner 'greenfield' disposal area, within the SBMP/SBWHA. • DAWE Sea Dumping permit required.	**Option not progressed** due to feedback from DWER related to the inner disposal site; positioned within the SBMP and potential loss of perennial seagrass, which also represents a 'greenfield' site for disposal.
2	Offshore – all material to the outer previously approved disposal area	**Engineering** • Less equipment required compared to onshore disposal options (Options 3–7). • Avoid 'greenfield' area and potential loss of 26 ha of perennial seagrass from the inner disposal site. • Located outside of the SBMP boundary. **Environment** • Previously used outer area (brownfield site) for disposal of entrance channel dredge material in 1982. • Previously approved disposal site in 2001, approval extended in 2004.	**Engineering** • Increased time to complete disposal run due to distance of disposal site relative to the berth pocket (~2-hour turnaround). **Environment** • Located within the SBWHA. • DAWE Sea Dumping permit required.	Option initially considered based on pre-referral discussions and an ability to retain disturbance within an existing 'brownfield' site. Based on stakeholder concerns regarding elevated concentrations of tributyltin (TBT) within berth pocket sediments, **offshore disposal for ALL material will not be progressed.**
3	Onshore – salt pond (placement 'C' in Figure 2-1)	**Engineering** • Use dredge material to even out depressions within the Shark Bay Resources (SBR) lease area (excised from the SBWHA) to create a suitable site for a new salt crystalliser. Potential stockpiling of dredge material for use on site as fill material, though no available site use evident at the time of completing this assessment.	**Engineering** • All onshore disposal options require material from dredging to be stockpiled onshore with return water to the marine environment. The following land disturbance activities will be required to stockpile material for reuse or trucking offsite to a resource recycling facility: – a reclamation area to be constructed – borrow site to win material to be used to construct reclamation bund wall	**Option not progressed** as the salt pond 'C' site was only available for a limited time due to near-term necessity, which is no longer a viable option. This site would have only accounted for a small

Disposal option		Advantages	Disadvantages	Decision
		Environment • DAWE Sea Dumping permit not required. • Beneficial reuse of dredged material.	– construction of a pipeline corridor. • Additional cost associated with mobilisation of earth moving plant and equipment. • Not all material will fit within the salt pond and so placement option 3 would need to be completed in unison with another option – likely increasing costs for plant and equipment if different disposal options are chosen. • Geotechnical survey data to confirm acceptable for use in salt pond. **Environment** • Onshore stockpiling and resource recycling would require additional environmental monitoring against: – Contaminated Site Guidelines (DER 2014) – to investigate the disposal of sediments with potential to create a contaminated site and/or contaminated leachate. – Landfill Waste Classifications and Waste Definitions 1996 (as amended 2019; DWER 2019) – to determine whether disposal of dredged material to a gazetted landfill site is required. – Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) – to determine impacts as a result of return water discharged to the marine/freshwater environment. • Turbidity generated at the site of return water and potential impacts to nearshore/shallow water perennial seagrass meadows. • Consideration of other guidance and regulations for use of the waste-derived materials. • Stockpiling material may require a Works Approval (licence) under Part V of the EP Act. • Native vegetation clearing permit may be required. • The availability for re-use in salt ponds is highly dependent on the results of soil sampling and subsequent landfill/contamination classification.	volume of total dredge material and so could only be considered in unison with other disposal option(s).

Disposal option		Advantages	Disadvantages	Decision
			• An assessment of SBR's site indicated limited space for stockpiling material and wind-blown dust may have other environmental/operational impacts for consideration (Figure 2-1). • Depending on the site, land disturbance may require cultural heritage approval. • No beneficial re-use options evident at the time of preparing the DEIA	
4	Onshore – stockpile to resource recovery (placement 'A–C' in Figure 2-1)	**Engineering** • Potential stockpiling of dredge material for use on site as fill material, though no available site use/need evident at the time of completing this assessment (Option 3). **Environment** • DAWE Sea Dumping permit not required. • Beneficial reuse of dredged material, though additional testing for use of the waste-derived materials required. • SBR lease area excised from the SBWHA/SBMP.	**Similar to Option 3**, with the inclusion of the below points. **Engineering** • At the time of preparing this impact assessment there were no known resource recycling plants in Shark Bay, meaning considerable costs/logistics in relation to trucking material out of Useless Loop. • Additional cost associated with mobilisation of earth moving plant and equipment. • Not all material will fit within any one of the onshore placement areas and so duplication of onshore disposal areas or staging of stockpiling material would be required to effectively place all material onshore, with significant cost/time implications. **Environment** • The choice of disposal site is highly dependent on the results of soil sampling and subsequent landfill/contamination classification. • If dredged material is disposed via a third-party the local landfill site and government levy/fees apply, adding considerable costs to the Project. • Additional risks to seagrass at placement option 'A' due to reclamation, halo effect, return water turbidity. • Comparisons required in-line with Option 3 and no beneficial re-use options evident at the time of preparing the DEIA.	**Option not progressed** given lack of resource recycling options and negligible contamination risk attributed to majority of dredge material.
5	Onshore – stockpile to beach nourishment	**Engineering** • Potential stockpiling of dredged material as beach nourishment material.	**Similar to Option 3**, with the inclusion of the below points.	**Option not progressed** due to lack of viable beach renourishment options as well as

Disposal option		Advantages	Disadvantages	Decision
		Environment • DAWE Sea Dumping permit not required if above low water mark. • Beneficial reuse of dredged material, though additional testing for use of the waste-derived materials required.	**Engineering** • Most likely requirement for beach nourishment would be the Denham town beach, adjacent to the local boat ramp. It is noted that these beaches are generally nourished by maintenance works that the Department of Transport carry out at the local boating facility (Oceanica & BMT JFA 2012). Significant transport distance to the disposal site would add to the logistic and economic challenges (~20–50 km from the berth and channel dredge areas). The water depths adjacent to the disposal site are shallow, thus direct placement via the dredge and a pipeline would require mobilisation and installation of a large length of steel pipeline (and potential impacts to benthic habitat where pipe is installed). • It is unlikely that <u>all</u> material could be used for beach nourishment and so secondary options would need to be considered in parallel to beach nourishment near Denham, with significant cost/time implications. **Environment** • Project works beyond SBR's lease holding would require additional stakeholder consultation to ensure Project does not disrupt Shire of Shark Bay precinct and other environmental aspects at this new location. • Comparisons required in-line with Option 3 and no beneficial re-use options evident at the time of preparing the DEIA.	logistical consideration for pursing beach renourishment.
6	Onshore disposal of contaminated material within SBR Lease area (placement 'A–C' in Figure 2-1), remaining material disposed offshore within the SBWHA but outside the SBMP (proposed disposal site Figure 1-1)	**Engineering** • Potential stockpiling of dredge material for use on site as fill material, though no available site use evident at the time of completing this assessment (Option 3) and implications for acceptable use in-line with relevant guidelines.	**Similar to Option 3**, with the inclusion of the below points. **Environment** • offshore placement within the SBWHA. • DAWE Sea Dumping permit required. • Third-party landfill/resource recovery and government levy/fees apply, adding considerable costs to the Project.	<u>**Option not progressed in the near-term**</u>, with preference to level high spots adjacent to the berth, avoiding introduction of any contaminants to offshore area, and limiting potential secondary environmental impacts associated with

Disposal option		Advantages	Disadvantages	Decision
		Environment • Potential options for beneficial reuse of dredged material, though additional testing for use of the waste-derived materials required.	• Comparisons required in-line with Option 3 and no beneficial re-use options evident at the time of preparing the DEIA.	dewatering and creation of a newly disturbed onshore site.
7	Onshore disposal of contaminated material within SBR Lease area (placement 'A–C' in Figure 2-1), remaining material disposed offshore outside the SBWHA/SBMP	**Engineering** • Potential stockpiling of dredge material for use on site as fill material, though no available site use evident at the time of completing this assessment (Option 3) and implications for acceptable use in-line with relevant guidelines. **Environment** • Potential options for beneficial reuse of dredged material, though additional testing and guideline comparisons required in-line with Option 3, and no beneficial re-use options evident at the time of preparing the DEIA. • Disposal outside the SBWHA/SBMP.	**Similar to Option 3**, with the inclusion of the below points. **Engineering** • Duplication of dredge plant to provide scope for both onshore and offshore disposal options is logistically complex and has significant cost/time implications. • Disposal of material offshore beyond the SBWHA/SBMP would include transfer 80–100 km offshore, which would, at a minimum, double the current estimated timeline for the Project (~4-hour turnaround on disposal runs), adding considerable costs to the Project. **Environment** • DAWE Sea Dumping permit required. • Placement of material on undisturbed 'greenfield' site, not within an existing footprint for dredge disposal.	<u>**Option not progressed**</u> given negligible risk of contamination attributed to remaining (channel) dredge material and preference to avoid creation of a new 'greenfield' site of disturbance, onshore or offshore.
8	All material disposed of offshore outside of the SBWHA and SBMP	**Engineering** • Single disposal option (e.g. offshore only) reduces requirements for mobilisation of earth moving plant and equipment associated with onshore disposal (Options 3–7). **Environment** • Disposal outside the SBWHA/SBMP • No requirement to assess against terrestrial receptors/guidelines (refer disadvantages under Option 3).	**Engineering** • Disposal of material offshore beyond the SBWHA/SBMP would include transfer 80–100 km offshore, which would, at a minimum, double the current estimated timeline for the Project (~4-hour turnaround on disposal runs), adding considerable costs to the Project. **Environment** • DAWE Sea Dumping permit required. • Placement of material on undisturbed 'greenfield' site, not within an existing footprint for dredge disposal.	<u>**Option not progressed**</u> given negligible risk of contamination attributed to majority of dredge material and a preference to avoid creation of a new 'greenfield' site of disturbance, onshore or offshore.
9	All material disposed of onshore outside of the SBWHA.	**Environment** • Disposal outside the SBWHA/SBMP.	**Similar to Option 3**, with the inclusion of the below points.	<u>**Option not progressed**</u> given lack of resource recycling options, the negligible contamination risk attributed to majority

	Disposal option	Advantages	Disadvantages	Decision
			Engineering • At the time of preparing this impact assessment there were no known resource recycling plants in Shark Bay, meaning considerable costs/logistics in relation to trucking material out of Useless Loop. • Additional cost associated with mobilisation of earth moving plant and equipment. • Not all material will fit within any one of the onshore placement areas for stockpiling and so duplication of onshore disposal areas or staging of stockpiling material would be required to effectively place all material onshore prior to trucking off-site, with significant cost/time implications. **Environment** • Limited brownfield space within the existing SBR lease within the proximity of the water for dewatering. • The choice of disposal site is highly dependent on the results of soil sampling and subsequent landfill/contamination classification. • If dredged material is disposed via a third-party the local landfill site and government levy/fees apply, adding considerable costs to the Project.	of dredge material, and a preference to avoid creation of a new 'greenfield' site of disturbance, onshore or offshore.
10	Entrance channel material to the outer previously approved disposal area and seabed levelling within the berth pocket (proposed option)	**Engineering** • Less equipment required compared to onshore or split onshore/offshore disposal options (Options 3–7) **Environment** • Avoid potential loss of 26 ha of perennial seagrass from the inner 'greenfield' disposal site. • Avoid disposal of potentially contaminated berth pocket material at offshore disposal site; maintains material within area excised from the SBMP. • Offshore disposal site previously approved and historically used for disposal of dredged material (i.e. use of a brownfield site).	**Engineering** • Material remains in and around the berth pocket area and is available for resuspension by vessel wash, increasing risk of future high spots that affect available drafts **Environment** • Offshore site located within the SBWHA. • Contaminated material remains in the system is not removed, mixed/diluted or capped. • DAWE Sea Dumping permit required.	<u>**Current proposal**</u> proposed due to: • seabed levelling minimising spread of potentially contaminated material (kept in situ) • minimise potential for secondary environmental impacts from onshore disposal • avoid creating a new 'greenfield' site of disturbance • salt operations, including dredging and disposal of material within the World Heritage

Disposal option		Advantages	Disadvantages	Decision
		• Located outside of the SBMP boundary. • Avoid secondary environmental impacts associated with onshore placement, e.g. return water and terrestrial receptors.		property, were “not deemed to be a threat to the heritage values or integrity”.

Note:
1. 'DAWE' = Department of Agriculture, Water and the Environment, 'EP Act' = Environmental Protection Act 1986, 'SBMP' = Shark Bay Marine Park, 'SBR' = Shark Bay Resources, 'SBWHA' = Shark Bay World Heritage Area

Source: GoogleMaps (2019)

Figure 2-1 Aerial image of Useless Loop berth and potential onshore disposal sites

2.4 State dredging projects

The proposed Project is small in the context of other WA capital and maintenance dredging projects. Estimated volumes and durations for recent selected WA capital and maintenance dredging projects are presented in Table 2-4 to add context to the relative size and duration of SBR's proposed Project. However, regardless of the size of the proposed Project, SBR are acutely aware of the cultural and environmental significance of the region in which the Project occurs and are working with key stakeholders and the community to ensure that the Project is carried out in-line with environmental legislative requirements (Appendix K and Section 3). In recognition of concerns regarding to the proposed Project, SBR has revised the key project characteristics to avoid disposal of berth pocket material at the offshore disposal site (Sections 2.2 and 2.3).

Table 2-4 State dredging projects

Project name and type	Volume (m^3)	Year	Duration	Reference
Wheatstone LNG, Onslow	25 000 000	2015	2 years	BMT (2018)
Pilbara Port Authority CROP Dredging, Port Hedland	Up to 3 266 000[1]	2019	5 months	PPA (2019)
Beadon Creek Capital Dredging Stage 2, Onslow	950 000	2018	12 months	O2 Marine (2017), BMT (2018)
Pilbara Port Authority – Port Hedland Maintenance Dredging	~500 000	Annually	2 months	GHD (2018)
Rio Tinto Dampier and Cape Lambert Port Maintenance Dredging	480 000	2016	3 months	BMT (2018)
Pilbara Port Authority – Port of Ashburton Routine and Emergency Maintenance Dredging	Routine: 300 000 per year to a max of 1 500 000 over five years Emergency: 1 000 000 over five years for emergency dredging associated with cyclone events	~Annual dredging for five years from 2018	Unknown	PPA (2019)
Port Walcott, Maintenance Dredging	168 000	2019	1 month	BMT (2020)
Onslow Salt Maintenance Dredging	168 000	2016	1 month	BMT (2018)
Port of Broome Channel Optimisation Project, Capital Dredging	140 000	2019	2 weeks	BMT (2018)
Beadon Creek Capital Dredging Stage 1, Onslow	65 000	2015	8 months	BMT (2018)

Notes:
1. This is the approved dredge volume; it is unclear what volume was dredged due to lack of publicly available data.
2. This table does not provide an exhaustive list of all recent state projects due to a lack of publicly available data at the time of writing this report.

3 Relevant Environmental Legislation and Approvals

3.1 Decision making authorities

The following key State and Commonwealth decision-making authorities have been identified for the Project:

- DWER, Environmental Protection Authority Services (EPA Services)
- DAWE
- DBCA
- Shark Bay World Heritage Advisory Committee
- Department of Jobs, Tourism, Science and Innovation (DJTSI)
- Department of Primary Industries and Regional Development (DPIRD)
- Department of Planning, Lands and Heritage (DPLH)
- Yamatji Marlpa Aboriginal Corporation (YMAC)
- Malgana Aboriginal Corporation (MAC).

3.2 Relevant legislation and guidance material

3.2.1 Environmental Protection Act 1986

The EP Act is the major piece of legislation relating to the environment in WA. For projects proposed within WA State Waters, the EP Act defines the primary approvals process for undertaking environmental impact assessment (EIA). The EP Act (mainly Part IV) together with its Administration Procedures (2016a) specify the objectives and requisite procedures for EIA of proposals, which must be complied with by all stakeholders, including: the proponent, DWER EPA Services and any other relevant party.

The proposed Project will be referred to the EPA Services under Section 38(1) of the EP Act (Part IV) to determine the level of assessment. The EPA Services applies a Significance Framework to make decisions through the environmental impact assessment process, based on the concept of significance established under the EP Act. The EPA will determine if the proposal is likely to impact on any key environmental factors (e.g. Benthic Communities and Habitat, Marine Environmental Quality, Marine Fauna; see Section 5) by determining the likely significance of the expected impacts in relation to meeting the EPA's objectives for each key factor using the proponent's Environmental Referral Document (EPA 2020a).

3.2.2 Environmental Protection and Biodiversity Conservation Act (1999)

The EPBC Act is the Australian Government's key piece of environmental legislation. EIA is required under the EPBC Act for projects that are likely to have a significant impact on Matters of National Environmental Significance (MNES) defined under the EPBC Act, or in Commonwealth Waters.

Potentially relevant MNES for the Project in State Waters include (see Appendix E):

- Listed threatened and/or migratory species–including protected marine fauna.
- SBWHA and associated values.

Where there is the potential (or uncertainty) that a proposal may significantly impact upon any of these matters, a referral to DAWE is required; for a determination on whether the proposal constitutes a ‘controlled action’ necessitating assessment and approval under the EPBC Act.

The EPBC Act also provides Australia's key heritage law administered at a national level by DAWE, including the registration, maintenance and protection of sites on the Australian Heritage Database. The DAWE also administers the following Commonwealth heritage legislation:

- *Historic Shipwrecks Act 1976*
- *Aboriginal Torres Strait Islander Heritage Protection Act 1984*
- *Australian Heritage Council Act 2003*.

3.2.3 Environment Protection (Sea Dumping) Act 1981

Applications for a sea dumping permit for ocean disposal of dredged material are assessed under the Commonwealth EPSD Act by DAWE. Through the EPSD Act, the Australian Government assesses proposals to load and dump wastes and other materials at sea, permits acceptable activities and sets conditions of approval to mitigate and manage environmental impacts.

3.2.4 Biodiversity Conservation Act 2016

The *Biodiversity Conservation Act 2016* (BC Act) and the *Biodiversity Conservation Regulations 2018* provide for the conservation and protection of wildlife within WA. The underlying principles of the BC Act are to conserve and protect biodiversity, biodiversity components, and to promote the ecologically sustainable use of biodiversity components, throughout WA, with regard to the principles of ecologically sustainable development. It is likely that threatened species and ecological communities will be adequately assessed under Part IV of the EP Act and the EPBC Act; however, DBCA will be consulted as a key stakeholder during referral under the EP Act, to ensure all matters of biodiversity protection are adequately addressed.

3.2.5 Aboriginal Heritage Act 1972

Early consultation with the Malgana Aboriginal Corporation and Yamatji Marlpa Aboriginal Corporation has confirmed that there are no registered sites or heritage related issues within the Project area that are protected under the Aboriginal Heritage Act 1972. However, the Malgana traditional owners will continue to be consulted as the Project progresses.

3.2.6 Historic Shipwrecks Act 1976 and Maritime Archaeology Act 1973

The WA Museum is responsible for protection of pre-1900 maritime archaeological sites, under the *Maritime Archaeology Act 1973*, while the *Historic Shipwrecks Act 1976* protects shipwrecks older than 75 years that rest in federal waters. Some sites may also be protected under the *Heritage of Western Australian Act 1990* due to their cultural heritage significance.

3.2.7 Biosecurity Act 2015

The Commonwealth *Biosecurity Act 2015* provides a regulatory framework for management of biosecurity risks, including: non-indigenous species, pests, disease and contaminants. This is managed under the Australian Government Department of Agriculture, Water and the Environment. The *Biosecurity Act 2015* includes regulations for ballast water, biofouling and biosecurity risks associated with marine pests and will be managed according to SBR's existing introduced marine species (IMS) management plan (SBR 2018).

4 Existing Environment

4.1 Shark Bay World Heritage and Marine Park Values

Shark Bay was added to the World Heritage List in 1991, and included in the National Heritage List in 2007, due to number of significant natural features of the region. Seagrass covers some ~3500 km^2 of Shark Bay and provides a key component in the structure and productivity of the area (CALM 1996, Strydom et al. 2020). This includes the Wooramel Seagrass Bank, located off the coast to the east of Peron Peninsula, which is the largest single seagrass meadow in the world. With 12 species of seagrass known to occur in Shark Bay, it is one of the most diverse seagrass assemblages in the world. The diverse seagrass meadows and sheltered bays of the region provide refuge and breeding grounds for numerous other threatened and ecologically significant species, including turtles, whales, sharks and rays, and an internationally significant population of *Dugong dugon* (McCluskey 2008; Section 4.3.2). Increased rates of sediment accretion associated with extensive seagrass coverage has also resulted in the development of substantial sandbanks (CALM 1996), which help to maintain a steep salinity gradient within Shark Bay. Three distinct salinity zones culminate in hypersaline basins, such as Hamelin Pool, which support a significant stromatolite population (CALM 1996). The four Shark Bay World Heritage values and their relevance to the Project are summarised in Table 4-1.

The SBMP was gazetted as an A Class Marine Park Reserve in 1990 (CALM 1996). The values of the SBMP are similar to the SBWHA values, however the SBMP values place more emphasis on the social values of tourism, and commercial and recreational fishing (CALM 1996). Both tourism and fishing depend on the maintenance of marine environmental quality and benthic communities and habitats (BCH) that support the diverse range of species at Shark Bay. These values with regards to the Project definition are addressed through the maintenance of marine environmental quality (Section 5.2), the protection of BCH (Sections 5.1) and threatened/migratory marine fauna (Sections 5.3), and the consideration of potential impacts to commercial and recreational fisheries (Sections 5.4.1). The indigenous and European cultural heritage values of the region are also largely linked with the marine and terrestrial environments of Shark Bay, and are addressed in Sections 4.4.2, 4.4.3, and 5.4.4.

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Table 4-1 Shark Bay World Heritage values relevant to the Project area

World Heritage critera[1]	Values or attributes relating to the criteria	Potential interaction with Project?	Evidence and section reference(s)
Criterion vii: superlative natural phenomena, formation or features, for instance, outstanding examples of the most important ecosystems, areas of exceptional natural beauty or exceptional combinations of natural and cultural elements[2]	Stromatolites	N	Project works not near Hamelin Pool, which is in the eastern bay.
	Hypersaline environment of Hamelin Pool	N	Project works not near Hamelin Pool, which is in the eastern bay.
	Faure sill	N	Project works not near Faure sill, which is in the eastern bay.
	Wooramel seagrass bank	N	Project works not near Wooramel seagrass bank, which is in the eastern bay.
	Coastal scenery – Zuytdorp cliffs, Dirk Hartog Is, Peron Peninsula, Heirisson and Bellefin Prongs	Y	No physical interaction with coastal scenery but work may temporarily influence visual amenity (Section 5.4.2).
	Fragum beaches of L'haridon Bight	N	Project works not near L'haridon Bight, which is in the eastern bay.
	Inundated birridas and lagoons such as Big Lagoon	N	Project works not near Big Lagoon, and are not expected to interact with hydrologic or salinity structures influencing other lagoons or birridas.
	Strongly contrasting colours of the dunes/cliffs, beaches and adjacent ocean of Peron Peninsula	Y	No physical interaction with coastal scenery but work may temporarily influence visual amenity (Section 5.4.2).
	Abundance of marine fauna (dugongs, dolphins, sharks, rays, turtles and fish)	Y	Existing environment: Sections 4.3.2 and 4.4.1. Potential environmental impacts: Sections 5.3.1 and 5.4.1.
Criterion viii: outstanding examples representing the major stages of the earth's evolutionary history	Stromatolites and microbial mats of Hamelin pool	N	Project works are not near Hamelin Pool, which is in the eastern bay.
	Hamelin Pool, L'haridon Bight and Holocene deposits	N	Project works not near Hamelin Pool, L'haridon Bight or Holocene deposits, which are all in the eastern bay.
Criterion ix: outstanding examples representing significant ongoing geological process, biological evolution and man's interaction with his natural environment[2]	Unique hydrological structure, banks and sills, steep salinity gradients, three biotic zones	N	No physical interaction with hydrologic structures and no impacts to salinity structure expected due to dredge volume (Sections 2.2).
	Faure sill	N	Project works not near of Faure sill, which is in the eastern bay.
	Hypersaline environment of Hamelin Pool	N	Project works not near Hamelin Pool, which is in the eastern bay.
	Microbial communities	N	Assumed that this refers to the microbial communities that inhabit the hypersaline marine environments of Shark Bay. Project works are not expected to influence these communities or the salinity structures that support them.
	Fragum eragatum shell deposits	N	These shell deposits are distributed around the shores of Hamelin Pool and L'haridon Bight (Burne and Kench 2012). Project works not near Hamelin Pool or L'haridon Bight, which are in the eastern bay.

World Heritage critera[1]	Values or attributes relating to the criteria	Potential interaction with Project?	Evidence and section reference(s)
	High genetic biodiversity (e.g. snapper, venerid clams, bivalves)	Y	Existing environment: Sections 4.3.2 and 4.4.1. Potential environmental impacts: Sections 5.3 and 5.4.1.
	Seagrass meadows, and their role in the evolution of the marine environment	Y	Existing environment: Section 4.3.1. Potential environmental impacts: Section 5.1.
	Wooramel seagrass bank, expanse of meadows and diversity of seagrass species	Y	Project works not near Wooramel seagrass bank, which is in the eastern bay. Potential environmental impacts to seagrass meadows near the Project are discussed in section 5.1.
	Carbonate deposits and sediments	N	Generally associated with the eastern margin of Shark Bay (including the Sedimentary Deposits Reserve). Project works are in the western bay.
	Northern limit of transition region between temperate and tropical marine environments, resulting in high species diversity (e.g. 323 fish species, 218 bivalve species, and 80 coral species)	Y	Existing environment: Sections 4.3 and 4.4.1. Potential environmental impacts: Sections 5.1, 5.3 and 5.4.1.
Criterion x: the most important and significant natural habitats where threatened species of animals or plants of outstanding universal value still survive[2]	35 migratory bird species	Y	Existing environment: Section 4.3.3.
	Dugong (approx. one eighth of the world's population)	Y	Existing environment: Sections 4.3.2. Potential environmental impacts: Section 5.3.1.
	Humpback Whale and Southern Right Whale migratory staging post	Y	Existing environment: Section 4.3.2. Potential environmental impacts: Section 5.3.1.
	Loggerhead and Green Turtles	Y	Existing environment: Section 4.3.2 Potential environmental impacts: Section 5.3.1.

Notes:
1. A description of the World Heritage values can be found on the UNESCO official listing of Shark Bay (http://whc.unesco.org/en/list/578). The World Heritage values quoted here are from the Shark Bay World Heritage Strategic Plan 2008–2020 (McCluskey 2008), as these represent more current and site-specific knowledge.
2. Terrestrial values for Criterion 2, 3 and 4 are not included here as these will not be impacted by Project works.

4.2 Physical environment

4.2.1 Climate

Shark Bay represents a meeting point of three major climatic regions, and has a semi-arid to arid climate, with mild winters and hot, dry summers (CALM 1996). The mean daily temperature range at Denham (~20 km from Useless Loop) is ~20–32°C in summer and ~13–23°C in winter (BoM 2020). The average annual rainfall is 222 mm with ~68% of rainfall occurring from May to August (BoM 2020). The mean wind speed during the day varies from 16.7 km/h to 31.5 km/h (BoM 2020). Shark Bay is often subject to strong prevailing southerlies, with higher wind speeds generally occurring from October to March (Playford et al. 2013; CALM 1996). Cyclone season is from November to April although cyclones do not frequently affect the Shark Bay region; occurring approximately once every 5 years (CALM 1996, DBCA 2020, Shire of Shark Bay 2020).

4.2.2 Geology and geomorphology

The distinctive 'W' shape of the Shark Bay shoreline is comprised of the Edel Land Peninsula and Dirk Hartog Island to the west, Peron Peninsula in the centre and a coastal strip to the east (Playford et al. 2013). Underlain by anticlinal structures and rocky limestone, the land surfaces of Shark Bay are primarily Holocene sand dunes (Playford et al. 2013). The Zuytdorp Cliffs on the southwest side of the Edel Land Peninsula are contrasted by tidal flats and shell/sand beaches within the rest of Shark Bay (Playford et al. 2013, DBCA 2020). Evaporative pans known as birridas developed between some interdune depressions, with many mined for gypsum (Playford et al. 2013). The SBR Useless Loop evaporative ponds are located on Heirisson Prong, on the northern side of the Edel Land Peninsula (Playford et al. 2013). The coastline here is characterised by shallow sandy bays and small rocky islands, including Slope Island, which is utilised by SBR for salt storage (Playford et al. 2013, DBCA 2020).

4.2.3 Coastal processes and hydrodynamics

Water depth within the large embayment of Shark Bay is generally less than 15 m, averaging ~9 m (CALM 1996, DBCA 2020). Shark Bay contains many extensive shallow sand bars that restrict water movement and flushing to the south, partly cutting off some basins, narrow inlets and broad gulfs to the Indian Ocean and causing areas to turn hypersaline (e.g. Useless Loop and Hamelin Pool; CALM 1996). Influx of water occurs through the northern Geographe Channel, the Naturaliste Channel between Dorre and Dirk Hartog Islands and South Passage between Dirk Hartog Island and Steep Point (CALM 1996). The Bar Flats sill, to the north of Useless Inlet, separates the Freycinet Reach and Denham Sound, influencing flushing of oceanic water into the Project area (Logan & Cebulski 1970).

Tides are an important source of water movement in Shark Bay and are largely influenced by changing winds and air pressures (CALM 1996, Playford et al. 2013). Tides vary from a neap range of 0.61 m to a spring range of 1.71 m at Carnarvon, varying further across the different embayments of Shark Bay (CALM 1996).

4.2.4 Sediment quality

Material from the proposed dredging and disposal areas was sampled from 2 to 8 July 2019 with additional sampling completed on 18 February 2020, as outlined in the Sampling and Analysis Plan (SAP) and SAP Implementation Report (SAPIR; BMT 2019b, Appendix F).

Particle size distribution (PSD) analysis indicated that the material is broadly similar across the dredging and disposal areas (Appendix F). Dredge area sediments were predominately characterised by medium grained (250–500 µm) sands, and disposal area sediments were predominately characterised by fine to medium (125–500 µm) grained sands. Small portions of silts/clay (<63 µm) and gravel (>2000 µm) were present in both the dredge and disposal area sediment samples. The settling times for 50% of particles to settle through 1 m of water was <1 minute for all dredge and disposal area sediment samples, and the settling times for 90% of particles to settle through 1 m of water was between <1 to ~40 minutes (Appendix F). These results indicate a low risk of persistent plume generation through dredging.

Concentrations of metals and hydrocarbons in sediments were all below the NAGD screening levels in samples collected from the entrance channel and berth pocket. As such, it is unlikely that the dredging, disposal or seabed levelling of these sediments will result in adverse effects on the environment due to metals or hydrocarbons.

Sediments sampled at six sites within the berth pocket exhibited total concentrations of tributyltin (TBT) above the relevant National Assessment Guidelines for Dredging (NAGD) screening level and were resampled to determine elutriate concentrations (Table 4-2; CA 2009). Elutriate concentrations of TBT at three of these sites also exceeded the 99% and 95% species protection guideline levels (ANZG 2018; Appendix F). Analysis of TBT breakdown products indicates this contamination was recent (within 5 years). However, TBT contamination has also been an issue at the berth pocket historically, with similar levels of TBT detected in 2001 (PG Newstead, Chief Executive Officer of Shark Bay Resources, pers. comm., 27 March 2001[3]).

All other analytes in the berth pocket sediments met relevant guidelines (Appendix F). Consideration of initial dilution and the potential to release TBT into the water column has been detailed in Section 5.2.2, lowering the potential environmental risk to an acceptable level.

Contaminant analyses indicates the entrance channel sediments are clean and suitable for unconfined disposal (Appendix F). Total organic carbon (TOC) was generally low across the dredge and disposal areas, although slightly higher at the disposal area (Appendix F).

Table 4-2 Elutriate tributyltin concentrations within sediment samples from Shark Bay Resources berth pocket seabed levelling area

Sample	Elutriate TBT (µg/L)
99% species protection level (ANZG 2018)	**0.0004**
95% species protection level (ANZG 2018)	**0.006**
90% species protection level (ANZG 2018)	**0.02**
Berth pocket dredge area	
BS8_S	0.018
BS9_G	<0.002
BS10_S[3]	0.009
BS12_S	<0.002
BS15_S1	<0.002
BS16_S	**0.137**
Elutriate water sample	<0.002

Notes:
1. Only samples with normalised tributyltin concentrations above relevant NAGD screening levels were tested for elutriate concentrations of tributyltin (TBT).
2. The laboratories were not able to meet the limit of reporting (LoR) required for elutriate TBT, which is above the 99% species protection level (ANZG 2018). Background organotin concentrations become evident when the LoR is lowered to such a degree, and so it is difficult for laboratories to meet this level for elutriate TBT (L. Baker, National Measurement Institute, pers. comm., 17 April 2020). In cases where elutriate TBT was below LoR, the LoR was conservatively applied for dilution calculations (Section 5.2.2).
3. The value presented for BS10_S is an average of the two split samples.
4. Red text indicates exceedance of the 90% species protection level, **red bold text** indicates exceedance of the 99% and 95% species protection levels.

[3] Letter in response to Environment Australia (now DAWE) regarding the 2001 Sea Dumping Permit application assessment comments (Ref:PN081 01).

4.2.5 Sediment transport

PSD analyses indicated that material to be dredged is characterised by medium grained sands with only small portions of silt/clay (Appendix F). Sediment settling times were generally rapid across the dredging/seabed levelling areas (50% of particles settle through 1 m of water within <1 minute, 90% of particles settle through 1 m of water within <1 to ~40 minutes) indicating a low risk of persistent plumes generated during dredging and seabed levelling (Appendix F).

Plume dispersion modelling was completed to estimate depth averaged total suspended solid (TSS) concentrations in the water column at any given time before, during and after dredging and disposal (Appendix G). Plume dispersion modelling was conservatively based on ~103 000 m^3 of dredged material, far exceeding the proposed Project volumes (up to 80 000 m^3; Section 2.2). The plume dispersion modelling also included ~21 000m^3 from the berth pocket (Appendix G), which will be levelled instead under the new Project scope (Section 2.2). Regardless, the model provides a conservative estimate of the plume generated adjacent to the berth during seabed levelling.

The modelling was completed for two likely dredge scenarios based dredging equipment likely available at the time of completing this report:

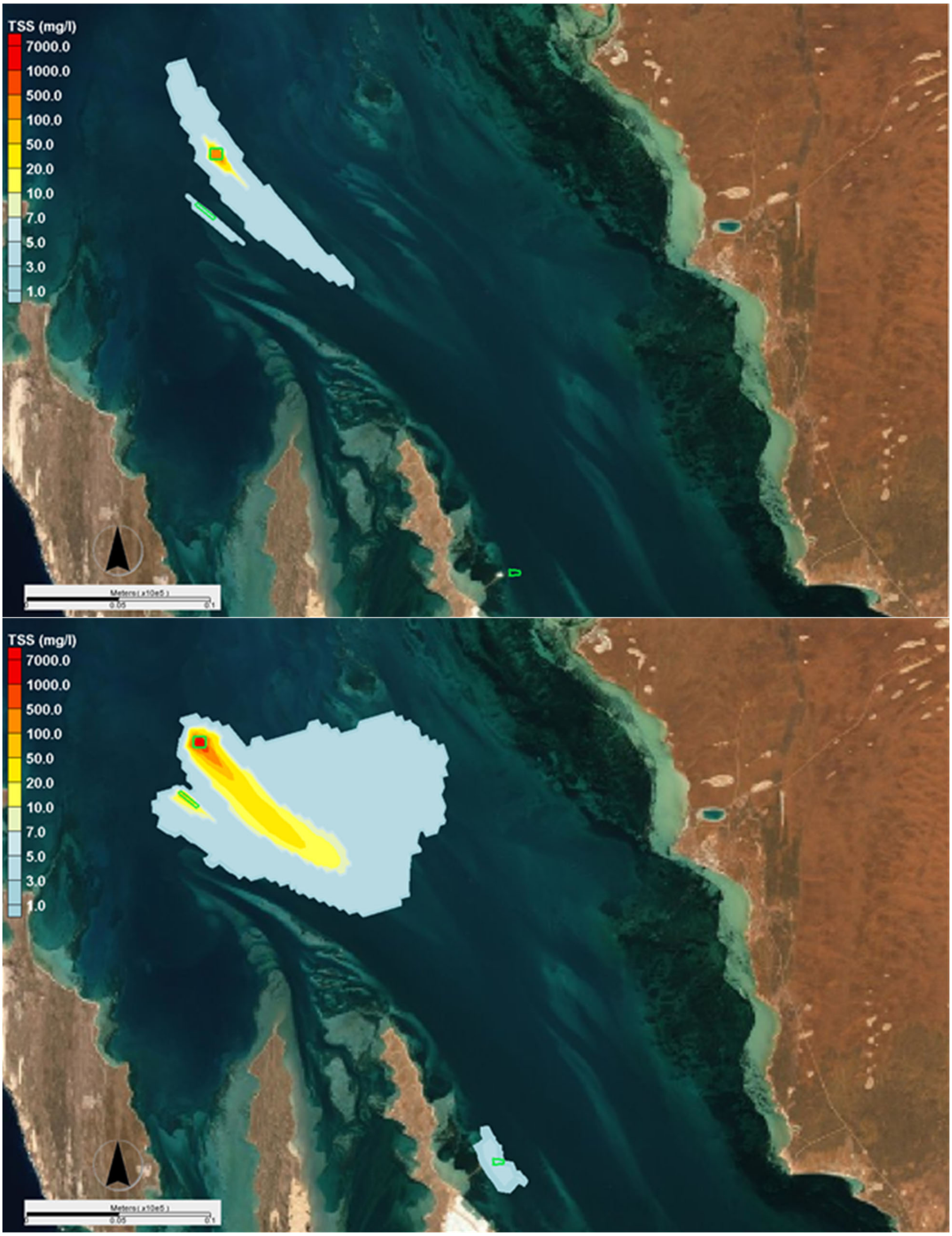
- low production rate dredging completed over a 20.1-day period
- high production rate of dredging completed over a 2.2-day period (Appendix G).

Modelled scenarios were simulated over a period of strong wind (January 2019), which was selected as the most energetic month of the year likely to result in the largest plume extent (Appendix G). Plume dispersion was also modelled for a period of low wind and calm seas and resulted in a smaller plume extent, as expected (Appendix G).

Modelled depth-averaged TSS showed that the plume was localised to the disposal area, with limited elevated TSS concentrations (<5 mg/L above ambient) for the duration of the Project at the berth pocket (Figure 4-1 and Figure 4-2). At the disposal area, modelled depth-averaged TSS concentrations will be elevated above ambient by ~50–100 mg/L for 5% of the entire period of turbidity generating activities, equivalent to ~3 or 24 hours under high and low production dredging, respectively (Figure 4-1). For 50% of the entire period of turbidity generating activities, depth-averaged TSS concentrations will be below 5 mg/L above ambient, except adjacent to the disposal area, where elevated concentrations adjacent to the disposal area range from 20–50 mg/L above ambient (Figure 4-2); 50% of the of the entire period of turbidity generating activities is equivalent to ~1 or 10 days under high and low production dredging, respectively.

Following cessation of turbidity generating activities (completion of dredging and disposal), it will take 1.5–7 days for TSS to return to near ambient conditions (<2 mg/L above ambient) for low and high production rate dredging, respectively. TSS >20 mg/L above ambient will occur up to 12 km from the disposal area at the furthest modelled extent but for no more than ~3–24 hours over the entire dredging program, for high and low production dredging, respectively (Appendix G). Therefore, TSS concentrations will be above ambient conditions for no more than 28 days for the entire Project, regardless of the production rate.

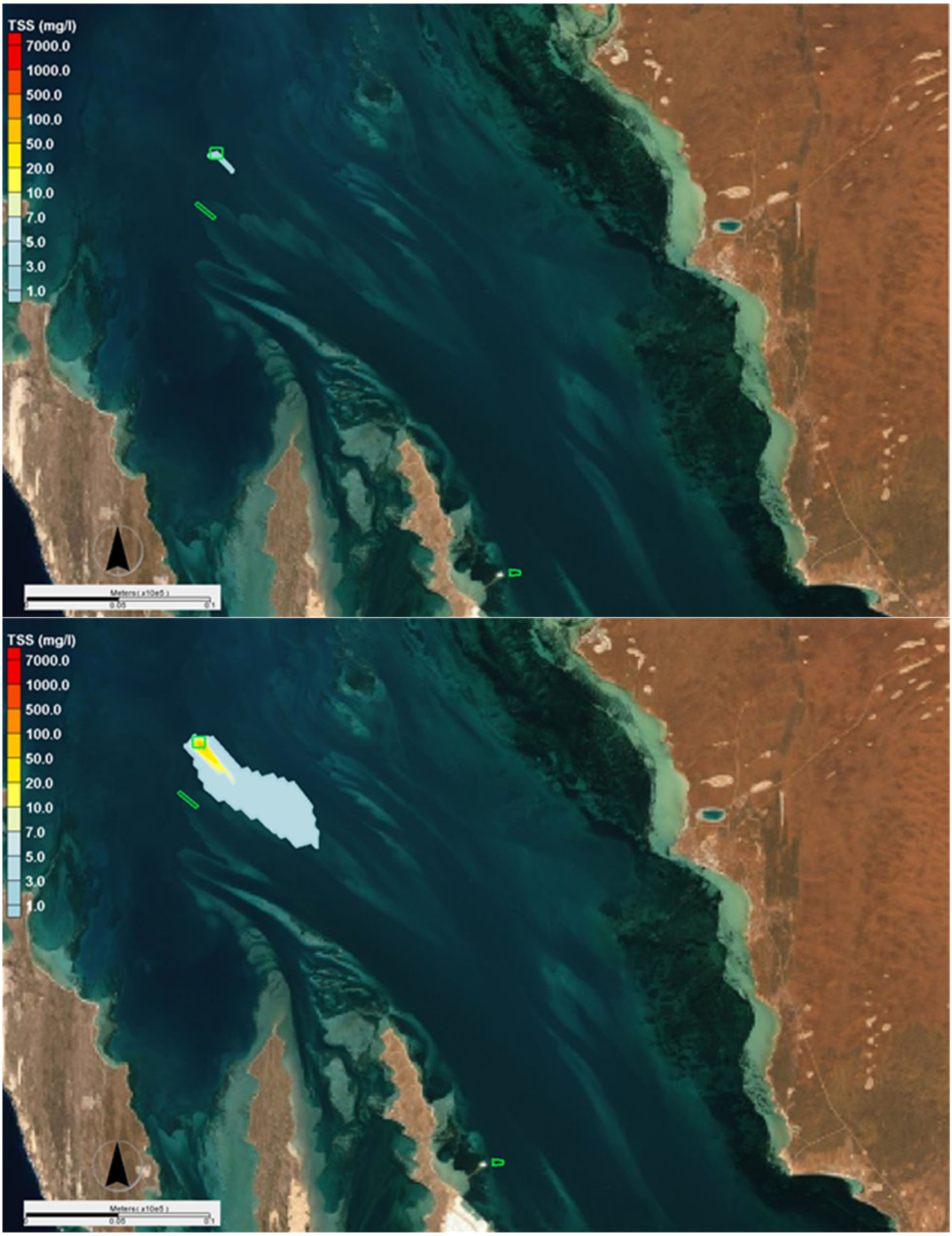
Based on these results, and due to limited turbid plumes resulting at the berth pocket, indirect effects to BCH are only likely within and adjacent to the entrance channel and disposal area. These results are incorporated into the development of relative zones of impact (Section 5.1.3), to inform management of potential impacts of increased turbidity to BCH (Appendix A).



Note:

1. Green polygons indicate the position of the disposal and dredge areas in relation to the modelled plume extent

Figure 4-1 95th percentile of modelled depth averaged total suspended solid concentrations above ambient for low (top) and high (bottom) production rate scenario for January



Note:

1. Green polygons indicate the position of the disposal and dredge areas in relation to the modelled plume extent

Figure 4-2 50th percentile of modelled depth averaged total suspended solid concentrations above ambient for low (top) and high (bottom) production rate scenario for January

4.2.6 Water quality

Waters in Shark Bay are generally clean and clear due to minimal runoff (intermittent river flow and low rainfall), high evaporation and permeable soils (CALM 1996). Inshore areas of Shark Bay may be prone to periods of elevated turbidity during strong wind and/or rain events resulting in increased water movement and runoff (CALM 1996, Kangas et al. 2006). In December 2010, an extreme cyclonic rain event (200–300 mm of rainfall over a 24-hour period), followed by two smaller events in January and February 2011, resulted in flooding of the Gascoyne and Wooramel Rivers and freshwater-sediment discharge into Shark Bay (Waddell et al. 2012, Strydom et al. 2020).

Water temperature varies greatly across different parts of the bay (17°C in winter to 27°C in summer), with warm low-salinity tropical water from the Leeuwin Current flowing southward into the Shark Bay area from autumn to winter (CALM 1996). During the summer of 2010/2011, an extreme marine heatwave affected the bay with seawater temperatures 2–5°C warmer than average (Strydom et al. 2020). Seawater in Shark Bay can be characterised into three salinity zones; oceanic, metahaline and hypersaline (Playford et al. 2013). The Port facility falls within the Freycinet Reach (salinity range of 38–46 ppt), which is considered metahaline, and the entrance channel falls within the Cape Peron Salinocline, bordering oceanic waters (Logan & Cebulski 1970).

4.3 Biological environment

4.3.1 Benthic communities and habitat

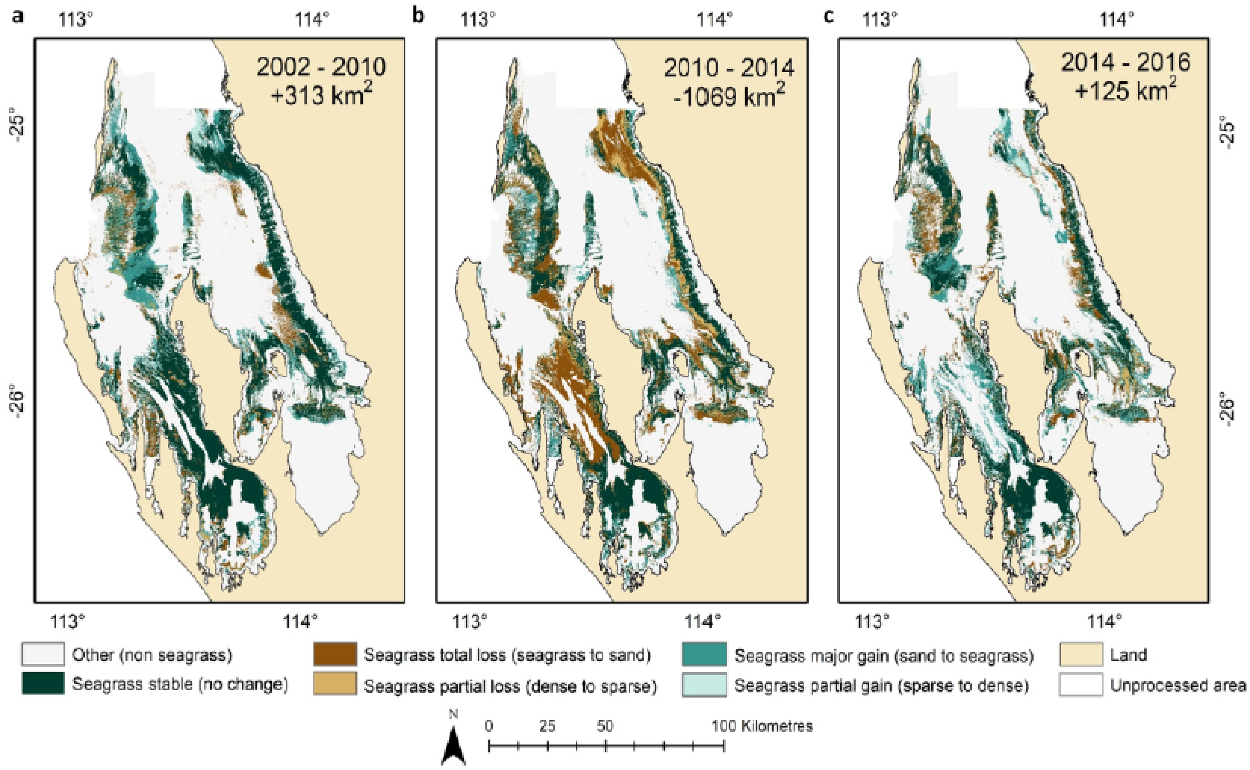
The unique environmental conditions within Shark Bay have a major influence on the extent and distribution of BCH. Shark Bay has one of the largest and most diverse seagrass assemblages in the world (~3500 km^2). Twelve seagrass species are known to occur in the region with particularly high densities present in shallower waters, generally <5 m deep (Burkholder et al. 2013, Bessey 2013). The temperate perennial seagrasses *Amphibolis antarctica* and *Posidonia australis* are the most prevalent species in the region and are generally associated with shallower water depths (<5 m, Oceanica 2009, Burkholder et al. 2013, Strydom et al. 2020). *P. coriacea* and *P. sinuosa*, also occur in the region, although are less common. Species such as *Halophila spinulosa*, *H. ovalis*, *Cymodocea* spp. and *Halodule uninervis* are relatively common but in lower densities confined to deeper waters (CALM 1996, Anderson 1994, 1998, McCluskey 2008, Burkholder et al. 2013). An extreme marine heatwave event during the 2010/2011 summer caused an estimated 36% loss of seagrass coverage, mostly affecting dense seagrass meadows consisting of *A. antarctica* in the western gulf and Wooramel Bank between 2010 to 2014, however there has been some recovery of colonising seagrass species between 2014 and 2016 (Arias-Ortiz et al. 2018, Strydom et al. 2020; Figure 4-3). Between 2014 and 2016 there was evidence of seagrass recovery in the western gulf, which was largely attributed to sparse cover of colonising species (like *Halophila* spp.) recolonising areas of bare sand (Strydom et al. 2020).

Benthic habitat mapping was undertaken by BMT to characterise the diversity and extent of benthic habitats within the Project areas (Appendix C). A preliminary local assessment unit (LAU) was defined for the subtidal benthic habitat mapping scope and has since been altered to capture the relative extent and area of influence of the Project, to ensure alignment with the Environmental Protection Authority *Technical Guidance: Protection of Benthic Communities and Habitats* (EPA 2016b). The LAU encompasses an area of ~72.2 km^2 that is split between the southern survey area that encompasses the Port (47.2 km^2) and the northern survey area that encompasses the entrance channel and proposed offshore disposal area (25.1 km^2; Figure 4-4, Table 4-3). The LAU falls within the SBWHA, and SBMP boundaries, however part of the southern survey area (the area immediately surrounding the Port facility) is excised from both, and part of the northern survey area falls outside of the SBMP boundary. The values of both the SBWHA and the SBMP will be applied to the whole LAU, in recognition of the ecological significance of the area.

Seagrass was the dominant benthic habitat within the LAU (total cover of 54% or 38.9 km^2), consisting of mixed ephemeral and perennial seagrass meadows (Table 4-3). The remaining area was largely unvegetated sand and rocky rubble substrates (43.4% or 31.4 km^2) (Table 4-3). Filter feeders (i.e. sponges and hydroids) were largely associated with bare sand and/or rock/rubble substrate and were not classified taxonomically due to species variation and very low abundance. Sponges included branching, fan, barrel and cup morphotypes.

Seagrass diversity and density varied across these areas, largely dependent on depth. In the southern survey area, in shallow waters around the Port (<5 m), there was dense coverage of the perennial seagrasses *P. australis* and *A. antarctica*, similar to mapping completed by Oceanica (2009). In deeper waters (>5 m) offshore from the Port there were mixed assemblages of seagrasses, dominated by *H. spinulosa*, with sparse occurrences of *Posidonia* spp. There were also intermittent patches of bare sand and rocky rubble that contained infrequent filter feeders such as gorgonians, tubular and cup sponges, and hydroids. In deeper waters (>5 m) within the northern survey area, adjacent to, and north of the entrance channel, transects yielded mostly unvegetated sand and rocky substrate with patches of sparse seagrasses, including mixed assemblages dominated by *H. spinulosa*, interspersed with patches of bare sand, rock rubble and occasional filter feeders. Shallower areas to the north east of the northern study area contained stands of *Posidonia* spp. at almost 100% coverage.

The mapped benthic habitats were representative of known regional and local habitats and no new BCH were observed. Species identified within the LAU that are known to occur at the extremities of their geographic ranges (temperate and tropical seagrass species) are also known to occur throughout the broader Shark Bay area. The *Halophila* spp. identified as occurring within the LAU are known food sources for dugongs and green turtles, and known habitat for prawns (McMahon et al. 2017a; Section 4.4.1). *Amphibolis antarctica* is also a source of food for dugongs in this area during winter (Anderson 1986).



Source: Strydom et al. (2020)

Figure 4-3 Seagrass extent and distribution changes from 2002–2010, 2010–2014 and 2014–2016

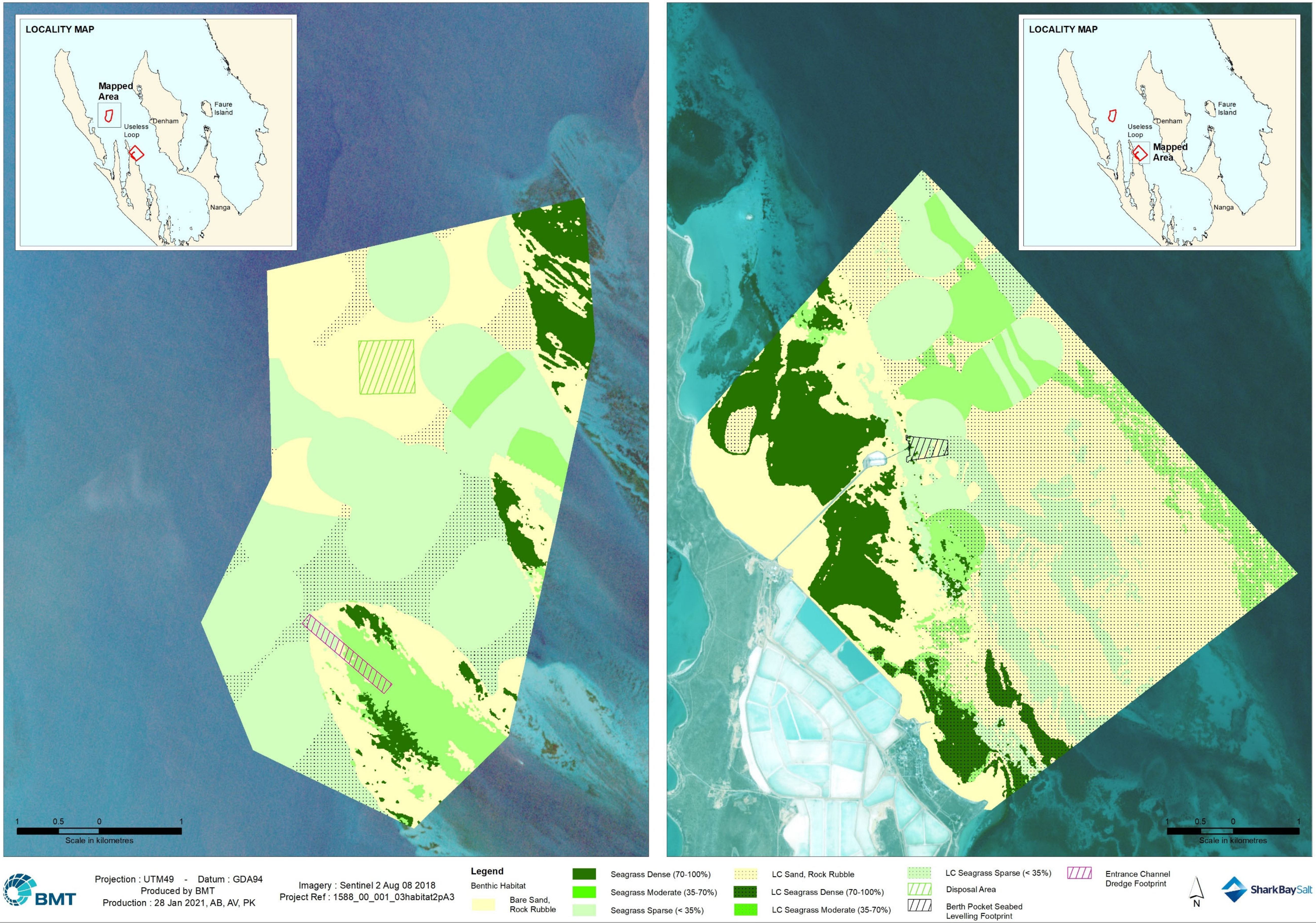


Figure 4-4 Benthic habitat classification within the local assessment areas, adjacent to the entrance channel and offshore disposal (left) area and the berth pocket (right)

Table 4-3 Extent of benthic habitat categories in mapped area

Habitat	Species/description	Area (km^2)	Proportion (%)
Seagrass dense (70–100%)	Generally dominated by *P. australis* and *A. antarctica*	8.9	12.4
Seagrass moderate (35–70%)	Dominated by *H. spinulosa*	7.9	11.0
Seagrass sparse (<35%)	Mixed species, although significant *H. spinulosa*	22.1	30.6
Bare sand, rock rubble	–	31.4	43.4
Infrastructure footprint	–	1.9	2.6
Total	–	72.2	100

4.3.2 Threatened and migratory marine fauna

The marine waters surrounding the Project support a variety of fauna, several of which are significant and protected under the EPBC Act. A search of the online EPBC Act Protected Matters Reporting Tool (Appendix E) identified nine listed threatened marine species and 14 listed migratory marine species that may occur near the Project[4]. The listed marine species include: five marine mammals (whales), four marine reptiles (turtles) and three shark species. There were also six listed marine migratory species (sharks, whales, dugong, and rays). The potential impacts to threatened and migratory marine fauna are assessed in Table 4-4 and summarised below. Additional marine species listed as possibly occurring within the project area (other matters protected by the EPBC Act) included 17 fish (pipefish, seahorses and sea dragons), 8 reptiles (seasnakes), and 6 whales and other cetaceans (whales and dolphins). A search of the DBCA NatureMap Species search tool (Appendix H) did not identify any additional species not already identified in the EPBC Act Protected Matters Reporting Tool.

4.3.2.1 Marine mammals

The marine mammals identified for the Project area include dugongs and whales (Table 4-4). Shark Bay hosts one of the world's largest populations of dugongs (>10 000 individuals, with a density of ~0.7 dugongs per km^2; Gales et al. 2004, Holley et al. 2006). Dugongs are known to feed on both above and below-ground seagrass biomass, so their distribution broadly coincides with seagrass (DoE 2020a). While preferentially feeding on species such as *Halophila* and *Halodule* (Marsh et al. 2011a), dugongs are capable of feeding on a range of seagrass species, macro-invertebrates and algae (Marsh et al. 1982; Anderson 1989; Preen 1995). Dugongs are mainly associated with tidal and subtidal shallow protected bays and may also be found in offshore waters (DoE 2020a). Dugongs utilise a variety of habitats across Shark Bay, including deeper water for predator avoidance (Wirsing et al. 2007), and avoid shallow areas (such as Henri Freycinet Harbour, Faure Island and the Wooramel seagrass banks) of Shark Bay in winter as a form of thermoregulation, tending to concentrate in deeper, warmer waters in the western bay during this time (Holley et al. 2006; Marsh & Grech 2011). Dugongs breed seasonally, during spring (September–November), with calving occurring from December (DoE 2020a).

Of the four whale species identified, only the humpback whale is known to commonly occur in Shark Bay, which is an important resting area during the species' southerly feeding migration (August–October) (DoE 2020b). Humpback whales tend to stay further offshore during their northerly migration to breeding grounds, however, may use the protected waters of Shark Bay as a resting point during this time as well (May–August) (Jenner at al. 2001, DoE 2020b). Migrating killer and bryde's whales are most often seen in relatively deeper waters and in Australia are most commonly seen along the continental slope and shelf areas (IFAW 2011, Chevron Australia 2013). Occurrence of southern right whales north of Perth is considered rare, though they have been recorded as far north as Exmouth and may use Shark Bay as a staging post during this migration (Table 4-1; Bannister 2001, DoE 2020c).

4.3.2.2 Reptiles

Sea turtle species are commonly found in coral and rocky reef, sandy beach and seagrass habitats along the west coast of Australia, with four sea turtle species identified as occurring within the vicinity of the Project (DEWHA 2008; Table 4-4). Shark Bay hosts Australia's largest nesting colony of loggerhead turtles, with 800–1500 females breeding per year (DBCA 2020, DoE 2020d). The sandy beaches of islands near Shark Bay including Dirk Hartog Island are utilised as principle nesting sites, with breeding occurring from November to March and peaking in late December/early January (DoE 2020d). Hatchling and subadult loggerhead turtles forage in open ocean, moving onto benthic foraging habitats, including rocky reefs, coral reefs and seagrass meadows, as adults (Limpus et al. 1984; Limpus et al. 1994).

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[4] Within a 5 km of a straight line from the berth pocket dredge area to the entrance channel dredge area (Appendix E)

While not a key nesting or inter-nesting area (DEH 2005, DEWHA 2008), both resident and migratory populations of green turtles are known to utilise the reefs around Shark Bay (Pendoley 2005, DEC 2007). Resident green turtle nesting likely occurs from November to March (DoE 2020e). Shark Bay does not support leatherback or flatback turtles, and sightings of either in the area are rare (DBCA 2020, DoE 2020f,g).

Considering the Project works are to be largely concentrated near the existing Port and offshore in the Denham Channel, the Project will not impact any turtle nesting areas. Other potential impacts to turtles and turtle habitats are discussed in Sections 5.3.1 and 5.1, respectively.

4.3.2.3 Sharks and rays

Grey nurse sharks typically inhabit rocky caves and gravel filled gutters, and occasional sightings of this species have been recorded around Dirk Hartog Island (DoE 2020h). Great white sharks are generally associate with rocky reefs, shallow coastal bays and areas of high prey abundance (DSEWPaC 2012b). While not commonly sighted in Shark Bay, great white sharks may be present in the area during migration up (from ~September) and down (until ~February) the WA coast (DoE 2020i). The porbeagle is a wide-ranging, coastal and oceanic shark, that is not generally considered to inhabit waters any further north than Perth in WA (DEWHA 2010, Bray 2020a).

Manta rays range from Geraldton through to the tropics and are commonly sighted along productive coastlines where regular upwelling occurs, around shallow reefs and in sandy bottom areas. Giant manta rays and reef manta rays were identified as occurring within the Project area and are commonly sighted around Dirk Hartog Island and in the waters off Francois Peron National Park (DBCA 2020).

4.3.2.4 Other protected matters

Other matters protected under the EPBC Act, not already covered under threatened or migratory status, included: pipefish, seahorses, seadragons, seasnakes, other whales, and dolphins (Appendix E). The type of presence for these species was listed as "species or species habitat may occur within area", except for *Tursiops aduncus* (indian ocean bottlenose dolphin/spotted bottlenose dolphin), for which the species or species habitat was "likely to occur" within the area. Pipefish and seahorses/seadragons are typically associated with macroalgal and seagrass habitats within Shark Bay (DPIRD 2020a). Seasnakes are abundant in Shark Bay and may be found from reef habitats to open ocean (DBCA 2020, DPIRD 2020a).

A population of more than 2000 dolphins inhabit Shark Bay, comprised of both *T. truncatus* and *T. aduncus* (DBCA 2020, DoE 2020j,k). These species are known to inhabit inshore, nearshore and offshore waters, and have been known to associate with other cetacean species (Reynolds et al. 2000). The primary sources of food for dolphins include fish, invertebrates and squid (DoE 2020j,k).

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Table 4-4 Likely interaction with threatened and migratory marine fauna

Species	Conservation Status		Habitat/distribution	Period of habitat use within Project area	Type of presence identified	Likelihood of interaction with Project
	State[2]	EPBC Act[3]				
Marine mammals						
Balaenoptera edeni Bryde's whale	–	Cetacean, Migratory	No specific breeding or feeding grounds are known in Australian waters (DoE 2020l). However, this species is known to inhabit temperate and tropical inshore and offshore waters (Bannister et al. 1996) and undergo migration between subtropical and tropical waters during winter (Best 1977).	–	Species or species habitat may occur within area	Low
Dugong dugon Dugong	Other protected fauna	Marine, Migratory	Known to occur, feed and breed within the Shark Bay area, associated with near tidal and subtidal seagrass meadows (Holley et al. 2006). Breeding territories known to have been established in the eastern bay (CALM 1996). Dugongs also utilise offshore waters in Shark Bay for feeding and predator avoidance (Wirsing et al. 2007).	Year-round presence. Shallow waters in summer and deeper waters winter (Holley et al. 2006). Breeding occurs September–November, calving in December.	Breeding known to occur within area	Moderate to high
Eubalaena australis Southern right whale	Vulnerable	Endangered, Cetacean, Migratory	Present along the Australian coastline from mid-May to mid-November (occurrence north of Perth in Western Australia is rare; however, they have been recorded as far north as Exmouth; Bannister 2001, DoE 2020c). Generally feed in deeper offshore waters south of Australia with shallow, near-shore waters preferred as calving grounds (DoE 2020c).	If migration occurs further north of Perth (up to Exmouth), Shark Bay may be used as a staging post (mid-May to mid-November).	Species or species habitat likely to occur within area	Low
Megaptera novaeangliae Humpback whale	Conservation Dependent	Vulnerable, Cetacean, Migratory	Known to rest in Shark Bay during southern migration and possibly during the northern migration (Jenner at al. 2001).	August–October (northern migration) May–August (southern migration, less frequent).	Congregation or aggregation known to occur within area	Low to moderate
Orcinus orca Killer whale, orca	–	Cetacean, Migratory	–	–	Species or species habitat may occur within area	Low
Reptiles						
Caretta caretta Loggerhead turtle	Endangered	Endangered, Marine, Migratory	Associated with coral, rocky reef and seagrass habitats. Nesting and foraging occurs from Shark Bay northwards, with Australia's largest nesting colony (800 to 1500 females breeding per year) known to occur at Dirk Hartog Island within the SBWHA (DoE 2020d, DBCA 2020).	Likely year round with breeding occurring from November to March, peaking in late December/early January (Limpus 1985). Interaction with Project likely during breeding, however no interaction with nesting beaches as these are not near the Project area.	Foraging, feeding or related behaviour known to occur within area	Moderate
Chelonia mydas Green turtle	Vulnerable	Vulnerable, Marine, Migratory	Resident Green Turtles are known to inhabit the reefs around Shark Bay (DEC 2007). Some Green turtles that nest further north are known to migrate through Ningaloo Marine Park to feed in Shark Bay (Pendoley 2005). Shark Bay is not considered a key nesting or inter-nesting area (DEH 2005, DEWHA 2008).	Resident turtles occur year-round, nesting from November to March (DoE 2020e). Interaction with Project likely during breeding, however no interaction with nesting beaches as these are not near the Project area.	Foraging, feeding or related behaviour known to occur within area	Moderate
Dermochelys coriacea Leatherback turtle, leathery turtle	Vulnerable	Endangered, Marine, Migratory	No major nesting sites are known to occur within Australia (DoE 2020g). Leatherback Turtles may be found foraging in Australian waters year-round (Hamann et al. 2006), however sightings in Shark Bay are rare (DBCA 2020). Nesting in Australia only occurs every 2–4 years from December to January (DBCA 2020).	–	Species or species habitat known to occur within area	Low
Natator depressus Flatback turtle	Vulnerable	Vulnerable, Marine, Migratory	Shark Bay is not a major location for Flatback Turtles, with this species generally occurring further north along the Kimberley Coast and North West Shelf (DoE 2020f).	–	Species or species habitat known to occur within area	Low

Species	Conservation Status		Habitat/distribution	Period of habitat use within Project area	Type of presence identified	Likelihood of interaction with Project
	State[2]	EPBC Act[3]				
Sharks and rays						
Carcharias taurus (west coast population) Grey nurse shark (west coast population)	Vulnerable	Vulnerable	Typically inhabit rocky caves and gravel filled gutters (DSEWPaC 2012). Only occasional sightings within the Shark Bay area, at Dirk Hartog Island (DoE 2020h).	–	Species or species habitat likely to occur within area	Low to moderate
Carcharodon carcharias Great white shark	Vulnerable	Vulnerable, Migratory	Associated with rocky reefs and shallow coastal bays, and areas of high prey abundance (DSEWPaC 2012). This species is known to move up the Western Australian coats, as far as the North-West Cape, during spring, and return south during summer (DoE 2020i).	Potential to occur around Shark Bay from September to February.	Species or species habitat known to occur within area	Low
Lamna nasus Porbeagle, mackerel shark	–	Migratory	Coastal and oceanic shark (DEWHA 2010), with wide distribution, however not generally considered to inhabit water north of the Perth region (Bray 2020a).	–	Species or species habitat may occur within area	Low
Mobula alfredi (previously Manta alfredi) Reef manta ray, coastal manta ray	–	Migratory	Manta rays known to occur in Shark Bay and are commonly found around Dirk Hartog Island. They may also be seen the waters around Francois Peron National Park (DBCA 2020).	Seen between Kalbarri and Shark Bay in December and January (DBCA 2020).	Species or species habitat known to occur within area	Moderate
Mobula birostris (previously Manta birostris) Giant manta ray	–	Migratory			Species or species habitat likely to occur within area	
Rhincodon typus Whale shark	Other protected fauna	Vulnerable, Migratory	Oceanic and coastal, tropical to warm-temperate pelagic shark. Not generally associated with the Shark Bay area (DoE 2020m).	–	Species or species habitat may occur within area	Low

Notes:
1.'–' indicates there are no available data related to the species' distribution or habitat association with Shark Bay (specifically the Project area) or species occurs in the area, but Shark Bay is not considered significant habitat for that species. Southern right whale: present along the Australian coastline from mid-May to mid-November, however no clear association with the Project area (DoE 2020c).
2. See Appendix H for the DBCA NatureMap Species Report.
3. See Appendix E for the EPBC Act Protected Matters Search Tool Report.

4.3.3 Threatened and migratory marine avifauna

The marine waters and islands surrounding the Project may be visited by seabirds and shorebirds throughout the campaign, many of which are significant and protected under the EPBC Act. A search of the online EPBC Act Protected Matters Reporting Tool (Appendix E) identified 20 listed threatened bird species, eight listed migratory marine bird species, 15 listed migratory wetland bird species and one migratory terrestrial bird species that may occur in the vicinity of the Project[3]. Many of these species are also listed in all or one of the following international treaties for migratory birds: the Japan-Australia Migratory Bird Agreement, the China-Australia Migratory Bird Agreement and Republic of Korea-Australia Migratory Bird Agreement.

Migratory bird species may be present in Australia from August to May each year, during the non-breeding season (DAWE 2017). Several of the bird species identified are also known to breed near (<5 km) of the Project area, including the wedge-tailed shearwater (visits in summer only), Australian fairy tern, caspian tern, bridled tern and roseate tern (terns breed on the islands year-round; Birdlife 2018). In addition, it is likely that the white-capped and Indian yellow-nosed albatross forage or feed within the vicinity (<5 km) of the Project area (Appendix E). Most of the birds listed are largely associated with mudflats and adjacent nearshore and onshore vegetation, which will remain unaffected by the proposed Project. Dirk Hartog, Dorre and Bernier Islands (~10–20 km, ~70–100 km and ~100–130 km away from the Project area, respectively) are important habitats for migratory and resident birds, however the Project works will not directly impact these islands. There were no Ramsar Wetlands of International identified in the search area. One wetland of national importance (Shark Bay East) was identified in the area, however this is 20 km east of Denham and so not near the Project area (Jaensch 1993; Appendix E).

Most of the birds listed are largely associated with mudflats and adjacent nearshore and onshore vegetation, and it is unlikely that dredging/seabed levelling within the entrance channel, berth pocket, or offshore disposal of material, will impact these birds. Further, the presence and/or operation of the dredge vessel for the duration of the Project is not outside of current Port/fishing/tourism operations/activities that would cause any additional risks to avifauna. Turbidity generated by the Project is also not anticipated to impact any important food sources for avifauna.

4.3.4 Invertebrates

Infauna surveys were conducted in support of the previous sea dumping permit application, granted in 2001 (Section 2.1). Two species of larval penaeid prawns were found at the disposal site, at an approximate density of 12 animals per m^2 (PG Newstead, Chief Executive Officer of Shark Bay Resources, pers. comm., 27 March 2001[3]). The disposal site had low infauna species diversity at moderate abundance, and very low numbers of gastropods, which was deemed representative of the general Shark Bay area. The deeper portions of the entrance channel were not identified as nursery areas for prawns, however shallower seagrass meadows, including those on the margins of the entrance channel, are regarded as prawn nursery areas (PG Newstead, Chief Executive Officer of Shark Bay Resources, pers. comm., 27 March 2001[3]). The Denham Channel and Denham Sound were found to be largely devoid of epifauna.

4.3.5 Introduced and pest marine species

A Ballast Water Management Plan (BWMP) was prepared in 2002, in accordance with the Australian Quarantine and Inspection Service (AQIS) guidelines at the time, as a requirement of Ministerial Statement 513 for the Useless Loop Port Maintenance Works and Infrastructure Upgrade. As part of these previous site works, the BWMP was reviewed, updated and renamed the Introduced Marine Pest Management Plan (IMPMP; SBR 2018); in recognition of the possible vectors for IMS from both ballast water and vessel associated biofouling. Introduced marine species (IMS) surveys were conducted in-line with revisions of the BWMP and IMPMP at Useless Loop in 2001, 2006, 2010, 2017 and 2020[5] within the broader Shark Bay area in 2009 (SBR 2018).

Initial IMS surveys (2001 and 2006) focused on the Australian Ballast Water Management Advisory Council (ABWMAC) target species (Table 4-5; SKM 2006). These surveys, conducted at the Slope Island loading facility, bar flats and Denham Channel, indicated that no ABWMAC target species or other marine pest species were present at Useless Loop (SKM 2006). One possible exotic species was recorded (the barnacle *Megabalanus tintinnabulum*; SKM 2006).

Further studies and reviews focussed on the National Introduced Marine Pests Coordination Group target list (SBR 2018; Table 4-6). During these studies, none of the 55 listed species were present, however twelve non-listed introduced species were identified in the broader Shark Bay area, of which four were present at Useless Loop (SBR 2018). These four species were barnacles (*M. occator* and *M. ajax*), a bryozoan (*Schizoporella errata*), and a hydroid (*Obelia dichotoma*) (Aquenal & Oceanica 2011). Several potential cryptogenic and non-indigenous species were identified during 2010 and 2017 IMS surveys, however no species on the target monitoring list were detected (Aquenal & Oceanica 2011, Gardline 2017). These data suggest that Useless Loop is uncompromised by significant IMS on monitoring target lists, likely resulting from:

- patterns of shipping traffic (low numbers of vessels visits, low volumes of ballast water discharge; low numbers of vessels from high risk ports),
- low numbers of recreational boating movements,
- shortage of suitable colonisable substrates,
- inhospitable environmental conditions for some introduced species (hypersaline waters),
- the absence of diverse sampling methods and limited search effort to date, and
- the potential effectiveness of SBR's IMS management plan (Aquenal & Oceanica 2011, SBR 2018).

Table 4-5 The Australian Ballast Water Management Advisory Council list of marine pests targeted in the first and second monitoring surveys of Useless Loop in 2001 and 2006

Count	Phylum	Class/Order	Scientific Name
ABWMAC introduced pest species targeted by SKM 2006			
1	Annelida	Polychaeta	*Sabella spallanzanii*
2	Arthropoda	Decapoda	*Carcinus maenas*
3	Echinodermata	Asteroidea	*Asterias amurensis*
4	Heterokontophyta	Dinophyceae	*Alexandrium catenella*
5	Heterokontophyta	Dinophyceae	*Alexandrium minutum*
6	Heterokontophyta	Dinophyceae	*Alexandrium tamarense*
7	Heterokontophyta	Dinophyceae	*Gymnodinium catenatum*
8	Heterokontophyta	Phaeophyceae	*Undaria pinnatifida*
Additional marine pest species that pose a threat to Australia			
9	Ctenophora	Lobata	*Mnemiopsis leidyi*
10	Mollusca	Bivalvia	*Mytilus galloprovincialis*
11	Mollusca	Bivalvia	*Potamocorbula amurensis*
12	Mollusca	Gastropoda	*Philine auriformis*
13	Chlorophyta	Codiaceae	*Codium fragile tomentosoides*
ABWMAC target introduced pest species not targeted by SKM 2006			
14	Mollusca	Bivalvia	*Corbula gibba*
15	Mollusca	Bivalvia	*Crassostrea gigas*
16	Mollusca	Bivalvia	*Musculista senhousia*

Source: Aquenal and Oceanica (2011)
Note: ABWMAC = Australian Ballast Water Management Advisory Council

[5] The results of the 2020 IMS survey were not available at the time of preparing this report.

Table 4-6 Introduced Marine Species targeted during the 2010 and 2017 survey

Phylum	Scientific name	CCIMPE trigger list	Reported from trading nations[1]	Temperature and salinity tolerance[2]	2010 monitoring list[3]	Mobile taxa[4]
Crustacea	*Acartia tonsa*		yes		✓	
Holoplankton	*Alexandrium catenella*		?		✓	
Holoplankton	*Alexandrium minutum*		?		✓	
Holoplankton	*Alexandrium monilatum*		no			
Holoplankton	*Alexandrium tamarense*	✓	?		✓	
Echinoderm	*Asterias amurensis*	✓	?	Unsuitable		✓
Crustacea	*Balanus eburneus*		yes		✓	
Crustacea	*Balanus improvisus*	✓	no	Unsuitable		
Cnidaria	*Beroe ovata*		?		✓	✓
Cnidaria	*Blackfordia virinicia*		yes		✓	✓
Algae	*Bonnemausionia hamifera*		no			
Crustacea	*Callinectes sapidus*		no	Unsuitable		✓
Crustacea	*Carcinus maenas*	✓	Australia		✓	✓
Algae	*Caulerpa racemosa var. cylindrica*		Australia		✓	
Algae	*Caulerpa taxifolia (exotic strains only)*	✓	yes		✓	
Holoplankton	*Chaetoceros concavicornis*	✓	yes		✓	
Holoplankton	*Chaetoceros convolutus*	✓	yes		✓	
Crustacea	*Charybdis japonica*	✓	yes		✓	✓
Algae	*Codium fragile fragile*		yes		✓	
Algae	*Codium fragile spp. tomentosoides*	✓	yes		✓	
Mollusca	*Corbula (Potamocorbula) amurensis*	✓	?		✓	
Mollusca	*Crassostrea gigas*		yes		✓	
Mollusca	*Crepidula fornicata*	✓	no			✓
Ascidiacea	*Didemnum spp. (invasive strains only)*	✓	yes		✓	
Holoplankton	*Dinophysis norvegica*	✓	?		✓	
Mollusca	*Ensis directus*	✓	no			
Crustacea	*Eriocheir spp*	✓	no	Unsuitable		✓
Algae	*Grateloupia turuturu*	✓	?		✓	
Holoplankton	*Gymnodinium catenatum*		?		✓	
Crustacea	*Hemigrapsus sanguineus*	✓	yes		✓	✓
Crustacea	*Hemigrapsus takanoi/penicillatus*	✓	yes		✓	✓
Annelida	*Hydroides dianthus*		no			
Mollusca	*Limnoperna fortunei*		yes	Unsuitable		✓
Mollusca	*Maoricolpus roseus*	✓	Australia		✓	✓
Annelida	*Marenzelleria spp*	✓	no	Unsuitable		✓
Cnidaria	*Mnemiopsis leidyi*	✓	no			✓
Mollusca	*Musculista senhousia*	✓	yes		✓	
Mollusca	*Mya arenaria*	✓	no			
Mollusca	*Mytilopsis sallei*	✓	yes		✓	

Phylum	Scientific name	CCIMPE trigger list	Reported from trading nations[1]	Temperature and salinity tolerance[2]	2010 monitoring list[3]	Mobile taxa[4]
Fish	*Neogobius melanostomus*	✓	no	Unsuitable		✓
Mollusca	*Perna perna*	✓	yes		✓	
Mollusca	*Perna viridis*	✓	yes		✓	
Holoplankton	*Pfiesteria piscicida*	✓	?		✓	
Annelida	*Polydora websteri*		Australia		✓	
Crustacea	*Pseudodiaptomus marinus*		yes		✓	✓
Holoplankton	*Pseudo-nitzschia seriata*	✓	?		✓	
Mollusca	*Rapana venosa (syn Rapana thomasiana)*	✓	yes		✓	✓
Crustacea	*Rhithropanopeus harrisii*		no	Unsuitable		✓
Annelida	*Sabella spallanzanii*	✓	Australia		✓	
Algae	*Sargassum muticum*	✓	yes		✓	
Fish	*Siganus luridus*		no			✓
Fish	*Siganus rivulatus*	✓	no			✓
Ascideacea	*Styela clava*		yes		✓	
Mollusca	*Theora lubrica*		Australia		✓	
Crustacea	*Tortanus dextrilobatus*		yes		✓	
Fish	*Tridentiger barbatus*		yes	Unsuitable		✓
Fish	*Tridentiger bifasciatus*		yes	Unsuitable		✓
Algae	*Undaria pinnatifida*	✓	yes		✓	
Mollusca	*Varicorbula gibba*	✓	Australia		✓	
Algae	*Womersleyella*		yes		✓	

Source: Aquena and Oceanical (2011), Gardline (2017)

Notes:

1. Distribution of pest known to include Singapore, Indonesia, Malaysia, Japan, Taiwan, Philippines, China, Korea, India or Thailand. Pests previously detected in Australian waters are also indicated.
2. Determined using the Monitoring Design Package developed by the Australian Government Department of Agriculture, Fisheries and Forestry. Blank cells indicate suitable conditions for survival and reproduction, or that environmental tolerances are unknown for that taxa.
3. Invasive marine pest monitoring list for 2010 surveys at Useless Loop, Bars Flat and Denham Channel.
4. Highly mobile taxa that are unlikely to be detected from fouling communities or plankton sampling.
5. CCIMPE = Consultative Committee on Introduced Marine Pest Emergencies

4.4 Social environment

4.4.1 Commercial and recreational fisheries

Commercial fisheries in the Shark Bay region include western rock lobster, abalone, scalefish, crab, prawn and scallop fisheries (Table 4-7). A small pearl farm operates in the eastern bay of Shark Bay, near Monkey Mia, however the farm is ~45 km away from the Project area (on the other side of the Peron Peninsula) so no impacts to pearl oysters are anticipated. Recreational fishing of crabs, prawns and scallops is not well developed in the region; however, fishing of demersal species is a common recreational activity (CALM 1996; DPIRD 2019a). The seagrass meadows, shallow sand banks and deeper sandy/muddy habitats of Shark Bay provide important nursery habitat for many finfish and invertebrate species that are commercially and recreationally important (Table 4-7 and Table 4-8; DPIRD 2019a).

The main fisheries operating east of Dirk Hartog, Dorre and Bernie Islands in Shark Bay, include the:

- Shark Bay Prawn Managed Fishery (SBPMF)
- Shark Bay Crab Managed Fishery
- Shark Bay Scallop Managed Fishery
- Inner Shark Bay Scalefish Resource/Shark Bay Beach Seine and Mesh Net Fishery (Table 4-7).

The scalefish fisheries generally operate within total allowable catch throughout Shark Bay (DPIRD 2019a; Table 4-7). The West Coast Roe's Abalone Resource area within Shark Bay has been closed since the 2011/2012 (DPIRD 2019a). There is a trial fishery for cockles operating within the region, but these species only occur in very shallow and hypersaline waters which are beyond the extent or the Project footprint.

The SBPMF is open from March through November each year, with Carnarvon Peron Line (CPL) areas closed at various times to protect brown tiger prawns during their spawning period (during spring and summer; DoF 2013a; Figure 4-5). The key nursery areas for the SBPMF are the East Peron and West Peron nursery areas, the latter of which includes the berth pocket dredge area (Figure 4-5). The SBPMF trawled areas between 2011 and 2016 were concentrated within Denham Sound, Inner Shark Bay and the CPLs areas (Figure 4-6). The SBPMF licence holders can retain saucer scallops (Figure 4-7) and blue swimmer crabs from within zone 1 and 2 areas (Figure 4-8), although additional licences exist.

The only specific closure areas for the Shark Bay Crab Managed Fishery are adjacent to Carnarvon, Denham and Monkey Mia (Figure 4-8). Historical data indicate that important spawning grounds for crabs are likely in the deeper waters south of the eastern bay and north-east of Koks Island (Harris et al. 2014). Scallops are mainly fished from within the Denham Sound area as the Northern Shark Bay scallop stock fell below acceptable limits in 2019 (DPIRD 2020a; Figure 4-7).

The breeding stock status of most commercially important species in Shark Bay is 'sustainable–adequate' indicating that egg production is sufficient and recruit survival is largely dependent on environmental factors (DPIRD 2019a). Fish are vulnerable to increased turbidity and habitat loss during early life stages (Harvey et al. 2017), with >50% of temperate and tropical Western Australian fish species spawning between October and April (Harvey et al. 2017). Most species identified as commercially important in Shark Bay, including invertebrates, also spawn during this period (Table 4-8).

Table 4-7 Relevant Western Australian fisheries to the Project area

Fishery	Commercial or recreational use	Target species	Operational area, vessels/licence holders and closure periods
West Coast Rock Lobster Managed Fishery	Both	Western rock lobster (*Panulirus cygnus*)	Cape Leeuwin to Shark Bay. Most abundant between Perth and Geraldton. There are ~234 commercial vessels that operate within this fishery and ~60 000 recreational licence holders in WA. Operates 12 months of the year.
Shark Bay Prawn Managed Fishery	Commercial	Western king prawns (*Penaeus latisulcatus*), brown tiger prawns (*Penaeus esculentus*) and lesser quantities of endeavour (*Metapenaeus endeavouri*) and coral prawns (*Metapenaeopsis* spp).	Within Shark Bay. Deeper areas (predominantly sand/mud/shell habitats) of the central bay, north of Cape Peron, and in the northern area of Denham Sound (Figure 4-5). There are ~18 licensed fishing boats within this fishery, with 10 based in Carnarvon. Trawling season is typically March to November.
Shark Bay Crab Managed Fishery	Both	Blue swimmer crab (*Portunus armatus*)	Carnarvon and Shark Bay, north of Cape Inscription and Cape Peron North. There are 32 licences; three that trap in zone 1 only, two that trap in both zone 1 and zone 2, and the remaining licences are held by the prawn and scallop sectors. The fishery operates 12 months of the year, moving to shallower areas only during the prawn trawling season. Closure areas at Carnarvon, Denham and Monkey Mia (Figure 4-8).
Gascoyne Demersal Scalefish Resource/ Gascoyne Demersal Scalefish Managed Fishery	Commercial	Pink snapper (*Chrysophrys auratus*) and goldband snapper (*Pristipomoides multidens*)	Gascoyne Coast Bioregion and recreational vessels/charter vessels out of Denham, Carnarvon and around the Ningaloo-Exmouth. In Shark Bay fishing generally occurs around the entrance to Shark Bay and the adjacent ocean. There are large numbers of recreational vessels and a limited number of licensed charter vessels that fish out of Denham and Carnarvon. In 2017 there were 16 vessels that fished during the season. Area closures and spawning closures are put in place as required to manage stock.
	Recreational	60+ demersal species inhabiting marine waters deeper than 20 m in the Gascoyne Coast Bioregion	
Inner Shark Bay Scalefish Resource/Shark Bay Beach Seine and Mesh Net Fishery	Commercial	Whiting (*Sillago schomburgkii* and *S. analis*), sea mullet (*Mugil cephalus*), tailor (*Pomatomus saltatrix*) and western yellowfin bream (Acanthopagrus morrisoni)	Eastern Gulf, Denham Sound and Freycinet Estuary in inner Shark Bay. Recreational vessels and a limited number of licensed charter vessels operate

Fishery	Commercial or recreational use	Target species	Operational area, vessels/licence holders and closure periods
	Recreational	Pink snapper (*Chrysophrys auratus*, three separate stocks), grass emperor (*Lethrinus laticaudis*), whiting (*Sillago* spp.), mackerel (*Scomberomorus* spp., *Grammatorcynus bicarinatus*), blackspot tuskfish (*Choerodon schoenleinii*), goldspotted rockcod (*Epinephelus coioides*) and western butterfish (*Pentapodus vitta*)	out of Denham and Monkey Mia. In 2017 there were six vessels that operated in this fishery.
Shark Bay Scallop Managed Fishery	Commercial	Saucer scallops (*Ylistrum balloti*, formerly *Amusium balloti*)	Shark Bay (incl. Denham Sound and Northern Shark Bay). There are 11 boats licenced to take scallops, only, and an additional 18 boats licenced to target prawns as well. Seasonal closures are generally during spawning season (mid-April to November) and dependent on moon phases and stock assessment. The Northern Shark Bay scallop fishing region was closed in 2019 due to stock falling below acceptable limits (Figure 4-7).
West Coast Roe's Abalone Resource	Both	Roe's abalone (*Haliotis roei*)	South Australian border to Shark Bay. There are ~23 commercial vessels that operate within this fishery and ~17 400 recreational licence holders in WA, though most activity is between Perth and Eucla. Closed in Zone 8 (the area including Shark Bay) since the 2011/2012 season.
Shark Bay Developmental Cockle Fishery (John Leyland Craike and Harold Richard [Bobby] Hoult)	Commercial	Venus clams (*Callista inpar*) and a waved Venus clam (*Gomphina undulosa*)	Shallow (knee-deep) hypersaline regions of Shark Bay (FRDC 2013). This is a developmental fishery with 2022 expiry.

Source: DPIRD (2019a,b, 2020a)

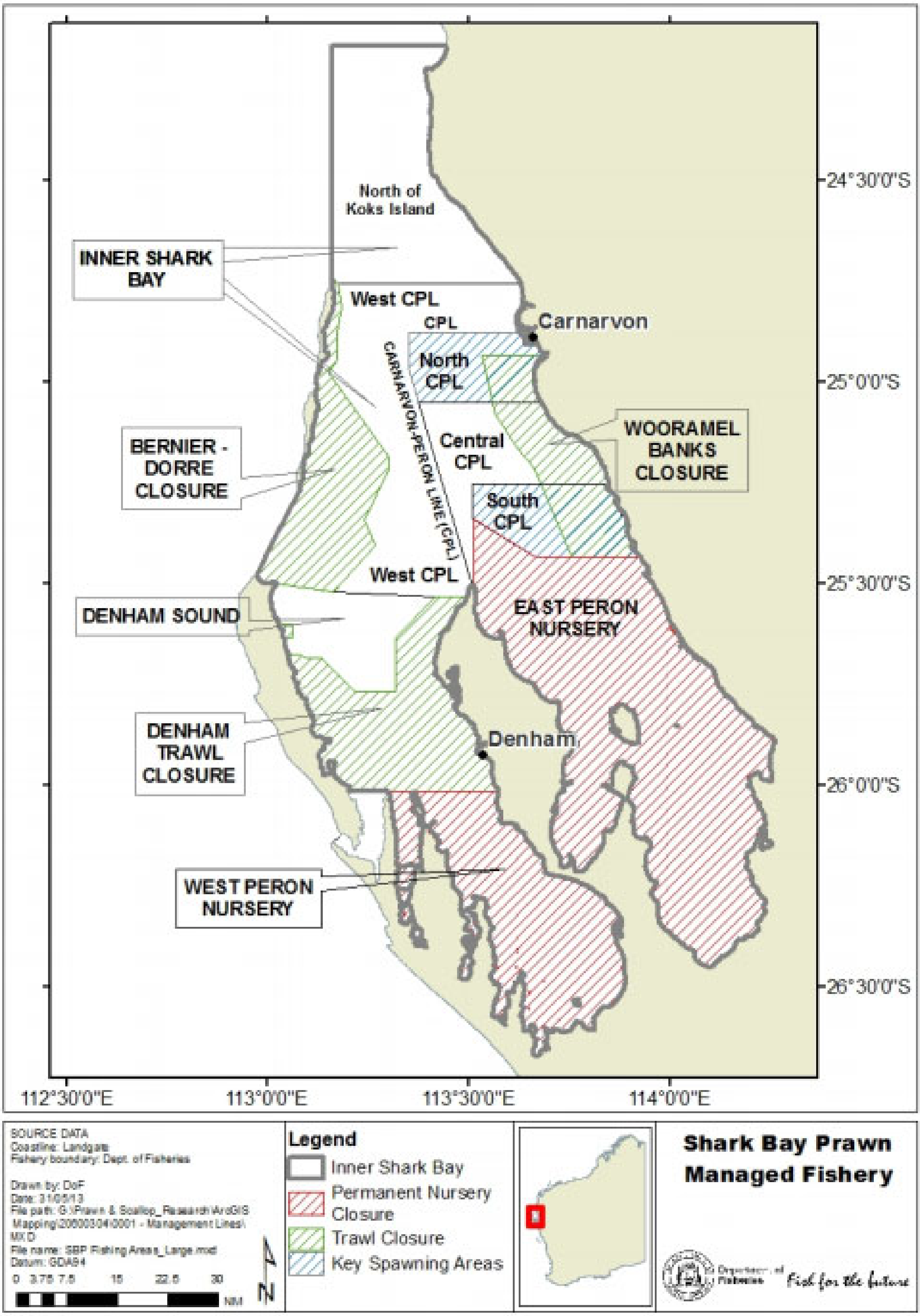
Table 4-8 Distribution and habitat associations of commercially and recreationally important species in Shark Bay

Species	Distribution/key life strategies	Habitat associations	Likelihood of interaction with Project[1]
Blackspot tuskfish (*Choerodon schoenleinii*)	Widespread in northern Australia from the Houtman Abrolhos Islands, Western Australia (WA), around to Julian Rocks, New South Wales (Bray 2017). Occupy inner gulf reefs and rocky shorelines; in Shark Bay predominantly found in the two inner gulfs (Fairclough 2005). Spawn from September to December (Harvey et al. 2017).	Reef	Low
Blue swimmer crab (*Portunus armatus*)	Found Australia-wide, mainly between Karratha and Dunsborough in Western Australia (DoF 2011a). Inhabit sandy, muddy, algal and seagrass habitats in estuaries, sheltered bays and offshore waters up to 50 m deep (DoF 2011a). Spawn year-round with peaks during the cooler autumn/winter months (DPIRD 2020a).	Sand, mud, macroalgae and seagrass	Low–Moderate
Brown tiger prawns (*Penaeus esculentus*)	Endemic to tropical and subtropical waters of Australia (FishSource 2016a). Inhabit coastal waters down to ~60 m (have been recorded to a depth of 200 m) over mud or sandy mud substrates (FishSource 2016a). Near coastal seagrass beds are known nursery habitats for tiger prawns (Patterson et al. 2019). Spawn mainly during spring and summer (DoF 2013a).	Sand, mud and seagrass	Low–Moderate
Coral prawns (*Metapenaeopsis* spp.)	Inhabit Australian waters from west of South Australia, up the west coast to the Northern Territory (NT; Shark Bay Prawns 2020).	–	–
Endeavour prawns (*Metapenaeus endeavouri*)	Endemic to Australia, distributed from south-west WA and north to north-west Queensland (QLD; FishSource 2016b). Spawning occurs throughout the year and peaks in March and September (AMFA n.d.).	–	–
Goldband snapper (Pristipomoides multidens)	Widely distributed throughout the Indo-Pacific, inhabiting reefs and hard bottomed areas at depths of 60–180 m (Lloyd et al. 1996). Spawning occurs from January to April (Harvey et al. 2017).	Reef	Low
Goldspotted rockcod (*Epinephelus coioides*)	Recorded in Australia from near Carnarvon, WA, around the tropical north to the Solitary Islands, New South Wales (NSW; Bray 2019a). Juveniles inhabit sandy, muddy, gravel and mangrove areas in shallow estuaries, with adults found on coastal reefs and muddy and rubble bottoms in brackish waters (Bray 2019a). Spawning occurs from January to December with peak spawning from October to March (Harvey et al. 2017).	Sand, mud, estuaries, mangroves and reef	Moderate
Grass emperor (*Lethrinus laticaudis*)	Distributed from north-west WA to southern QLD (Fishes of Australia 2020). Juveniles inhabit seagrass beds and mangrove estuaries, while adults are associated with coral reefs (NT Government 2020). Spawn from December to March (Harvey et al. 2017).	Seagrass, estuaries, mangroves and reef	Moderate

Species	Distribution/key life strategies	Habitat associations	Likelihood of interaction with Project[1]
Pink snapper (*Chrysophrys auratus*)	Endemic to southern Australia. Generally, inhabit deep reef habitat along the continental shelf (DoF 2019). Spawning occurs from April to October for the Carnarvon stock (Harvey et al. 2017).	Reef	Low
Mackerel (*Scomberomorus* spp., *Grammatorcynus bicarinatus*)	Widespread across Australia from Cape Naturaliste (*Scomberomorus* spp.) and the Houtman Abrolhos Islands (*Grammatorcynus bicarinatus*) in WA, north around the east coast and down to Byron Bay, NSW (*Grammatorcynus bicarinatu*) and Tasmania (*Scomberomorus* spp.) (Bray & Schultz 2017, Bray & Schultz 2020). Epipelagic/pelagic species with a depth range of 0–200 m, associated with offshore and coastal reefs (DoF 2013b, Bray & Schultz 2017, 2020). Spawning occurs from October to January for Pilbara *Scomberomorus commerson* stock (Harvey et al. 2017).	Reef	Low
Roe's abalone (*Haliotis roei*)	Distributed from Shark Bay south around to Victoria (Strain & Heldt 2018). Inhabit rocky reef platforms and sub-tidal areas feeding on drifting algae (DoF 2017; DPIRD 2019a). Spawning occurs during winter (DoF 2011b).	Reef	Low
Saucer scallops, (*Ylistrum balloti*, formerly *Amusium balloti*)	Found off the coast of WA between Broome and east of Esperance, with high abundance in Shark Bay (Kangas et al. 2006). Inhabit sandy bottom areas often in sheltered environments found in bays or the lee of islands and reef systems (Kangas et al. 2006). Spawning during winter (DPIRD 2020a).	Sand	Low–Moderate
Sea mullet (*Mugil cephalus*)	Widespread across Australia, found in tropical and temperate coastal marine and estuarine waters (Gomon & Bray 2019). Sea mullet can tolerate a range of salinity conditions and while usually found inshore they can occur offshore to depths of 330 m (Gomon & Bray 2019). Bottom-dwelling detritivore that often feeds on algae covered rocks (Gomon & Bray 2019). Spawning likely occurs from March to September in WA (Chubb et al. 1981).	–	–
Tailor (*Pomatomus saltatrix*)	Distributed in Australia from Hervey Bay, QLD, south around to the Dampier Archipelago, WA (Bray 2020b). Pelagic species usually found in the open ocean, move inshore to feed in coastal waters, bays and estuaries, to depths of 15 m (Bray 2020b). Tailor hunt along inshore coastal waters, estuaries and nearshore reefs (Bray 2020b). Spawning occurs offshore during late winter and spring (Bray 2020b).	Estuaries and reef	Low

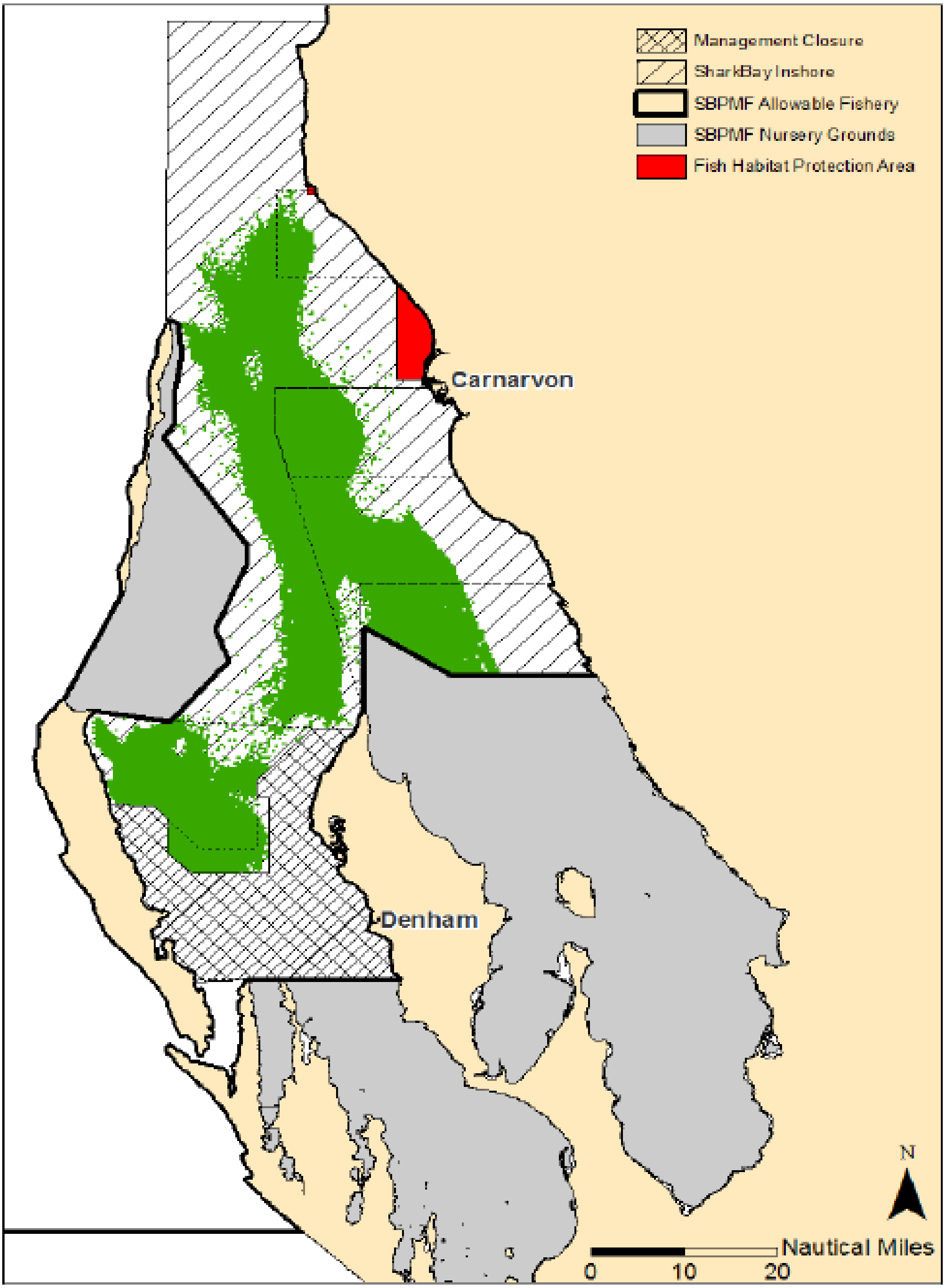
Species	Distribution/key life strategies	Habitat associations	Likelihood of interaction with Project[1]
Western butterfish (*Pentapodus vitta*)	Endemic to WA and inhabits areas of coral reef, rocky reef, seagrass and soft sediment in waters up to 15 m deep (Mant et al. 2006, RLS 2008). Spawning occurs from October to January in Shark Bay (Mant et al. 2006).	Reef, seagrass and sand	Low–Moderate
Western yellowfin bream (*Acanthopagrus morrisoni*)	Endemic to north-western Australia, from Shark Bay, WA, to Weipa, Gulf of Carpentaria, QLD, and predominantly inhabits estuaries and coastal waters (Bray 2020c). In Shark Bay spawning occurs from late winter to early spring, and juveniles shelter within mangroves then move to inshore rocky habitats as they mature (Platell et al. 2007).	Mangroves, estuaries and rock	Low
Western king prawns (*Penaeus latisulcatus*)	Found along the entire coast of WA, inhabiting nearshore coastal waters and estuaries (DoF 2013a). Mature king prawns are found generally offshore, over sandy or muddy-bottomed areas 10–30 m deep (DoF 2013a). Spawn throughout the year (DoF 2013a).	Sand, mud and estuaries	Low–Moderate
Western rock lobster (*Panulirus cygnus*)	Temperate species found on the continental shelf off the coast of WA (DoF 2011c). Juvenile and adult rock lobsters associate with onshore reef habitats (DoF 2011c). Mating occurs during late winter and spring, peaking from October to November (Melville-Smith & de Lestand 2006)	Reef	Low
Whiting (*Sillago schomburgkii* and *S. analis*)	Found in sandy and seagrass habitats in shallow inshore waters, mangroves/estuarine waters throughout the Indo-West Pacific region, with Shark Bay representing the southern end of the distribution of *S. analis* and the northern end of the distribution of *S. schomburgkii*. (Coulson et al. 2005, Bray 2018, Bray 2019b). Spawning occurs from August to March for *S. schomburgkii* and October to April (peak from December to March) for *S. analis* in Shark Bay (Harvey et al. 2017).	Sand, estuaries, seagrass and mangroves	Moderate

Note:
1. Likelihood of interaction with Project based on habitat associations and likelihood of habitat occurring in the Project area (see Section 4.3.1).
2. '–' indicates no data available on specific habitat associations.



Source: DPIRD (2020a)

Figure 4-5 Shark Bay Prawn Managed Fishery

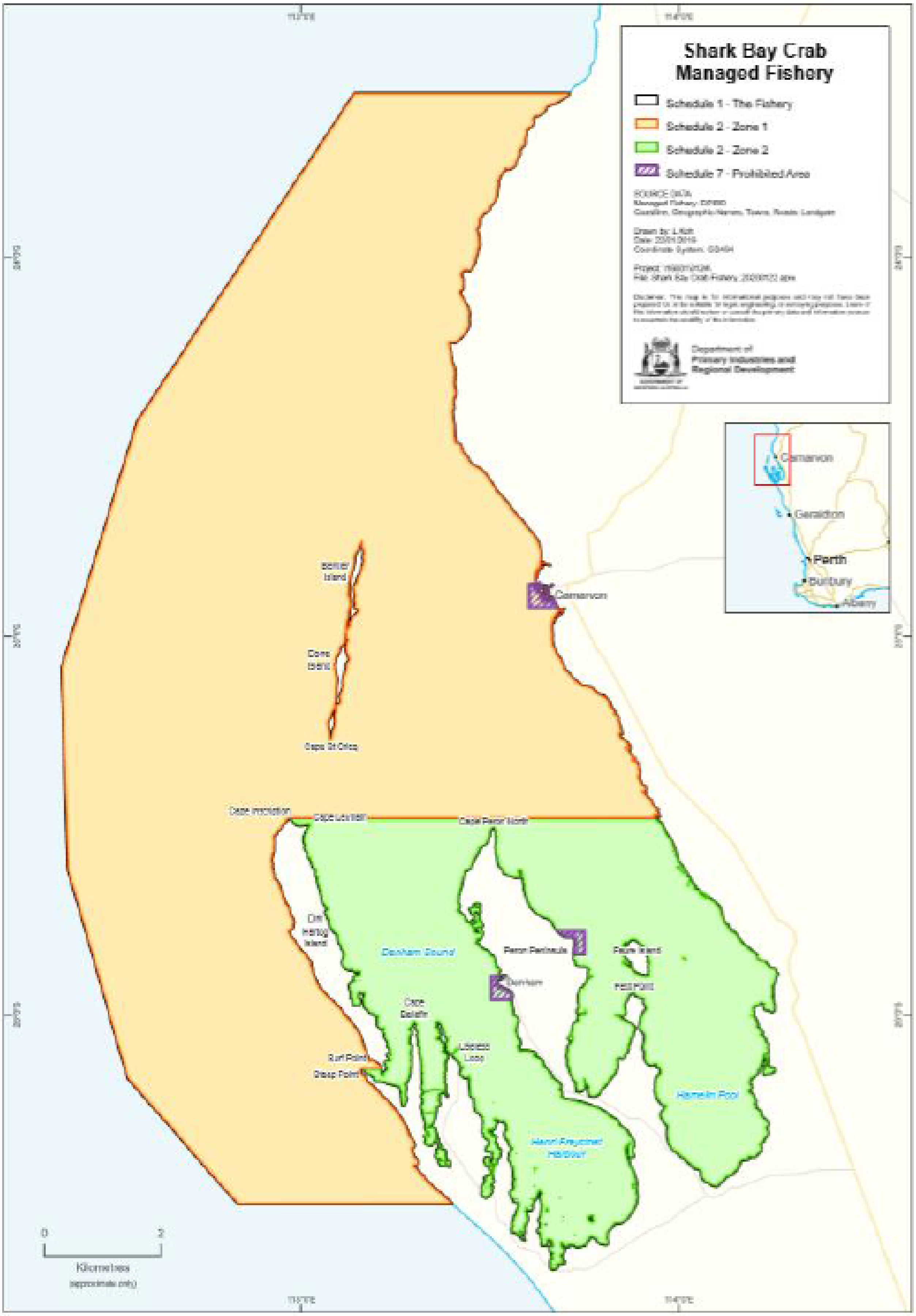


Source: DPIRD (2020a)

Figure 4-6 Shark Bay Prawn Managed Fishery cumulative trawl footprint between 2012 and 2016

Source: DPIRD (2020a)

Figure 4-7 Shark Bay Scallop Managed Fishery



Source: DPIRD (2020a)

Figure 4-8 Shark Bay Crab Managed Fishery

4.4.2 Aboriginal heritage

There is a long history of Aboriginal occupation in Shark Bay, which has been dated to 30 000 years ago, with recent evidence suggesting a historic reliance on the marine resources of the region (CALM 1996). There are three claimant groups for the region: the Malgana, Nanda and Gnulli people. Native Title was granted in 2018 for the Malgana people over large parts of the lands and waters within the SBWHA. A search of the DPLH Aboriginal Heritage inquiry system generated 43 registered aboriginal sites in the locality of Shark Bay (Appendix I). Of these, only one registered site is near the Project area (Useless Loop 6609), attributed to: midden/scatter. The Project works will not interact with this registered site and so no impacts to this site are anticipated. SBR recognises the significance of the marine and terrestrial environment in Shark Bay to the local indigenous groups, and the Yamatji Marlpa Aboriginal Corporation (YMAC) and Malgana Aboriginal Corporation will continue to be consulted throughout the Project to further minimise any risk to Aboriginal heritage and culture.

4.4.3 European heritage

Shark Bay was the first recorded site of European landing in Australia (1616) and was first settled by Europeans in the 1850s (CALM 1996). Since settlement, the area has historically been utilised for pearling, fishing, mining (guano), and pastoral activities (sheep farming and sandalwood harvesting). A search of the Heritage Council of Western Australia InHerit Database indicted 24 heritage sites in the Shark Bay region (Appendix J), however none of these sites are near (within 30 km of) the Project area and so will not be impacted by the works.

A search of the Western Australian Museum Online Shipwreck database showed seven shipwrecks near Shark Bay. None of the shipwrecks are near the Project area, however some may be passed by vessels entering Shark Bay (such as the Perseverant and Santa Magdelena north of Dirk Hartog Island). These will be avoided by all vessels associated with the Project works and so will not be impacted by the Project.

Table 4-9 Shipwrecks near Shark Bay

Ship name	Date wrecked	Location
Zuytdorp	09/06/1712	North of Kalbarri (-27.1861141667, 113.9364534167)
Perseverant	16/03/1841	Off the north-east tip of Dirk Hartog Island, Shark Bay (-25.5071573333, 113.01808975)
Gudrun	23/10/1901	North of Peron Peninsula, Shark Bay (-25.425, 113.5251666667)
Kormoran lifeboat 1	19/11/1941	North-west of Giraud Point, Carrang Station, Shark Bay (-26.430063, 113.564784)
Raconteur Ex-Nanango	1976	North-eastern side of Bernier Island, Shark Bay (-24.787144, 113.16404)
Santa Magdelena	1992	Off northern tip of Dirk Hartog Island (Cape Inscription), Shark Bay (-25.4824055556, 112.9648833333)
Faure Island unidentified	Unknown	North-east of Faure Island, Shark Bay (-25.8068333333, 113.9026666667)
Gladstone Jetty 1918	Unknown	West of Gladstone National Park, Shark Bay (-25.952533, 114.244146)

Source: WAM (2020)

5 Potential Environmental Impacts

5.1 Benthic communities and habitat

Mapped seagrass communities near the dredge and disposal areas consist of *Posidonia* spp. (primarily *P. australis*), *Amphibolis* spp. (primarily *A. antarctica*) and *Halophila* spp. (primarily *H. spinulosa*; Appendix C; Section 4.3.1). In the berth pocket area, shallow waters immediately surrounding the Port (<5 m) were primarily dense coverage of *P. australis* and *A. antarctica*, and deeper waters (>5 m) consisted of sparse mixed seagrass meadows dominated by *H. spinulosa* with sparse occurrences of *Posidonia* spp. There were also patches of bare sand and rocky rubble present in the berth pocket area. Within the entrance channel habitats mainly consisted of moderate cover *H. spinulosa* and sparse cover mixed seagrass meadows dominated by *H. spinulosa* with sparse occurrences of *Posidonia* spp. The remaining habitat within the entrance channel was bare sand and rocky rubble. Shallow areas adjacent to the entrance channel contained stands of *Posidonia* spp. at almost 100% coverage. The disposal area consists of only bare sand/rock rubble substrate and is adjacent to areas of sparse mixed seagrass dominated by *H. spinulosa*.

Dredging and disposal activities have the potential to directly impact BCH through physical removal or burial of vegetation, and indirectly through increased turbidity (light reduction) and sedimentation. In addition, temporarily reduced dissolved oxygen concentration, release of nutrients and pollutants from (contaminated) sediments, and hydrographic changes may also indirectly impact the seagrass ecosystem (Erftemeijer & Lewis 2006).

Direct impacts from the removal and smothering of seagrasses is discussed in Section 5.1.1. Indirect impacts from a reduction in light attenuation is discussed in Section 5.1.2. Other impacts (such as release of contaminants etc.) are discussed in the context of impacts to marine environmental quality (Section 5.2).

5.1.1 Direct loss

The berth pocket dredge area consists mainly of sparse seagrass and bare sand/rock rubble, with some areas of dense seagrass, predominantly *P. australis* and *A. antarctica.* The areas of dense seagrass were conservatively mapped as seagrasses via review of satellite imagery and so could be an artefact of shading caused by berth infrastructure rather than full seagrass coverage (Appendix C). The entrance channel dredge area consists mainly of sparse to moderate seagrass (predominantly *H. spinulosa*), with some bare sand and rock rubble. Previous sweeping works in the channel suggest that these seagrass meadows exist in an already disturbed state; mainly comprised of sparse to moderate stands of ephemeral *H. spinulosa*. The disposal area is covered by bare sand and rocky rubble, and borders areas of sparse seagrass cover, hence direct loss of seagrass is not expected for this area.

Modelling to assess the degree of sedimentation identified localised effects of elevated sediment deposition within the dredge and disposal areas. Sediment deposition is expressed as bottom concentration (g/m^2) where each 1000 g/m^2 will approximate a deposited thickness of 1 cm surface layer. There are no guidelines for assessing impacts associated with sedimentation on seagrasses, but most species communities are expected to persist through a level of 3 cm of sedimentation (Cabaco et al. 2008), particularly those that are larger and faster growing. Impacts to *Posidonia* spp. typically occur at burial levels of 9 cm for *P. oceanica*, and 20 cm for *P. australis* and *P. sinuosa* (Cabaco et al. 2008). *A. griffithii* can tolerate burial up to 16 cm (Coupland 1997). Therefore, impacts to BCH from smothering are anticipated to be restricted to the disposal area and the area immediately adjacent to the disposal area due to the fall of material after disposal (with ~550 m of disposal area; refer Section 5.1.3 and Figure 5-2).

The total area of loss due to direct removal and burial has been calculated in Section 5.1.4 with inclusion of relevant indirect loss as defined in Section 5.1.2.

5.1.2 Indirect loss

In addition to direct removal and sediment burial, BCH are also vulnerable to indirect losses from increased turbidity caused by dredging activities (Walker & McComb 1992, Collier et al. 2009, Strydom et al. 2017). The primary impact of an increase in water column turbidity is the associated reduction in photosynthetically available light to benthic primary producers (McMahon & Lavery 2008, 2014, Lavery et al. 2009). Resulting impacts can be short or long-term in nature, depending on the period and intensity of shading.

Seagrass initially responds to stress from light reduction through physiological adjustments, before responding through morphological adjustments like reduced leaf extension, shoot density or canopy height (Collier et al. 2007, 2008, 2009, 2012a,b; Lavery et al. 2009; McMahon et al. 2011, 2013). Research indicates that minimum light requirements (MLR) and resistance to sediment stress vary between and within species, based on growth form, growth rate, seedling survival and seedbank persistence (Warry & Hindell 2009). Larger perennial species (e.g. *Posidonia* spp. and *Amphibolis* spp.) are generally considered to have higher resistance to sediment stress, but a lower recovery potential (Kilminster et al. 2015). Ephemeral/colonising species like *H. spinulosa* exhibit some shade adaption characteristics due to inhabiting deeper waters (up to 20 m) (McMahon et al. 2017a). While ephemeral species have generally lower resistance to disturbances (like increased TSS) they also have high recovery potential (Table 5-2; Kilminster et al. 2015). *H. spinulosa* has a higher capacity for recovery than other colonising species due to seed reserves (Unsworth et al. 2010, McMahon et al. 2017a).

Shading experiments by Fitzpatrick and Kirkman (1995) indicated that the MLR for *P. australis* is >10% of ambient. *P australis* exposed to high shading (~1–10% of ambient light) for 3 months resulted in a reduction of shoot density to zero after 8 months, rhizome death after 9 months, and no recovery after 17 months (Table 5-1; Fitzpatrick & Kirkman 1995). The response of *A. griffithii* to extended periods of light reduction has been investigated extensively and demonstrates that a reduction to 5–19% ambient light for a period greater than 6 months will result in an 80–99% reduction in leaf biomass without recovery for at least a 2 year period (Table 5-1; McMahon & Lavery 2008, 2014, Lavery et al. 2009, McMahon et al. 2011). These experiments also showed that *A. griffithii* may be able to recover within 2 years when exposed to similar shading (5-19% of ambient) for only 3 months (McMahon & Lavery 2008). Studies have suggested that *H. spinulosa* can tolerate light levels as low as 1–11% of surface irradiance for up to 28 days without a reduction in biomass or abundance, however significant declines may occur after 30 days exposure (Longstaff 2003; Collier et al. 2016). *H. spinulosa* exposed to light levels of <2-4 mol m^{-2} d^{-1} for 70 days showed some recovery after 9–10 months (Longstaff 2003).

Based on plume modelling results (Appendix G) indirect effects are only likely within and adjacent to the entrance channel and disposal area, and not within or near the berth pocket area. This is particularly relevant given the modelling was based on dredging of the berth pocket without overflow, however the updated Project scope only provides for levelling or sweeping at the berth, which would likely result in an even smaller plume adjacent to the berth. Given the relatively fast settling velocity of sediments (Section 4.2.4; Appendix F) and the short duration of the dredging and disposal activities (1–4 weeks, depending on high or low modelled production rate) the increase in turbidity associated with the Project is expected to be of short duration and low intensity. Given TSS concentrations will be elevated above ambient conditions for <28 days, regardless of dredge production rate, and all species are likely to tolerate a high level of shading (up to 11% of surface irradiance or <2-4 mol m^{-2} d^{-1}) for this period of time, applying these parameters of duration and intensity is considered a conservative approach for protection of all BCH in the Project area.

In Section 5.1.3 we discuss how thresholds relative to the species present within and adjacent to the entrance channel and disposal area were incorporated into relative zones of impact. A cumulative loss assessment based on these predicted impacts, and previous losses within the Project area, is presented in Section 5.1.4.

Table 5-1 Survival periods of *P. australis*, *Amphibolis* spp. and *H. spinulosa* exposed to different light conditions

Species	Life cycle	Light availability[2]	Survival period, long term loss	Minimum light requirement	Region	Reference
Posidonia australis	Perennial	1–10% ambient (~1.7 mol m^{-2} d^{-1})	Reduction in shoot counts to zero after 3–8 months and death of rhizome after 9 months 3 months shading result in no recovery after 17 months	>10% of subsurface irradiance	Jervis Bay, NSW	Fitzpatrick and Kirkman (1995) Short et al. (2017)
Amphibolis spp.*	Perennial	5-19% ambient (~1–8 mol m^{-2} d^{-1})	6 or 9 months result in reduction in leaf biomass and no recovery for at least 2 years	Unclear, but higher than experimental light reductions	Jurien Bay, WA	McMahon and Lavery (2008)
Halophila spinulosa	Ephemeral	Up to 11% of surface irradiance for 70 days (<2 mol m^{-2} d^{-1} for 17 days, 2–4 mol m^{-2} d^{-1} for the remaining 56 days)	Biomass remained stable for up to 30 days, with a significant decline occurring between 30 and 70 days Some recovery after 9–10 months	Low minimum light requirements due to shade adaptive characteristics (Campbell et al. 2008)	Hervey Bay, QLD	Longstaff (2003)
		Indicatively similar % surface irradiance as above (2.5 mol m^{-2} d^{-1})	Abundance not affected if less than 28 days exposure to this low light threshold			Collier et al. (2016)

Note:

1. '*' = no species-specific data was available for *A. antarctica*, and so data for *A. griffithii* is quoted here. These species are known to have similar photosynthetic responses to irradiance and so it is assumed their response to reduced light availability will be similar (Masini & Manning 1997).
2. Conversion of µmol m^{-2} s^{-1} to mol m^{-2} d^{-1} is approximated as 1 µmol m^{-2} s^{-1} = 0.0864 mol m^{-2} d^{-1}. This conversion is valid under continuous light and so converted values are an approximation only due to the variable nature of daily sunlight.

Table 5-2 Resistance and recovery potential to low light and burial stress of key seagrass species within and adjacent to the Project

Species	Resistance to low light stress	Resistance to burial stress	Overall resistance	Recovery potential
Posidonia spp.	High[1]	High[2]	High	Low[3]
Amphibolis spp.	Moderate–High[1]	High[2]	High	Low-Moderate[3]
Halophila spp.	Low[1]	Low[2]	Low	High[3]

Notes:

1. Resistance to low light stress based on adult plant (derived from the function and form model of Walker et al. 1999; cited in McMahon et al. 2017b) and seedling survival (based on seed size and seed storage reserves from Larkum et al. 2006; cited in McMahon et al. 2017b)
2. Resistance to burial stress based on adult plant (based on Cabaco et al. 2008 thresholds and Vermaat et al. 1995 vertical rhizome growth; cited in McMahon et al. 2017b) and seedling survival (based on length of hyptocotyl, Halophila: McMillan 1988, Birch 1981; cited in McMahon et al. 2017b)
3. Recovery potential based on rhizome extension rate (Halophila; Duarte et al. 2006; cited in McMahon et al. 2017b) and seed bank persistence (McMahon et al. 2017b)

5.1.3 Zones of impact

In accordance with the EPA's (2016d) *Technical Guidance: Environmental Impact Assessment of Marine Dredging Proposals* three zones of impact/influence were conservatively established, based on predictive modelling of the dredge plume extent and intensity (Section 4.2.5); and the tolerance of benthic biota (Sections 5.1.1 and 5.1.2). Dredge plume extent and intensity were modelled as depth averaged total suspended solids (TSS) concentration for two dredging scenarios (low volume/longer duration and high volume/shorter duration), and based on PSD data obtained during the 2019 and 2020 sediment sampling (Appendix F; Appendix G; Sections 4.2.4 and 4.2.5). Noting the additional conservatism in modelled elevated water column turbidity and subsequent zones of impact (detailed below) given plume dispersion modelling included dredging and disposal of berth pocket material, which has been replaced with seabed levelling under the revised Project (Section 2.2).

Potential impacts on BCH have been defined for the Zone of High Impact (ZoHI; Figure 5-1–Figure 5-3) and Zone of Moderate Impact (ZoMI; Figure 5-1 and Figure 5-2). TSS are not directly relevant to seagrass tolerance to shading, and indirect loss of seagrass as a result of water column turbidity is a function of concentration and duration of the turbid plume (Section 5.1.2). Therefore, photosynthetically active radiation (PAR) received at the seabed was modelled as a way of defining zones of impact that were ecologically relevant to the dominant seagrass species in the region adjacent to the offshore disposal area, where the plume was more persistent and there was a higher concentration of depth averaged TSS (Section 4.2.5; Appendix G). As such, thresholds relating to *H. spinulosa*. were adopted in the development of zones of impact for the following reasons:

- Seagrass meadows within and adjacent to the entrance channel primarily consist of *H. spinulosa.*
- Plume modelling indicates the BCH within and surrounding the berth pocket area are not likely to be impacted by turbid plumes beyond the berth pocket (i.e. the dense stands of *Posidonia* and *Amphibolis* spp. adjacent to the berth pocket are less likely to be impacted) (Section 4.2.5; Appendix G).
- *Halophila* spp. are more vulnerable to changes in light climate over shorter periods of time (Table 5-1), and therefore thresholds developed by Collier et. al. (2016) for *H. spinulosa* are protective of other dominant seagrass species in the region (including *Posidonia* and *Amphibolis* spp.).
- TSS concentrations will be elevated above ambient conditions for <28 days, regardless of dredging scenario (low or high production), which is within the reported tolerance limits of *H. spinulosa* (loss of biomass following 28–30 days of shading of <11% ambient or 2.5 mol m-2 d-1).
- *Halophila* spp. are less tolerant to sedimentation and burial than *Posidonia* and *Amphibolis* spp. (tolerating up to 3 cm compared to 9–16 cm, respectively; Section 5.1.1), and therefore direct loss was conservatively attributed to any area with modelled sedimentation >3 cm.

The ZoHI designates the area where impacts on BCH are predicted to be irreversible; where the term irreversible means “lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years”. In this case, the ZoHI has been nominally designated as the dredge and disposal footprint and sites where sedimentation exceeds the most sensitive tolerance limits for seagrass species (>3 cm depth) (Figure 5-1 and Figure 5-3). The ZoHI is also defined as areas of the seabed that receive on average ≤2.5 mol m^{-2} d^{-1}, which represents <28 days of turbidity generating activities (Section 4.2.5). The ZoHI is restricted to the offshore disposal area, the berth pocket and entrance channel dredge/seabed levelling areas (Figure 5-1 and Figure 5-3).

The ZoMI is defined as 'the area within which predicted impacts on benthic organisms are recoverable within a period of five years', and here has been designated to the offshore disposal area only (Figure 5-1 and Figure 5-3). The ZoMI is based conservatively on the areas immediately adjacent to the ZoHI that receive mean daily PAR of ≤2.5 mol m^{-2} d^{-1} for 7 consecutive days. It is noted that it was only possible to model an average PAR for two consecutive days over the high production dredging scenario (~2-days of turbidity generating activities in total; Section 4.2.5). As such, the final contour (outer-most line) for the ZoMI was defined as the mid-line extent of mean daily light of ≤2.5 mol m^{-2} d^{-1} between low and high production dredging (7-day and 2-day rolling average), during each modelled season (January and September) (Figure 5-1; Appendix G). The ZoMI is considered a conservative estimate given that high production is based on only a 2-day rolling average of the highest levels of modelled TSS concentrations, when the trigger criteria is 7 days (Appendix G).

The Zone of Influence (ZoI) has also been defined in accordance with EPA (2016d) as the area within which changes in environmental quality associated with the dredge plume may occur, but will not result in a detectable impact on benthic biota (EPA 2016d) (Table 5-3; Figure 5-1 and Figure 5-3). The ZoI was defined as the area directly adjacent to the ZoMI, or ZoHI in the case of the berth pocket, with the outer-most reach of the ZoI representing a TSS concentration up to 2 mg/L above ambient (visible plume) (Figure 5-1 and Figure 5-3). The depth averaged TSS concentrations used to define the ZoI represent water column TSS concentrations for 1% of the dredging campaign (99% exceedance) under both low and high production, and during each season (January and September) (Appendix G).

The zones of impact have not been updated since the change to the key project characteristics; seabed levelling instead of dredging of berth pocket material (Section 2.2). However, the changes to the Project represent an additional layer of conservativism built into the existing monitoring and management associated with the zones of impact. The potential impacts to each of these zones will be monitored, and subsequent management for protecting benthic communities and habitat has been developed in accordance with the EPA's (2016d) *Technical Guidance: Environmental Impact Assessment of Marine Dredging Proposals* (Appendix A).

Table 5-3 Impact zone definitions

Zone	Definition[2]	Threshold definition
Zone of High Impact (ZoHI)[1]	The area where impacts on benthic communities or habitats are predicted to be irreversible. The term irreversible means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'. Areas within and immediately adjacent to proposed dredge and disposal sites are typically within zones of high impact.	• Boundary of the dredge and disposal areas; and • An area that receives mean daily light of 2.5 mol m^{-2} d^{-1} for ≥28 days or more; and • Sedimentation/burial >3 cm or 3000 g/m^2
Zone of Moderate Impact (ZoMI)	The area within which predicted impacts on benthic organisms are recoverable within a period of five years following completion of the dredging activities. This zone abuts, and lies immediately outside of, the zone of high impact.	• An area that receives mean daily light of 2.5 mol m^{-2} d^{-1} for 7 consecutive days but <28 days or more
Zone of Influence (ZoI)	The area within which changes in environmental quality associated with dredge plumes are predicted and anticipated during the dredging operations, but where these changes would not result in a detectible impact on benthic biota.	• An area that receives reduced light beyond ZoMI but is >2 mg/L above ambient (visible plume); and • Sediment/burial <3 cm or 3000 g/m^2

Notes:
1. The zone of high impact (ZoHI) associated with the berth pocket and channel areas includes a 50 m buffer to allow for GPS and positioning just beyond the Project design areas.
2. As defined by EPA (2016d)

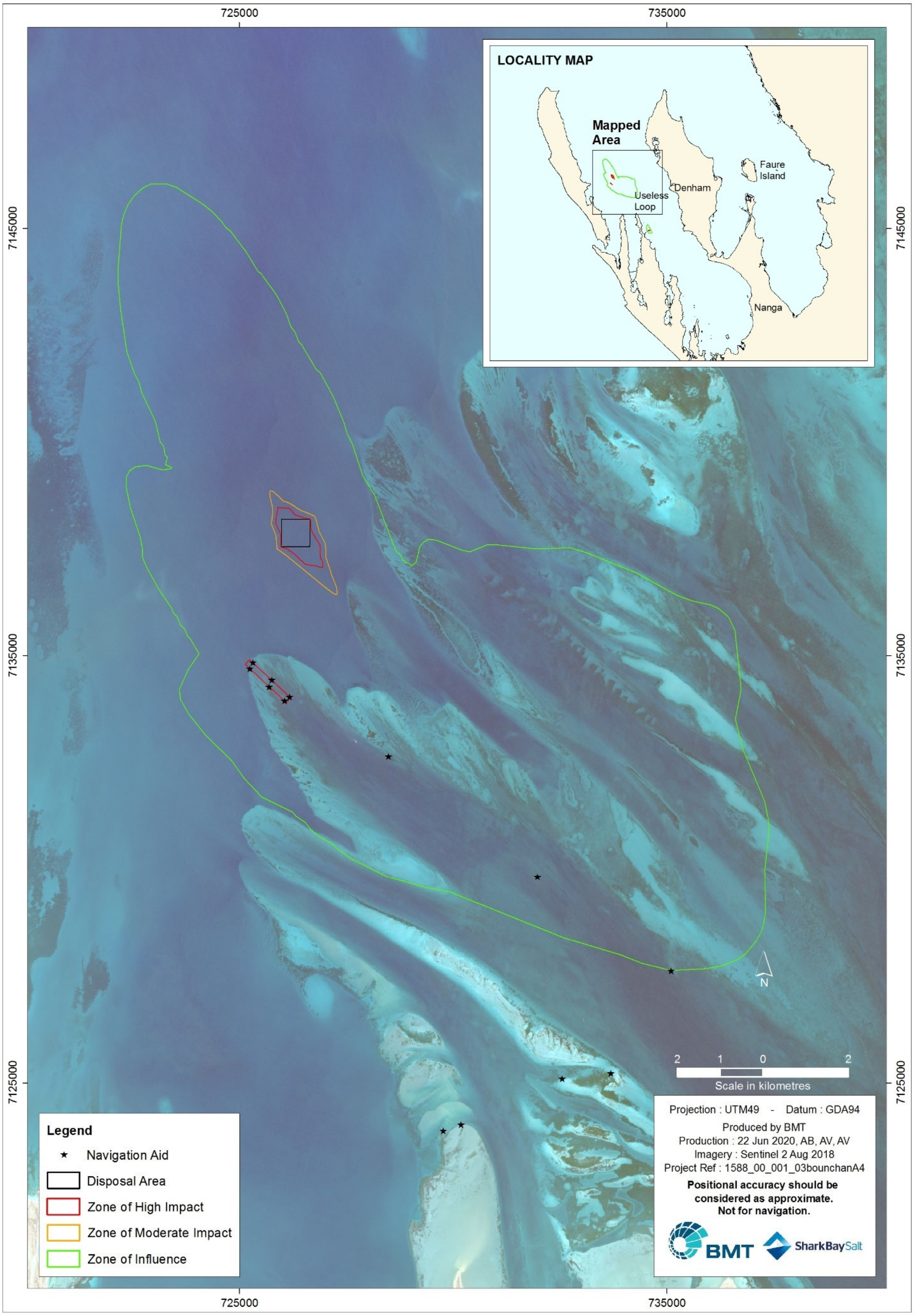


Figure 5-1 Defined zones of impact, including zone of influence, adjacent to the entrance channel and offshore disposal area

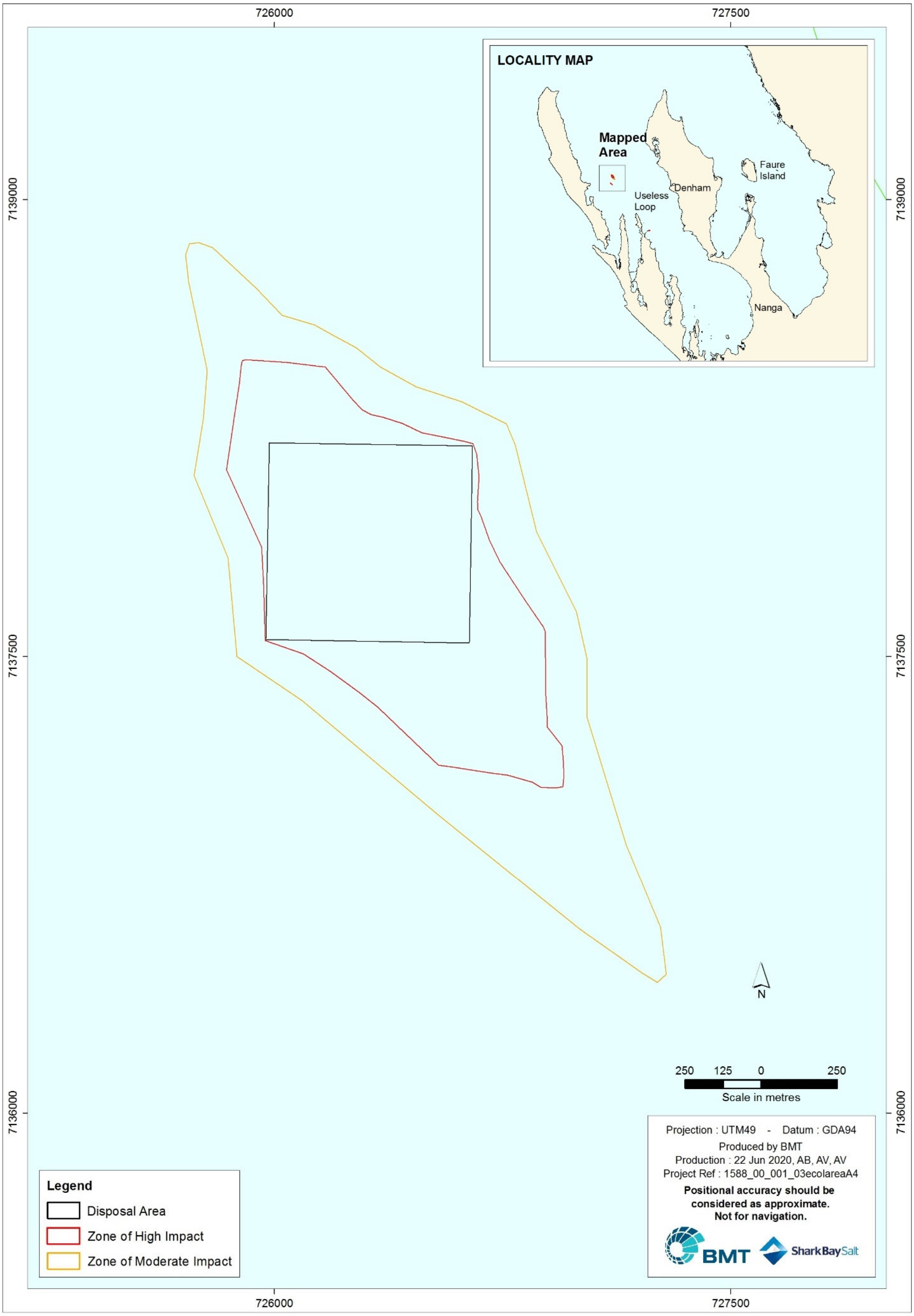


Figure 5-2 Defined zone of moderate and high impact adjacent to the offshore disposal area

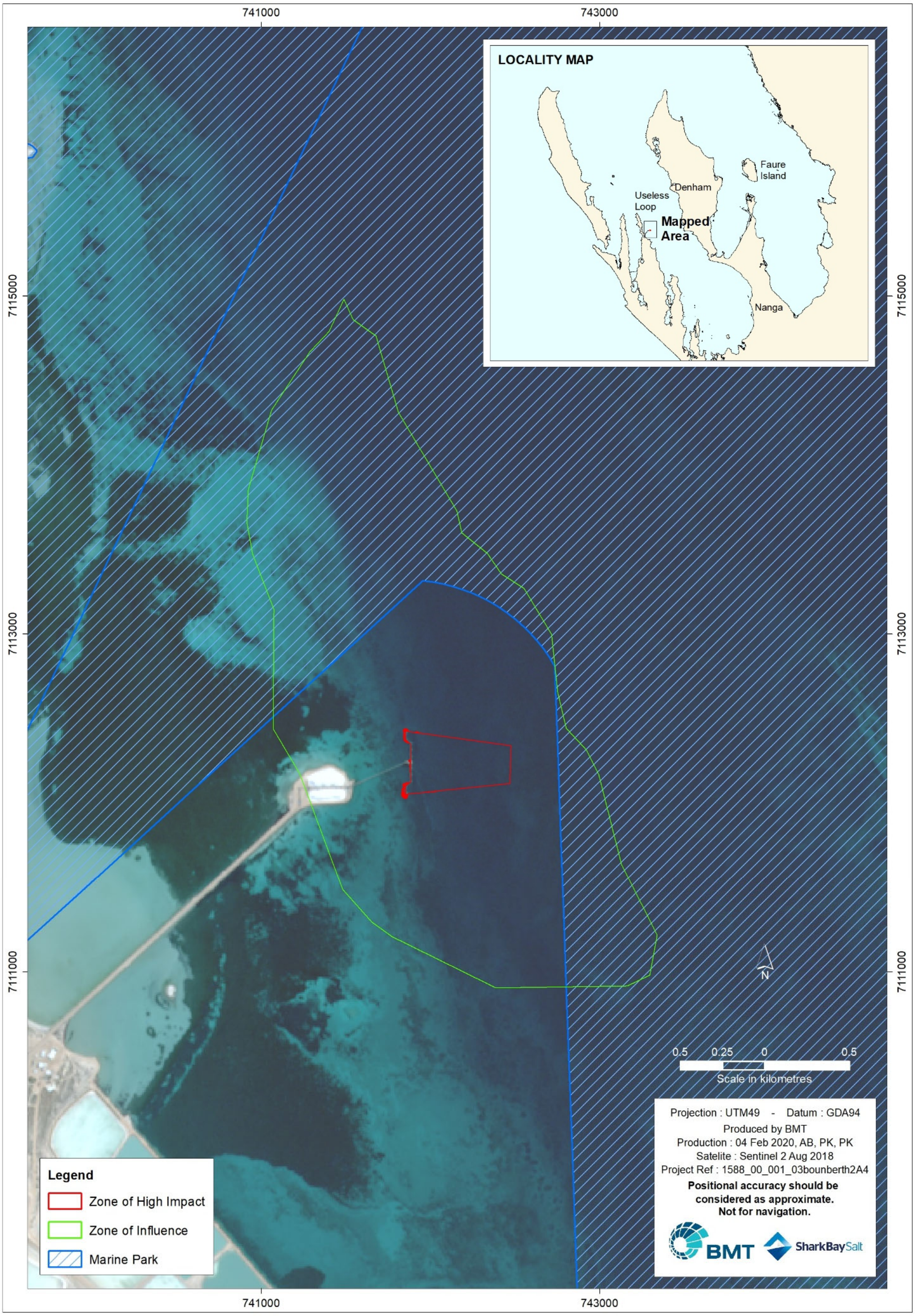


Figure 5-3 Defined zones of impact adjacent to the berth pocket sweeping area

5.1.4 Cumulative impacts and loss

Two separate LAUs were defined (Section 4.3.1) and percentage loss of BCH was calculated from the proportion of each mapped habitat type at the offshore area (including the channel and disposal area; ~25 km^2) and the berth pocket area (~47 km^2). The proportion of BCH within the ZoHI (permanent loss) and ZoMI (recoverable loss) has been determined based on EPA (2016b) *Technical Guidance – Protection of Benthic Communities and Habitats*, as follows.

5.1.4.1 Historical loss, original baseline and percent of original BCH remaining

BMT was unable to source historical imagery of the region for the purpose of assessing historical loss. However, SKM (2009) assessed seagrass loss attributed to the discharge of bitterns between construction in the late-1960s up until 1989, which allowed for comparisons of seagrass meadow extent before and after Port and crystalliser pond extensions adjacent to the berth pocket. It was established that ~1.22 km^2 of seagrass was lost as a result of brine discharges (SKM 2009), indicating a further 0.66 km^2 was lost as a result of Port and crystalliser pond infrastructure (Table 5-4).

Historical loss in the offshore area is attributed to the construction of the entrance channel in the late-1960s, though seagrass has re-established within the channel since this site was last dredged in the 1980s (0.29 km^2; Table 5-4). Seagrass loss associated with the channel and berth pocket was included as historical loss, as these regions have been previously dredged, and it is unlikely these seagrass meadows represent the former extent or biological diversity of these benthic communities. It is reasonable to include seagrass in areas established as a shipping channel and berth pocket as historical project loss given these areas of loss were “existing or approved at the time of the proposal” (EPA 2016b), and considered acceptable loss under previous regulatory approvals.

In summary, the ‘original baseline’ for BCH surveyed within the LAUs (Step 4 in Table 5-4; EPA 2016b) was determined by estimating historical project loss as a result of:

- Construction of Port infrastructure at Slope Island in the late-1960s (Figure 5-4; amber shading).
- Construction of a new series of crystalliser ponds, approved in June 1999 under Ministerial Statement 513 (Figure 5-4; amber shading).
- Discharge of bitterns adjacent the salt pond and subsequent loss of seagrass between the late-1960s and 1989 (Figure 5-4; amber shading).
- Berth pocket construction resulting in loss of re-established seagrass as measured in this region in 2019/2020.
- Construction of the entrance channel in the late-1960s.

Though the disposal site was used for the purpose of maintenance dredging in 1980s, this area falls within the SBWHA and adjacent to the SBMP and has conservatively been considered as potential permanent (ZoHI) and recoverable loss (ZoMI) as a result of the proposed Project (Section 5.1.4.2). Only seagrass was considered recoverable loss within the ZoMI as sedimentation of <3 cm is not expected to indirectly impact marine fauna associated with bare sand and rock/rubble habitat (refer Section 5.3.2 and 5.4.1).

Therefore, the percent of original BCH cover remaining for each habitat type (Step 5; EPA 2016b) was 100% for the offshore LAU (e.g. the extent of habitat surveyed in 2019/2020), and ~81% for dense seagrass, 100% for moderate seagrass, ~98% for sparse seagrass, and 100% for bare sand habitat within the berth pocket LAU (Table 5-4).

5.1.4.2 Calculation of permanent and recoverable loss

The permanent seagrass loss attributed to the current proposal (Table 5-4; Step 6; EPA 2016b) is ~0.16% (0.02 km^2) of sparse seagrass from within the offshore LAU (ZoHI, adjacent to the disposal area). An additional ~2.15% (0.27 km^2) of sparse seagrass is predicted to be lost but recoverable within a period of 5 years (ZoMI) following completion of the Project. No other BCH loss is expected to occur within either LAU as a result of the Project.

The predicted total area of permanent seagrass loss, including historical project loss, within the offshore LAU (Step 7; EPA 2016) is 1.04% (0.13 km^2) for sparse seagrass cover and 8.11% (0.18 km^2) for moderate seagrass cover (Table 5-4). There is no estimated historical or proposed project loss of dense seagrass cover within the offshore LAU. There were historical losses of BCH within the berth pocket LAU as a result of historical project works, however, no additional losses are expected as a result of the proposed Project.

The above calculations are considered very conservative estimates of potential Project loss of BCH given the offshore LAU is half the typical size recommended by EPA (2016b; 50 km^2). It is also noted that the above calculations exclude the 36% loss of seagrass associated with the 2010/2011 marine heat wave (Strydom et al. 2020), as suggested by EPA (2016b) guidance. The historical loss of all seagrass attributed to the 2010/2011 marine heat wave (i.e., 36% loss) would represent ~6 km^2 and ~8 km^2 as a percent of BCH mapped within the offshore and berth pocket LAUs, respectively. This regional seagrass loss far exceeds expected permanent seagrass loss attributed to the current proposal (0.02 km^2), or cumulative historical seagrass loss attributed to the project (0.29 km^2), within the offshore LAU.

All historical and proposed Project loss within the LAU adjacent to the berth is within an area excised from the SBWHA and SHMP (Figure 5-4). Historical loss associated with the entrance channel is within the SBWHA and SHMP. Loss associated with the proposed Project, namely areas of permanent (ZoHI) and recoverable loss (ZoMI) adjacent to the disposal area, are within SBWHA and in most instances also within the SBMP (Figure 5-4). Therefore, potential small-scale loss as a result of dredging and disposal activities is not anticipated to result in a significant impact to the ecological values of the SBWHA or the SBMP (refer Section 4.1). This small potential habitat loss is also not expected to result in loss of habitat critical for survival of threatened and migratory marine fauna in the region (Section 5.3).

To ensure that impacts to limited light conditions created by the turbid plume are equivalent to those modelled and the ZoHI and ZoMI are appropriate, light will be monitored during dredging and sea levelling activities. Light and/or turbidity monitoring and management requirements are provided in Appendix A.

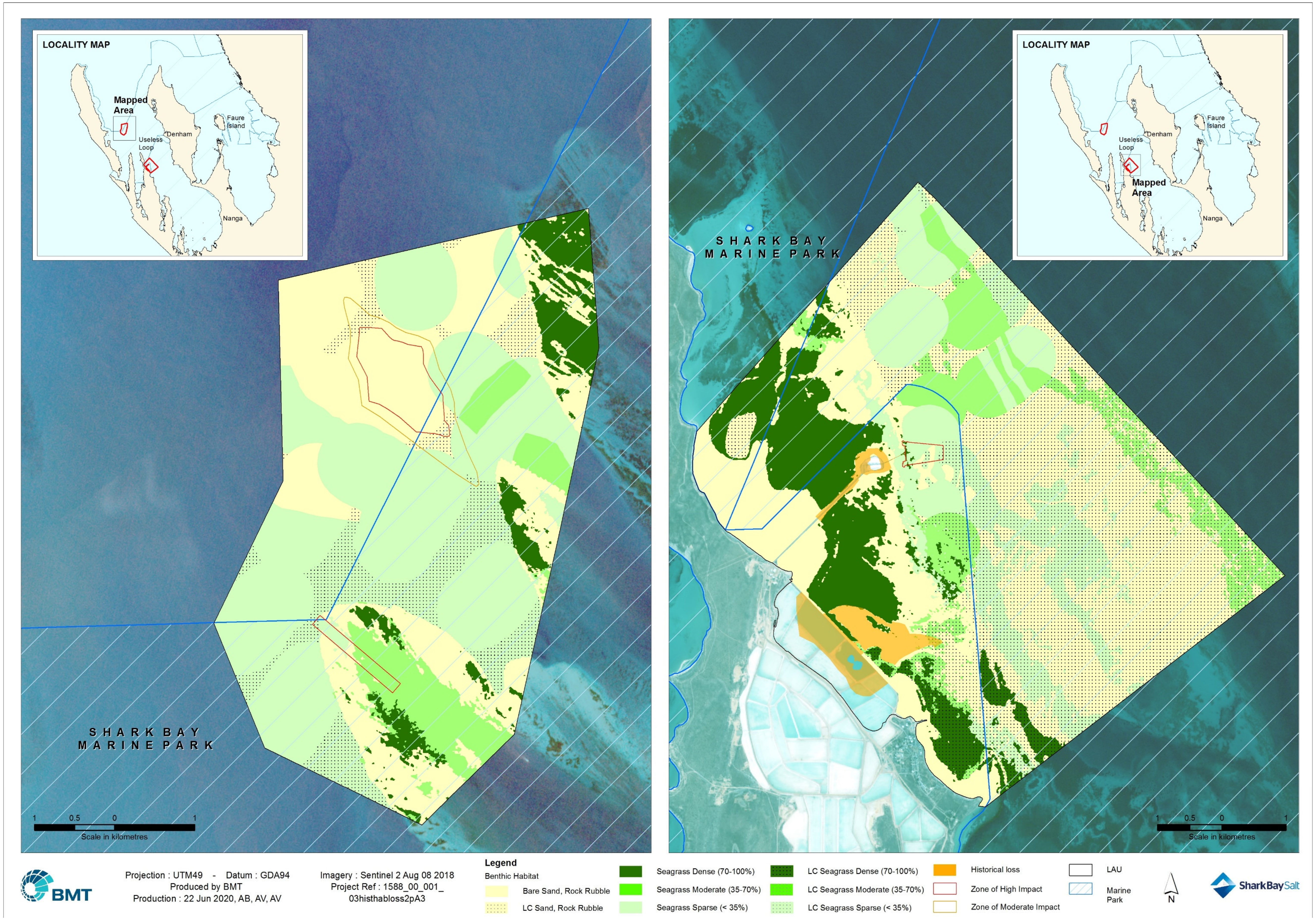


Figure 5-4 Historical and proposed Project loss of benthic communities and habitat within the offshore (left) and berth pocket (right) local assessment units (LAU)

Table 5-4 Anticipated cumulative permanent and temporary benthic habitat loss[1] for the Project

Benthic habitat type	Area mapped	Historical loss[2]	Original baseline (Step 4; EPA 2016b)[3]	Percent of original BCH remaining (%) (Step 5; EPA 2016b)	Area of permanent loss (ZoHI)[4]	Proportion of permanent current Project loss (%) (Step 6; EPA 2016b)	Area of recoverable loss (ZoMI)[4]	Proportion of recoverable current Project loss (%) (Step 6; EPA 2016b)	Proportion of permanent cumulative Project loss (%) (Step 7; EPA 2016b)
Offshore entrance channel and disposal area									
Seagrass dense (70–100%)	1.87	0.00	1.87	100.00	0.00	0.00	0.00	0.00	0.00
Seagrass moderate (35–70%)	2.22	0.18	2.22	100.00	0.00	0.00	0.00	0.00	8.11
Seagrass sparse (<35%)	12.56	0.11	12.56	100.00	0.02	0.16	0.27	2.15	1.04
Bare sand, rock rubble	8.40	0.07	8.40	100.00	0.88	10.48	0.00	0.00	11.31
Infrastructure[2]	0.00	n/a		n/a	n/a	n/a	n/a	n/a	n/a
Total	25.05	0.35	25.05	n/a	0.91	n/a	0.27	n/a	n/a
Berth pocket area									
Seagrass dense (70–100%)	7.06	1.67	8.73	80.87	0.00	0.00	0.00	0.00	19.13
Seagrass moderate (35–70%)	5.71	0.00	5.71	100.00	0.00	0.00	0.00	0.00	0.00
Seagrass sparse (<35%)	9.56	0.21	9.77	97.85	0.00	0.00	0.00	0.00	2.15
Bare sand, rock rubble	22.95	0.05	22.95	100.00	0.00	0.00	0.00	0.00	0.22
Infrastructure[2]	1.91	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total	47.19	1.93	47.16	n/a	0.00	n/a	0.00	n/a	n/a

Notes:
1. All areas presented in kilometres squared unless otherwise noted.
2. Includes known areas of infrastructure and inferred loss of unknown seagrass cover as a result of infrastructure or bitterns (Figure 5-4; amber shading). Excludes the 36% loss of seagrass as a result of the 2010/2011 marine heat wave (Strydom et al. 2020), in-line with EPA (2016b).
3. Original baseline or original benthic communities and habitats (BCH) within the LAU prior to European settlement (refer Note 2). Historical loss of moderate and sparse seagrass already included in the mapped totals for these habitat types.
4. Habitat types impacted within the zone of high impact (ZoHI) is predicted to be irreversible, habitat types impacted within the zone of moderate impact (ZoMI) are predicted to recover within 5 years following completion of dredging activities. The ZoHI associated with the berth pocket and channel areas includes a 50 m buffer to allow for GPS and positioning just beyond the Project design areas. The area of predicted permanent loss associated with the Project has been calculated based on the BCH within the ZoHI at the disposal area.
5. LAU = local assessment unit, n/a = not applicable.

5.2 Marine environmental quality

5.2.1 Increase in water column turbidity

Due to the mobilisation of sediments during dredging, disposal and seabed levelling, the Project works will likely cause a temporary increase in water column turbidity. Plume modelling based on "worst case" local hydrodynamic conditions and site-specific PSD analysis indicated that the plume will likely be localised to the entrance channel and disposal area only (Section 4.2.5). TSS concentrations will be above ambient conditions for <28 days for the entire Project, regardless of the dredging production rate. Elevated water column turbidity can have both social and environmental impacts, with the latter detailed in Section 5.1. Social impacts include reduced visual amenity within the SBWHA. However, it is unlikely that turbidity generated will have a significant negative social impact because:

- TSS concentrations above ambient conditions will occur for <28 days, and turbidity generated by dredging will be <5 mg/L above ambient within 1.5–7 days of cessation of turbidity generating activities, for low and high production rate dredging, respectively.
- Plume dispersion modelling suggests that turbidity generated by dredging beyond the berth pocket design will be <5 mg/L above ambient for the duration of the dredging project (Appendix G).
- TSS generated in excess of 20 mg/L above ambient will span a distance of ~12 km from the disposal area (at the furthest modelled extent) but for no more than 3–24 hours over the entire dredging program, for high and low production rate dredging, respectively; noting that with 24 hour dredging operations it is likely that some of this time may be at night (Appendix G).
- Turbid plumes will likely be localised to the offshore entrance channel and disposal area (>10 km from Denham), and so will not likely be visible from land.

Note additional conservatism in modelled elevated water column turbidity given modelled plume dispersion included dredging and disposal of berth pocket material, which has been replaced by seabed levelling under the revised Project (Section 2.2).

5.2.2 Release of contaminants

5.2.2.1 Entrance channel

In areas with declared high conservation values, a 99% species protection level [SPL]) is applied i.e., within the SBWHA/SMBP. Concentrations of TBT, metals and hydrocarbons in entrance channel sediments were below the NAGD screening levels in all samples. As such, it is unlikely that the dredging and disposal of these sediments will result in adverse effects on the environment. Based on these results, the entrance channel material is considered suitable for ocean disposal under the EPSD Act and there is no requirement for assessment against NAGD Phase III tests or active management during the Project (Section 4.2.4).

5.2.2.2 Berth Pocket

The berth pocket is excluded from the SBWHA/SBMP and is assigned (by the WA EPA) a moderate level of ecological protection (90% SPL) "to accommodate any accumulation of contaminants from anti-foulant paints" (EPA 2016c). Material from high spots within the berth pocket will be spread to areas lower than design, retaining the material within and adjacent to the berth and within the area of moderate ecological protection/ZoHI for the berth pocket (Section 5.1.3). The sediments adjacent to the berth with concentrations of TBT above the relevant NAGD screening level were assessed for elutriate concentrations to determine the risk to the receiving marine water environment during remobilisation of sediments through sweeping operations (Section 4.2.4). Only one of the sediment samples within the berth pocket contained concentrations of elutriate TBT exceeding the ANZG (2018) 90% species protection guideline (Section 4.2.5; Appendix F).

To conservatively estimate the concentration of TBT that is potentially bioavailable within the material to be swept from the western berth pocket, the weighted 95th percentile[6] concentrations of elutriate TBT were calculated based on the volume of material to be levelled at and adjacent to the sites within the 'contaminated' area (Sites BS6–12 and BS16; Figure 5-5). Elutriate testing was not conducted on sediment samples that were below the relevant NAGD screening levels and these were assumed to have elutriate TBT concentrations of zero for the purpose of these calculations. The weighted 95th percentile concentration of elutriate (1:4) TBT (0.007 µg/L) meets the 90% SPL (0.02 µg/L) at the site of seabed levelling, as required within a moderately disturbed environment like the berth pocket.

Outside the berth area, the expectation is that a high level of ecological protection (99% SPL) will be achieved at the boundary of the SBMP. Dilution must be considered to give a robust estimate of concentrations within the receiving environment at the SBMP/SBWHA boundary for comparison to the guidelines. Based on the total weighted concentration of elutriate TBT, a 31.6 dilution is required to meet the 99% SPV at the boundary of the SBMP, ~1 km from the berth (Table 5-6).

It is estimated that a 1:127 dilution of the total weighted elutriate concentration (0.0126 µg/L) would occur in the water column within 250 m of the berth. The calculation is based purely on volume of water to achieve dilution of potential release of TBT and does not factor the additional mixing that may occur in the receiving environment from coastal processes such as interactions between wave, tide, wind etc., that would further dilute potential TBT concentrations in the water column. This 1:127 dilution achieves a TBT concentration of 0.0001 µg/L in the water column, which meets the 99% SPV. The 1:127 dilution was calculated based on the total weighted concentration of elutriate TBT in the volume of material to be levelled within the contaminated area of the berth (~4936 m^3; Figure 5-5) being dispersed into the water column. Noting that the volume of pore water was conservatively assumed equivalent to the volume of material above design; even though pore water volume would be considerably less. The 625 000 m^3 volume of receiving water was limited to the ~10 m water depth and within 250 m of the disturbance, which is typically the distance from the

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[6] The use of a weighted 95th percentile calculation accounts for the sampling bias towards areas of potential contamination to provide a robust estimate of concentrations in the material that will actually be disturbed.

edge of infrastructure in which the moderate level of ecological protection applies, “to accommodate any accumulation of contaminants from anti-foulant paints” (EPA 2016c). This volume dilution calculation indicates that total weighted elutriate TBT concentrations can achieve the 99% SPV within 250 m of the disturbance if it is assumed there is even distribution in the water column. Therefore, based on the relative distance from the berth to the SBMP/SBWHA boundary (~1 km), and limited resuspension of material during the seabed levelling process, it is likely that dilution, well above 32 dilutions, will be achieved to meet the relevant 99% SPV for TBT at the SBMP boundary. However, to ensure the 99% SPV will be achieved at the boundary, SBR will actively monitor receiving waters before, during and after seabed levelling activities in-line with outcome-based provisions and relevant contingencies outlined in the DEMP (Appendix A).

5.2.2.3 Summary

Entrance channel material is considered suitable for ocean disposal under the EPSD Act and will be disposed of offshore. Seabed levelling in the berth pocket retains potential seabed levelling impacts with an area of moderate ecological protection where a 90% level of species protection applies. The weighted 95th percentile concentrations of elutriate TBT prior to dilution (a measure of bioavailability) met the 90% SPV suggesting potential impacts to benthic and pelagic flora and fauna within the at the berth pocket from the release of TBT during seabed levelling of the contaminated area is negligible. Outside the area designated a moderate level of ecological protection a high level of ecological protection applies. It is expected that the 99% species protection levels for TBT will be met and a high level of ecological protection maintained after dilution between the release of contaminates and the boundary of the area of high ecological protection (SBMP/SBWHA boundary).

To ensure contaminants meet the 90% species protection guidelines within the berth area excised from the SBMP/SBWHA, and the 99% species protection guidelines outside the area, receiving waters will be monitored before, during and after seabed levelling activities (Appendix A).

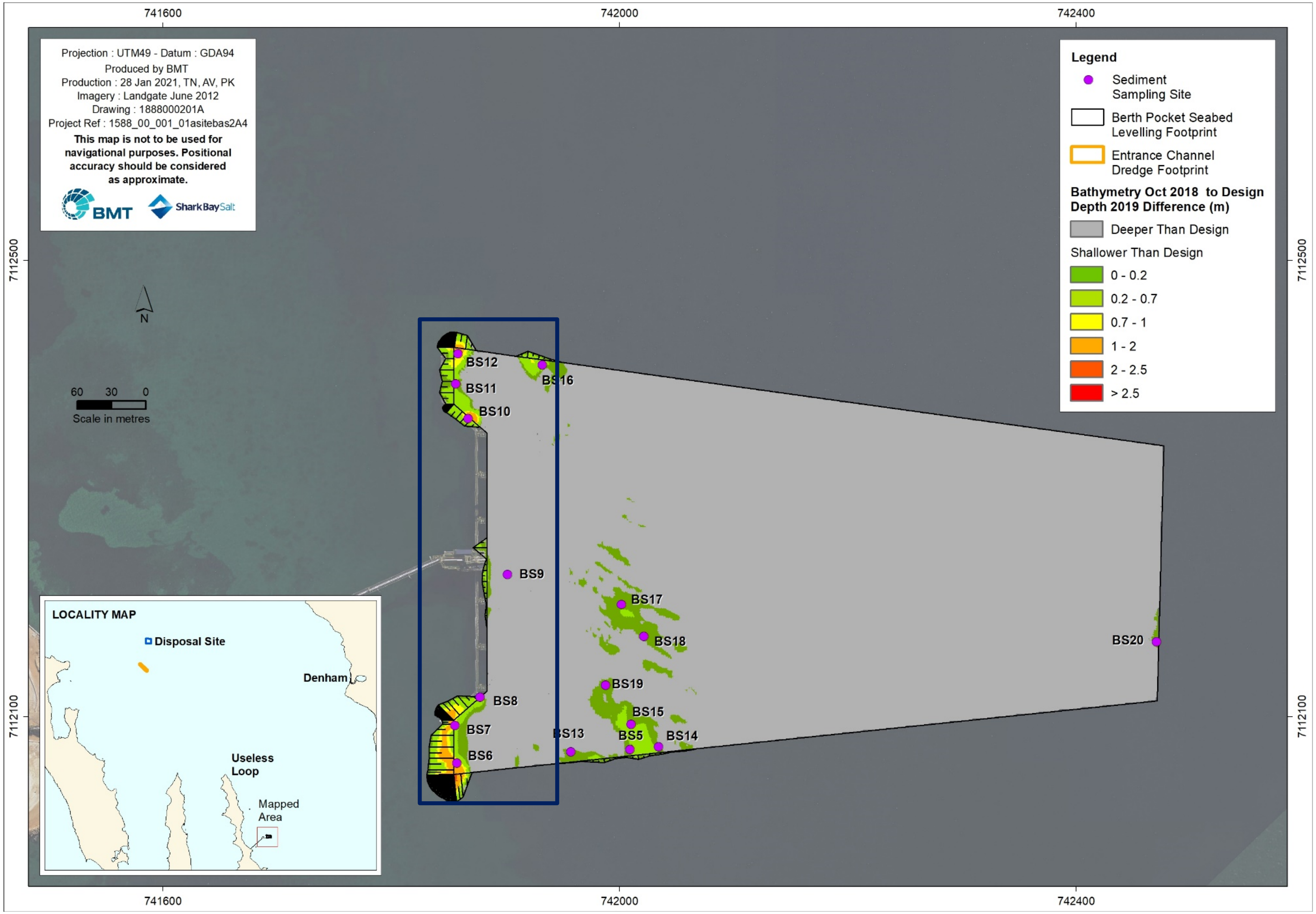


Figure 5-5 Berth pocket "contaminated" area (blue box)

Table 5-5 Weighted 95th percentile, maximum and total concentration of elutriate tributyltin[1] in sediments from the berth pocket compared to the moderate species protection value

90% species protection value[2]	0.02000 µg/L
95th percentile[2]	0.00711 µg/L
Max	0.01135 µg/L
Total (sum)	0.01262 µg/L

Notes:
1. Dilution of 1:4 wet sediment: added seawater is the concentration the laboratory used to undertake the elutriate testing.
2. ANZG (2018) trigger values for TBT for the 90% species protection value applicable within moderately disturbed environments (EPA 2016c).

Table 5-6 Weighted 95th percentile, maximum and total concentration of elutriate tributyltin[1] in sediments from the berth pocket and estimate dilution required to meet the 99% species protection value

Contaminant	Tributyltin 95th percentile[2]	Maximum	Total
Weighted concentration by volume[2]	0.00711 µg/L	0.01135 µg/L	0.01262 µg/L
Background concentration	0.00000 µg/L	0.00000 µg/L	0.00000 µg/L
99% species protection value[3]	0.00040 µg/L	0.00040 µg/L	0.00040 µg/L
Dilutions required to meet the trigger	17.8	28.4	31.6

Notes:
1. Dilution of 1:4 wet sediment: added seawater is the concentration the laboratory used to undertake the elutriate testing.
2. Weighting based on estimated volume of material above design in the vicinity of each sampling site. Estimate volume of material to be levelled within the contaminated area is ~4936 m^3.
3. ANZG (2018) trigger values for TBT for the 90% species protection value applicable within moderately disturbed environments (EPA 2016c).

5.2.3 Hydrocarbons and waste generation

Various hydrocarbons will be used during the Project, including fuel, oil and lubricants for machinery. There is a risk of hydrocarbon spills negatively impacting marine flora and fauna as well as beach users. Rubbish and hazardous waste may also be generated, which can pollute the environment if not contained and removed from site. Therefore, hydrocarbon use and waste will be actively managed (Appendix A).

5.2.4 Hypoxia

Hypoxia is the condition in which dissolved oxygen is below the level necessary to sustain most animal life. The oxidation of iron sulphides and bacterial decomposition of organic material in the sediments can increase the chemical and biological oxygen demand of water. If large amounts of organic material were to be released into the water column at the dredge or disposal areas, bacterial decomposition of this material could deplete oxygen levels and lead to hypoxia.

Sediment sample results indicated that only small amounts of organic matter were present and TOC concentrations of sediments were low (Section 4.2.4; Appendix F). Furthermore, currents and water movement in the dredging and disposal areas will ensure constant mixing of oxygen and dispersion of dredged material, including organic matter. For these reasons, the risk of hypoxia developing in the water column during dredging is low and does not require active management during the Project.

5.2.5 Introduced marine species

There is a risk of IMS being introduced into the region from ballast water and biofouling by vessels to be used during the maintenance dredging. IMS can have significant impacts on marine ecosystems and marine industries; however, only a small fraction of IMS are able to thrive and successfully colonise new habitats (Mack et al. 2000). IMS have the potential to displace native species, change community structure and food webs, and alter ecosystem processes such as nutrient cycling and sedimentation or damage marine industries through diminishing fisheries, fouling ship's hulls and clogging intake pipes (Molnar et al. 2008). The primary means by which non-indigenous marine species may be introduced is via biofouling (the attachment of organisms) to vessel hulls and/or ballast water (water that a vessel takes on board to provide stability).

In Australia, around 250 introduced marine pests have been identified, of which over 75% are believed to have been introduced through biofouling rather than in ballast water (Bax et al. 2003). Indeed, biofouling may pose a higher potential risk of introducing marine species. The unique environment at Useless Loop is largely inhospitable for colonisation by IMS (Section 4.3.5). As demonstrated by the failure of IMS to become established at Useless Loop over the last 40 years of port operations, the risk of IMS being introduced and colonising at Useless Loop is very low. Regardless, the potential for the introduction of IMS by the dredging vessels will be managed through SBR's existing IMS management plan (Section 3.2.7; SBR 2018). Before mobilising vessel(s) contracted to the Project, SBR will also verify that the vessels comply with DPIRD biosecurity requirements. This process may involve contracted vessels completing the DPIRD risk assessment (likely including liaison with the DPIRD; see https://vesselcheck.fish.wa.gov.au/) for any vessel entering the Port from international or interstate waters.

5.3 Marine fauna

5.3.1 Impacts to threatened and migratory species

The marine fauna known to occur in the Project area (Section 4.3.2) may be impacted by vessel movements and operational noise during the Project, potentially leading to behavioural avoidance, injury or fatality in the case of collisions. Marine fauna species may also be impacted by removal or disturbance of key habitats. The habitat types identified within the dredging and disposal areas are known habitats of foraging and breeding for several marine species identified in the area. Dugongs in particular are known to inhabit seagrass meadows south of the Project area. Therefore, it is likely that marine fauna will be seen in close proximity to the Project area throughout the duration of the Project, posing a moderate risk to threatened and migratory marine fauna. Given the variety of marine species present and active within the Project area year-round, it is not possible to avoid migration and breeding windows for all species (Section 4.3.2). Considering the short duration of the Project, these potential impacts can be effectively managed to reduce the risk to threatened and migratory marine fauna through implementation of monitoring and management measures outlined in the DEMP (start-up procedures and marine fauna monitoring zones; Appendix A). Potential loss of BCH as a result of dredging is detailed in Section 5.1 and will be monitored and managed to reduce potential impacts to marine fauna relating to habitat loss (Appendix A).

Vessel collision may result in injury or fatality of marine fauna, and species that rest on the sea surface such as whales, dugongs and turtles may be more vulnerable to this type of impact. The mobility of marine fauna such as dolphins suggests avoidance of vessels is likely, reducing the risk of these species being injured or entrained by the slow moving (~7–14 knots) and audible TSHD. This is also the case for slower moving marine fauna including dugongs, whales and turtles. Avoidance of dredge vessels and equipment may require additional energy expenditure, however due to the short duration of the Project this impact is only short-term. Risk of entrainment is slightly higher for species that forage on the seabed, such as dugongs and turtles, however the risk is still relatively low due to their strong swimming ability and avoidance of BCH where possible (Section 5.1). This risk can be further reduced by turning off the dredge suction when the drag-head is raised above the seabed. Proposed mitigation measures for prevention of collision and entrainment are detailed in the DEMP (Appendix A).

Noise generated by dredging activities has the potential to disturb marine fauna, causing temporary or even long-term avoidance of an area that may be important for feeding, reproduction or sheltering. Underwater noise may interfere with communication systems of fish and marine mammals, masking important biological cues or causing behavioural disturbance (Richardson et al. 1995, National Research Council 2005, Southall et al. 2007). Intense underwater noise near marine fauna may cause temporary or permanent hearing damage or death (Southall et al. 2007). These impacts may affect critical behaviours and functions, such as feeding, migration, breeding and response to predators, all of which may ultimately affect an individual animal's survival (National Research Council 2005). In general, noise generated by (and the auditory bandwidth of) large marine mammals are low frequency to allow communication over long distances underwater (Table 5-7).

The proposed machinery used during the Project (TSHD, tug and any transfer vessel/s) generate noise that may disturb wildlife within hearing range. However, sounds generated by dredging at the source of the TSHD (i.e. thruster, inboard pump, propeller, engine and mechanical sounds, pump and drag-head sounds) are at the lower end of noise emission pressures in the aquatic environment (CEDA 2011; Figure 5-6) and outside of the auditable bandwidth of the marine mammals likely to occur in the region (Table 5-7). Further, the Project is within an active channel and berth pocket, where large vessels are commonplace and can be the source of similar, if not a higher, underwater noise compared to a TSHD (CEDA 2011; Figure 5-6). Noting that noise generated by the TSHD is dependent on a number of variables i.e. sediment characteristics, vessel size, water quality and depth. Therefore, due to the small scale and short duration of the dredging campaign, it is unlikely that fauna will not be significantly impacted by the noise generated by the Project.

If artificial lighting is used during the Project works, it has the potential to disrupt the behaviour of light sensitive marine fauna, specifically marine turtle hatchlings (DoEE 2017). Artificial lighting is not expected to be a key environmental impact during or following Project completion, given the: Project works will be temporary and small-scale and there are no turtle nesting beaches adjacent to the dredging or disposal areas (Section 4.3.2.1).

Table 5-7 Auditory bandwidth of marine mammals likely to occur within the vicinity of the Project

Species	Estimated auditory bandwidth
Southern Right Whale (*Eubalaena australis*) Bryde's Whale (*Balaenoptera edeni*) Humpback Whale (*Megaptera novaeangliae*)	Low-frequency (7 Hz to 22 kHz)
Killer Whale/Orca (*Orcinus orca*) Bottlenose dolphins (*T. truncatus* and *T. aduncus*)	Mid-frequency (150 Hz to 160 kHz)
Dugong (*Dugong dugon*)	Mid-frequency (1 to 18 kHz)

Source: Southall et al. (2007) and GBRMPA (2016)

Sound source	Source level at 1m	Bandwidth	Main energy	Duration	Directionality	Source
Explosives	272dB-287dB re 1μPa zero-to-peak	2Hz-~1kHz>	6Hz-21Hz	~1ms	Omni-directional	1)
Seismic air gun arrays	220dB-262dB re 1μPa peak- to-peak	5Hz-100kHz	10Hz-120Hz	10ms-100ms	Downwards	2)
Pile driving	220dB-257dB re 1μPa peak-to-peak	10Hz >-20kHz	100Hz-200Hz	5ms-100ms	Omni-directional	1), 2)
Echosounders	230dB-245dB re 1μPa rms	11.5kHz-100kHz	Various	0.01ms-2ms	Downwards	2)
Low-frequency military sonar	240dB re 1μPa peak	0.1kHz-0.5kHz	-	6s-100s	Horizontally focussed	3)
Sperm whale click	236dB re 1μPa rms	5kHz-40kHz	15kHz	100μs	Directional	4)
Mid-frequency military sonar	223dB-235dB re 1μPa peak	2.8kHz-8.2kHz		0.5s-2s	Horizontally focussed	1)
Sparkers, boomers, chirp sonars	204-230 dB re 1μPa rms	0.5-12kHz	Various	0.2ms	Downwards	2)
Harbour porpoise click	205dB re 1μPa peak-to-peak	110kHz-160kHz	130kHz-140kHz	100μs	Directional	5)
Shipping (large vessels)	180dB-190dB re 1μPa rms	6Hz >-30kHz	<200Hz	Continuous	Omni-directional	1)
TSHD	186dB-188dB re 1μPa rms	30Hz>-20kHz	100Hz-500Hz	Continuous	Omni-directional	6), 7)
Snapping shrimp	183dB-189dB re 1μPa peak-to-peak	<2kHz-200kHz	2kHz-5kHz	Milliseconds	Omni-directional	8)
CSD	172dB-185dB re 1μPa rms	30Hz>-20kHz	100Hz-500Hz	Continuous	Omni-directional	6), 7)
Construction and maintenance ships	150dB-180dB 1μPa rms	20Hz-20kHz	<1kHz	Continuous	Omni-directional	1)
Drilling	115dB-117dB re 1μPa (at 405m and 125m)	10Hz- ~1kHz	<30Hz-60Hz	Continuous	Omni-directional	1)

Source: CEDA (2011)

Figure 5-6 Biological and manmade sound sources listed in decreasing order of source levels at 1 m

5.3.2 Impacts to invertebrates

Invertebrates may be impacted by direct impacts such as smothering during disposal, and indirect impacts such as release of contaminants during dredging and disposal. Any loss of prawns due to smothering by disposal material is restricted to the relatively small disposal area (~0.4 km^2) positioned south of the Denham Sound area where the southern extent commercial trawling operations are concentrated for prawns and scallops. Impacts to commercially significant aquaculture species are discussed further in Section 5.4.1.

5.4 Social surroundings

5.4.1 Commercial and recreational fisheries

There is the potential for the Project to impact commercial and recreational fisheries through direct and indirect loss of significant habitats, decreased marine environmental quality (such as increased water column turbidity and/or release of contaminants), and access issues/navigational hazards. Fisheries in Shark Bay are not anticipated to be significantly impacted by the Project for the following reasons:

- The habitats identified within the Project area are representative of the broader Shark Bay region, and so any direct loss of habitat specific to species targeted via the Inner Shark Bay Scalefish Resource/Shark Bay Beach Seine and Mesh Net Fishery is not expected to significantly reduce habitat availability for commercially important species. Noting that exclusion areas for specific species like prawns are in the eastern bay, beyond the extent of the project footprint (CPLs; Section 4.4.1).
- TSS concentrations above ambient conditions will occur for <28 days, and turbidity generated by dredging will be <5 mg/L above ambient within 1.5–7 days of cessation of turbidity generating activities, for low and high production rate dredging, respectively.
- Plume modelling indicates that increases in turbidity above ambient will be localised in extent, short in duration, with the highest levels of turbidity in excess of 20 mg/L above ambient adjacent to the disposal area present for no more than 3–24 hours over the entire dredging program (depending on high or low production dredging rate).
- Given the sediments in the dredge area is deemed suitable for ocean disposal, negative impacts from contaminants/nutrients are not anticipated (Section 5.2.2 and 5.2.4).
- Due to the short duration of the Project (1–4 weeks of turbidity generating activities) and position within an active Port/channel area it is unlikely that commercial or recreational vessel movement will be impeded (refer Section 5.4.3).

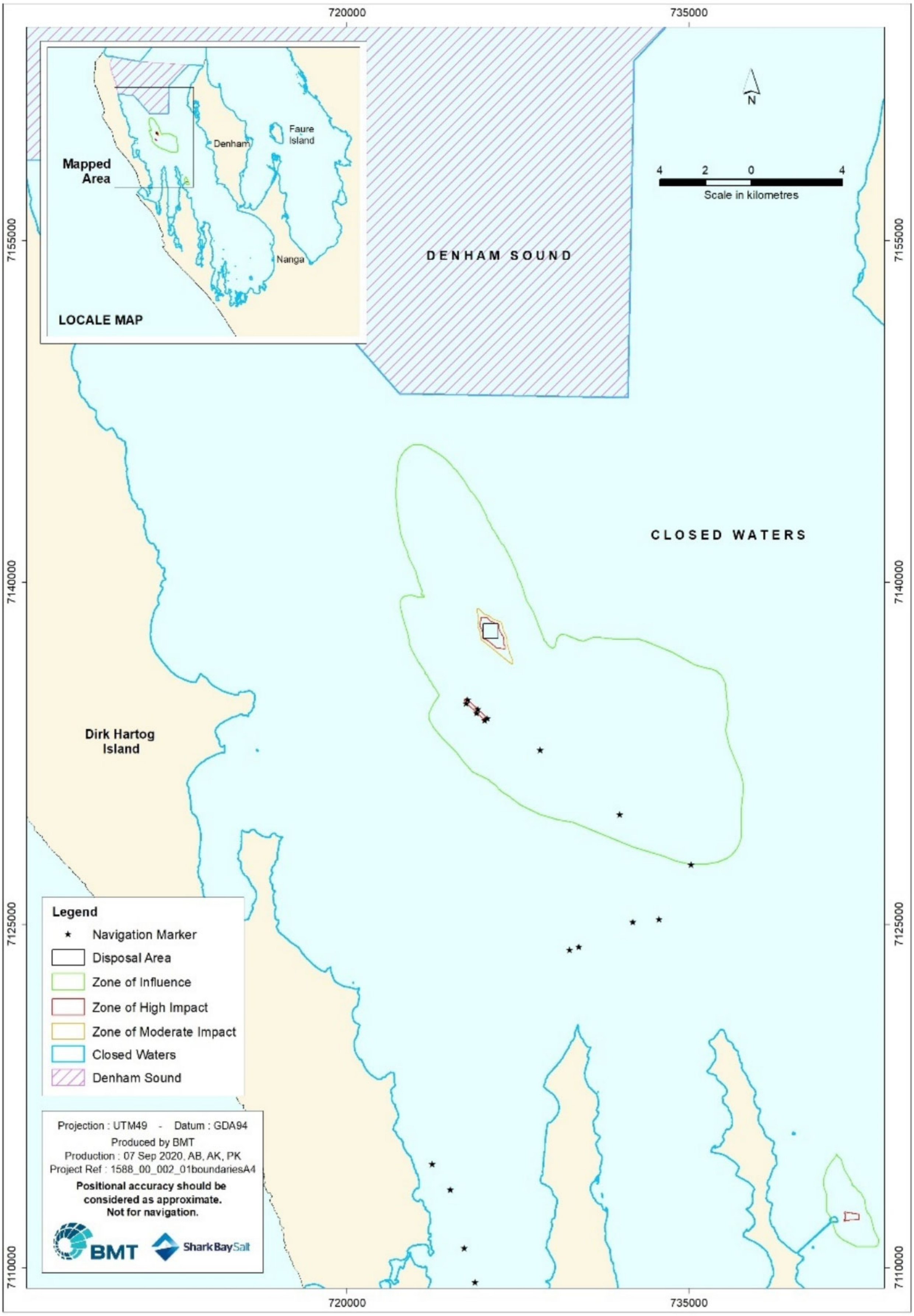
Sections 5.4.1.1–5.4.1.3 deatails specific responses to concerns raised by DPIRD and the Western Australian Fishing Industry Council (WAFIC) on behalf of key commercial fisheries in the region.

Note additional conservatism in modelled elevated water column turbidity given modelled plume dispersion included dredging and disposal of berth pocket material, which has been replaced by seabed levelling under the revised Project (Section 2.2).

5.4.1.1 Smothering and impacts to scallops:

Survival from smothering or burial is attributed to an ability to move away from or above the material deposited. There are several studies that indicate the mortality of scallops increases with depth of burial (length of time taken to emerge) and reduced particle size (Armstrong et al. 1982, Szostek et al. 2013, Hendrick et al. 2016). Incidents of mortality increase when scallops are buried in 3–5 cm (measured from the seabed) of sediment, and were less likely to emerge from material characterised by a smaller particle size (<0.3 mm) (Szostek et al. 2013, Hendrick et al. 2016).

The ZoHI associated with the spoil disposal, where impacts to benthic communities and habitat are predicted to be irreversible, was defined by several factors, including the sedimentation >3 cm (Figure 5-1). The ZoHI equates to ~1.1 km^2 (including the berth pocket [0.2 km^2], the channel [0.2 km^2] and the disposal area [0.7 km^2]) and does not interact directly with the Shark Bay Scallop Managed Fishery (SBSMF) (Figure 5-7). However, had the disposal ground and associated ZoHI been located within the designated SBSMF, the ZoHI would equate to 0.2% of the total Denham Sound SBSMF area (~720.3 km^2), the impacts of which are considered negligible in terms of scallop stock abundance.



Notes:
1. Fisheries boundaries align with DPIRD (2020a)
2. The Denham Sounds Shark Bay Scallop Managed Fishery is also part of the Shark Bay Prawn Managed Fishery
3. Refer to Section 5.1.3 for more detail regarding the zones of impact

Figure 5-7 The Shark Bay Scallop Managed Fishery[1] and defined zones of impact associated with the Project

5.4.1.2 Interaction with crabs (Zone 2) and juvenile prawn migration

The key nursery areas for the SBPMF are the East Peron and West Peron, the latter of which includes the berth pocket sea levelling area (Figure 4-5). Between 2011 and 2016 the SBPMF trawled areas were concentrated within Denham Sound (Figure 5-7), Inner Shark Bay and the Carnarvon Peron Line areas (Figure 4-6). As indicated, the disposal area is within the trawl closure site south of Denham Sound, between the SBPMF and the West Peron nursery areas.

The only specific closure areas for the Shark Bay Crab Managed Fishery (SBCMF) are adjacent to Carnarvon, Denham and Monkey Mia (Figure 4-8). Historical data indicate that important spawning grounds for crabs are likely in the deeper waters south of the eastern bay and north-east of Koks Island (Harris et al. 2014), far east and north of the proposed project area. The channel and proposed disposal area are within the Zone 2 SBCMF area, where there are fewer fishing licences, some of which are held by prawn and scallop operators.

Like the potential to smother scallops (Section 5.4.1.1), the sediment deposition within the ZoHI (>3 cm) may be too deep for crabs and prawns to resurface. However, crabs and prawns should be considered as highly mobile and/or physiologically adapted to partial burial, with literature indicating that burial up to 10 cm will not affect survivorship of crabs (Armstrong et al. 1982, Vavrinec et al. 2007). The ZoHI equates to ~1.1 km^2 and is unlikely to have a material impact on the wider population dynamics of crabs and prawns, regardless of the season for dredging.

Crabs and prawns also demonstrate a high tolerance for extended periods of elevated turbidity. The table below provides examples of suspended sediment tolerance levels that are reported to cause either acute or chronic mortality for adult and juvenile decapods and crustaceans (Table 5-8). The lowest suspended solid concentration resulting in mortality was 180 mg/L over a 21-day period (Table 5-8). Conservative estimates of suspended solid concentrations above ambient for the Project will be:

- <150 mg/L within 2 km of disposal site for the ~2-day dredging campaign
- <20 mg/L within 2 km of disposal site for the ~20-day dredging campaign (Figure 5-8).

The 2 km modelled plume extent is within the mapped zone of moderate impact (ZoMI) associated with spoil disposal (Figure 5-1). Regardless, disposal events will be intermittent in nature (~2–6-hour intervals between dredging and disposal runs) and occur over a period of ~2–20 days, so crabs and prawns adjacent to the disposal site will not be exposed to consistently elevated levels of total suspended sediments, and will likely move away/avoid the disposal area over the short duration of dredging.

Table 5-8 Lowest total suspended solid (TSS) concentrations reported to cause mortality in various life stages of decapod crustaceans and other taxa

Taxa/life stage	Lowest suspended solid causing mortality (mg/L)	Effect
Crabs	10 000	10% mortality after 8 days
Juvenile crabs	1800	5% mortality after 28 days
Other adult decapod crustaceans	230	40% mortality after 28 days
Other juvenile decapod and crustaceans	180	10% mortality after 21 days

Source: Wilber and Clarke (2001)

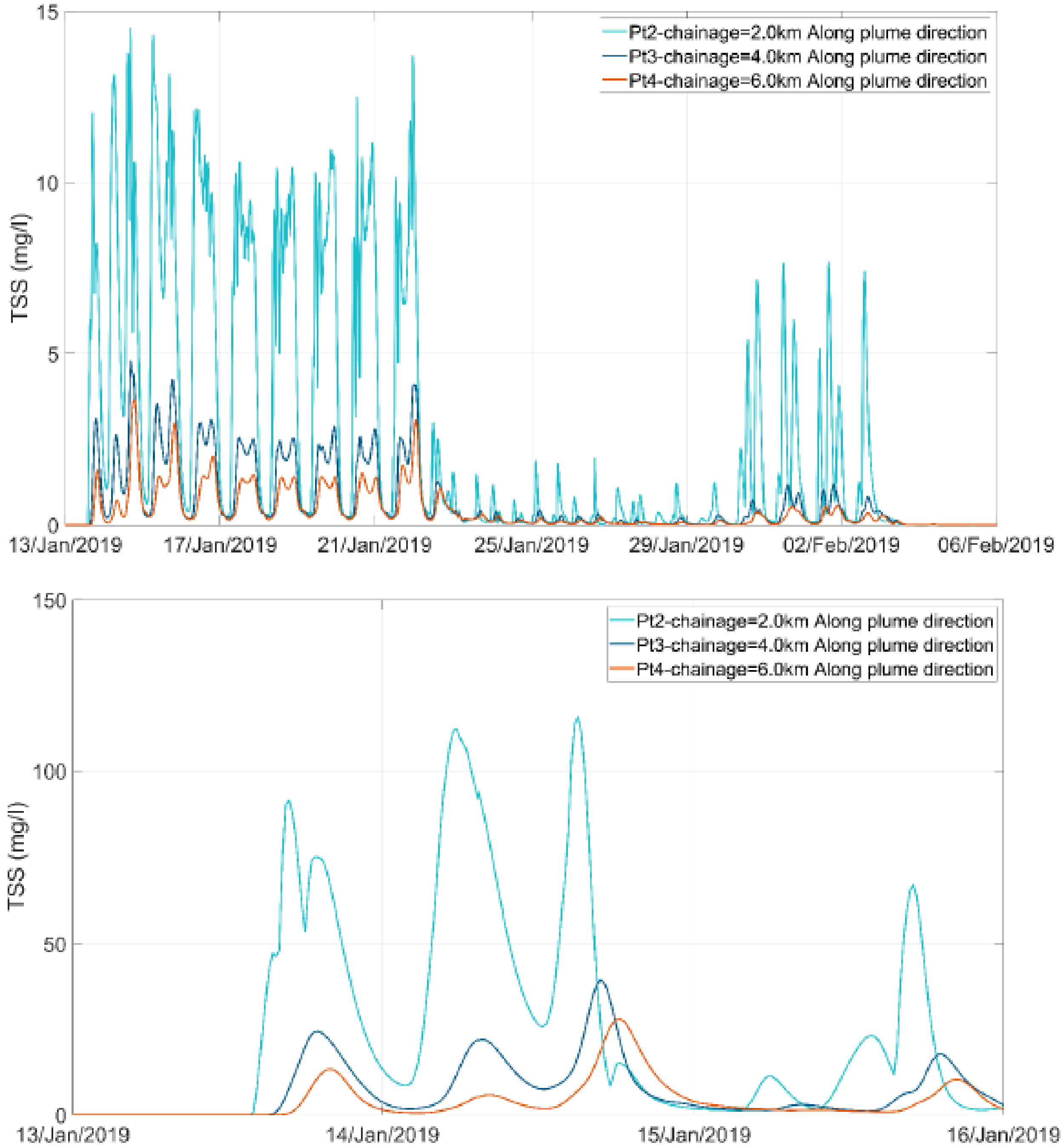


Figure 5-8 Modelled suspended solid concentrations for the small (top) and medium (bottom) trailer hopper suction dredge along the prevailing plume trajectory (Appendix G)

5.4.1.3 Interaction with snapper spawning season

Elevated suspended solid concentrations during snapper spawning could impact egg and larvae survival within the restricted area of disposal. Surveys of snapper spawning over multiple years have shown that there are distinct temporal and spatial patterns in the snapper spawning behaviour in Shark Bay (Figure 5-9; Jackson 2007, Jackson et al. 2012). Key spawning grounds for snapper have been defined by higher egg abundances during sampling between 1997 and 2007 in the inner gulf. The closest spawning ground to the proposed Project and offshore disposal area is the Denham Sound site, east of Dirk Harthog Island (Figure 5-9). The levels of spawning activity are greatest in Denham Sound between May and July, corresponding to the new moon and to a lesser extent around a full moon, similar to stocks in Cockburn Sound, which is likely an adaptation to maximise egg and larvae dispersal during high tides (Jackson et al. 2012). The total area of spawning in Denham Sound was estimated at 700 km^2, with average egg production during peak spawning ranging from 1.63 to 3.69 eggs m^2 day^{-1} between 1998 and 2003 (Jackson et al. 2012).

Partridge and Michael (2009; as cited in Water Corporation 2019) developed suspended solid exposure thresholds for snapper eggs and larvae, in support of the Perth Seawater Desalination Plant Public Environmental Review (Table 5-9; Water Corporation 2019). Suspended solid exposure thresholds, based on concentration and duration of exposure, were applied to the two proposed Project dredging scenarios (high or low production) and two modelled seasons (January and September) for the 24-hours of dredging that resulted in the highest consistent elevated turbidity (Figure 5-8). The contours for lethal and sublethal impacts to pink snapper larvae were mapped in relation to the key spawning area defined by Jackson (2012; Figure 5-9c).

The area of lethal and potential sublethal impacts to larvae will be restricted to the disposal site and represents an area of ~0.2–1.1 km^2 and 0.2–2.7 km^2, respectively, within the broader ~700 km^2 Denham Sound spawning area (Figure 5-10and Figure 5-11). Noting that the area of lethal impacts to larvae conservatively includes the channel dredge area (0.2 km^2), even though this area is not subjected to elevated concentrations of TSS over a consecutive period of time likely to result in lethal effects to larvae (>12 hours); similar to low production dredging in September where no lethal effects are evident at the disposal site (Figure 5-11). Modelled suspended solid simulations are representative of the largest plume dispersion expected over a 24-hour period in January during high wind action, and comparatively in September during low wind and calm sea conditions. Plume dispersion during autumn/winter months (between May and July in Shark Bay) are likely to result in plume dispersion somewhere between the two modelled scenarios.

Based on the highest daily egg production value of 3.69 eggs m^2 day^{-1} it is estimated that on average up to 0.39% of eggs/larvae may incur a potential sublethal impact and 0.15% eggs/larvae are likely to be lost due to contact with TSS in the Denham Sound spawning area, within the modelled 24-hour period of peak TSS concentrations (highest TSS over a 24-hour period; refer Figure 5-8). Research indicates that estimated natural mortality of larvae (between spawning and hatching) is 49% day^{-1} but is thought to be somewhere closer to the ~83% day^{-1} recognised by other snapper spawning studies (Jackson et al. 2012). As such, the proposed dredging and disposal activities pose a very low risk to snapper eggs and larvae, and in turn, there are not expected to be any impacts to snapper stocks in Shark Bay, even if dredge timing were to coincide with peak spawning periods.

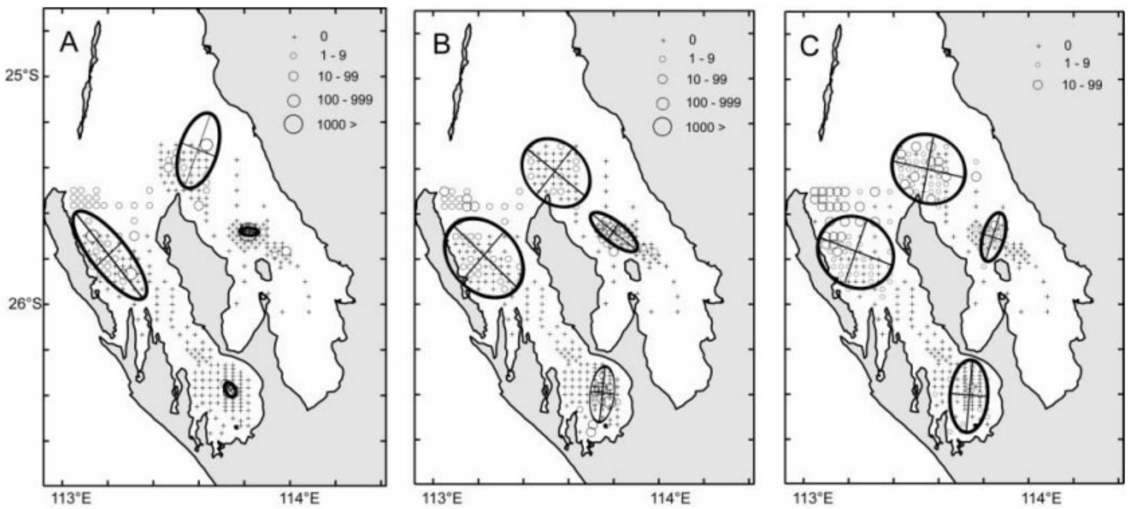


Figure 2.3. *P. auratus* egg and larval distributions from ichthyoplankton surveys in 2000. (A) eggs < 2 hours old; (B) eggs > 24 hours old; (C) all larvae. Units are numbers 100 m^{-3}. Ellipsoids represent 95% confidence intervals from rotated axes of the centroids of distribution for spawning areas defined in Fig. 2.2.

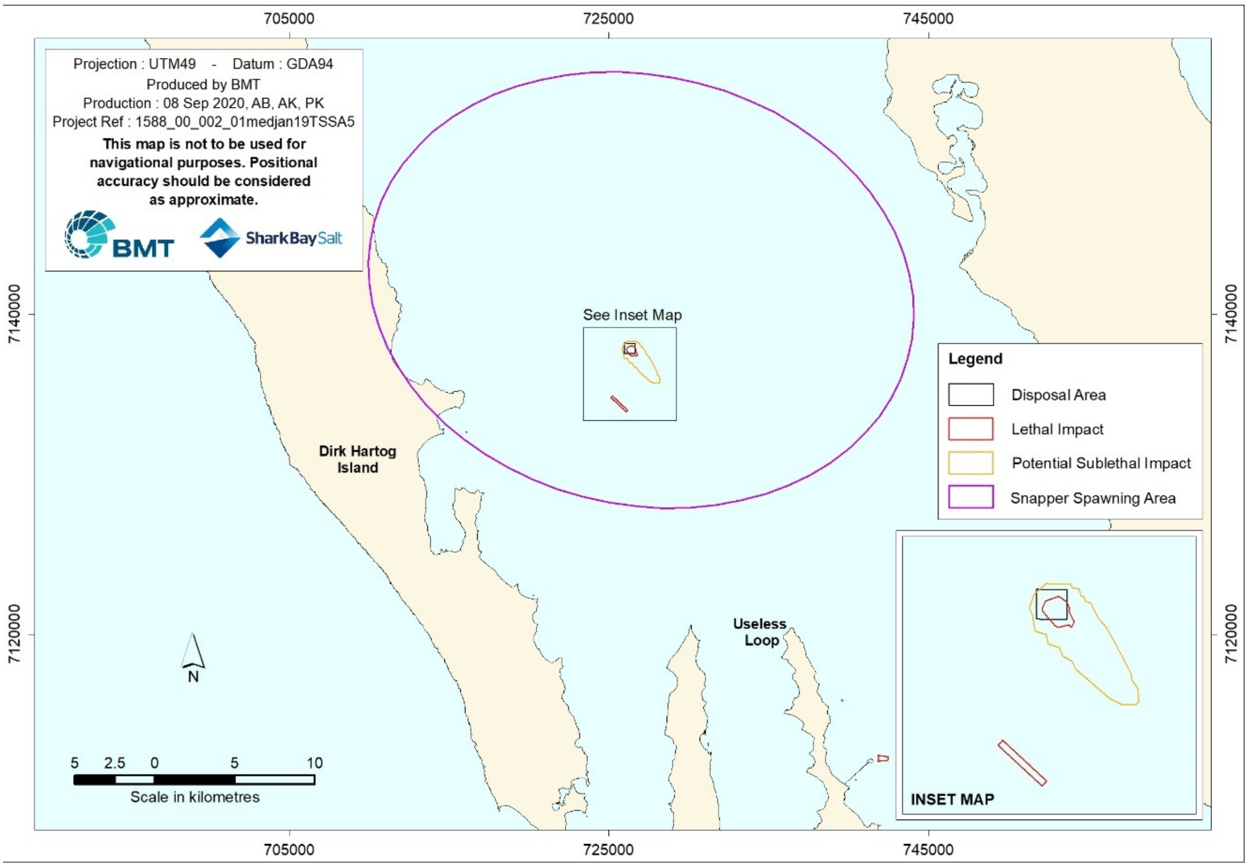
Source: Jackson (2007)

Figure 5-9 *Pagrus auratus* egg and larval distribution from ichthyoplankton surveys in 2000 (see full title above)

Table 5-9 Assessment criteria for potential impacts of elevated total suspended solids on pink snapper larvae

Level of impact	Suspended solid threshold (mg/L)[1]	Duration (hours)
No impact	≤14	≤12
Potential sublethal impact	14<TSS≤70	>12[2]
Lethal impact	>70	>12[2]

Notes:
1. Median (50th percentile) daily suspended solid concentration
2. Threshold exceed for period of greater than 12 hours within a 24-hour period



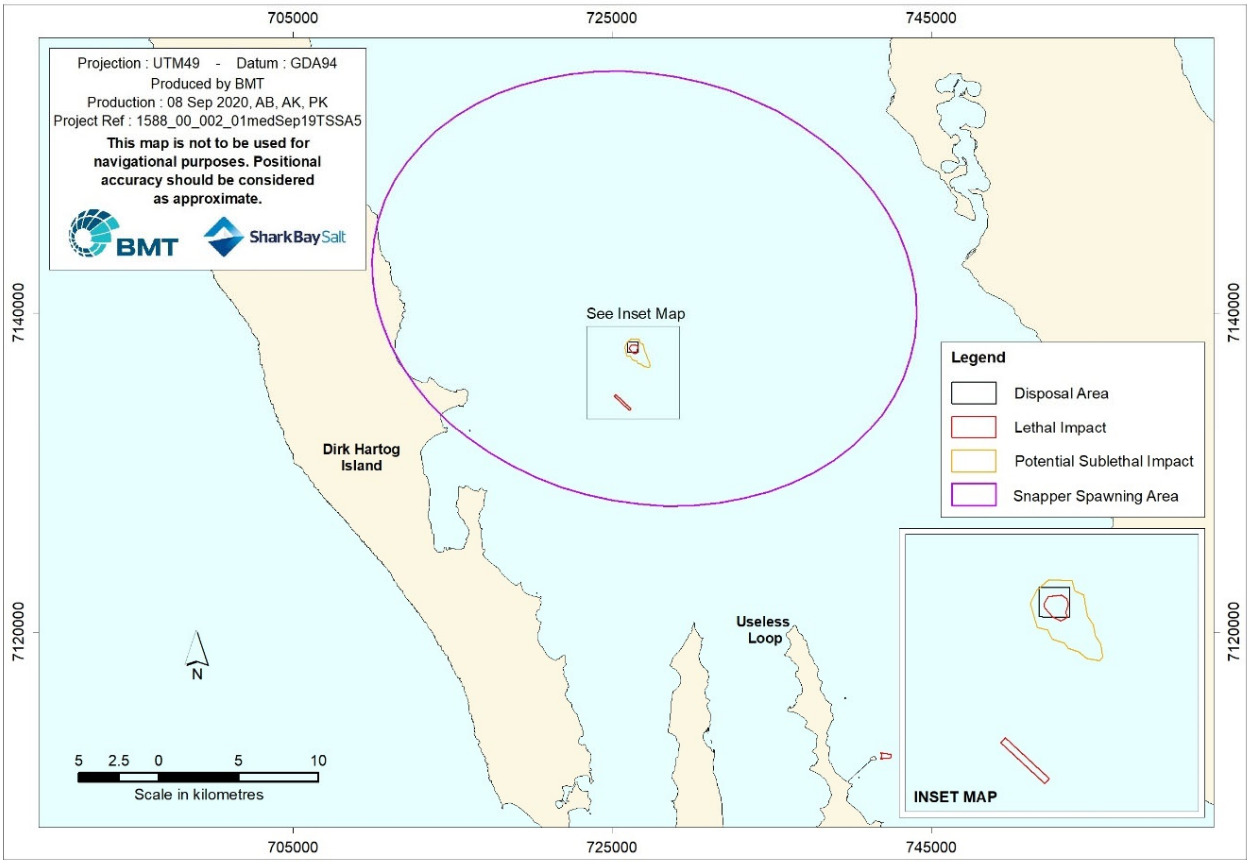


Figure 5-10 Potential extent of the dredging plume based on high production dredging depth-averaged 50th percentile of daily total suspended solid concentrations, relevant to potential lethal and sublethal impacts to snapper larvae, in January (top) and September (bottom)

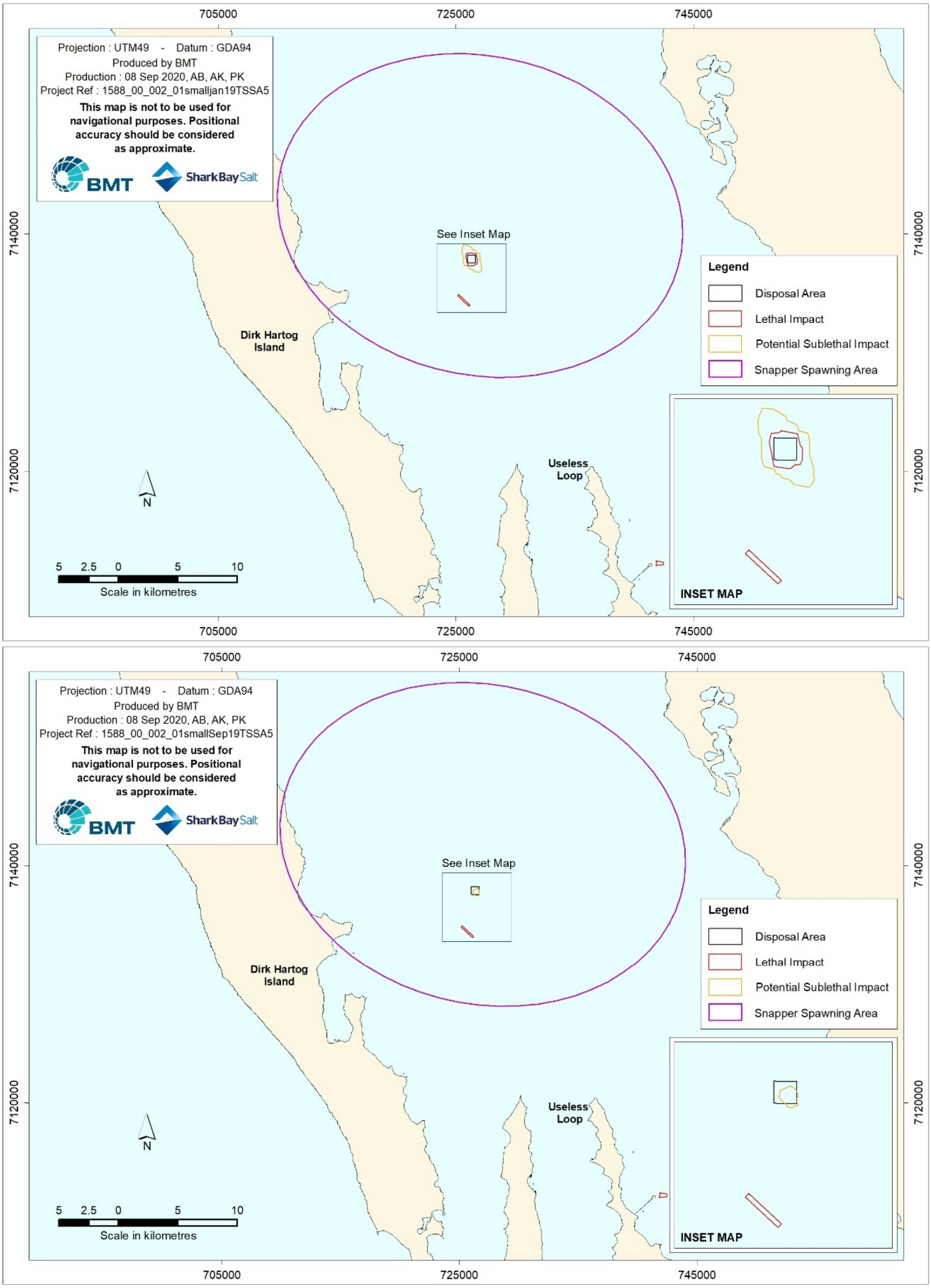


Figure 5-11 Potential extent of the dredging plume based on low production dredging depth-averaged 50th percentile of daily total suspended solid concentrations, relevant to potential lethal and sublethal impacts to snapper larvae, in January (top) and September (bottom)

Other potential impacts to commercial and recreational fisheries relating to BCH, marine environmental quality and navigational hazards are assessed in Sections 5.1, 5.2 and 5.4.3, and will be monitored and managed as outlined in the DEMP (Appendix A).

5.4.2 Public safety, visual amenity and access

The operation of heavy machinery in the dredge and disposal areas during the Project may temporarily impact visual amenity and pose a short-term risk to public safety. Further, the generation of turbid plumes during maintenance campaigns may reduce aesthetics near the disposal area. Any negative impacts on visual amenity are likely to short-term and small scale in nature due to the short duration of the project and short plume duration and extent. Given the location of the Project area (>10 km from Denham, and the berth pocket within the SBR lease), it is not likely that operations will significantly impact visual amenity or public access. The potential risks to public safety will be managed as navigational hazards (Section 5.4.3).

5.4.3 Navigational hazards

The Project works may pose a navigational hazard to vessels within the western bay of Shark Bay, which includes commercial and recreational fishing vessels. The TSHDs and work vessels are slow moving and audible so other vessels should be able to avoid any navigational hazards associated with the dredge equipment. The impact on navigation from the Project should be limited because:

- vessels will be clearly visible during the day and night
- the dredge will maintain a navigable vessel access to the Maritime Facility
- relevant stakeholders will be consulted prior to Project commencement
- a Temporary Notice to Mariners will be issued to inform the public of navigational hazards associated with dredging, if required.

In addition to the above measures, marine safety will be actively managed throughout the Project (Appendix A).

5.4.4 Indigenous or non-indigenous heritage sites and values

There are no anticipated impacts to registered Aboriginal or European heritage sites associated with the Project works (Sections 4.4.2 and 4.4.3). However, the strong indigenous cultural ties to marine fauna, fish species and associated benthic habitats are recognised by SBR and potential impacts to these factors have been addressed in Sections 5.1, 5.3 and 5.4.1. Potential impacts to these cultural values will be monitored and managed as outlined in the DEMP (Appendix A). The YMAC and MAC will continue to be consulted throughout the Project to further minimise any risk to Aboriginal heritage and culture. In addition, monitoring and management outlined in the DEMP will reduce any further risk of disturbance to unregistered indigenous or non-indigenous heritage sites or values (Appendix A).

6 Environmental Objectives and Monitoring

The key environmental factors that may be affected by the Project are (Table 6-1):

- benthic communities and habitats
- marine environmental quality
- marine fauna
- social surroundings.

Details of the outcome- and/or management-based provisions to achieve the environmental protection objectives associated with potential residual impacts to environmental factors are provided in the DEMP (Appendix A), with an overview provided in Table 6-1. Based on the results of technical studies and the impact assessment carried out in this document, it has been concluded that the EPA's relevant objectives will be met while implementing this Project, and implementation of management and monitoring controls will ensure any residual environmental risk is as low as reasonably possible. As a result, the proposed action will not significantly impact relevant World Heritage criteria and Marine Park values.

Table 6-1 Key environmental issues, potential impacts and monitoring/management requirement

Factor[1]	Potential impact	Environmental protection objective (EPO)	Monitoring/management target
Benthic communities and habitats (BCH)	Direct loss of BCH	Restrict permanent loss of BCH to the zone of high impact (ZoHI)	Dredging operations do not occur outside of approved Project footprint
	Indirect impacts on BCH due to increase in water column turbidity and reduced light availability	No indirect damage to BCH (seagrasses) due to reduced water clarity	Maintain water quality to meet criteria at the zone of moderate impact (ZoMI)/zone of influence (ZoI) boundary
Marine Environmental Quality	Increased water column turbidity	No indirect damage to BCH (seagrasses) due to reduced water clarity	Maintain water quality to meet criteria at the ZoMI/ZoI boundary
	Hydrocarbon spills and waste generation	No release of contaminants that have the potential to deteriorate water quality and impact marine fauna	Maintain a clean and tidy work site and follow chemical storage and refuelling procedures
	Release of contaminants	No release of contaminants that have the potential to deteriorate water quality and impact marine fauna	Maintain water quality to meet criteria adjacent to the berth and at the marine park boundary
Marine fauna	Marine fauna disturbance (collisions/noise)	No harm of individuals and/or declines in the population of the range of species protected under state/federal legislation	No reported incidents of marine fauna injury or death as a result of the Project
	Introduced marine species (IMS)	No introduction of non-native marine species	Implement procedures to minimise the risk of IMS to the Project area
Social surroundings	Indirect impact on commercial and recreational fisheries	No loss or harm of commercially or recreationally important species as a result of reduced water clarity	Maintain water quality to meet criteria at the zone of moderate impact (ZoMI)/zone of influence (ZoI) boundary
	Impacts to indigenous or non-indigenous heritage and cultural values	No disturbance to or loss of indigenous or non-indigenous heritage areas or values	No reports of disturbance to a registered or unregistered indigenous or non-indigenous heritage site or significant heritage values
	Navigational hazards	No navigational safety incidents as a result of the Project	No complaints or reported public safety hazard, near miss, or incident as a result of navigational issues

Notes:
1. Environmental factors in accordance with EPA (2020b)
2. BCH = benthic communities and habitats, EPO = environmental protection objective, IMS = introduced marine species, ZoI = zone of influence, ZoMI = zone of moderate impact

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