Port of Gladstone
Gatcombe and Golding Cutting
Channel Duplication Project

Environmental Impact Statement

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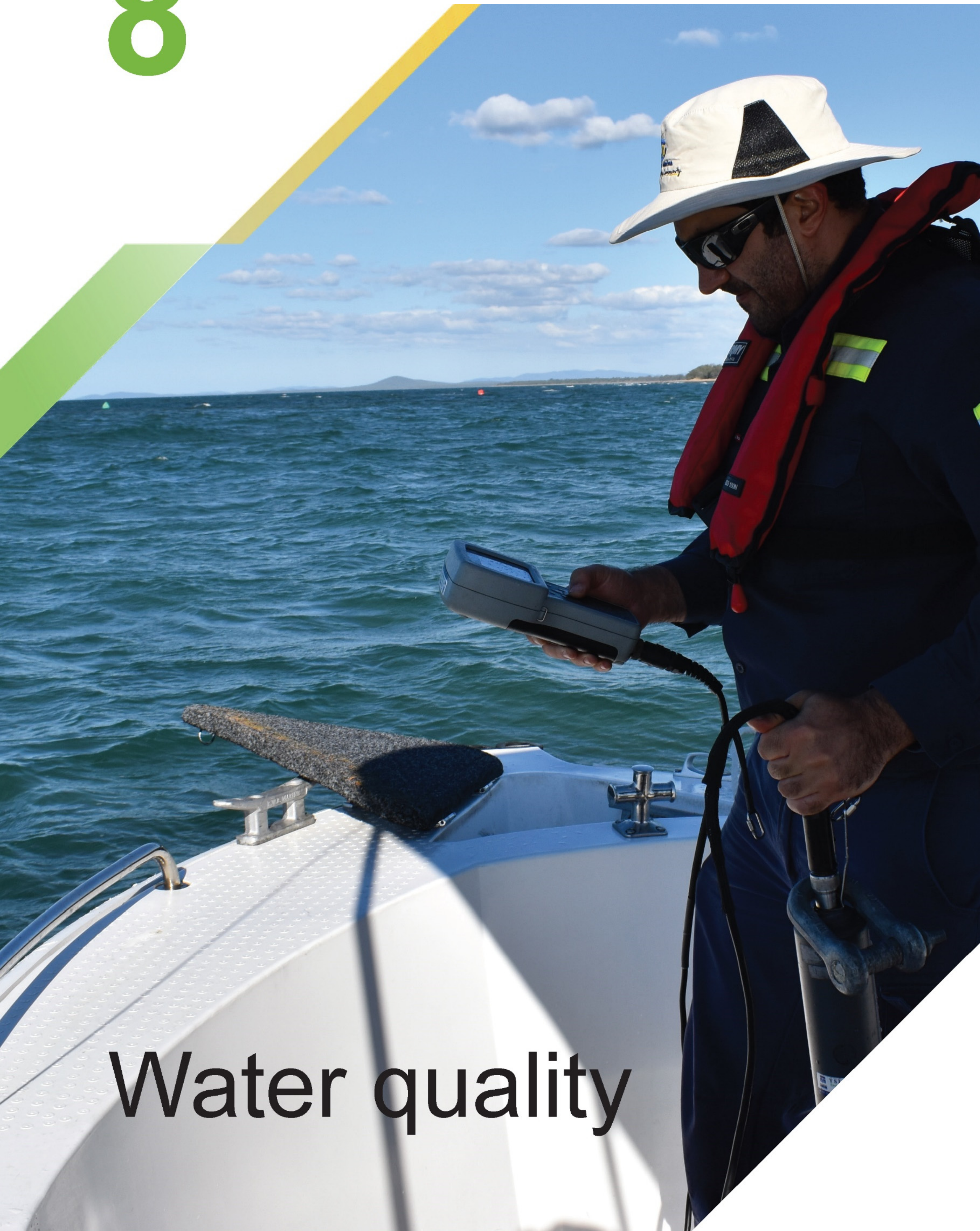

Water quality

Contents

8 Water quality

8.1 Chapter purpose

This chapter details marine water quality characteristics within Port Curtis. Baseline water quality data has been obtained and summarised from a combination of available sources, including desktop reviews and documentation of previous studies in the area, a baseline water quality investigation undertaken for this Project EIS, and additional baseline data provided from other monitoring programs, including the Port Curtis Integrated Monitoring Program (PCIMP) and Integrated Aquatic Investigation Program for Gladstone Harbour.

A detailed Water Quality Technical Report providing information on the existing water quality values of the Port is provided in Appendix H1.

Coastal processes and hydrodynamic modelling (refer Chapter 7 and Appendix G) was undertaken to inform the discussion of potential water quality impacts of the establishment of the WBE reclamation area and Project dredging on water quality and sensitive receptors (i.e. seagrass meadows and coral reef communities). An assessment of the potential Project impacts on intertidal and marine flora and fauna is provided in Chapter 9 (nature conservation).

The assessment of potential impacts from dredging and dredged material placement has provided input into the development of water quality and seagrass monitoring and mitigation measures for the construction and maintenance phases of the Project. Water quality mitigation measures are provided in Section 8.7 and in the Project Environmental Monitoring Procedure (Appendix Q3).

8.2 Methodology

In order to complete the water quality assessment for the Project, the following tasks have been undertaken:

- Review of Commonwealth and State legislation, guidelines, environmental values (EVs) and WQOs relevant to water quality for the pre-construction, construction and maintenance phases of the Project
- Review of previous water quality investigations and research in Port Curtis to inform the design of the baseline monitoring program
- Completion of a baseline water quality monitoring program, specifically designed to meet the requirements of the Project activities
- Review of existing and ongoing monitoring program data and use of this data to supplement the baseline water quality monitoring program (where applicable)
- Assessment of the potential impacts and risks associated with water quality for the following activities:
  - BUF construction
  - WBE reclamation area bund wall
  - Dredging of the barge access channel
  - Dredging for the duplication of shipping channels
  - Placement of dredged material into the WB and WBE reclamation areas, including unloading and placement activities

– Operation of the duplicated shipping channels
– Stabilisation and maintenance activities on the reclamation areas

- Identification of management and monitoring measures to minimise impacts to water quality.

The methodology adopted for the development of water quality zones of impact is provided in Section 8.4.3.1.

8.2.1 Baseline water quality methods

8.2.1.1 Overview

A water quality monitoring program was undertaken by Vision Environment (VE) in Port Curtis from 1 June 2014 to 5 July 2015 to provide interpreted baseline data. The baseline monitoring program was designed to provide 13 months of continuous water quality data to describe the existing environment of the Port, to calculate water quality trigger values for use during dredging and material placement works, and to potentially use the data to refine the WQOs assigned to the area. The data was collected during a period of no capital dredging works over both wet and dry seasonal conditions. The 13 months of monitoring data has been complemented by data from other monitoring programs, including PCIMP and Gladstone Healthy Harbour Partnership (GHHP).

Water quality monitoring methods included continuous automated water quality loggers, sedimentation rates recorded with acoustic altimeters, benthic photosynthetically active radiation (BPAR) monitoring, and discrete water sampling from a vessel for analysis of total suspended solids, metals, nutrients and organic contaminants.

Ambient baseline data was collected and analysed to account for spatial, temporal and vertical variations.

Additional detail in relation to baseline water quality monitoring methods implemented is provided in Appendix H1 (Section 4.7).

8.2.1.2 Monitoring locations and rationale

Eight water quality monitoring sites (labelled CD1, CD2, CD3, CD4, CD5, P5/MH10, P2B/WB50, and QE3) (refer Figure 8.1), spanning from The Narrows to open coastal waters east and south of Facing Island, were selected in 2014 as part of the Project EIS baseline data collection strategy in consultation with Commonwealth and State regulatory agencies (i.e. DoEE, Great Barrier Reef Marine Park Authority (GBRMPA), and the former EHP and Department of Science, Information Technology, Innovation and the Arts (DSITIA) (now DES)). The location of each monitoring site was guided by the results of preliminary hydrodynamic modelling (BMT WBM 2014), and located inside and outside of the Project direct impact and potential indirect impact areas, as well as in the vicinity of known sensitive receptors (i.e. seagrass meadows and coral reefs).

All monitoring locations were selected to provide data to characterise the current baseline water quality of Port Curtis, with the potential for these sites to transition into compliance and reference monitoring sites during dredging works. The location of monitoring sites may be reviewed following the finalisation of hydrodynamic plume modelling, to ensure that they are best placed to determine potential water quality impacts during dredging works.

The monitoring sites were spread across a wide area throughout Port Curtis and as a result, the factors influencing the background conditions at the surface and seabed varied between some sites. During the design of the baseline monitoring strategy water quality monitoring sites were split into two groups: 'offshore' (i.e. CD1, CD2, CD3, CD4 and CD5) and 'inshore' (i.e. P5/MH30, P2B/WB50 and QE3) (refer Figure 8.1 and Table 8.1) based on historical water quality data and knowledge of background environmental influences on Port Curtis waters.

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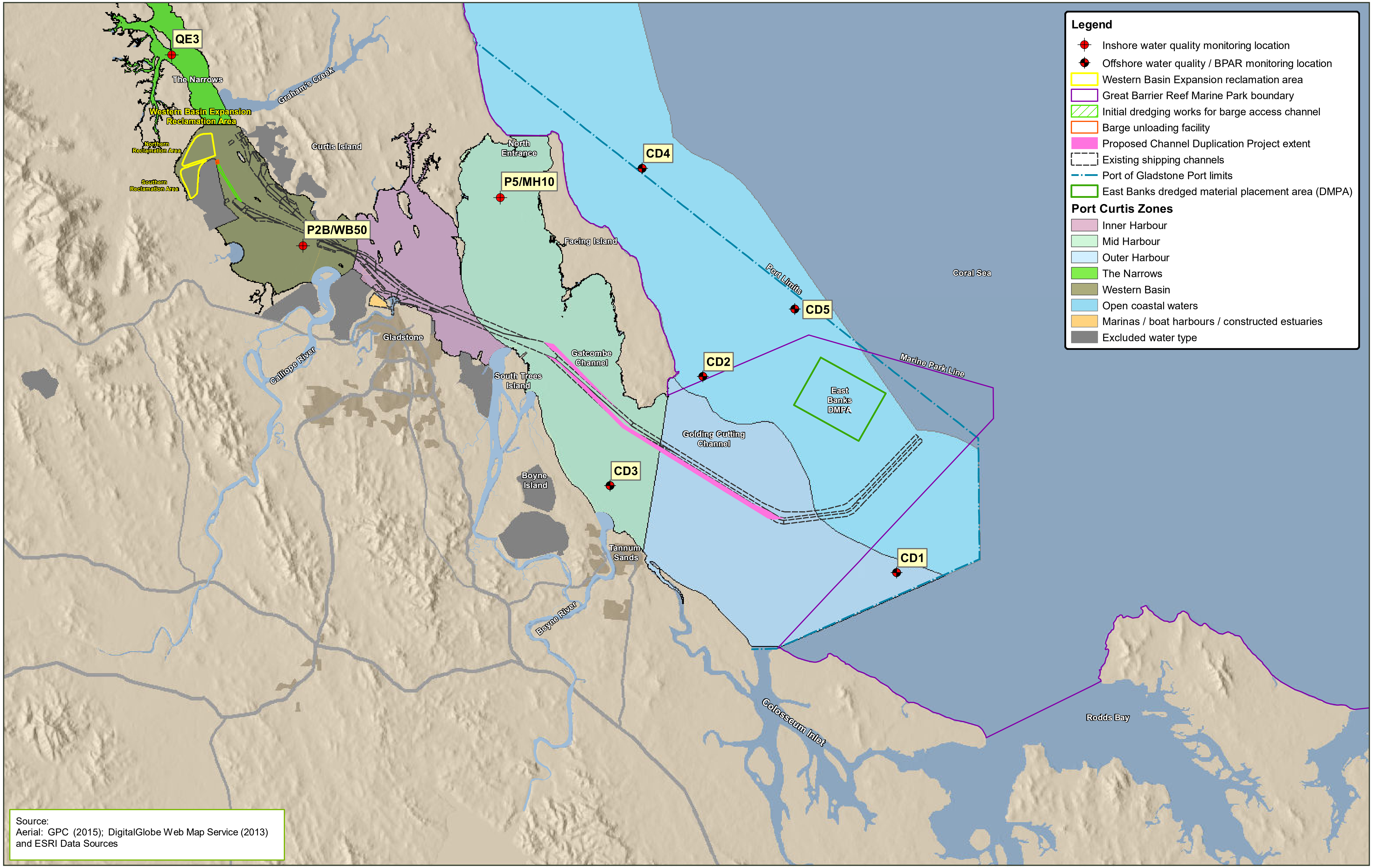

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Figure 8.1: Baseline water quality monitoring locations

The inshore sites were characterised by a shallow environment (approximately 5m depth), highly tidally influenced with a large tidal run (approximately 0.4m per second) with a well-mixed depth profile of the water column, including little to no stratification during rain events (i.e. sub-surface measurements are similar to those above benthos). The offshore sites were characterised by a deeper water environment (generally > 15m) highly influenced by wind and wave action.

While site CD3 was grouped among the offshore sites for the purposes of this monitoring program, it was noted that the location of CD3 exhibits both inshore and offshore characteristics (CD3 lies within the Mid Harbour zone, close to the Outer Harbour zone boundary). Scientists from VE consider that this site exhibited characteristics closer to the offshore environment, when compared to the characteristics and influences of sites further inshore of the estuary (e.g. P2B/WB50 and P5/MH10). This was based on historical water quality data collected at nearby PCIMP monitoring site MH60.

Further details on each monitoring site are provided in Appendix H1 (Section 4.7.1).

Table 8.1 Project baseline water quality monitoring sites

Grouping[1]	Monitoring site name	Location (WGS84)	Zone[2]	Location description	Environmental Protection (Water) Policy management intent/ level of protection	Monitoring period
Offshore	CD1	S23 57.469 E151 30.115	Open coastal waters	Adjacent to Seal Rocks	Moderately disturbed	June 2014 to July 2015
	CD2	S23 52.017 E151 24.380	Open coastal waters	Off East Point off Facing Island	Slightly moderately disturbed	June 2014 to July 2015
	CD3	S23 54.989 E151 21.569	Mid Harbour[3]	Located outside the mouth of the Boyne River	Moderately disturbed	June 2014 to July 2015
	CD4	S23 46.269 E151 22.639	Open coastal waters	Off the eastern side of Facing Island, adjacent to Pearl Ledge	Slightly moderately disturbed	June 2014 to July 2015
	CD5	S23 50.187 E151 27.153	Open coastal waters	Off the eastern side of Facing Island, 3km northwest of East Banks DMPA	Slightly moderately disturbed	June 2014 to July 2015
Inshore	P5/MH10	S23 47.029 E151 18.388	Mid Harbour[3]	Adjacent to Pelican Banks seagrass meadows	Moderately disturbed	June 2014 to July 2015
	P2B/WB50	S23 48.289 E151 12.547	Western Basin	Outside the mouth of the Calliope River	Moderately disturbed	June 2014 to July 2015
	QE3	S23 42.965, E151 08.574	The Narrows	Adjacent to Worthington Island in The Narrows	Slightly disturbed	January 2014 to July 2014

Table notes:

1 Type refers to the general term used to group the Project EIS water quality monitoring sites
2 Water zones in accordance with EPP (Water) Schedule 1 – Plan WQ1312 (EHP 2014c)
3 While CD3 and P5/MH10 were both located in the Mid Harbour Zone they were grouped as 'inshore' and 'offshore', respectively. CD3 was located close to the edge of the Mid Harbour and Outer Harbour Zone boundaries and baseline water quality appeared to show more wind and wave influences. Conversely P5/MH10 was located in a more enclosed coastal location showing a more tidally influenced, well-mixed water column.

Source: VE (2015)

8.2.1.3 Sample collection

Table 8.2 outlines the methods utilised for collecting water quality, light, and sedimentation data during the Project EIS baseline monitoring period. Monitoring at offshore sites included both sub-surface and benthic water quality monitoring equipment, while inshore sites had sub-surface monitors only (due to a well-mixed water column).

Table 8.2 Summary of Project EIS baseline water quality, light and sedimentation monitoring at all sites

Data type	Parameters	Method	Frequency
Water quality	▪ Turbidity ▪ Temperature ▪ pH ▪ Conductivity ▪ DO	Water quality telemetry and remote loggers: ▪ Dual surface Aqualab DS5X water quality sonde ▪ Dual benthic Aqualab DS5X water quality sonde (CD1 to CD5 only)	Logged every 15 minutes
	▪ Turbidity ▪ Temperature ▪ pH ▪ Conductivity ▪ DO	In situ depth profiling - YSI 6820 multi-parameter water quality meter	Monthly
	▪ TSS	Water sampling - Van Dorn sampler	Monthly
	▪ Metals/metalloids ▪ Nutrients ▪ Chlorophyll *a*	Water sampling - Perspex pole sampler	Monthly
	▪ Organic contaminants	Water sampling - Perspex pole sampler	Quarterly
Light	▪ BPAR	BPAR telemetry and remote loggers: dual LI-COR LI192SA Underwater Quantum Sensors	Logged every 15 minutes
	▪ Light attenuation	In situ depth profiling - LI-COR LI192SA Underwater Quantum Sensor	Monthly
Sedimentation	▪ Sedimentation rate	Acoustic altimeters	Logged every 15 minutes

Table notes:

TSS = total suspended solids
DO = dissolved oxygen
pH = potential of hydrogen

Water quality loggers

Both benthic and surface water quality loggers were concurrently utilised at the offshore monitoring sites (CD1 to CD5) due to the deep water oceanic environment, with turbidity highly driven by wind speeds and wave heights, causing resuspension of material from the seabed. Only sub-surface water quality loggers were required at inshore sites (QE3, P2B/WB50 and P5/MH10) due to the shallow environment and well mixed water column with little to no stratification.

Surface and benthic water quality loggers recorded turbidity (nephelometric turbidity units (NTU)), temperature (degrees Celsius (°C)), pH, conductivity (millisiemens per centimetre (mS/cm)) and DO (% saturation) with parameters logged every 15 minutes.

Further details on water quality equipment, calibration and data management are provided in Appendix H1 (Section 4.7.2).

Benthic photosynthetically available radiation

Telemetered BPAR units were located at the five offshore sites (CD1 to CD5) with BPAR logged every 15 minutes. BPAR was measured to determine the light environment at subtidal seagrass and coral habitats. In order to record changes and fluctuations in daily ambient photosynthetically active radiation (PAR) (e.g. reductions in light due to cloud cover), a telemetered light sensor was stationed at the VE base in Gladstone as a ‘control’ site. Further details on BPAR are provided in Appendix H1 (Section 4.7.3).

Sedimentation

Sedimentation rates were measured at all eight monitoring sites using fixed deployment acoustic altimeters. Further details on sedimentation are provided in Appendix H1 (Section 4.7.4).

In situ physiochemical profiling

Physicochemical parameters (i.e. temperature, conductivity, pH, DO and turbidity) were also measured in situ from a boat at each monitoring site using a YSI® 6820 multi-parameter water quality meter. The water quality metre was slowly lowered through the water column from the surface to the seabed, with triplicate sub-surface readings (0.5m depth) recorded at each site.

Light attenuation

Down-welling PAR, measured in micromoles per square metre per second (µmol/m^2/s), was measured in situ from a boat through the water column at 0.5m depth intervals. Further details on light attenuation are provided in Appendix H1 (Section 4.7.6).

Water sample collection

Monthly collection of water samples for analysis was done concurrently with discrete physicochemical measurements at each monitoring site. Samples were collected and analysed monthly for TSS and metals/metalloids, while organic contaminants were analysed quarterly. Further details on water sample collection are provided in Appendix H1 (Section 4.7.7).

8.2.1.4 Data analysis

Monthly and seasonal (wet season: 1 November to 30 April; dry season: 1 May to 31 October, as per EHP 2014b and DSITIA 2014) statistics were calculated for each site, including means, standard errors, ranges and percentiles. When plotting data, a smoothing technique was applied.

One and two-way analyses of variance ($p < 0.05$, 95% confidence intervals) were used to determine statistical differences in water quality parameters among sites, depth (surface and seabed), and seasons (wet season and dry season). Data were tested for homogeneity of variance and normality.

For reference purposes water quality results have been compared against their relevant WQOs under the EPP (Water), specific to each zone.

8.3 Legislative and policy context

8.3.1 Environmental Protection Act 1994

The object of the EP Act is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends. The EP Act, which is administered by the DES, seeks to achieve this by an integrated management system that is consistent with ecologically sustainable development.

Under the EP Act, the EPP (Water) provides the framework for developing EVs, management goals and WQOs for Queensland waters.

8.3.2 Environmental Protection (Water) Policy 2009

The EPP (Water) is subordinate legislation that supports the EP Act. The purpose of this policy is to achieve the objectives of the EP Act in relation to Queensland waters. As stated in the EPP (Water) Part 2:

The purpose of this policy is achieved by—

(a) identifying environmental values and management goals for Queensland waters; and

(b) stating water quality guidelines and water quality objectives to enhance or protect the environmental values; and

(c) providing a framework for making consistent, equitable and informed decisions about Queensland waters; and

(d) monitoring and reporting on the condition of Queensland waters.

8.3.2.1 Environmental values

The EP Act, Section 9 defines EVs as:

(a) a quality or physical characteristic of the environment that is conducive to ecological health or public amenity or safety; or

(b) another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

The EVs for Queensland waters are described as:

The qualities that make water suitable for supporting aquatic ecosystems and human use. These EVs need to be protected from the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways are safe for community use. All tidal and non-tidal waters, including wetlands, lakes and groundwater have EVs. Aquatic ecosystem health is an environmental value of all Queensland waters (EHP 2014a).

8.3.3 Water Quality Objectives

WQOs are long term goals for water quality management. They are measures, levels or narrative statements of particular indicators of water quality (such as salinity or turbidity) that protect EVs. They define what the water quality should be to protect the EVs, after consideration of the socio-economic assessment of protecting the water quality.

WQOs are defined for a range of physical indicators (e.g. turbidity, suspended sediment and temperature), chemical indicators (e.g. oxygen demand and toxicants), biological indicators (e.g. macroinvertebrates and fish), pathogens, and measures of waterway condition (e.g. erosion and riparian vegetation extent and condition).

Indicators and water quality guidelines for an EV are decided under the EPP (Water) according to (in order of preference):

- Site-specific scientific studies
- The Queensland Water Quality Guidelines (QWQG) (EHP 2009a)
- The Australian Water Quality Guidelines (AWQG) for fresh and marine water quality (ANZECC/ARMCANZ 2000a)
- Other documents published by recognised entities.

Section 8.3.5 outlines the EVs and WQOs developed for waters of the Port Curtis region.

8.3.4 Water quality guidelines

Water quality guidelines are quantitative measures or statements for indicators that protect a stated EV. An overview of the applicable water quality guidelines for the Project is provided below.

8.3.4.1 Australian Water Quality Guidelines for Fresh and Marine Waters

The AWQG for fresh and marine waters were developed by the Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) in 2000 (ANZECC/ARMCANZ 2000a).

The AWQG have been prepared under the auspices of Australia's National Water Quality Management Strategy (NWQMS). They provide government, industry, consultants and community groups with a sound set of tools that will enable the assessment and management of ambient water quality in a wide range of water resource types, and according to designated EVs.

The guidelines provide values or descriptive statements for different indicators to protect both aquatic ecosystems and human uses of waters (e.g. primary recreation, human drinking water, agriculture, stock watering). The default water types outlined in the AWQG are generic in their characterisation and consequently, the direct application of the default AWQG values may not necessarily reflect local water types or water quality characteristics. The AWQG recommends that, where applicable, locally relevant guidelines be adopted (refer Section 8.3.5) for EVs and WQOs for waters of the Port Curtis region).

8.3.4.2 Queensland Water Quality Guidelines

The QWQG (EHP 2009a) are intended to address the need for local guidelines as identified in the AWQG guidelines by:

- Providing guideline values (numbers) that are tailored to Queensland regions and water types
- Providing a process/framework for deriving and applying local guidelines for waters in Queensland (i.e. more specific guidelines than those in the AWQG).

The QWQG provide a mechanism for recognising and protecting local Queensland waters and are not mandatory legislative standards or WQOs. It is important to note that WQOs are generally reserved for the waters' schedule in the EPP (Water).

8.3.4.3 Water quality guidelines for the Great Barrier Reef Marine Park

The Water Quality Guidelines for the Great Barrier Reef Marine Park (GBRMP) are administered by the GBRMPA and address the AWQG processes of defining EVs and WQOs for local conditions. The guidelines describe the concentrations and trigger values for sediment, nutrients and pesticides that have been established as necessary for the protection and maintenance of marine species, and ecosystem health of the Great Barrier Reef.

The guidelines have been established to support initiatives, including the Commonwealth Government's Reef Rescue Plan, Reef Water Quality Protection Plan, Coastal Catchment Initiative, NWQMS, the Queensland Wetlands Program and the EPP (Water).

The majority of the Port of Gladstone is located outside the GBRMP, however it is located within the GBRWHA. Some baseline water quality monitoring sites for the Project water quality assessment were located within the GBRMP. Ongoing consultation has been undertaken with GBRMPA throughout the scoping, planning and investigative stages of the Project EIS.

8.3.5 Port Curtis water quality objectives

The Curtis Island, Calliope River and Boyne River Basins Environmental Values and Water Quality Objectives report (EHP 2014) has been prepared pursuant to the provisions of the EPP (Water).

The document contains EVs and WQOs for waters in the Curtis Island, Calliope River and Boyne River basins, Gladstone Harbour, The Narrows and adjacent coastal waters (refer Figure 8.2), and is listed under Schedule 1 of the EPP (Water).

The purpose of the document is to identify locally relevant EVs and WQOs for the region, based on local historical data and in close consultation with the local community. These WQOs are used as an input into setting development conditions, influence local government planning schemes and underpin report card grades for ecosystem health monitoring programs like the GHHP and other similar programs. These WQOs have been refined from national (AWQG) and state water quality guidelines (QWQG) and present a truer picture of the values and water quality of local waterways. This ensures the values the community holds for its waterways can be maintained and improved into the future, without imposing unrealistic standards from national guidelines that may be inappropriate for local conditions.

EVs identified within the EPP (Water) for the Port of Gladstone adjacent coastal waters and nearby estuaries include:

- Aquatic ecosystems – biodiversity, ecological interaction, plants, animals, key species (turtles, seagrass, dugongs etc) and their habitat, food and drinking water
- Human consumption – humans consuming aquatic food from this area, including fish, crustaceans and shellfish
- Primary recreation – activities with full body contact with water include swimming, windsurfing, diving and water skiing
- Secondary recreation – indirect contact and low probability of water being swallowed including wading, boating, rowing and fishing
- Visual recreation – amenity of waterways for recreation which does not involve contact with water such as walking or picnicking
- Drinking water (waters in which desalination for drinking water may apply) – suitability of a raw drinking supply assuming minimal treatment required
- Industrial use – suitability of water supply for industrial use. Industries usually treat water supply for their individual needs
- Cultural and spiritual values

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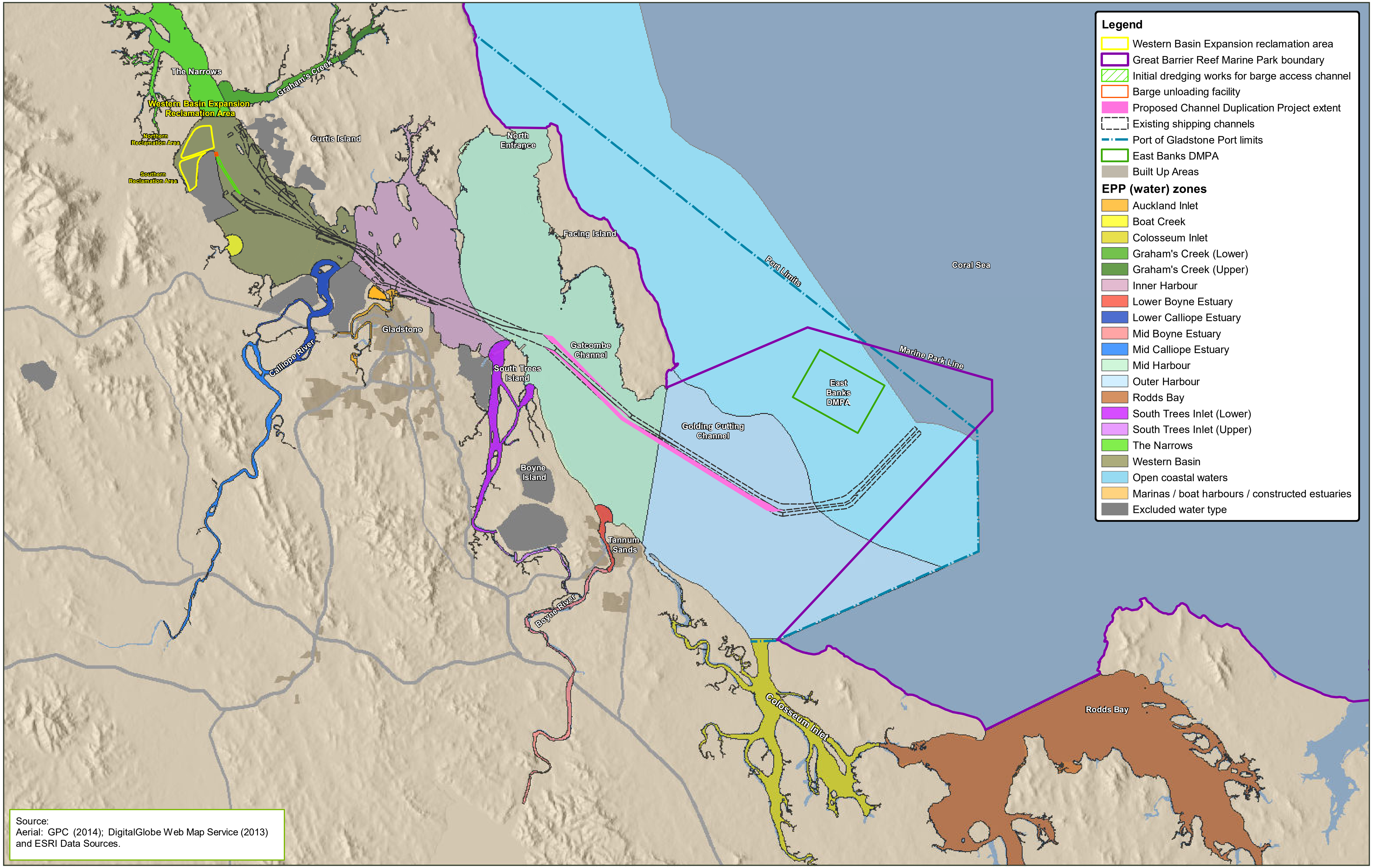

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Figure 8.2: EPP (water) zones for Port Curtis, The Narrows and adjacent coastal waters

- Aquaculture – health of aquaculture species and human consuming aquatic food from commercial ventures in this area.

The EPP (Water) also contains the management intent for Queensland waters, and the decision to release wastewater or contaminant to waters must ensure the following:

- For high ecological value (HEV) waters: the measures for the indicators are maintained
- For slightly disturbed (SD) waters: the measures for the slightly modified physical or chemical indicators are progressively improved to achieve the WQOs for high ecological value water
- For moderately disturbed (MD) waters:
  - If the measures for indicators of the EVs achieve the WQOs for the water: the measures for the indicators are maintained at levels that achieve the WQOs for the water, or
  - If the measures for indicators of the EVs do not achieve the WQOs for the water: the measures for indicators of the EVs are improved to achieve the WQOs for the water
- For highly disturbed (HD) waters: the measures for the indicators of all EVs are progressively improved to achieve the WQOs for the water.

Most waters in the Port of Gladstone are described as MD. Waters in The Narrows area to the north are described as SD and waters outside of the Port and seaward of the plume line (into the GBRMP) adopt a HEV.

Following stakeholder consultation and analysis of water quality data, WQOs were derived for both baseflow and event WQOs in Gladstone Harbour and other waterways where data was available. The WQOs that baseline results have been compared to in this report apply to baseflow conditions only. Section 3.1 of the EPP (Water) outlines WQOs to protect the identified EV. The relevant WQOs tables in the document for the protection of aquatic ecosystems include:

- Table 2A: Gladstone Harbour, The Narrows, adjacent coastal waters and estuaries – baseflow WQOs
- Table 2B: Gladstone Harbour and The Narrows: time/flow thresholds for applying baseflow WQOs
- Table 2D: Gladstone Harbour and Boat Creek: event WQOs.

Table 8.3 outlines the EVs that have been assigned to waters in the Port of Gladstone. WQOs for the protection of the aquatic ecosystem EV are outlined in Table 8.4 to Table 8.6.

Table 8.3 Environmental values for Port of Gladstone, The Narrows, and adjacent coastal waters

Zone	Water type	Environmental value							
		Aquatic ecosystems	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water[1]	Industrial use	Cultural and spiritual values
The Narrows[2]	Enclosed coastal/Lower estuary	●	●		●	●			●
Western Basin	Enclosed coastal/Lower estuary	●	●	●		●		●	●
Inner harbour	Enclosed coastal/Lower estuary	●	●	●	●	●	●	●	●
Mid harbour	Enclosed coastal/Lower estuary	●	●	●	●	●	●	●	●
Outer harbour	Enclosed coastal/Lower estuary	●	●	●	●	●	●	●	●

Zone	Water type	Environmental value							
		Aquatic ecosystems	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water[1]	Industrial use	Cultural and spiritual values
Coastal waters outside Port of Gladstone[3]	Open coastal waters	●	●	●	●	●	●		●

Table notes:

1 Waters in which desalination for drinking water may apply
2 The Narrows (north of Graham's Creek), Deception Creek, East Balaclava Island, Connor Creek and Kamiesh Passage (estuarine reaches)
3 Coastal waters outside Port of Gladstone east and south of Facing Island (to southern limits of the Port)

Source: EHP (2014b)

Table 8.4 Water quality objectives (nutrients) to protect aquatic ecosystem environmental value under baseflow conditions (peak discharge < 100m³/sec)

Parameter	WQO	Zone and level of protection					
		The Narrows HEV	Western Basin MD	Inner harbour MD	Mid harbour MD	Outer harbour MD	Open coastal waters adjacent to Gladstone SMD
Ammonium Nitrate (µg/L)	20th percentile	3	3	3	3	3	-
	50th percentile	3	3	3	3	4	-
	80th percentile	10	8	10	12	5	< 3
Oxide Nitrogen (µg/L)	20th percentile	2	1	2	1	1	-
	50th percentile	3	4	5	3	3	-
	80th percentile	9	16	12	9	6	< 1
Particulate Nitrogen (µg/L)	Annual mean	-	-	-	-	-	≤ 20
Total Dissolved Nitrogen (µg/L)	80th percentile	-	-	-	-	-	< 70
Total Nitrogen (µg/L)	20th percentile	140	145	130	110	115	-
	50th percentile	170	170	160	135	130	-
	80th percentile	220	210	220	200	170	< 100
Filterable Reactive Phosphate (µg/L)	20th percentile	3	1	1	1	1	-
	50th percentile	3	3	3	2	1	-
	80th percentile	7	7	6	3	3	< 1
Particulate Phosphorus (µg/L)	Annual mean	-	-	-	-	-	≤ 2.8
Total Dissolved Phosphorus (µg/L)	80th percentile	-	-	-	-	-	< 6
Total Phosphorus (µg/L)	20th percentile	15	14	15	9	9	-
	50th percentile	20	18	21	14	13	-
	80th percentile	29	29	33	23	21	< 8

Parameter	WQO	Zone and level of protection					
		The Narrows HEV	Western Basin MD	Inner harbour MD	Mid harbour MD	Outer harbour MD	Open coastal waters adjacent to Gladstone SMD
Chlorophyll *a* (µg/L)	Annual mean	-	-	-	-	-	≤ 0.45
	20th percentile	0.5	0.5	0.5	0.5	0.5	-
	50th percentile	1.0	1.0	1.0	1.0	1.0	-
	80th percentile	20	2.0	2.0	2.0	2.0	-

Table notes:

SMD = slightly to moderately disturbed
WQOs for indicators are shown as 20th, 50th and 80th percentiles, lower and upper limits (20th/80th percentiles, e.g. pH), or as a single values (median or 80th percentile) (e.g. < 15)

Source: EHP (2014b)

Table 8.5 Water quality objectives (physicochemical) to protect aquatic ecosystem environmental value under baseflow conditions (peak discharge < 100m^3/sec)

Parameter	WQO	Zone and level of protection					
		The Narrows HEV	Western Basin MD	Inner harbour MD	Mid harbour MD	Outer harbour MD	Open coastal waters adjacent to Gladstone SMD
DO (% saturation)	20th percentile	87	91	93	94	94	95
	50th percentile	92	96	96	97	97	-
	80th percentile	95	100	98	101	100	105
Turbidity (NTU) Dry (May to October)	20th percentile	4	4	4	2	1	-
	50th percentile	7	8	8	4	3	-
	80th percentile	12	17	17	7	6	-
Turbidity (NTU) Wet (November to April)	20th percentile	8	7	7	4	2	-
	50th percentile	15	13	13	9	7	-
	80th percentile	30	29	29	16	13	-
Secchi disk (m)	Annual mean	-	-	-	-	-	≥ 10
pH	20th percentile	7.2	7.2	7.2	7.2	8.0	8.1
	50th percentile	-	-	-	-	8.1	-
	80th percentile	8.2	8.2	8.2	8.2	8.2	8.4
TSS (mg/L)	Annual mean	-	-	-	-	-	≤ 2
Silicate (µg/L)	80th percentile	-	-	-	-	-	> 60
Temperature (°C)	-	-	-	-	-	-	Increases of no more than 1°C above long term (20 year) average maximum

Table notes:

WQOs for indicators are shown as 20th, 50th and 80th percentiles, lower and upper limits (20th/80th percentiles, e.g. pH), or as a single value (median or 80th percentile (e.g. < 15)

Source: EHP (2014b)

Table 8.6 Water quality objectives (toxicants) to protect aquatic ecosystem environmental value under baseflow conditions (peak discharge < 100m^3/sec)

Metal/toxicant	Water quality objectives for marine waters, SMD (95% species protection unless specified) (µg/L)
Aluminium	24 (MD waters – 95%) 2.1 (HEV/SD waters – 99%)
Arsenic (AsIII)	Insufficient data (value to be updated in guidelines when available)
Arsenic (asV)	Insufficient data (value to be updated in guidelines when available)
Cadmium	0.7 (99%)
Chromium (CrIII)	27.4
Chromium (CrVI)	4.4
Copper	1.3
Cyanide	4
Gallium	Insufficient data (value to be updated in guidelines when available)
Lead	4.4
Molybdenum	Insufficient data (value to be updated in guidelines when available)
Nickel	7 (99%)
Zinc	15
Other toxicants	Refer to AWQG Volume 1 Section 3.4—'water quality guidelines for toxicants' (including Tables 3.4.1 and 3.4.2, and Figure 3.4.1), and AWQG Volume 2 (Section 8, including Section 8.3.4.4 on application in estuarine waters). AWQG values for the MD level of protection typically correspond to protection of 95% species (in a small number of cases where bioaccumulation may occur, the AWQG recommends 99% species protection level)
Pesticides	As per Water Quality Guidelines for the GBRMP and AWQG, to protect marine species at the HEV level of protection (except where noted)

Source: EHP (2014b)

8.4 Existing environment

8.4.1 Overview

Port Curtis is one of the most studied ports in Australia (Commonwealth of Australia 2013). Relevant existing studies have been used throughout the Project EIS to ensure a complete and accurate description of the existing and historical environmental conditions has been evaluated. A desktop data review of existing historic studies within the Port has been undertaken as part of the baseline water quality assessment. This desktop review revealed that there is a large amount of information available from studies previously undertaken within Port Curtis. A summary of the outcomes of these studies is provided in Appendix H1 (Section 3).

Data sources include reports from industry initiatives such as the PCIMP, regional environmental inventory reports commissioned by GPC, Commonwealth and State Government reports, and various reports from independent proponents as part of development impact assessments, including previous dredging campaigns.

Previous water quality studies have consisted of short and long term monitoring programs, capturing biological and physicochemical water quality parameters, contaminant concentrations, photosynthetically available light, and nutrients. Studies have predominantly focussed on sites in the Calliope and Boyne estuaries and the Western Basin, Inner Harbour and Mid Harbour zones (between Facing Island and The Narrows) although more recent work has included reference sites within the zones of Outer Harbour, Rodds Bay, and sites in Queensland coastal waters (refer Appendix H1 (Section 3.2)) (GHD 2009; VE 2008). A large number of the investigations have focussed on water quality and its potential to impact on the conservation of significant marine species found in Port Curtis (i.e. seagrass meadows). This includes significant research into the benthic photosynthetic light available to benthic primary producers, and the impacts that reduced light through increased turbidity and TSS have on these species.

Historical studies show the water quality of Port Curtis is strongly correlated with tidal state and associated bedload resuspension. Previous studies have described the Port as having a large tidal range (up to approximately 4m) and the associated tidal regime induces high current velocities in the main channel. The Port has naturally high turbidity during large spring tides, associated with new and full moon events, which generate strong tidal currents eroding and resuspending fine sediments. Turbidity at the surface is generally lower than at the bottom of the water column due to bottom sediment resuspension.

The estuary receives freshwater flows from the Boyne and Calliope Rivers, along with occasional flows through The Narrows from the Fitzroy River. It is a well-connected estuary which allows dissolved material to be dispersed evenly, although material does not as readily leave the estuary to the offshore environment. Hydrodynamic studies have found that the Port has a reduced flushing time, which may contribute to some metals bio accumulating in Port Curtis biota (Andersen et al. 2005).

Contaminant pathway studies, have found that flows from the Fitzroy River have the potential to supply dissolved metals to Port Curtis via The Narrows to the north and that various industrial and other anthropogenic discharges, along with mobilisation of metals from mangrove regions, are likely to contribute to trace metals distributions in Port Curtis. Metals present in suspended sediments and benthic sediments in Port Curtis are in low concentrations and are not thought to be a source of trace metals in the water.

DO and pH also show increasing gradients of DO and decreasing acidity from the Inner Harbour towards the Outer Harbour and open coastal waters, typical of estuarine environments.

8.4.2 Previous water quality investigations

The key existing reports and programs utilised in the Project water quality assessment are summarised below.

8.4.2.1 Port Curtis Integrated Monitoring Program

Established in 2001, PCIMP is a consortium of members from 16 representative bodies from industry, government (both local and state), research institutions and other stakeholders. The aim of PCIMP is to develop a cooperative monitoring program to assess the ecosystem health of Port Curtis with a focus on maintaining the health and sustainability of Port Curtis marine environments. The PCIMP addresses themes, including water quality (including biomonitoring), intertidal health (e.g. oil spill assessments), seagrass health and sediment assessments and monitoring has been undertaken since 2005.

To date the PCIMP has funded two Port Curtis Ecosystem Health Report Cards (refer Section 8.4.2.3). The report card system was established to document ecosystem health in Port Curtis using indicators that reflect ecological condition. The inaugural Port Curtis ecosystem health report card was released by PCIMP in 2007 (Storey et al. 2007) with the majority of these results collected under the 2005 and 2006 PCIMP programs. Another report card was released in 2011 (VE 2011a) based on data collected from July 2008 to November 2010.

The program was redesigned in 2012 into its current format of quarterly water quality monitoring, biannual oyster deployments and annual sediment quality surveys. Data is now provided to the GHHP who publish report cards covering the environmental, social, cultural and economic health of the Port (refer Section 6.4.2.3). A large focus of the PCIMP monitoring program has centred on bioavailable metals which have been highlighted as potential contaminants of concern in the Port Curtis environment. Further details are provided in Appendix H1 (Section 3.5.2).

Recent water quality data collected by PCIMP has been utilised in the EIS as supplementary data where appropriate (refer Appendix H1 (Section 4.9.2)).

8.4.2.2 Government reports

Both the Commonwealth and Queensland Government have prepared reports focussed on Port Curtis in recent years. Queensland Government reports, published by the former DERM, EHP and DSITIA (now DES) have utilised long term water quality datasets to inform studies on the water quality of Port Curtis.

8.4.2.3 Gladstone Healthy Harbour Partnership

The GHHP was formed in November 2013 as a forum representing 25 partners, including community, industry, science, government and statutory bodies, to report and contribute to improving the health of Port Curtis. The role of the GHHP is to provide an annual report card on the health of Port Curtis focussing on four key indicators, environmental, social, cultural and economic health. The pilot GHHP report was released in November 2014. The first full report card was issued in February 2016.

The GHHP is informed by an Independent Science Panel comprising members with expertise such as water quality, ecosystem health, marine biodiversity, toxicology and biogeochemistry among others. The role of the panel is to provide independent scientific advice to the GHHP on the Gladstone Harbour Report Card, as well as on the monitoring programs that support the report card.

Water quality data collected by PCIMP is published by GHHP as part of the report card process. A summary of GHHP report cards from 2015 to 2017 is provided in Appendix H1 (Section 4.9.3).

8.4.2.4 GPC internal data

GPC has undertaken its own water quality monitoring since the 1990s in Port Curtis and maintains several large data sets. Parameters monitored include turbidity, temperature, pH, conductivity, DO, metals, hydrocarbons, nutrients and other contaminants.

8.4.2.5 Investigations from independent proponents

Over the last 20 to 30 years a large number of water quality monitoring programs in Port Curtis have been undertaken for the purposes of impact assessment, compliance, and incident investigations. While investigations often differ in their objectives, spatial range and temporal continuity, they provide a large and varied source of baseline water quality data for Port Curtis. Baseline monitoring programs in recent years have been undertaken for the environmental impact statements associated with the Curtis Island LNG developments (e.g. GLNG, QCLNG, Arrow Energy, WICT) as well as for the WBDDP. Reports for these assessments have also included desktop literature reviews, which have been reviewed for as part of this water quality assessment.

8.4.2.6 Western Basin Dredging and Disposal Project baseline water quality monitoring (GHD 2009a)

The WBDDP (Stage 1A) was a major capital dredging project undertaken by GPC from May 2011 to September 2013. Baseline water quality information within the WBDDP area was summarised in the *Water Quality Report* for the WBDDP EIS (GHD 2009a).

Water quality monitoring was undertaken in the study area which included the Western Basin reclamation area, proposed Western Basin areas to be dredged, and surrounding areas of The Narrows, Targinie Channel, Fisherman's Landing Basin, Pelican Banks, and southeast of Curtis Island (GHD 2009a).

Results for turbidity and total suspended solids indicated that the study area is a naturally turbid system with continuous logger data regularly recording results above AWQG (ANZECC/ARMCANZ 2000a) and QWQG (EHP 2009a) guideline values. During the dry season it was found that turbidity during spring tide conditions is two to four times those in neap tide conditions (GHD 2009a). The study found that tidal state and current speeds induce sediment resuspension at the seabed therefore increasing sediment concentrations in the water column. Wet season inflows were also observed to increase suspended sediment concentrations (GHD 2009a).

The majority of water quality parameters analysed from the vessel-based monitoring program were below the LOR. Minor exceedances of guidelines for contaminants (i.e. herbicide, pesticide, cadmium and nutrients), indicated potential anthropogenic input from urban and agricultural sources, or naturally high levels in the study area. Elutriate water quality results indicated concentrations of metals, metalloids and ammonia were generally much higher than those levels recorded in the water column or the relevant ecosystem water quality guidelines (GHD 2009a). Additional information on the WBDDP water quality monitoring program is provided in Appendix H1 (Section 3.9.2).

8.4.3 Natural influences on water quality in Port Curtis

An understanding of the role that external influences play in affecting water quality is key to understanding baseline water quality conditions. Natural influences (i.e. waves, tides, currents, wind, depths, rainfall, extreme weather and the frequency and severity of storms and cyclones, and freshwater flows from surrounding catchments) are described below.

8.4.3.1 Climate

Port Curtis is located along the Central Queensland coast which lies 95km south of the Tropic of Capricorn. This coastal area experiences a sub-tropical maritime climate with a wet/dry regime which includes high rainfall in the summer months of December, January and February, which account for half the region's annual rainfall (BoM 2015a). Dryer conditions are experienced in the winter months. The annual rainfall average is around 891 millimetres (mm) in Gladstone, but variability between years is large, ranging from 433mm to 1,732mm per annum since 1957 (BoM 2018a).

Numerous flood events have occurred along the Calliope River and Boyne River catchments, and these events have generally been associated with cyclones or associated rain depressions (GPC 2012). Significant rainfall events in previous years that have resulted in flooding, including the rain depression associated with Cyclone Benni in February 2003, flood events of the 2010/2011 wet season (Queensland's largest rainfall on record), and the significant rainfall event associated with ex-Tropical Cyclone (TC) Oswald in January 2013. A low pressure system in mid-January 2015 brought heavy rain, flooding and high winds, and TC Marcia which made landfall in Central Queensland in February 2015 also brought heavy rain and high winds to the region. Above average rainfall associated with ex- TC Debbie was also seen in March 2017 (BoM 2017).

The water quality in Port Curtis can be heavily influenced by weather extremes, particularly turbidity and conductivity when turbid freshwater reaches Port Curtis via the Calliope River and Boyne River (and Fitzroy River plume in some circumstances). The influx of freshwater into the Port during flood events has also been shown to increase the levels of contaminants such as nutrients, herbicides, pesticides and metals found in the water column (DERM 2011; Hale 2013).

Generally surface winds of the region blow in an arc from the southwest to the northeast depending on both time of day and season (GPC 2014c). The wave climate is characterised by a predominance of southeasterly wind in the morning, swinging to the east and northeast in the afternoon. Southeasterly winds in the morning are not as strong (20 to 30km/hour for 10% of time) as the easterly winds in the afternoon (30 to 40km/hour for 10% of time) (GPC 2012). In addition, easterly winds in the afternoon at 20 to 30km/hour occur for a further 25% of time (GPC 2012). Wind direction and speed is known to directly influence turbidity and TSS in Port Curtis, as a result of wave action and currents which can mobilise and transport sediments. These impacts are more evident at shallower inshore areas of the Port. The Port is subject to locally generated sea waves under the influence of local wind conditions (GPC 2012).

8.4.3.2 Hydrodynamics

The water quality of Port Curtis has been shown to be strongly correlated with tidal state and associated bedload resuspension. The Port has a large tidal range from low to high, around 4m during neap tide periods and around 1m during spring tides (Herzfeld et al. 2004). The Port experiences a neap-spring tide cycle over a period of approximately 14 days with the associated tidal regime inducing high current velocities in the main channel (Herzfeld et al. 2004). The region is therefore commonly described as a naturally turbid environment.

The waters of Port Curtis are generally well mixed both vertically and horizontally. The flushing time (i.e. the time for total mass of material to decrease to a third of its original mass) for the estuary is 19 days (Herzfeld et al. 2004). This reduced flushing time is likely to contribute to the anomalous bioaccumulation of some metals in biota of Port Curtis (Andersen et al. 2005).

The estuary receives freshwater flows from the Boyne and Calliope Rivers, along with some influence through The Narrows from the Fitzroy River. The Port is a well-connected estuary which allows dissolved material to be dispersed evenly, although material does not as readily leave the estuary to the offshore environment (Herzfeld et al. 2004).

8.5 Baseline monitoring program results

This section provides a summary of the Project EIS baseline water quality, BPAR, and sedimentation data presented in Appendix H1 (refer Appendix B (*Baseline Data Collection, Water Quality Monitoring, June 2014 to June 2015*)). Statistical analyses have been presented to identify temporal, spatial and seasonal trends, and water quality results have been compared against relevant guidelines for reference.

Historically, water quality monitoring data from Port Curtis has been compared to QWQG and AWQG. While the AWQG include aquatic ecosystem water quality guideline values for broad water regions and water types, it recommends that wherever possible, local guidelines should be developed. The Queensland Government have therefore developed EVs and developed local WQOs for the Capricorn-Curtis Coast region via a process of stakeholder consultation and analysis of available water quality data (DSITIA 2014; EHP 2014b).

Schedule 1 of the EPP (Water) lists the EVs and WQOs for Queensland waters, including those for Curtis Island, Calliope River and Boyne River Basins (Basins 131, 132 and 133, including all waters of Gladstone Harbour, The Narrows, Curtis Island, Calliope River and Boyne River Basins, and adjacent coastal waters) (EHP 2014b). Plan WQ1312 of Schedule 1 of the EPP (Water) also outlines water types and zones along with EVs and the current management intent of these waters (refer Section 8.3.5).

WQOs are long term goals for water quality management and are used to help set development conditions, influence local government planning schemes and underpin report card grades for ecosystem health monitoring programs such as the GHHP and other similar programs (DSITIA 2014).

For the purposes of this EIS, water quality results, which represent ambient baseline conditions across eight sites in Port Curtis from June 2014 to July 2015, have been compared against WQOs for reference purposes only as the EIS baseline data have the potential to be utilised in refining the WQOs. Where there is no local WQO provided, results have been compared against QWQG and AWQG as a default (EHP 2014b).

EHP (2014b) states that the median water quality value measured within waters should be compared against the WQO, when multiple WQOs are provided (e.g. 20^{th}, 50^{th} and 80^{th} percentile values). However, when only a single WQO value is provided, such as for most parameters in the coastal waters area, these should be compared to the mean value. Given a mix of multiple areas have been monitored in this Project, for ease of comparison both the mean and median values for results have been used to compare against WQOs at all sites.

WQOs have been derived for both baseflow and event flow in Gladstone Harbour and The Narrows. The WQOs that baseline results have been compared to in this report apply to baseflow conditions only. Schedule 1 of the EPP (Water) outlines the WQOs which apply during event flows, relative to peak discharges at the Castlehope gauging station (132001A). Time periods after which baseflow WQOs are to be applied to waters, following an event, are also outlined in EPP (Water) Schedule 1 (EHP 2014b).

It is important to acknowledge the influence of natural or extreme weather events on the variability of water quality during long term baseline monitoring programs. During the Project baseline data collection period two notable natural events impacted the Gladstone region. A low pressure system in mid-January 2015 brought heavy rain, flooding and high winds, and TC Marcia which made landfall in Central Queensland in February 2015 also brought heavy rain and high winds to the region.

It should be noted that maintenance dredging was undertaken in the Port of Gladstone as part of GPC's regular maintenance dredging program in 2014 during selected dates in February, March and July, and in 2015 between 4 June and 18 June (refer Appendix H1 (Section 3.9.3.2)). No other obvious anthropogenic events appear to have occurred in the Port during the Project baseline data collection period, outside of regular shipping and boating operations.

8.5.1 Climatic conditions

During the 13 month baseline monitoring period approximately 849mm of rainfall was recorded in Gladstone (BoM 2015b), slightly below the average annual rainfall (1957 to 2018) of 889mm recorded at the Gladstone Radar (station 039123) (BoM 2015a).

A low pressure system in mid-January 2015 brought heavy rain, flooding and high winds. In mid-February 2015 severe TC Marcia made landfall as a category five system in Central Queensland near Shoalwater Bay to the north of Gladstone, bringing heavy rains with almost 100mm of rainfall over a three day period to the Gladstone area and high winds to the region. Wave heights were also considerably higher than typical at this time. Inshore winds generally ranged between 0 and 40km/hour, with the highest winds of the monitoring period experienced on 20 February 2015, with gusts of up to 89km/hour recorded (BoM 2015b).

8.5.2 Turbidity

Surface turbidity was significantly higher at inshore sites (i.e. P2B/WB50, QE3 and P5/MH30) than at offshore sites (CD1 to CD5) with the highest turbidity results recorded during spring tides.

8.5.2.1 Inshore turbidity (P5/MH30, P2B/WB50 and QE3)

Of the three inshore sites, P2B/WB50 and QE3 recorded consistently higher turbidity values during both wet and dry seasons than site P5/MH10. This is most likely due to their locations in the inner estuarine Port Curtis, compared to P5/MH10, located close to the North Entrance between Curtis Island and Facing Island, which has a more oceanic influence.

At the three inshore sites, turbidity increases were evident bimonthly during the spring tides associated with the full and new moon periods. Higher tidal ranges associated with spring tides at inshore sites permit a higher level of mixing and resuspension of particles within the water column. When tidal ranges are lower, such as during neap tides associated with the quarter moon phases, the turbidity levels tend to decrease accordingly.

At QE3 the 20th, 50th and 80th percentile values were equal to or below their corresponding WQO values, with median turbidity values also equal to or lower than the 50th percentile WQO. At both P2B/WB50 and P5/MH10 20th, 50th and 80th dry season and wet season percentile values were slightly lower than the 20th, 50th and 80th percentile WQOs.

Results from the 13 month monitoring period indicate inshore turbidity trends were comparable to the studies used to calculate the WQOs for aquatic ecosystems in Port Curtis (DSITIA 2014).

8.5.2.2 Offshore turbidity (CD1 to CD5)

Benthic turbidity at each offshore site was significantly higher than surface turbidity most likely due to the proximity of the loggers to the benthic sediment. The offshore benthic sediments tended to be resuspended during strong winds and elevated wave heights. Turbidity at the majority of offshore sites also tended to be significantly higher during the wet season than during the dry season.

When comparing turbidity results across the offshore sites, CD2 and CD3 surface and benthic results exhibited the highest turbidity values during both the wet season and dry season. Higher turbidity at CD2 is likely to be due to its location closer to land masses in Port Curtis (i.e. more influenced by lunar and tidal cycles) and CD3's location closer to the main land and the Boyne River (i.e. more influence by rain events) in comparatively shallower depths.

CD3, located at the mouth of the Boyne River, tended to display more elevated benthic turbidity for several weeks during increased wind speed events following TC Marcia in mid-February 2015. It is likely that fine sediments washed down from the Boyne River were being easily resuspended during these events.

Lowest turbidity values were evident at CD1, CD4 and CD5, particularly during the dry season. Turbidity at CD4 and CD5 (the deepest sites) and CD1 was primarily related to wind events. Although CD1 is the third shallowest offshore site (depth < 9m), it is also located the furthest from any anthropogenic and estuarine influences.

Median turbidity at CD1 during the wet and dry season ranged between 20th and 50th percentile WQOs. Similarly, CD3 median wet and dry season turbidity ranged between the 20th and 50th percentile WQOs. For CD4 and CD5 only mean surface turbidity during the wet and dry season were below assigned WQOs. Mean CD2 turbidity results were all above the assigned WQOs.

Surface and benthic turbidity results from the baseline monitoring period are outlined in Table 8.7. Further details are provided in Appendix H1 (Section 4.8.2 and Appendix B (*Baseline Data Collection, Water Quality Monitoring, June 2014 to June 2015*)).

Table 8.7 Turbidity results at water quality loggers (June 2014 to July 2015)

Site	Statistic	Dry season turbidity (NTU)			Wet season turbidity (NTU)		
		Surface	Benthic	WQOs	Surface	Benthic	WQOs
QE3[2]	Mean ± se	7.0 ± 0.0	-	-	8.3 ± 0.1	-	-
	Range	< 1 to 77	-	-	< 1 to 520	-	-
	20th percentile	3.8	-	**4**	1.1	-	**8**
	50th percentile	7.3	-	**7**	3.8	-	**15**
	80th percentile	9.4	-	**12**	9.9	-	**30**

Site	Statistic	Dry season turbidity (NTU)			Wet season turbidity (NTU)		
		Surface	Benthic	WQOs	Surface	Benthic	WQOs
P2B/ WB50	Mean ± se	9.0 ± 0.1	-	-	7.2 ± 0.1	-	-
	Range	< 1 to 138	-	-	< 1 to 101	-	-
	20th percentile	4.0	-	**4**	2.1	-	**7**
	50th percentile	6.7	-	**8**	5.3	-	**13**
	80th percentile	13	-	**17**	11	-	**29**
P5/ MH10	Mean ± se	4.3 ± 0.0	-	-	4.7 ± 0.0	-	-
	Range	< 1 to 44	-	-	< 1 to 98	-	-
	20th percentile	1.8	-	**2**	1.1	-	**4**
	50th percentile	3.3	-	**4**	3.3	-	**9**
	80th percentile	5.9	-	**7**	6.6	-	**16**
CD1	Mean ± se	1.5 ± 0.0	3.3 ± 0.0	-	1.9 ± 0.0	5.2 ± 0.2	-
	Range	< 1 to29	< 1 to 142	-	< 1 to37	< 1 to 130	-
	20th percentile	<1	<1	**1**	<1	<1	**2**
	50th percentile	<1	1.9	**3**	1.4	2.2	**7**
	80th percentile	2.3	4.7	**6**	3.1	6.4	**13**
CD2	Mean ± se	2.3 ± 0.0	4.5 ± 0.0	**< 1**	2.0 ± 0.0	7.2 ± 0.1	**< 2**
	Range	< 1 to 25	< 1 to 104	-	< 1 to 201	< 1 to 250	-
	20th percentile	<1	1.6	-	<1	1.9	-
	50th percentile	1.9	3.3	-	1.3	4.9	-
	80th percentile	3.7	6.7	-	3.3	9.8	-
CD3	Mean ± se	4.1 ± 0.0	5.7 ± 0.0	-	3.1 ± 0.1	6.7 ± 0.1	-
	Range	< 1 to 42	< 1 to 110	-	< 1 to 40	< 1 to 313	-
	20th percentile	1.1	1.0	**2**	<1	<1	**4**
	50th percentile	3.2	3.9	**4**	2.5	3.7	**9**
	80th percentile	6.9	8.9	**7**	4.9	11	**16**
CD4	Mean ± se	1.0 ± 0.0	4.0 ± 0.0	**< 1**	1.5 ± 0.0	2.5 ± 0.0	**< 2**
	Range	< 1 to 35	< 1 to 173	-	< 1 to 13	< 1 to 44	-
	20th percentile	< 1	<1	-	<1	<1	-
	50th percentile	< 1	<1	-	1.0	<1	-
	80th percentile	1.7	6.0	-	2.6	4.9	-
CD5	Mean ± se	<1	1.7 ± 0.0	**< 1**	1.8 ± 0.0	3.0 ± 0.0	**< 2**
	Range	< 1 to 17	< 1 to 98		< 1 to 43	< 1 to 127	
	20th percentile	<1	<1	-	<1	<1	-
	50th percentile	<1	<1	-	<1	<1	-
	80th percentile	1.5	2.1	-	2.0	3.9	-

Table notes:

se = standard error

1. N = 7,858 to 20,773
2. WQOs Source: Curtis Island, Calliope River and Boyne River Basins EVs and WQOs (EHP 2014b)
3. QE3 results collected from January 2015 to July 2015
4. Statistics listed include 20th, 50th (median) and 80th percentiles

8.5.2.3 Influence of natural events on turbidity

Severe TC Marcia making landfall in Central Queensland around 20 February 2015 resulted in short term elevated turbidity at the offshore sites (CD1 to CD5) and at P5/MH10. Turbidity at the Mid Harbour site of P5/MH10 has historically been found to be influenced by increased wind, in addition to tidal phases (VE 2013b). Generally these types of events are acute in nature resulting in a rapid but short-lived elevation in turbidity, particularly when wind rather than rainfall is the driving factor, as observed with TC Marcia. Major rain events recorded in Gladstone such as during mid to late January 2015 (> 200mm) (BoM 2015b) were shown to be more influential on turbidity at the inshore sites than high wind speeds.

8.5.3 Other physiochemical parameters (temperature, pH, conductivity, dissolved oxygen)

8.5.3.1 Temperature

During the monitoring period, temperature at all sites exhibited a clear seasonal pattern, associated with ambient temperatures (refer Appendix H1 (Table 4.11)). As expected, temperature at all sites was significantly higher during the wet season than during the dry season, paralleling ambient air conditions. Of note were the small immediate decreases in temperature associated with rainfall events which were less evident at the deepest sites CD4 and CD5 further offshore. No WQOs are assigned for temperature. Further details are provided in Appendix H1 (Section 4.8.3).

8.5.3.2 pH

The pH at each site tended to remain reasonably consistent throughout the monitoring period (refer Appendix H1). While consistently lower pH was evident at inshore site QE3, typical of estuarine environments, only minor differences were evident between remaining sites. Benthic and surface pH at each site suggested a well-mixed water column at offshore sites. Tidal fluctuations in pH were also evident at QE3, while P2B/WB50, P5/MH10 and CD3 demonstrated this pattern to a lesser extent and generally only after significant rain events recorded in January and February 2015. All mean seasonal pH values were within their appropriate WQO range (EHP 2014b). Further details are provided in Appendix H1 (Section 4.8.4)

8.5.3.3 Conductivity

Conductivity tended to remain stable except for during and after large rainfall events (e.g. in January and February 2015), which resulted in noticeable decreases particularly at inshore sites and CD3, and to a lesser extent at site CD2 (refer Appendix H1). During mid-January and mid-February 2015, rainfall events (> 100mm) resulted in conductivity levels < 20mS/cm at inshore sites QE3 and P2B/WB50, < 40mS/cm at P5/MH10, and < 10mS/cm at CD3 (surface).

Recovery to almost typical dry season background conditions after the January and February 2015 rain events, did not occur at these sites until April 2015. At CD3, surface conductivity during these times was considerably lower than benthic conductivity with pronounced tidal fluctuations, indicating vertical stratification of the water column and the presence of a surface layer of freshwater outflow from the Boyne River on outgoing tides. No WQOs are assigned for conductivity. Further details are provided in Appendix H1 (Section 4.8.5).

8.5.3.4 Dissolved oxygen

DO levels tended to display reasonably consistent patterns throughout the baseline monitoring period, with little difference between median dry and wet season values for each site. Surface and benthic DO results for the baseline monitoring period are outlined in Appendix H1.

Across the sites, mean QE3 and P2B/WB50 DO levels were lower than offshore sites by between 3 to 12%, a spatial pattern which has been recorded previously in Port Curtis (VE 2013b). Only minor differences were evident between mean values for surface and benthic loggers. All mean surface and benthic DO concentrations for sites CD2, CD4 and CD5 in coastal waters outside Gladstone Harbour were within the assigned WQO range. For all other sites, median surface and benthic DO concentrations for the wet season and dry season were slightly above or equal their 50th percentile WQO except for QE3 surface.

Immediate decreases in DO were correlated to rainfall events in mid-January and mid-February 2015, particularly evident at inshore sites QE3 and P2B/WB50 where declines to < 70% and < 80% saturation, respectively, were recorded. Declines were also evident at site CD3 which were particularly pronounced and persistent at the seabed, and were directly related to tidal flows.

Diurnal patterns were evident at all sites but were most pronounced at the inshore sites of QE3, P2B/WB50 and P5/MH10. Diurnal patterns are likely to be due to plant (e.g. algae) photosynthesis and respiration, and were particularly noticeable at site P5/MH10 (which is adjacent to large seagrass meadows at Pelican Banks) and QE3 in The Narrows (which is a mangrove dominated environment).

Immediate declines after rain events in mid-January and mid-February 2015 were often followed by more pronounced diurnal patterns with peaks of DO > 120% recorded at P5/MH10. These patterns suggest post rain event increases in photosynthetic activity generally associated with algal blooms, due to the break-down of stormwater introduced detritus which can increase nutrients and therefore stimulate algal growth. Further details are provided in Appendix H1 (Section 4.8.6).

8.5.4 Sedimentation

Several external environmental factors were found to influence sediment flux with effects varying depending on the location of the site either inshore or offshore. To record the rate of sediment movement at each monitoring site (either deposition or erosion of sediment), acoustic altimeter instruments were positioned at the seabed at each monitoring site. Similar to a side-scan sonar, the instruments record seabed level measurements (i.e. millimetre scale) using a high frequency acoustic sensor. The two forms of information recorded by the altimeters were instantaneous bed level change (bed level flux) and cumulative bed level change over a given period.

Increases in sediment flux at inshore sites were associated with significant rain events over January and February 2015, as well as with spring tides coinciding with elevated turbidity and higher sediment resuspension. For the inshore sites, spring tides coinciding with elevated turbidity also generated more dynamic bed level flux.

Between the offshore sites, the driving factors for sediment resuspension at the furthest offshore sites appeared to be wind speed and wave heights. At those sites closer to land tidal influences appeared more evident.

Sediment flux appeared to be driven by lunar phases and/or wave heights, but not all resuspension events resulted in cumulative bed level change. In some cases bed level fluctuated around a fixed mean, whereas in other cases there was measured deposition or erosion. Wind direction and its influence on sediment flux, which results in deposition or erosion, appeared to be a major factor in bed level change during the baseline monitoring period. Further details on sedimentation are provided in Appendix H1 (Section 4.8.7).

8.5.5 Benthic photosynthetically available radiation

All five monitoring sites exhibited significant seasonal variation ($p < 0.05$), however, in contrast, dry season BPAR at these sites was found to be significantly higher than wet season BPAR, despite lower ambient PAR, indicating ambient light was not the only driving factor influencing BPAR at these sites.

Significant but weak linear regressions were evident in the data between turbidity and BPAR at each site, with BPAR decreasing as turbidity increased.

CD3 was located at a similar depth to CD1 and CD2 (~ 7m) but experienced overall higher benthic turbidity during the dry season. In addition, TSS concentrations were found to be uniform through the water column for CD3, indicating elevated turbidity was not entirely restricted to the seabed as it may have been for other offshore sites, thus resulting in greater light attenuation. The location of CD3 adjacent to the Boyne River mouth would predispose this location to a lower light regime. Further details on BPAR are provided in Appendix H1 (Section 4.8.8).

8.5.6 Total suspended solids

Monthly samples of TSS were collected at three depths in the water column at the five offshore sites (sub-surface, mid column and 1m above the seabed (benthic)). At the three inshore sites TSS samples were collected at the sub-surface only due to the well-mixed water column.

The TSS trends below were observed from monthly sample results collected across the eight monitoring sites during the baseline monitoring period:

- TSS concentrations paralleled the spatial patterns exhibited by turbidity measured by both continuous loggers and depth-profiling. A significant linear regression was evident between TSS results and depth-profiled turbidity measured concurrently. This indicates that as TSS increased, so did turbidity. As TSS was only sampled and analysed monthly, values are highly variable depending on the timing of sampling coinciding with spring or neap tides, and/or rainfall events, with sampling during spring tides resulting in higher TSS concentrations.
- Surface TSS was significantly higher in samples from site P2B/WB50 than at all other sites, with no significant seasonal variation found, which was a similar finding to that of surface logger turbidity results. Samples from sites QE3 and P5/MH10 exhibited intermediate TSS concentrations were similar to the majority of offshore surface sample TSS concentrations.
- Among the offshore sites (with the exception of CD3), concentrations of TSS in samples collected at benthic layers were significantly higher than concentrations of TSS in samples collected at the surface and mid-level of the water column. Results paralleled those of turbidity, with higher benthic compared to surface turbidity. No significant difference in TSS concentrations was evident in samples collected from different depths at site CD3 in either the wet season or dry season, indicating a well-mixed water column.
- Inshore TSS sample concentrations were compared to QWQG (EHP 2009a), with mean seasonal sample concentrations from all inshore sites lower than the WQO of 20mg/L
- Given the relatively low WQOs for all offshore sites, TSS concentrations were above the WQO on several occasions:
  - Samples from all depths from CD3 over both seasons
  - Samples from all depths from CD2 over both seasons except dry season surface
  - All benthic samples from CD1, CD4 and CD5
- Sampling on 2 February 2015 occurred approximately 10 days after > 200mm of rainfall was recorded for Gladstone (BoM 2015b). However these TSS results were no more elevated than other occasions suggesting rapid recovery of water clarity to background conditions. The exception was CD3, where benthic and mid-column TSS results were consistently elevated after the commencement of the wet season in December 2014, while previously being within range of other sites' results prior to this. Wind driven resuspension of sediments deposited during rain events was likely the cause.
- Light attenuation was measured monthly during depth-profiling and collection of TSS samples. Monthly values paralleled the spatial patterns exhibited by turbidity and TSS.

TSS sample results are outlined in Appendix H1 and further details on TSS are provided in Appendix H1 (Section 4.8.10).

8.5.7 Nutrients

The following nutrient trends were observed from monthly sample results collected across the eight monitoring sites during the baseline monitoring period:

- Total phosphorus concentrations were higher in samples collected at inshore sites QE3 and P2B/WB50, than in those collected at all offshore sites (CD1 to CD5), with no significant variation evident across seasons.
- A similar pattern was evident for the bioavailable phosphorus form, orthophosphate, with significantly higher concentrations in samples from QE3 and P2B/WB50, than in those from all offshore sites, and no significant seasonal variation. Intermediate concentrations of phosphorus forms were found in samples collected from site P5/MH30.
- Orthophosphate was undetected in samples from offshore sites on the majority of occasions, over both seasons, with the exception of March 2015 samples which were collected shortly after the rainfall event associated with TC Marcia in February 2015. Elevated orthophosphate concentrations were detected in samples from all monitoring sites on this occasion. Stormwater runoff increases the level of organic matter (from detritus) into the system which decomposes releasing available nutrients. Additionally, the flow of particulate bound phosphorous particles (potentially geologically derived) from freshwater into more saline environments, has the potential to result in an increase in the bioavailable forms of phosphorus (Fox et al. 1986).
- Similar to phosphorus, total nitrogen was significantly higher in samples from QE3 and P2B/WB50 than in samples from the offshore sites and total nitrogen was also significantly higher in samples collected during the wet season than during the dry season. This may be a result of an increase in microalgal populations which contain nitrogen, which are present in the warmer months (as evidenced by higher chlorophyll *a* concentrations).
- Nitrogen forms: ammonia (NH_3), oxides of nitrogen (NOx) and nitrite (NO_2-); did not exhibit significant seasonal or site variation.
- Chlorophyll *a* concentrations were significantly higher ($p < 0.05$) at QE3 and P2B/WB50 than at all remaining sites and were significantly higher ($p < 0.05$) during the wet season than during the dry season.

Further details on nutrients are provided in Appendix H1 (Section 4.8.11).

8.5.8 Metals and metalloids

The below trends were observed from monthly sampling and analysis of metals/metalloids concentrations at each monitoring site:

- Total and dissolved cadmium, chromium, gallium, mercury, selenium and silver were below the LOR in samples from all sites on the majority of occasions
- Statistically significant seasonal variation in metal concentrations was not evident for most metals/metalloids. However, total and dissolved copper, nickel and vanadium, and dissolved manganese were significantly higher in samples collected during the wet season.
- Overall there was a general trend for the majority of total and dissolved metals/metalloids in samples to be more elevated in sampling months after rain events. This has been a historical finding for Port Curtis with elevated total metals/metalloids in the post January 2011 and 2013 flood events (VE 2013a). Elevated metals/metalloids were also recorded in other catchment areas in Queensland following the January 2011 floods (DERM 2011; VE 2013a).

- A number of total metals/metalloids detected in samples were significantly correlated with TSS concentrations, indicating that in areas where TSS was higher (such as at the inshore sites of QE3 and P2B/WB50), metal concentrations were also higher. This included aluminium, copper, iron, lead, manganese and nickel. Similar relationships have been identified previously in Port Curtis with increased turbidity and TSS concentrations highly associated with increased total aluminium, iron, cobalt and manganese (VE 2013a), indicating metals/metalloids in the water column are predominately bound to particulates.
- For the detectable metals/metalloids, total concentrations were generally considerably higher than dissolved concentrations. This suggests that most metals/metalloids were predominantly bound to particulates, as supported by the linear regressions between TSS and total metal concentrations. Certain metals/metalloids are known to readily adsorb onto iron hydroxides and colloidal particles (Salomons et al. 1995).
- Significant spatial variation was also evident for a number of metals/metalloids. Concentrations of total aluminium, lead, iron and vanadium, and total and dissolved cobalt, copper, nickel, manganese were significantly higher in samples from P2B/WB50 and QE3 than in those samples from offshore sites. Decreasing metal concentrations from lower estuary and enclosed coastal waters to open coastal waters have been a consistent historical finding for Port Curtis (Storey et al. 2007; VE 2011a; VE 2013b).
- WQOs for metals/metalloids in Port Curtis have been set by EHP (2014b), with the majority of these originally established in the National Water Quality Management Strategy (ANZECC/ARMCANZ 2000a). DES has designated zones in Port Curtis into different levels of ecosystem protection, including HEV, SD, MD and HD. Zones which are designated HEV or SD are proposed to meet the AWQG trigger value for 99% level of species protection for metals/metalloids and other toxicants, while MD zones are proposed to meet the AWQG trigger value for 95% level of species protection (ANZECC/ARMCANZ 2000a). Previously, the 95% AWQG trigger value has been applied to all inshore sites, whereas the 99% AWQG trigger value was considered more appropriate for reference or offshore sites.
- Of the current monitoring sites, QE3 (The Narrows area) has been classified as HEV/SD, and thus 99% AWQG trigger values for metals/metalloids are applicable. Zones in which sites P2B/WB50, P5/MH10, CD1 and CD3 are located are classified as MD, indicating that the 95% AWQG are applicable. Sites CD2, CD4 and CD5 are located in coastal waters outside Gladstone Harbour, which are classified as SMD, and thus the 95% AWQG trigger values are considered most appropriate for use.
- Due to the use of more stringent guidelines (e.g. use of 99% rather than 95% AWQG trigger value) at QE3, a number of water quality samples collected for this Project at this site were above the WQOs assigned to these waters, including concentrations of total aluminium in both the wet season and dry season, and total and dissolved cobalt and copper in both seasons.
- For the remaining sites where the 95% AWQG trigger value has been designated for use, total aluminium sample concentrations from all sites were above the WQO during both wet and dry seasons, with the exception of samples from CD4 and CD5 which exceeded during the wet season only. However, dissolved aluminium sample concentrations remained well below the WQO at each site.
- Additionally in samples from site P2B/WB50, concentrations of total copper in both the wet and dry season were above the WQO, with dissolved concentrations remaining below the WQO. Although AWQG exceedances of certain total metals/metalloids in Port Curtis have been recorded previously, the majority of dissolved and therefore potentially bioavailable metals/metalloids, have generally been below AWQG (VE 2012a; VE 2013b; VE 2013c) and are therefore not current contaminants of concern in terms of biological or toxicological risk for this Project.

Further details on metals and metalloids are provided in Appendix H1 (Section 4.8.12).

8.5.9 Organics

Organic contaminants are those containing carbon and include herbicides, pesticides, oil and grease, which encompass petroleum hydrocarbons and PAH. Potential sources of herbicides and pesticides are thought to be minimal in Port Curtis due to the very low degree of horticulture and cropping in the catchment (Hale et al 2014).

Mean seasonal monthly sample results for organic compounds are outlined and PAH are provided in Appendix H1 (Section 4.8.13). None of the organic compounds analysed were detected in any samples collected from any sites.

8.5.10 Summary of key findings

8.5.10.1 Turbidity

The results of the Project EIS baseline water quality monitoring program indicate surface turbidity was significantly higher at inshore sites than at offshore sites with the highest turbidity results recorded during spring tides. Of the inshore sites, consistently higher turbidity values during both wet season and dry season were recorded in the inner estuarine areas of Port Curtis in the Narrows and the Western Basin. Oceanic forces are likely to influence turbidity in the Mid Harbour in waters close to the North Entrance between Curtis Island and Facing Island. Turbidity results were higher in the wet season at the monitoring sites in the Mid Harbour and The Narrows.

Benthic turbidity at each offshore monitoring site was significantly higher than surface turbidity which is most likely due to the proximity of the loggers to the benthic sediment. The offshore benthic sediments tended to be resuspended during strong winds and elevated wave heights. Turbidity at the majority of offshore sites also tended to be significantly higher during the wet season than during the dry season.

Higher turbidity was evident during the wet season across both inshore and offshore monitoring sites. Significant weather events, such as TC Marcia in mid-February 2015 resulted in short term elevated turbidity at offshore sites, particularly at the seabed. Significant rain events recorded in mid-January and mid-February 2015 resulted in elevated turbidity at inshore sites. One offshore site located at the mouth of the Boyne River, tended to display more elevated benthic turbidity for several weeks during increased wind speed events following TC Marcia in mid-February 2015. It is likely that fine sediments washed down from the Boyne River were being easily resuspended during these events.

When comparing turbidity results across the offshore sites, the monitoring sites closest to land masses in Port Curtis exhibited the highest turbidity values at both the surface and seabed, during both the wet and dry seasons. These sites also showed some effects from tidal action. The offshore monitoring sites located furthest offshore, east of Facing Island, recorded the lowest turbidity values across all monitoring sites, particularly during the dry season. Turbidity at offshore sites located in deeper waters was found to be less affected by wind driven resuspension.

8.5.10.2 Other physicochemical parameters

A spatial pattern was evident across the eight monitoring sites in regard to pH and DO, with inshore monitoring sites in The Narrows and the Western Basin exhibiting consistently lower values, similar to what has been previously recorded in other studies in Port Curtis. At these sites, diurnal patterns for DO due to plant photosynthesis and respiration was evident, particularly during the warmer months. At the offshore sites, only marginal differences were evident between benthic and surface temperature, conductivity, pH and DO, indicating the offshore water column was generally well-mixed, similar to the inshore sites. This was supported by water quality data collected from depth-profiling during monthly water sampling.

8.5.10.3 Sedimentation

Bed level flux at the furthest offshore sites was more stable and appeared to be wind driven. At those offshore monitoring sites located closest to land masses in Port Curtis, bed level flux was influenced by significant rain events and spring tides. This was particularly evident during TC Marcia in mid-February 2015, in which wind direction appeared to highly impact whether sediment was deposited or eroded. Bed level flux was quite volatile at the offshore monitoring site (CD2) close to Facing Island, where erosion was most commonly recorded. Overall deposition was primarily recorded at the offshore site (CD3) located at the mouth of the Boyne River, particularly after significant rain events. Erosion and deposition was generally equal at most inshore sites (QE3, P2B/WB50, P5/MH10), resulting in low cumulative bed level change. Although increased sediment flux corresponded with increases in turbidity, there appeared to be a critical minimum threshold of turbidity for offshore and inshore sites for this to occur in some cases.

8.5.10.4 Benthic photosynthetically active radiation

Previous research has determined the light requirements for certain species of seagrass in Port Curtis, which has been used as an ecological trigger value during previous Port of Gladstone capital and maintenance dredging campaigns. BPAR was therefore monitored at all offshore monitoring sites using underwater light sensors, along with a ‘control’ site on land to record surface PAR. BPAR was recorded at inshore areas in conjunction with seagrass surveys undertaken by JCU TropWATER, and are reported in the Project *Ecology Technical Report* (refer Appendix I1).

The main variables found to influence the benthic light climate at monitoring sites were the daily light integral, turbidity and water depth. Although the daily light integral, expressed as moles per square metre per day, was higher on average during the wet season, when daylight periods are longer, BPAR was significantly higher at all five benthic sites in the dry season, suggesting that ambient PAR was only a partial influence on variations in BPAR at these sites. BPAR was significantly higher at the shallower offshore sites which did not record the lowest turbidity values. Despite the relatively shallow depth (~ 6m), BPAR was lower at site CD3, located at the mouth of the Boyne River. This was likely due to the Boyne River causing elevated TSS in the water column.

8.5.10.5 Water sample analysis

Water samples were collected at each monitoring site for laboratory analysis of TSS, nutrients, and metals (all collected monthly), and organic compounds (collected quarterly). Samples for TSS were collected at three depths at each offshore monitoring site (sub-surface, mid-column, and seabed). Due to the well-mixed water column of the inshore areas, only one sample was collected (at the sub-surface) at these monitoring sites.

Surface TSS were significantly higher in samples collected from the inshore monitoring site located in the Western Basin area, outside the mouth of the Calliope River. Samples from other inshore sites exhibited intermediate TSS concentrations.

At offshore sites, TSS were significantly higher at the seabed than at mid-column and the surface. As expected, a strong and significant correlation was evident between TSS results and turbidity, indicating that as TSS increased, so did turbidity. However, no significant seasonal difference for TSS could be inferred from monthly sample results over the baseline monitoring period.

Nutrients (total phosphorus, total nitrogen and orthophosphate) and chlorophyll *a* were significantly higher in samples from the inshore monitoring sites located in the Western Basin and The Narrows zones (P2B/WB50, QE3), with intermediate concentrations found in samples from the Mid Harbour inshore site. Results were significantly lower in samples from the offshore sites, indicating a geographical gradient which has been previously recorded in Port Curtis. No statistically significant seasonal variation in nutrient concentrations could be inferred from monthly sample results, although chlorophyll *a* concentrations were significantly higher during the wet season.

As with nutrient results, concentrations of a number of metals (including total aluminium, lead, iron and vanadium, and total and dissolved cobalt, copper, nickel and manganese) were significantly higher in samples collected from the inshore monitoring sites located in the Western Basin and The Narrows zones, with intermediate concentrations found in samples from the Mid Harbour inshore site. Again, this geographical gradient has been previously recorded in Port Curtis.

Total and dissolved copper, nickel, vanadium and dissolved manganese were the only metals to exhibit seasonal differences, being significantly higher in samples collected during the wet season compared to the dry season. TSS sample concentrations were strongly correlated with a number of total metals, suggesting that a high proportion of metals are bound to suspended particulates in the water column. This is supported by the considerably lower dissolved concentrations found for most metals.

WQO's for metals were most notably exceeded in samples from QE3, where a 99% species protection level is adopted, including concentrations of total aluminium in both the wet season and dry season, and total and dissolved cobalt and copper in both seasons. Total aluminium sample concentrations from all sites were above the WQOs during both wet and dry seasons, with the exception of samples from CD4 and CD5 which exceeded during the wet season only. However, dissolved aluminium sample concentrations remained well below the WQOs at each site. Additionally, in samples from site P2B/WB50, concentrations of total copper in both the wet and dry season were above the WQOs, with dissolved concentrations remaining below the WQOs. Although AWQG exceedances of certain total metals in Port Curtis have been recorded previously, the majority of dissolved and therefore potentially bioavailable metals have generally been below these guidelines, and are therefore not considered current contaminants of concern in terms of biological or toxicological risk for this Project.

None of the organic compounds analysed were detected in any samples collected from any sites during the four sampling occasions of the baseline data collection period.

Overall the findings of the Project EIS baseline water quality monitoring program were generally consistent with results from previous water quality monitoring programs undertaken in the Port.

8.6 Potential impacts

8.6.1 Section content

This section details the potential impacts for water quality as a result of Project activities. Changes in water quality conditions can have ongoing impacts to other aspects of the local environment. This includes potential impacts on sensitive ecological receptors such as seagrass meadows, coral reef communities and other marine flora and fauna. The Port of Gladstone is also used as a fishing and recreational area, and therefore impacts to water quality can also have flow on effects to the community.

This section provides a discussion on the potential impacts to the receiving environment from changes in water quality conditions due to the Project activities summarised in Table 8.8.

Table 8.8 Summary of Project activities and cross reference to potential impact section

Project activity	Section
▪ Construction of the WBE reclamation area and BUF, including placement of core and armour material and geotextile fabric	Section 8.6.4.1
▪ Dredging activities, including: – Initial dredging works for the barge access channel – Dredging of the Gatcombe and Golding Cutting Channel Duplication area	Section 8.6.6
▪ Removal and installation of navigational aids	Section 8.6.7
▪ Stabilisation and maintenance activities on the WBE reclamation area	Section 8.6.8

Project activity	Section
▪ Maintenance dredging	Section 8.6.9
▪ Shipping operation within the duplicated shipping channels	Section 8.6.10

8.6.2 Hydrodynamic modelling overview

8.6.2.1 Methodology for coastal processes and hydrodynamic simulations

Two scenarios were assessed, with a numerical hydrodynamic model (BMT WBM 2019), to determine potential impacts from Project activities to coastal processes and hydrodynamics. The two scenarios assessed included:

- Base Case – Existing Port geometry, including existing LNG developments and completed WICT dredging
- Project Channel Geometry Case – Base Case plus duplicated channel (design level -16.1m LAT), the full proposed WBE reclamation area (refer Figure 8.3), barge access channel (design level -7.0m LAT) and BUF.

8.6.2.2 Methodology for dredge plume simulations

Summary of modelled scenarios

A suite numerical models have been developed by BMT WBM to assess the potential spatial and temporal impacts on coastal processes and hydrodynamics as a result of the Project, including suspended sediment plumes (expressed as turbidity (NTU)) and sediment deposition (expressed as milligrams per square centimetre per day (mg/cm^2/day)).

Specific details of the modelling methodology and assumptions are outlined in the Project *Coastal Processes and Hydrodynamic Technical Report* (BMT WBM 2019).

Seven Project scenarios were simulated, including:

- Initial dredging works (barge access channel)
- Stage 1 dredging
- Stage 2 dredging
- 'Worst Case' dredging
- 'Cumulative Case' Port-wide maintenance dredging
- 'Cumulative Case' flood event dredging
- Port-wide maintenance campaign.

Suspended sediment plumes are produced during the dredging operation by a number of processes, each of which are represented in the numerical model. The modelled sources of suspended sediment sources common to all simulated scenarios are outlined in Table 8.9. Key assumptions regarding the seven modelled scenarios are outlined in Table 8.10. Further detail is included in Appendix G (Section 5).

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0 255 510 Metres

Date: 29/01/2019 Version: 1 Job No: 237374
Coordinate system: GDA_1994_MGA_Zone_56

Gatcombe and Golding Cutting Channel Duplication Project

Figure 8.3 Western Basin Expansion reclamation area

Table 8.9 Modelled sources of suspended sediments

Plume sources	Model input
Trailing suction hopper dredger (TSHD)	
Draghead and propwash	4% of the fines in the materials to be dredged are released into the water column. The potential for propwash to generate plumes during dredging is modelled as a time-varying source which is a function of the underkeel clearance.
Overflow	80% of the fines in the materials to be dredged will go overboard through the barge overflow and 15% of this volume will go into the passive plume. 20 minutes of dredging time is non-overflow and the remainder is overflow.
Cutter suction dredger (CSD)	
Draghead	3% of the fines within the dredged material are released into the water column
Decant Waters	
Tailwater discharge	Water is discharged from the reclamation at a flow rate of 2.8m^3/s with a concentration of 100mg/L of clay particles. This concentration is derived from the maximum permitted suspended sediment concentration limit during previous dredging campaigns within the Port of Gladstone.

Table 8.10 Key assumptions for seven modelled scenarios

Dredging stage scenario	Key assumptions
Initial dredging works	▪ Small CSD 100 hours per week dredging, at 250m^3/hour production rate ▪ Small CSD campaign duration 4 weeks total in the barge access channel (near BUF) ▪ TSHD production of 900m^3 per load (restricted draft). Loading time of 35 minutes. ▪ TSHD cycle time 2 hours. Dredging 133 hours per week. Campaign duration 2.5 weeks in the barge access channel.
Stage 1 dredging	▪ Pumping rate of material into barges is 2,327m^3/hour for 165 minutes of dredging each cycle ▪ Each barge cycle takes 12-25 hours with 10 cycles per barge each week. Therefore 40 cycles per week using four barges ▪ Campaign duration 33 weeks
Stage 2 dredging	▪ Pumping rate of material into barges is 2,327m^3/hour for 165 minutes of dredging each cycle ▪ Each barge cycle takes 12 to 25 hours with 10 cycles per barge each week. Therefore 40 cycles per week using four barges. ▪ Campaign duration 25 weeks.
'Worst Case' dredging	▪ Dredging equipment as per Stages 1 and 2 dredging ▪ The highest modelled change in turbidity and deposition rate percentiles over all of the 5 day assessment windows through the dredging campaign
'Cumulative Case' Port-wide maintenance dredging	▪ A 'typical' Port-wide maintenance dredging campaign (260,000m^3) and Port capital dredging ▪ Parameters for maintenance event established in BTM WBM (2017b)
'Cumulative Case' flood event dredging	▪ A 1 in 100 year flood event and Project capital dredging ▪ Based on catchment loads for 2013 flood event (BMT WBM 2015b)
Port-wide maintenance dredging	▪ Parameters for maintenance event established in BTM WBM (2017b)

Time series analysis

Time series provide a simple way to present turbidity increases above baseline conditions due to dredging activities at predetermined points of interest or near sensitive receptors. Time series plots of depth averaged ambient and dredging-related turbidity, BPAR and sedimentation are provided for several sites in Appendix H2, for the simulated dredging activity campaigns.

Spatial representations of percentile analysis

Spatial representations of Project dredging activity impacts were based on percentile exceedance analysis of the model results and were derived by applying a moving 14 day analysis window over the entire simulation period to represent the approximate duration of two consecutive spring-neap tidal cycles. The moving window analysis was undertaken by moving the 14 day window by five day increments over the entire simulation period.

The percentile impact plots correspond to the predicted increase in turbidity/sedimentation over ambient conditions that are attributable to the dredging. Impacts at each percentile level were calculated for every 14 day window during the simulation, and the maximum increase for any window at each location in the model domain is presented.

Depending on the different locations within the model, some locations will have experienced their worst period at different times during the simulation and the different percentile statistics may also have occurred during different 14 day windows. It is important to note that the presented turbidity percentile plots do not represent the plume extent at any one particular instant in time (i.e. it is not a snapshot) rather a composite of turbidity predicted to be experienced.

Percentile values considered in this water quality assessment are 95th and 50th, which correspond to exceedance durations of 17 hours (5%) and 7 days (50%), respectively for the 14 day window. The highest percentiles correspond to relatively short-lived increases in turbidity/sedimentation, while the lower percentiles correspond to sustained (but temporary) increases.

The spatial percentile exceedance dredging impact plots are presented in tandem with the equivalent modelled ambient baseline percentile statistics, calculated as the average over all 14 day windows during the simulation period. This allows the increases in turbidity/sedimentation due to dredging activities to be seen relative to the modelled ambient conditions.

Key features of the moving window percentile analysis include:

- Consideration of a range of impact durations from short to long term
- Can be applied to a long term program and capture periods of high intensity versus low intensity impacts
- A similar analysis applied to the baseline data can quantify the ambient conditions, including natural variability across different periods. This can be used to derive meaningful thresholds for the potential water quality impacts.

The 13 months of Project EIS baseline turbidity monitoring were analysed to derive contour limits for the presentation of the percentile impact plots that are meaningful at specific sites. It should be noted that different thresholds (and therefore different contour limits) are appropriate for the different percentiles.

8.6.3 Water quality zones of impact

8.6.3.1 Background and methodology

Port of Gladstone specific threshold values were developed to assess potential impacts to marine water quality and marine ecological values. These impact predictions are presented as 'zones of impact' as per the Commonwealth EIS Guidelines, and are derived using the percentile exceedance plots described in Chapter 7 (coastal processes and hydrodynamics) and Appendix G. The zones of impact, which are generally based on dredging environmental assessment guidelines produced by the Western Australian Environmental Protection Agency (WA EPA) (2011), include:

- Zone of high impact = Excess turbidity from dredging activities most likely to cause water quality to deteriorate beyond natural variation
- Zone of moderate impact = Excess turbidity from dredging activities likely to cause water quality to deteriorate beyond natural variation
- Zone of low impact = Excess turbidity from dredging activities may cause water quality to deteriorate beyond natural variation
- Zone of influence = Extent of detectable plume (as measured by instrumentation) but no predicted ecological impacts.

A conceptual design of the zones of impact are shown in Figure 8.4, and a schematic representation of the impact zones are shown in Figure 8.5. The zone of low impact is included within the zone of influence in Figure 8.4 and Figure 8.5.

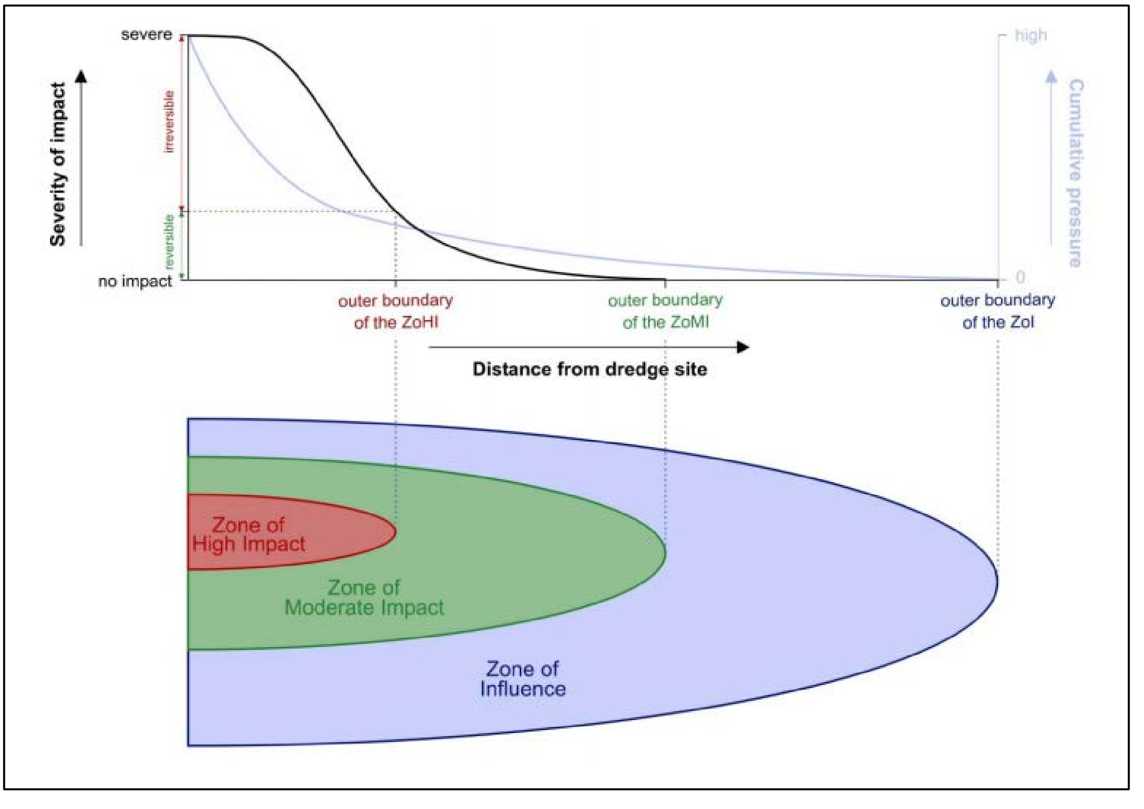

Figure 8.4 **Concept design of impact zones**

Source: WA EPA (2011)

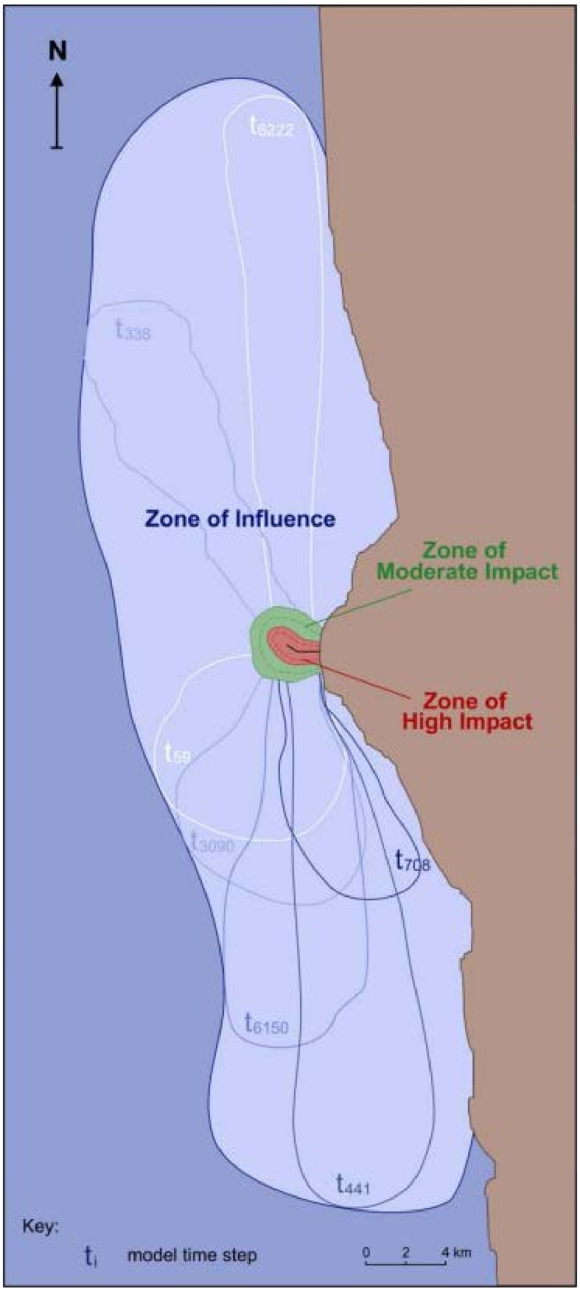

Figure 8.5 **Schematic representation of spatially based impact zonation scheme for representing dredging-related impacts**

Source: WA EPA (2011)

To determine the threshold values to delineate the zones of impact, a combination of referential and biological tolerances methods were used. This entailed using baseline water quality monitoring data to set initial threshold values (referential method). These values were then compared to biological tolerances from literature values as a ‘reality check’ to see if the threshold values are biologically meaningful.

8.6.3.2 Baseline water quality data

As described in Section 8.5, continuous turbidity data (and other parameters) were collected over a 13 month period (May 2014 to June 2015) at eight sites. The monitoring sites within the outer harbour (CD2, CD4 and CD5) and open coastal waters (CD1) were grouped as they exhibited similar turbidity, while the inner harbour monitoring sites (CD3, P5, P2B and QE3) were kept separate, as described in Table 8.11.

Table 8.11 Marine water areas for input into zones of impact

Marine area	EIS baseline water quality monitoring site	EPP (Water) Gladstone Harbour zones
1	C1, C2, C4 and C5 (outer harbour) (surface and benthic)	Outer harbour Queensland open coastal waters
2	CD3	Mid harbour (south)
3	P5/MH10 (surface)	Mid harbour (north) Inner harbour
4	P2B/WB50 (surface)	Western Basin
5	QE3 (surface)	The Narrows

Turbidity followed patterns previously established in historical monitoring programs (VE 2013a; VE 2013b). This was confirmed by mean seasonal turbidity values being generally within the 20th and 80th percentile WQOs, established for each EPP (Water) Gladstone Harbour Zone (EHP 2014).

The 13 month monitoring data set underwent a quality control process whereby data points that were obviously not valid (due to fouling or other malfunction) were removed.

Further information in regard to the 13 month Project EIS baseline water quality monitoring program is provided in Appendix H1.

8.6.3.3 Threshold values

As the long term data shows variability in turbidity among sites during the same time period, site-specific thresholds were deemed more appropriate than a 'one size fits all' approach. To determine initial impact threshold values, the 13 month Project EIS baseline water quality monitoring data set was analysed and percentile curves were produced. These percentile curves provide an indication of magnitude of turbidity and combined duration/frequency metrics for a range of conditions.

The 13 month Project EIS baseline data was analysed over a moving 14 day window period to give a range of percentile values over different periods. The 14 day window period is somewhat arbitrary but in a physical hydrodynamic context represents the approximate duration of two consecutive spring-neap tidal cycles, while in an ecological context it is a meaningful timescale for assessing impacts to some key sensitive receptors in the area (i.e. dominant seagrass *Halolphila ovalis*) (refer Appendix I1). The 14 day moving window analysis was undertaken by moving the 14 day window by 5 day increments over the entire monitoring period (approximately 77 different 14 day periods). This method provides an indication of natural variability around each percentile value and provides context for excess turbidity from dredging.

As an example, Figure 8.6 shows the percentile curves for data collected at site P2B/WB50. This shows the natural variability measured around the median (50th percentile) and other percentile values. The x-axis in Figure 8.6 represents the different percentile values extracted from the moving 14 day window analysis from frequently exceeded on the left to rarely exceeded on the right. The different curves are statistics representing the variability of the turbidity percentiles across the different 14 day periods (making up the 13 month baseline monitoring period). The lower curve represents the least turbid conditions during any window within the 13 month period, while the upper limit is the result for the windows with the most turbid conditions. The solid red line is the mean of the different 14 day window conditions.

Percentile curves for all monitoring sites are included in Appendix G, and summary statistics of the monitoring data is included in Appendix H1.

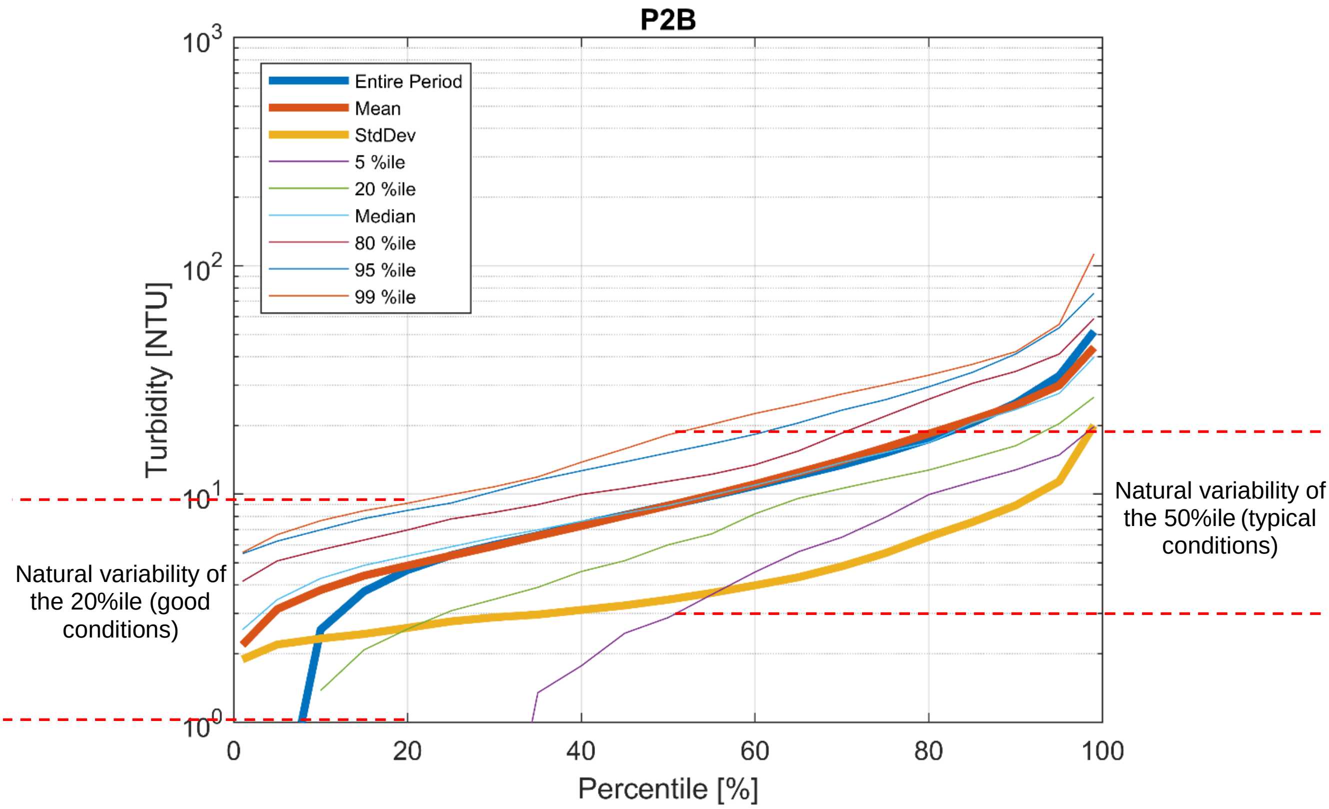

Figure 8.6 Example summary analysis of baseline data for Site P2B

Threshold values were derived from these percentile curves based on the natural variability around the 50th percentile (average conditions), 20th percentile (good conditions – neap tides/low winds and waves) and the 80th percentile (poor conditions – spring tides/moderate to high wind and waves). Therefore, this method considers both short term and sustained impacts.

A description of the threshold values for the three zones of impact and how they relate to the natural variability is provided in Table 8.12. The approach used to determine the threshold levels involve using the standard deviation from the natural background mean at each percentile (i.e. 20th, 50th and 80th percentiles). This is a similar approach developed by Orpin et al. (2004) to assess impacts from construction-related turbidity increases in Townsville. Orpin et al. (2004) suggested using one standard deviation from ambient conditions as a possible conservative upper limit of an acceptable increase in turbidity. Orpin et al. (2004) noted that the standard deviation of natural turbidity levels was considered to be a reasonable and convenient envelope within which an allowable construction-related increase could occur. If construction-related turbidity (such as from dredging) remained within one standard deviation, Orpin et al. (2004) suggested it would not be detectable over and above the natural variability. Extending this method out, threshold levels for the 'zone of medium impact' and the 'zone of high impact' were determined using two and three standard deviations from the mean. These levels were also tested against biological tolerance literature values (refer Section 8.6.3.4)

The 'zone of influence' was defined as the probable maximum extent of detectable plumes due to the proposed dredging. Turbid plumes were assumed to become detectable once they were approximately 20% to 30% above background conditions.

Table 8.12 Description of impact assessment threshold values

Zone of impact	Definition	Methodology
Zone of high impact	Excess turbidity from dredging activities most likely to cause water quality to deteriorate beyond natural variation	Excess turbidity greater than three standard deviations from the natural background mean at each percentile (i.e. 20^{th}, 50^{th} and 80^{th} percentiles)
Zone of medium impact	Excess turbidity from dredging activities likely to cause water quality to deteriorate beyond natural variation	Excess turbidity greater than two standard deviations from the natural background mean at each percentile (i.e. 20^{th}, 50^{th} and 80^{th} percentiles)
Zone of low impact	Excess turbidity from dredging activities may cause water quality to deteriorate beyond natural variation	Excess turbidity greater than one standard deviation from the natural background mean at each percentile (i.e. 20^{th}, 50^{th} and 80^{th} percentiles)
Zone of influence	Extent of detectable plume (as measured by instrumentation) but no predicted ecological impacts	Turbidity-related to dredging activities exceeds: ▪ 0.5 NTU above 50^{th} percentile conditions ▪ 2 NTU above 80^{th} percentile conditions ▪ 5 NTU above 95^{th} percentile conditions ▪ 10 NTU above 99^{th} percentile conditions

The output from the analysis of data using referential methods were impact threshold values for each impact zone at each monitoring site. These values represent turbidity above background levels, and are included in Table 8.13. It should be noted that with the use of these impact threshold values, an assumption has to be made in regard to what constitutes ‘background turbidity’. For the purposes of this impact assessment, background turbidity is assumed to be the mean turbidity of background data at each percentile.

It should be noted that these threshold values have been developed for impact assessment purposes only and have not been directly utilised in determining Project water quality trigger values during the establishment of the WBE reclamation area and Project dredging.

Table 8.13 Impact threshold values (above background) for each water quality monitoring site

Impact zone	Description	Method	Percentile	Descriptor	Water quality monitoring site							
					CD1	CD2	CD3	CD4	CD5	P2B	P5	QE3
					Turbidity threshold values (NTU) - above background							
Zone of high impact	Excess turbidity *most likely* pushes total turbidity beyond natural variation	3 x standard deviations from 20th percentile mean	20th percentile	Exceeded 80% of the time	4	5	6	4	2	8	3	12
		3 x standard deviations from 50th percentile mean	50th percentile	Exceeded 50% of the time	7	7	9	5	4	10	5	13
		3 x standard deviations from 80th percentile mean	80th percentile	Exceeded 20% of the time	12	12	16	8	8	20	13	20
Zone of moderate impact	Excess turbidity *likely* pushes total turbidity beyond natural variation	2 x standard deviations from 20th percentile mean	20th percentile	Exceeded 80% of the time	3	3	4	3	2	5	2	8
		2 x standard deviations from 50th percentile mean	50th percentile	Exceeded 50% of the time	5	5	6	4	3	7	4	9
		2 x standard deviations from 80th percentile mean	80th percentile	Exceeded 20% of the time	8	8	10	5	6	13	8	13
Zone of low impact	Excess turbidity *may* push total turbidity beyond natural variation	One standard deviation from 20th percentile mean	20th percentile	Exceeded 80% of the time	1	2	2	1	1	3	1	4
		One standard deviation from 50th percentile mean	50th percentile	Exceeded 50% of the time	2	2	3	2	1	3	2	4
		One standard deviation from 80th percentile mean	80th percentile	Exceeded 20% of the time	4	4	5	3	3	7	4	7
Zone of influence	Full extent of detectable plumes (including resuspension)	Dredging-related turbidity exceeds 0.5 NTU	50th percentile	Exceeded 50% of the time	0.5							
		Dredging-related turbidity exceeds 2 NTU	80th percentile	Exceeded 20% of the time	2							
		Dredging-related turbidity exceeds 5 NTU	95th percentile	Exceeded 5% of the time	5							
		Dredging-related turbidity exceeds 10 NTU	99th percentile	Exceeded 1% of the time	10							

Table 8.14 includes the biological tolerance literature values for seagrass in the Gladstone region.

As the seagrass tolerances are expressed as light requirements, the relationship between BPAR and turbidity (refer Appendix G) was used to convert light requirements to turbidity.

Further to the conservative nature of the literature values, it is acknowledged (including by regulators and scientists) that there are uncertainties regarding the responses of seagrass to high turbidity values, which is used here as a proxy for light. Therefore, the biological tolerance literature values are only used as a means for cross-checking potential ecological relevance of changes to turbidity values.

8.6.3.4 Biological testing of zones of impact

To determine the zones of impact the site-specific threshold values from the Project baseline water quality monitoring were interpolated spatially across the study area producing three-dimensional (3D) threshold grids. These threshold grids were then analysed against the 3D model output grids using GIS mapping software. This produced impact zone maps which illustrate predicted areas where modelled turbidity (ambient and dredging activity) is higher than the relevant turbidity threshold value for a specific zone of impact.

Seagrass light thresholds

The initial water quality zones of impact have been tested utilising biological tolerances for Port Curtis seagrass meadows. Based on the Port Curtis seagrass surveys and monitoring undertaken by JCU TropWater over the last five years, the seagrass light thresholds relevant for inclusion into the biological threshold testing are summarised in Table 8.14.

Table 8.14 Light thresholds for seagrass species within Port Curtis

Impact zone	Referential (water quality)	Biological tolerances for seagrass
Zone of high impact	Excess turbidity *most likely* to cause total turbidity to go beyond natural variation Threshold value = excess turbidity greater than three standard deviations from the natural background mean	*Zostera muelleri* subsp. *capricorni* – 14 day rolling average of < 6 mol photons m^{-2} day^{-1} over 28 days *Halodule uninervis* – 14 day rolling average of < 5 mol photons m^{-2} day^{-1} over 40 days *Halophila* spp. – 7 day rolling average of < 2 mol photons m^{-2} day^{-1} over 14 days
Zone of moderate impact	Excess turbidity *likely* to push total turbidity beyond natural variation Threshold value = excess turbidity greater than two standard deviation from the natural background mean	*Zostera muelleri* subsp. *capricorni* – 14 day rolling average of < 6 mol photons m^{-2} day^{-1} over 21 days *Halodule uninervis* – 14 day rolling average of < 5 mol photons m^{-2} day^{-1} over 21 days *Halophila* spp. – 7 day rolling average of < 2 mol photons m^{-2} day^{-1} over 10 days
Zone of low impact	Excess turbidity *may* push total turbidity beyond natural variation Threshold value = excess turbidity greater than one standard deviation from the natural background mean	*Zostera muelleri* subsp. *capricorni* – 14 day rolling average of < 6 mol photons m^{-2} day^{-1} *Halodule uninervis* – 14 day rolling average of < 5 mol photons m^{-2} day^{-1} *Halophila* spp. – 7 day rolling average of < 2 mol photons m^{-2} day^{-1}
Zone of influence	Extent of detectable plume (as measured by instrumentation) but no predicted ecological impacts. Observed change in background light threshold but above threshold.	**Seagrass** *Zostera muelleri* subsp. *capricorni* – 14 day rolling average of > 6 mol photons m^{-2} day^{-1}, however less than ambient *Halodule uninervis* – 14 day rolling average of > 5 mol photons m^{-2} day^{-1}, however less than ambient *Halophila* spp. – 7 day rolling average of > 2 mol photons m^{-2} day^{-1}, however less than ambient

Table note:

mol photons m^{-2} day^{-1} = moles of light per square metre per day

For each of the baseline water quality monitoring sites located on or in close proximity to seagrass meadows, the site-specific turbidity thresholds for the zone of influence and the three water quality zones of impact are converted into BPAR (using the correlation between turbidity, depth and light) and added to the baseline/ambient BPAR. The BPAR over a 7 or 14 day rolling average (dependent on the dominant seagrass species (refer Table 8.14)) is shown graphically over time (i.e. hydrodynamic modelling timescale).

Coral sedimentation thresholds

Factors which influence the level of impact on corals from sedimentation include the duration and intensity of the event, as well as the particle size of the sediment being deposited. Significantly high increases in sedimentation over extended periods (weeks) have been shown to cause more stress and mortality than over short periods of time (days) (Gilmour et al. 2006). At low rates of sedimentation on corals can remove sediment through active short term defences (e.g. mucus production, ciliary movement). During periods of continual exposure passive mechanisms (e.g. morphology, skeletal structure) may be employed (Stafford-Smith 1993). While fine sediment particles are easier to remove than course particles, fine sediment can often be associated with elevated organic nutrient content leading to tissue necrosis and/or mortality (Stafford-Smith 1993; Weber et al. 2006).

Several coral reef communities survive in environments which experience considerable natural variability in background turbidity and sedimentation rates due to sediment resuspension as a result of metocean conditions, including tides, wind, waves, storms, cyclones, tsunamis and floods (Erftemeijer et al. 2012). Inshore coral reef communities such as those located around Port Curtis generally experience naturally higher and more variable turbidity, and generally have greater tolerance to elevated turbidity and sedimentation deposition rates than offshore reef communities in clearer waters (Erftemeijer et al. 2012; Gilmour et al. 2006; McCook et al. 2015).

Current literature suggests there is a knowledge gap in the means to accurately measure net sediment deposition rates within sensitive ecosystems over appropriate timeframes which limits the understanding of sediment dynamics generally and dredging impacts specifically (McCook et al. 2015). In general, there is a lack of understanding on coral responses to sediments during events of varying intensity and duration, and how species specific sediment tolerances translate through to the community scale (Browne et al. 2015). Published thresholds for daily sedimentation rates range from 10 to 300mg/cm^2/day (Rogers 1990; Bak and Elgershuizen 1976). Rogers (1990) proposed a threshold for sedimentation for healthy reefs at 10mg/cm^2/day and moderate to severe effects on corals would occur at 10 to 50mg/cm^2/day, with severe to catastrophic effects at > 50mg/cm^2/day.

During the 2013 flood event, investigations found that most Port Curtis reefs were likely to experience sedimentation rates of less than 50mg/cm^2/day and peak deposition rates would be less than 10mg/cm^2/day. This is likely due to the strong hydrodynamic forces throughout Port Curtis preventing deposition despite the relatively high TSS (BMT WBM 2015).

In 2010, sedimentation limits for coral were developed by DHI for the Wheatstone Project in the Pilbara, Western Australia. It has been acknowledged that coral communities on inshore reefs within the Pilbara, like Port Curtis, are able to withstand discrete pulses of relatively high sedimentation due to the capacity for sedimentation to vary dramatically over small spatial and temporal scales (DHI 2010). Sedimentation limits were developed based on the most sensitive coral species as a conservative approach.

The proposed sedimentation rates for the Project have been based on the rates developed for the Wheatstone Project (DHI 2010), given the similarities in coral reef communities and background sedimentation conditions. Proposed preliminary sedimentation tolerance limits for corals are shown in Table 8.15.

Table 8.15 Preliminary matrix of impact zones for net sedimentation rate on corals

Zones	Sedimentation ($mg/cm^2/day$)	Sedimentation (mm/14 days)*
No impact	< 2.5mg/cm^2/day	0.9mm/14 days
Zone of influence and zone of low impact	< 25 to 10mg/cm^2/day	0.9 to 3.5mm/14 days
Zone of moderate impact	< 10 to 50mg/cm^2/day	3.5 to 17.5mm/14 days
Zone of high impact	> 50mg/cm^2/day	17.5mm/14 days

Table note:

* Conversion from kg/m^2/day to mm/14 days assumes an initial deposition dry density of 400kg/m^3

Source: DHI (2010)

The values detailed above apply to net sedimentation rates above ambient conditions. Sedimentation generated by the Project has been applied to the sediment plume model results from the initial dredging works, and Stage 1 and Stage 2 dredging campaigns. A density of 400kg/m^3 has been used to convert between the two measures to represent the layer thickness (i.e. mm/14 days). DHI (2010) proposed 400kg/m^3 as a conservative estimate of density for sedimentation during the initial deposition phase. DHI (2010) note that the period of 14 days is a biologically relevant duration, as most 'coral species are able to actively or passively reject sedimentation in the short term' but 'would experience stress or some level of impact if sedimentation continued consistently across a 14 day spring-neap cycle'. For more information on sedimentation and dredging impacts on coral reefs refer to Section 9.9.

The hydrodynamic modelling time series plots for points on or near sensitive coral communities have been used in the coral impact assessment and as an input into the development of the Project Environmental Monitoring Procedure and associated adaptive mitigation strategies to be implemented during the establishment of the WBE reclamation area and Project dredging. The sedimentation time series plots are provided in Appendix H2.

Biological testing (seagrass)

To test whether the zones of impact developed using turbidity thresholds in Table 8.14 are biologically meaningful, the turbidity thresholds were added to actual BPAR monitoring data (June 2014 to May 2015) for an intertidal site containing coastal seagrass and monitored by JCU TropWater. The sites include Pelican Banks South and Wiggins Island. Data from subtidal sites where coincident turbidity and BPAR data was collected (i.e. sites CD1 to CD5), along with surface PAR data, were used to develop a light attenuation coefficient (Kd) for the study area. This Kd value was used to convert turbidity to BPAR and vice versa at the intertidal seagrass sites.

The aim of undertaking this analysis was to assess the amount of BPAR available to this seagrass area if additional turbidity as per the turbidity impact thresholds was added to the measured PAR data. To achieve this, the time series BPAR was converted to time series turbidity using the light attenuation/turbidity correlation developed for the study area. Once the additional turbidity was added onto this time series it was converted back to BPAR using the same light attenuation/turbidity correlation.

The aim was to simulate a hypothetical scenario whereby a dredger would be operating with turbid plumes being created at these threshold values (note that in reality, a dredger would not be operating for this entire period). An outcome of this analysis, for example, should be that PAR available to seagrass after adding the low impact turbidity threshold should only result in predicted low impacts and not moderate or high impacts.

The 50^{th} percentile threshold values for site P5 (near to Pelican Banks) and P2B (near to Wiggins Island) from Table 8.13 were used in this analysis as this allowed a relatively simple addition of excess turbidity to the time series PAR data.

Two week rolling averages of the derived PAR data are presented in Figure 8.7, which also shows baseline monitoring data (actual recorded data). As *Zostera muelleri* subsp. *capricorni* is the dominant seagrass species found in these intertidal areas, the results were compared to the biological tolerances for *Zostera muelleri* subsp. *capricorni* in Table 8.13. The results indicate that:

- Using the low impact zone threshold (2-3 NTU), BPAR would remain above the *Zostera muelleri* subsp. *capricorni* light requirement at both sites, except for a short periods of time less than 14 days duration.
- Using the moderate impact zone threshold (4-7 NTU), there would be periods over 21 days at both sites when BPAR would be below the *Zostera muelleri* subsp. *capricorni* light requirement. However, BPAR would also remain above the light requirement for extended periods, especially during the seagrass growing season (July to December).
- Using the high impact zone threshold (5-10 NTU), the BPAR at both sites would mostly remain below the *Zostera muelleri* subsp. *capricorni* light requirement for longer than 28 days – this would potentially result in loss of seagrass at these sites (as expected of this zone).

Therefore, based on this analysis, the zones of impact derived using the turbidity threshold values in Table 8.13 are considered to be suitable for impact assessment purposes.

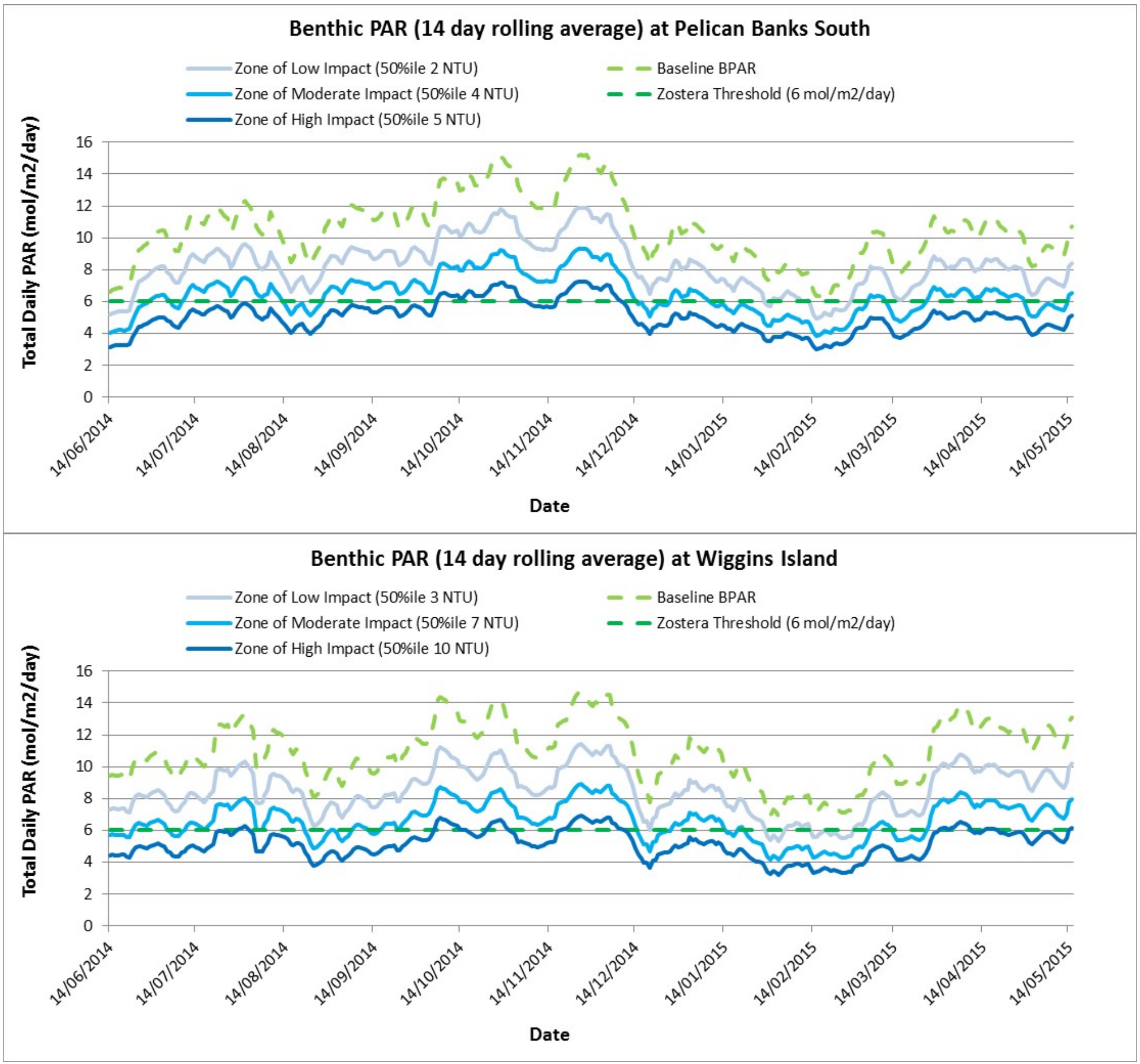

Figure 8.7 **Total daily PAR (mol/m2/day as 14 day rolling average) at Pelican Banks South (top) and Wiggins Island (bottom) showing baseline (actual monitoring data) and addition of impact zone thresholds**

Biological testing (corals)

The modelled impact to the 50th percentile deposition rate (refer Figure 8.21) is below the thresholds adopted for impacts to corals (refer Table 8.15).

Time series plots were also developed for sedimentation at coral reef sites to confirm the appropriate nature of the modelled results for impacts on corals. Six coral sites were chosen and reviewed to confirm the adequacy of the modelled results. The detailed time series plots are available in Appendix H2. All sites are predicted to be within the low impact zone, and the predicted sedimentation rates at all sites are well below 10mg/cm^2/day for both the base case and developed case. The biological testing at the six sites confirms that the zone of low impact is an appropriate zone for these locations.

8.6.3.5 Zones of impact mapping

Zones of impact have been developed for seagrass and corals based on the methodology above and were interpolated spatially across the study area to produce 3D threshold grids. These threshold grids were then analysed against the 3D model output grids using GIS mapping software. This produced impact zone maps which indicate areas where modelled turbidity is higher than the relevant impact threshold value. The impact zone map for the 'base case' is shown in Figure 8.8, with impact zones briefly described as:

- Zone of influence – full extent of detectable plume, but no ecological impacts.
- Zone of low impact – water quality may be pushed beyond natural variation potentially resulting in sub-lethal impacts to ecological receptors.
- Zone of moderate impact – water quality is likely be pushed beyond natural variation potentially resulting in some mortality with recovery < 12 to 24 months.
- Zone of high impact – water quality is very likely to be pushed beyond natural variation potentially resulting in mortality of ecological receptors with recovery > 24 months.

The estimated zones of impact for the Stage 1 and Stage 2 dredging are shown in Figure 8.9 and Figure 8.10, respectively.

8.6.4 Establishment of the Western Basin Expansion reclamation area and barge unloading facility

8.6.4.1 Bund wall material placement and barge unloading facility construction

This section outlines the potential water quality impacts associated with the establishment of the WBE reclamation area outer bund walls and the BUF.

Establishment of the WBE reclamation area will be undertaken over a three year period and will involve the placement of core material directly over existing sediments and seagrass areas, followed by armour material being placed along the outer bund wall exposed face. The construction activities associated with the establishment of the reclamation area have the potential to impact the water quality of downstream receiving environments (i.e. Port Curtis and nearby tributaries).

As the rock which forms the bund wall is placed directly onto the soft sediments of the seabed during construction, soft sediments will be mobilised into the water column and will also be pushed out the front and sides of the bund wall. This is likely to result in the generation of a small, but at times visible plume. Any sediment disturbed by the construction of the bund wall that deposit over the seagrass meadows and/or seabed will be remobilised and transported away from the tidal flats again during tidal movement and elevated wave action.

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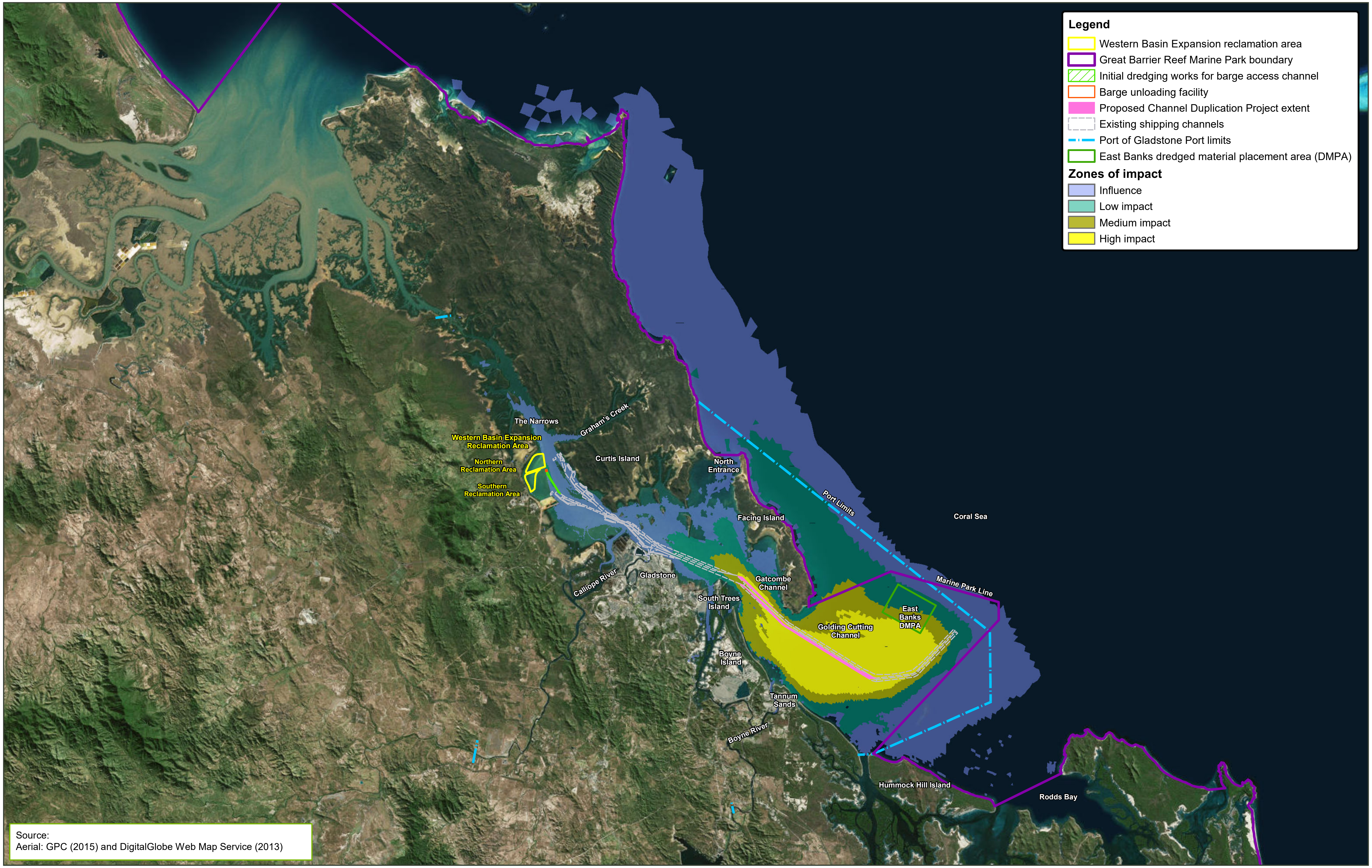

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 8.8: Water quality zones of impact (Stages 1 and 2 dredging)

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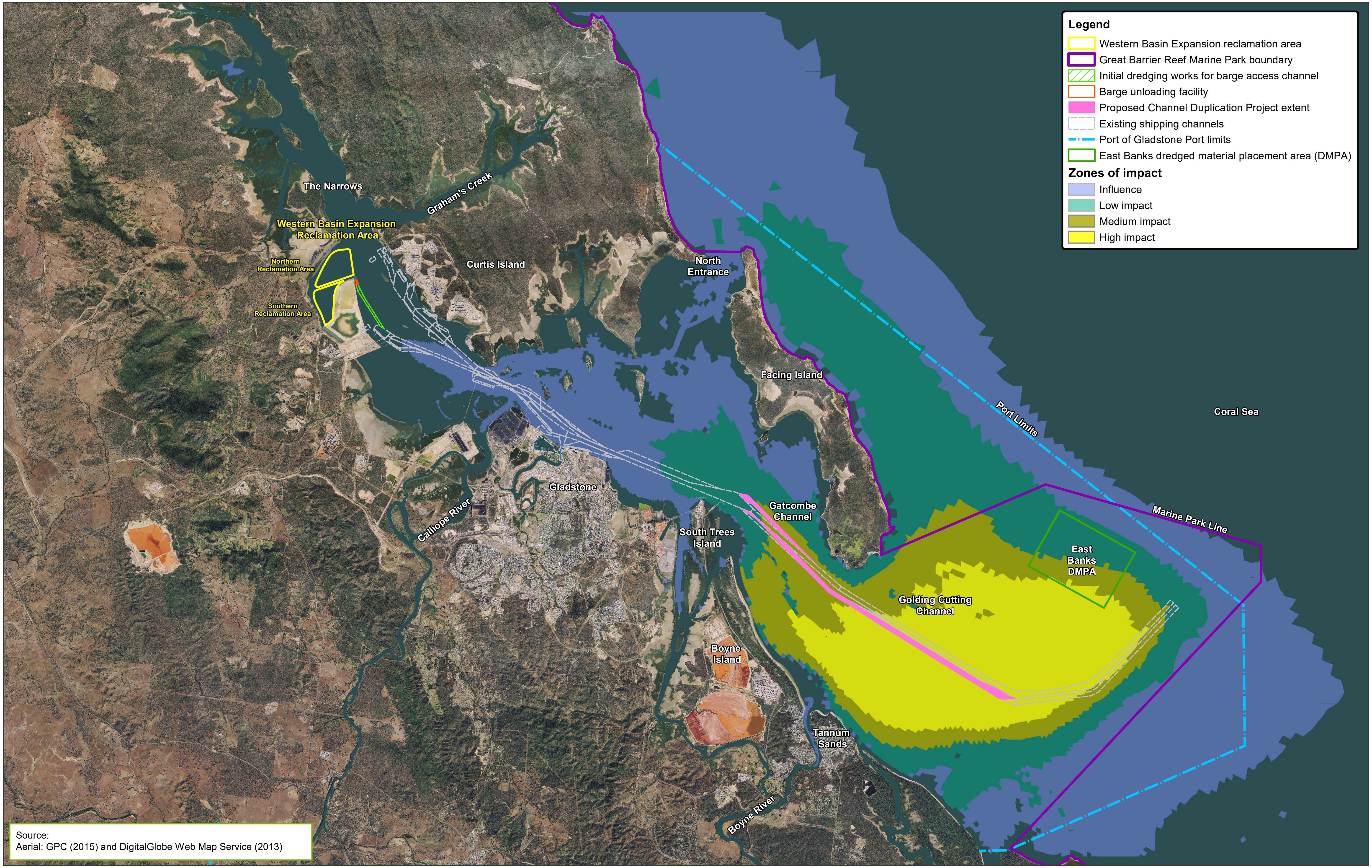

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 8.9: Water quality zones of impact (Stage 1 dredging)

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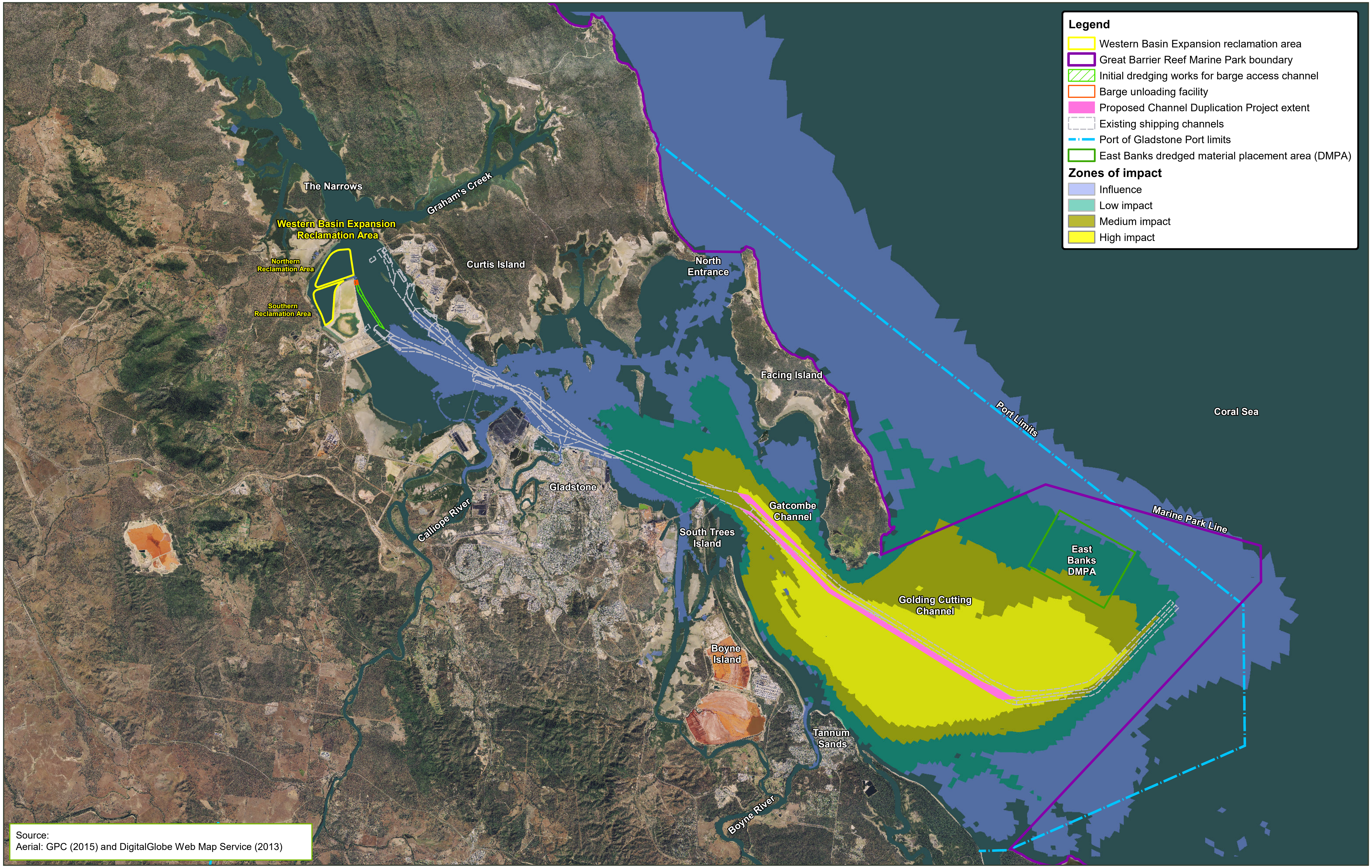

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Gatcombe and Golding Cutting Channel Duplication Project

Figure 8.10: Water quality zones of impact (Stage 2 dredging)

The mobilisation of soft sediment will be limited to the first layer of rocks after which any additional rock for that section will be placed on top of the initial rock layer and not the soft seabed sediments. Therefore, the generation of plumes through the placement of rock is likely to be a relatively short term impact.

Following the completion of the bund wall, the inner face will be lined with a geotextile fabric prior to dredging activities commencing. This will act as a filter layer to minimise the migration of fines through the bund wall into surrounding waters.

The construction of the BUF will involve the installation of sheet piles or similar earth retaining structure to form a ‘U shaped’ barge dock adjacent to the existing WB reclamation area. The footprint within the enclosed sheet pile or similar earth retaining structure will be filled with material to allow excavators and trucks to transport dredged material from the barges into the existing WB and WBE reclamation areas.

Two short rock bunds made up of core material and protected with armour sourced will be installed between the sheet pile or similar earth retaining structure dock and the existing WB reclamation area bund wall. The footprint within the rock bunds and sheet pile walls or similar earth retaining structure will be filled with material from within the existing WB reclamation area to allow excavators and trucks to travel between the BUF and the existing WB reclamation area.

The potential impacts to water quality through a release of sediment laden runoff and/or contaminants during the establishment of the WBE reclamation area and BUF will be generally restricted to a contained area and within the medium term, therefore moderate in magnitude.

Impacts from PASS will monitored by measuring pH (refer Section 5.6.1), although sediment samples have indicated the risk of this is low (refer Section 5.5).

It should be noted that the areas of Port Curtis, Rodds Bay and the northern end of The Narrows are commonly described as having naturally high background turbidity and that any short term decline in water quality as a result of the establishment of the WBE reclamation area is unlikely to elevate above the background level ranges, post implementation of mitigation measures.

There is the potential for spillage (either minor, through drips or major through leaks/accidents) of oils and fuels from construction equipment to impact on marine water quality. Small hydrocarbon or other chemical leaks have the potential to result in short term impacts, however larger spills have longer lasting impacts, not only to water quality but also impact on marine life (refer Chapter 9 (nature conservation)).

The independent review of the WBDDP bund wall (Commonwealth of Australia 2014) identified concerns regarding (refer Appendix D):

- Confidence in the water quality monitoring plan and applicable trigger levels
- Baseline data not considering the tidal implications to water quality
- Location of monitoring sites
- How and where different conditions from different approvals will be addressed.

To ensure that the findings and recommendations of this review have been addressed, long term baseline monitoring was undertaken for the Project in multiple locations to provide confidence in the data and trigger levels proposed, and continuous monitoring data was collected and assessed to ensure that tidal influences were also considered. The implementation of the Project Environmental Monitoring Procedure (refer Appendix Q3) during Project activities will ensure that all water quality monitoring requirements for all Project activities are contained in one document and can be regularly updated when required.

8.6.4.2 Impacts of reclamation area on coastal processes and hydrodynamics

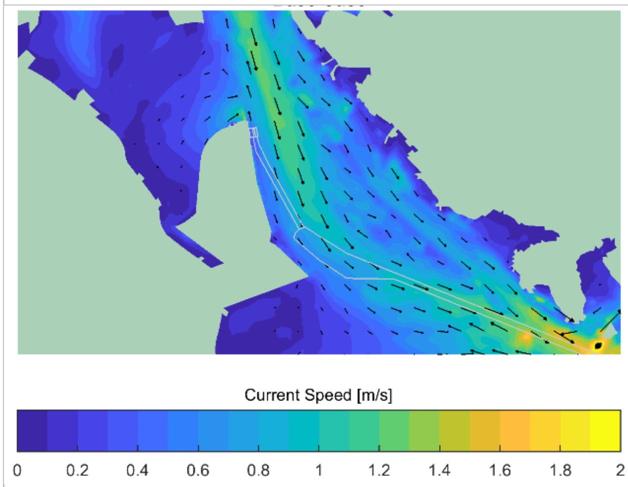
This section outlines the potential impacts of the WBE reclamation area and BUF on the hydrodynamics and flushing efficiency of the area. Changes to hydrodynamics (water level and current speed) can affect turbidity via resuspension. Changes to the flushing efficiency has the potential to modify the water quality because of differences with coastal oceanic exchange. Therefore the Project impacts to hydrodynamics and flushing have an influence on water quality within the vicinity of the WBE reclamation area and BUF.

Velocity impacts

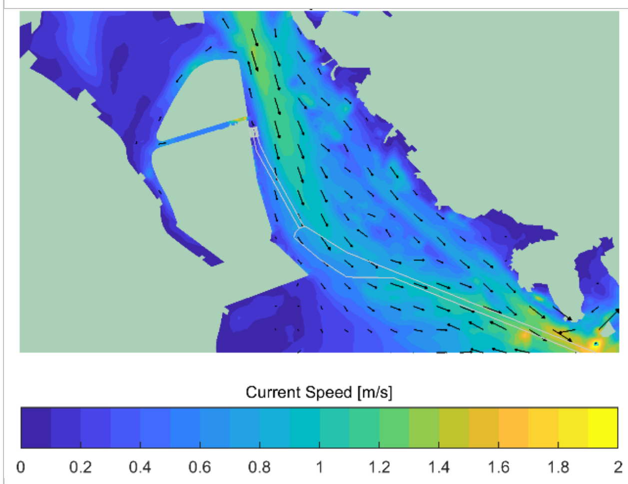
The full construction of the proposed WBE reclamation area would create an additional reclamation area to the north of the existing WB reclamation area and the proposed southern WBE reclamation area, and leave a narrow channel (~250m) along the existing shoreline and between the two reclamation areas (~100m) to allow for tidal flushing.

To illustrate the change in velocities, the maximum spring tide flood and ebb velocities were extracted for each point in the model domain during a 2 month simulation period. Figure 8.11 shows the peak ebb tide velocity patterns and magnitudes for the Base Case and the Project Channel Geometry Case, and the difference between them. Figure 8.12 shows the peak flood tide impacts. The model results indicate that there would be a reduction in velocity magnitudes immediately adjacent to the BUF and along the face of the northern part of the proposed WBE reclamation area. There would also be some increases in velocity magnitudes in the channels adjacent to the new reclamation areas.

Base Case



Project Channel Geometry Case



Difference

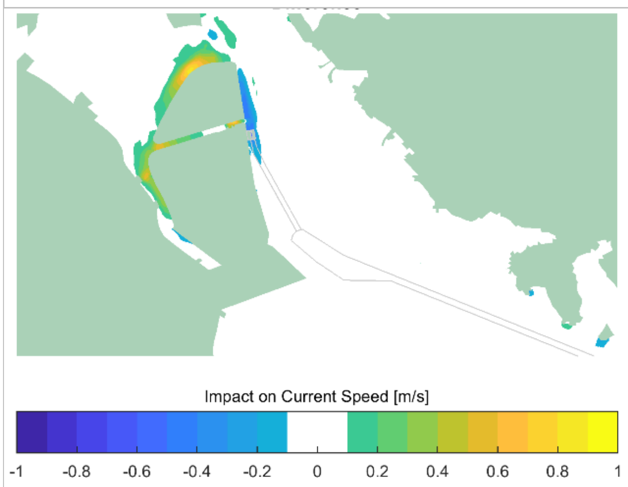
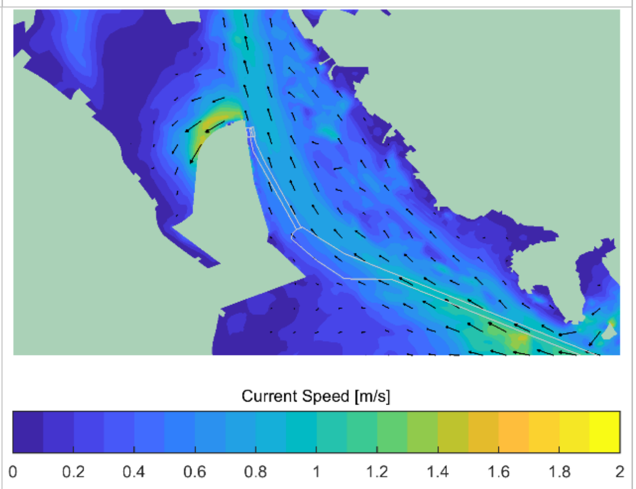
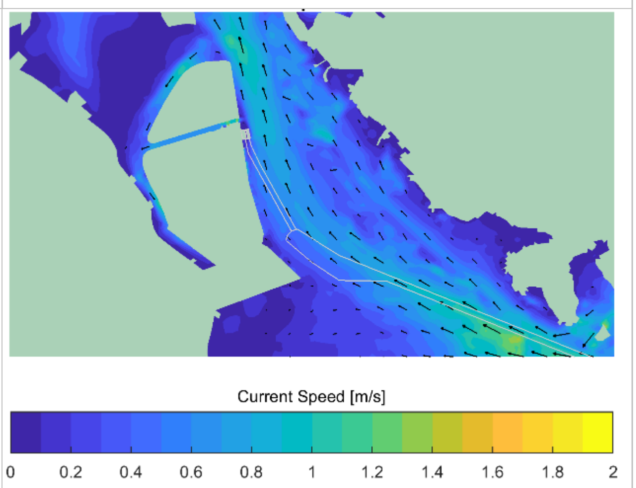


Figure 8.11 Ebb tide peak spring velocity

Base Case



Project Channel Geometry Case



Difference

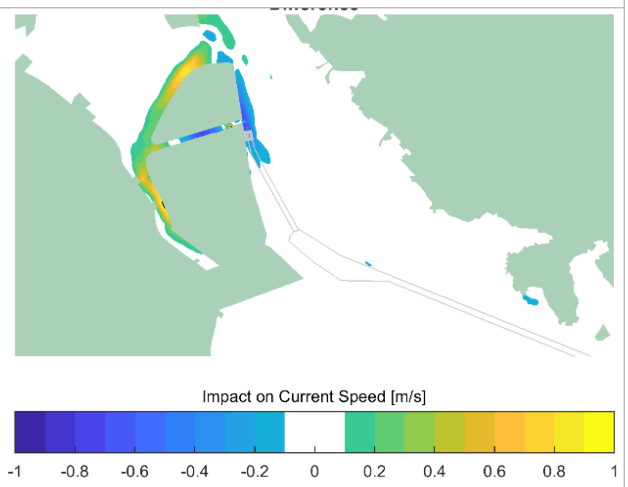


Figure 8.12 Flood tide peak spring velocity

Figure note: The bottom two figures have a different scale to the above figures.

The impact on water quality caused by hydrodynamic changes through the establishment of the WBE reclamation area and BUF, will only be short term as the channels surrounding the area create a new equilibrium environment. Turbidity and pH will be measured to monitor the potential impacts of the construction of the WBE reclamation area and BUF (refer Appendix Q3). This monitoring program will be finalised prior to the commencement of any works.

Wave climate

The effect of the proposed reclamation area was assessed by analysing the modification in the spatial distribution of wave height and direction in the vicinity of the WBE reclamation area and BUF using the numerical SWAN wave model. Analysis of the full 12 months of wave model results indicates that the dominant wave direction is from the east, and the area that is shielded from wave activity by the proposed reclamation area is relatively small.

The construction of the southern reclamation area eliminates the wave activity that currently occurs behind the existing WB reclamation area (during high tide periods when the area is inundated), however this is a sheltered area so the expected influence on the shoreline coastal processes is negligible.

Again, the model showed that the construction of the WBE reclamation area and BUF results in a reduction in wave heights along the shoreline adjacent to the reclamation (during high tide periods when the area is inundated). This reduction in wave height will reduce the amount of resuspension of sediments into the water column from this area.

At the same time there is an increase in current magnitudes in the channel between the shoreline and the reclamation areas. This is likely to cause an adjustment in the morphology of the channel. Figure 8.13 illustrates the difference between typical wave pattern for the Base Case and Project Channel Geometry Case.

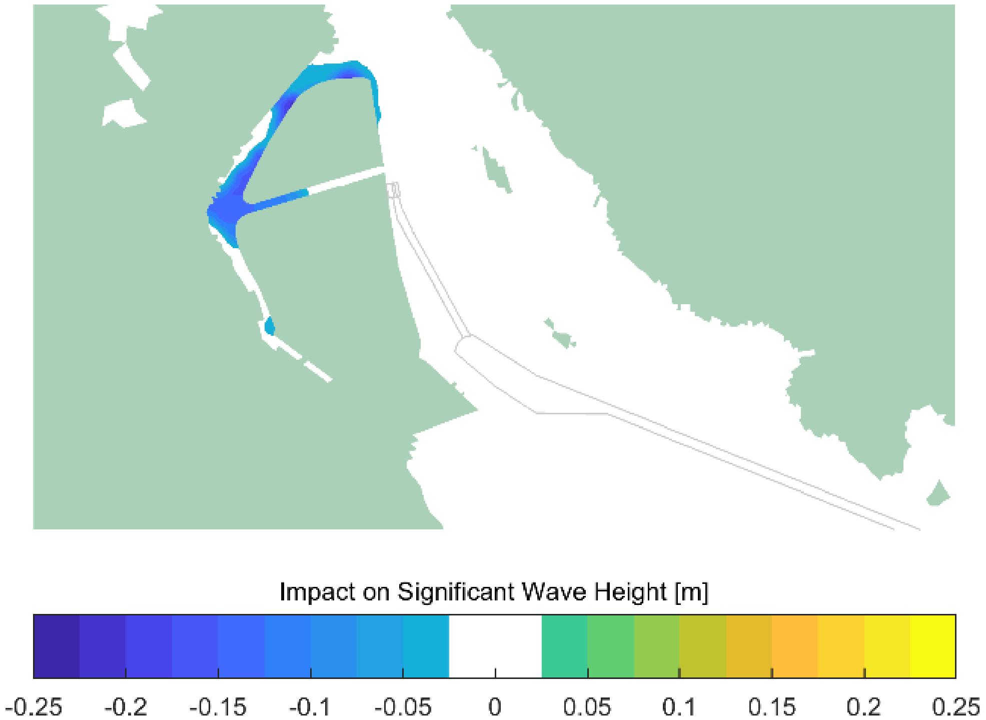


Figure 8.13 **Difference in the typical spatial wave height and direction distribution between the Base Case, and the Project Channel Geometry Case at high tide**

Erosion and siltation

The calibrated TUFLOW FV model was used to investigate the sediment dynamics of the Port for each of the assessment scenarios. The cohesive sediment transport module was used to simulate the ambient turbidity in the water column for the full 12 month assessment period. Sediment exchange with the seabed was modelled (deposition and resuspension), and included the influence of both wave and current generated bed shear stresses.

Figure 8.14 illustrates the modelled change to the annual siltation/erosion rate for the Base Case and the Project Channel Geometry Case (i.e. the expected change in the siltation/erosion rate due to construction of the WBE reclamation area). The model indicates the potential for some erosion in the channels surrounding the new reclamation areas. This erosion would continue (provided the bed material is erodible) until the channel reaches a new equilibrium depth. Note that this means that the predicted rates of erosion in the channels would not be sustained long term, since the bed morphology would adjust to the new regime and net erosion and accretion will trend towards zero as a new equilibrium profile is obtained. A monitoring program will be implemented to manage any observed impacts in the channels and along the shoreline adjacent to the new reclamation area.

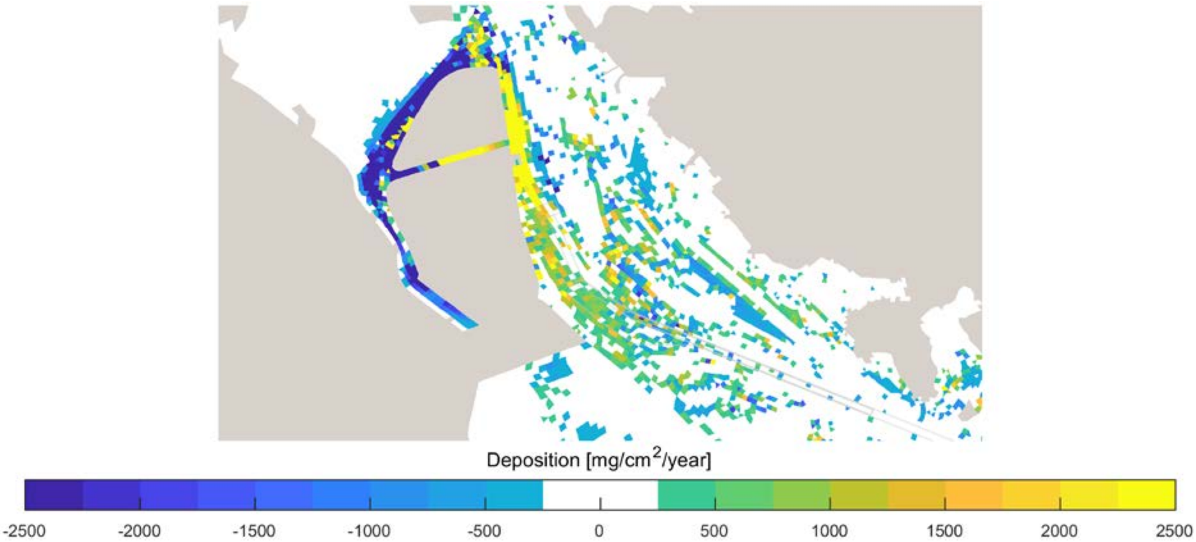


Figure 8.14 **Annual siltation rates and erosion areas near the Western Basin Expansion reclamation area due to the Project**

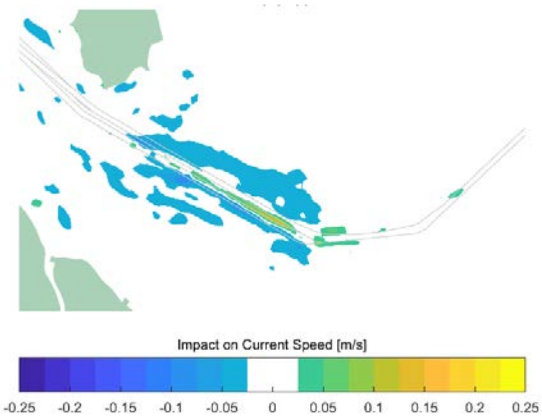
8.6.5 Established duplicated shipping channel

8.6.5.1 Velocity impacts

The TUFLOW FV model was used to investigate velocity changes due to the proposed dredging of the Gatcombe and Golding Cutting shipping channels to a bed elevation of -16.1m LAT. The model results indicate some slight reductions in velocity outside the channel in some areas, due to the reduced tidal prism, and within the duplicated channel there are increases in some areas and decreases in others. None of the predicted velocity impacts are significant in magnitude in the context of the existing velocity magnitudes.

The model results indicate that the channel duplication will have no effect on water levels within the Port and therefore a negligible impact on water quality.

Figure 8.15 (left) shows the peak ebb tide velocity patterns and magnitudes for the Base Case and the Project Channel Geometry Case, and the difference between them. Figure 8.15 (right) shows the peak flood tide impacts.



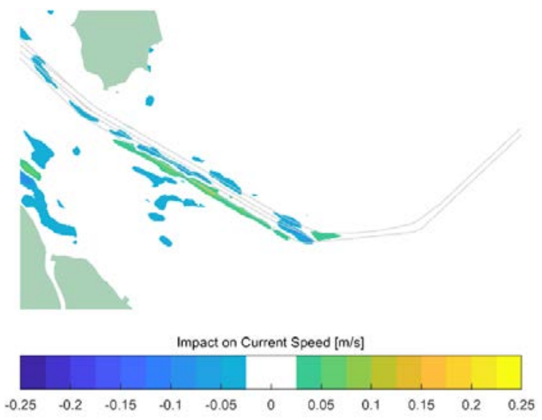


Figure 8.15 **Net difference in peak spring velocities in the ebb tide (left) and flood tide (right) for the Project Channel Geometry Case compared to the Base Case**

8.6.5.2 Wave climate

Figure 8.16 shows difference between the wave pattern for the Base Case and the Ultimate Channel Geometry Case. It is apparent that the deepening of the channels causes some additional wave refraction for waves from the dominant incident direction (east). The model indicates a very slight reduction in wave height to the southwest of the duplicated channels. The model results indicate a corresponding slight increase in wave height within the duplicated channels.

The wave climate impacts at two locations (refer Figure 8.16) were assessed by analysing the full 12 months of wave model results. The difference between wave roses for the Base Case and the Project Channel Geometry Case at the acoustic Doppler current profiler (ADCP) 4 and CD3 are negligible. This indicates that there will be no change in wave climate at these locations and therefore no consequential change in wave-driven sediment transport on the adjacent coastline. No discernible impacts on water quality are predicted due to changes in wave climate associated with the final Project profile of the duplicate channels.

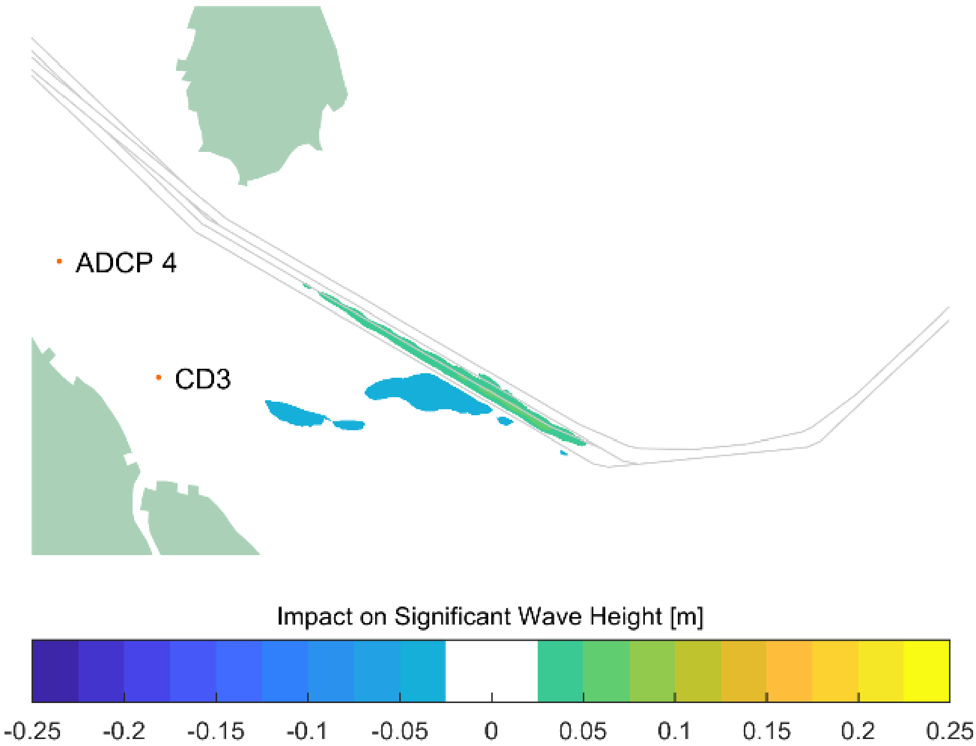


Figure 8.16 **Net difference between typical spatial wave height direction distribution for the Base Case and the Project Channel Geometry Case**

8.6.5.3 Siltation

The calibrated TUFLOW FV model was used to investigate the sediment dynamics of the Port for each of the assessment scenarios. The cohesive sediment transport module was used to simulate the ambient turbidity in the water column for the full 12 month assessment period. Sediment exchange with the seabed was modelled (deposition and resuspension), and included the influence of both wave and current generated bed shear stresses.

The model results indicate an increase in siltation in the Golding Cutting duplicated channel, due to a reduction in velocity caused by the increased water depth. Analysis of the modelling results indicates that the overall net annualised siltation rate within the shipping channels of the Port is likely to increase by approximately 7% following the duplication of the Gatcombe and Golding Cutting Channels. Figure 8.17 illustrates difference in the modelled annual siltation/erosion rate for the Base Case and the Project Channel Geometry Case (i.e. the expected change in the siltation/erosion rate due to change in bathymetry associated with the duplicated channels).

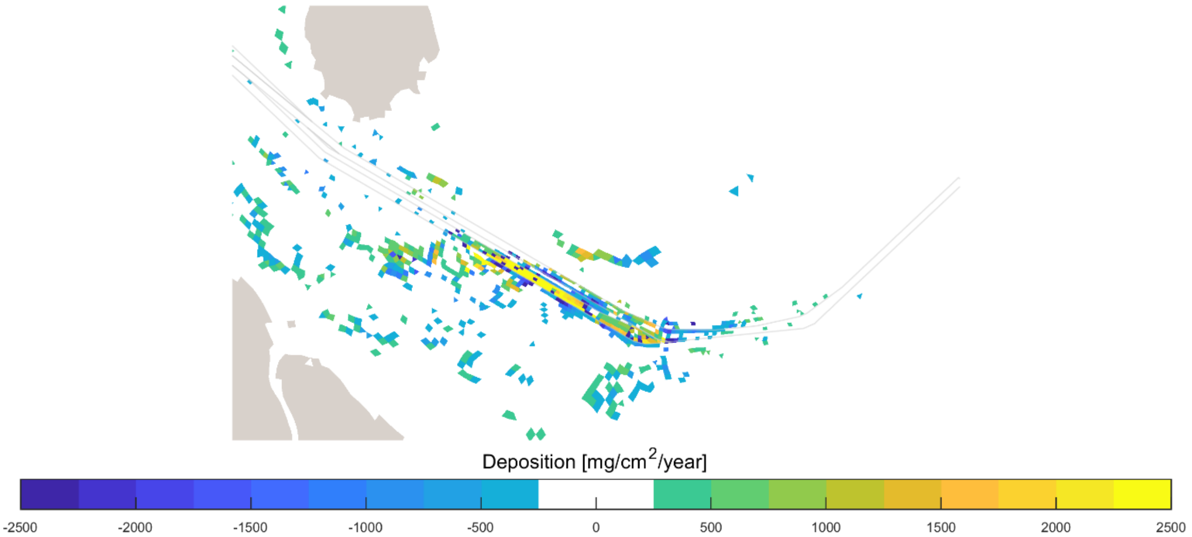


Figure 8.17 Impact on the annual net siltation/erosion rate between the Base Case and the Project Channel Geometry Case

8.6.6 Impacts of dredging activities and dewatering

8.6.6.1 Complete dredging program scenario

Modelling results

The overall Project capital works program scenario modelled the expected operations for all three components of the dredging program in series (i.e. initial dredging works, Stage 1 and Stage 2).

Figure 8.18 to Figure 8.21 give an overall indication of the spatial distribution of the predicted Project dredging impacts of the dredging program in its entirety. These figures show percentiles (depth-averaged turbidity) and deposition rate due to dredging overall of the 14 day windows during the campaign throughout the model domain.

These figures give an overall indication of the spatial distribution of dredging impacts characteristic of the dredging program in its entirety, including all sources of suspended sediment. The average change in the turbidity percentiles was calculated for each stage of the dredging campaign, and the overall impact at each location in the model was taken as the largest predicted impact from any of the Project stages. These impact figures are used as the basis for derivation of the zones of impact/influence results.

Percentiles of the bottom 1m turbidity from the dredging campaign are provided in Appendix G (Section 5.4).

Example time series of turbidity (dredging-related and total (including background) at five of the EIS water quality monitoring sites (sites CD1 to CD5), illustrate the relative contribution of dredging-related resuspension to the turbidity level in offshore areas (refer Appendix H2).

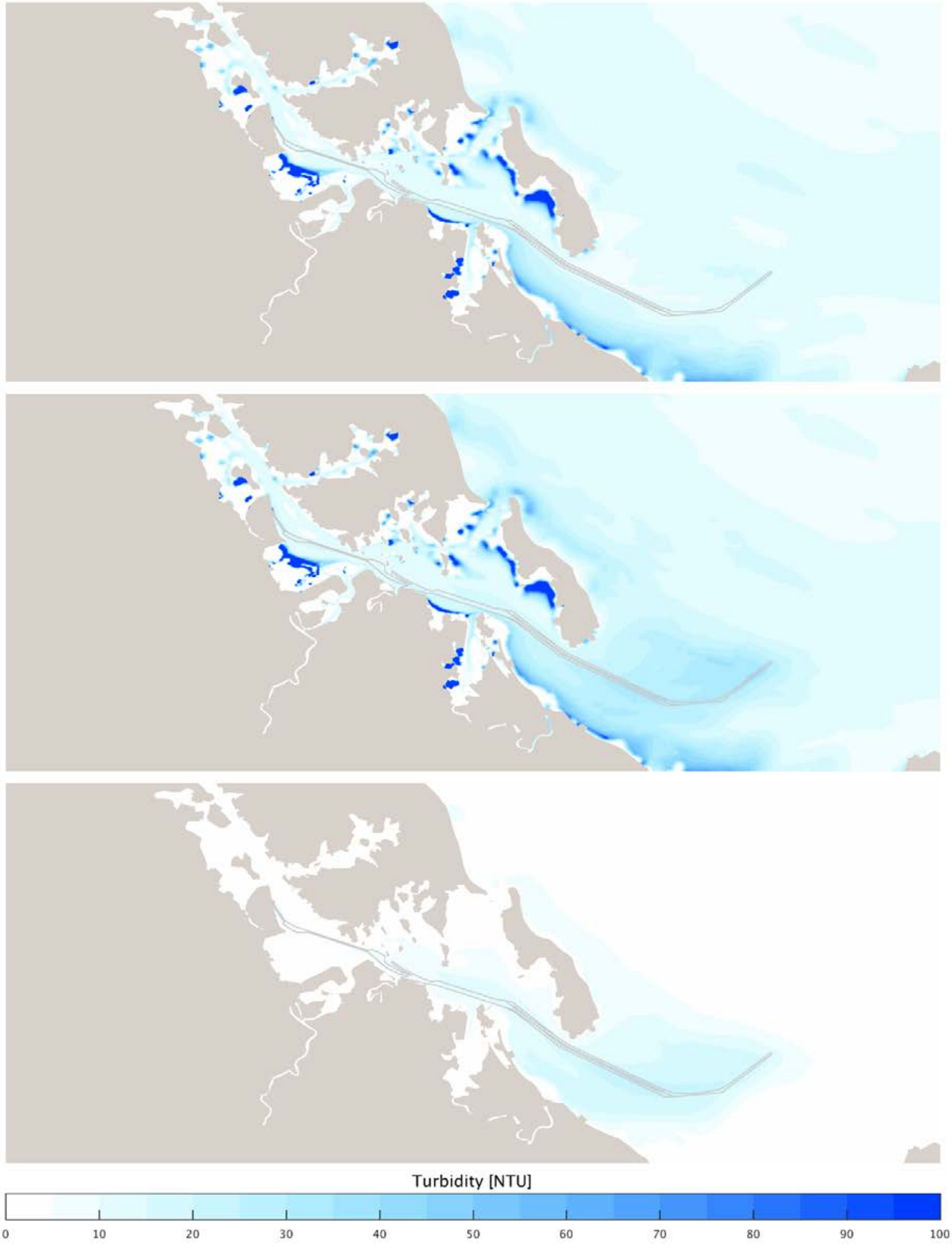


Figure 8.18 **95th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) overall dredging campaign**

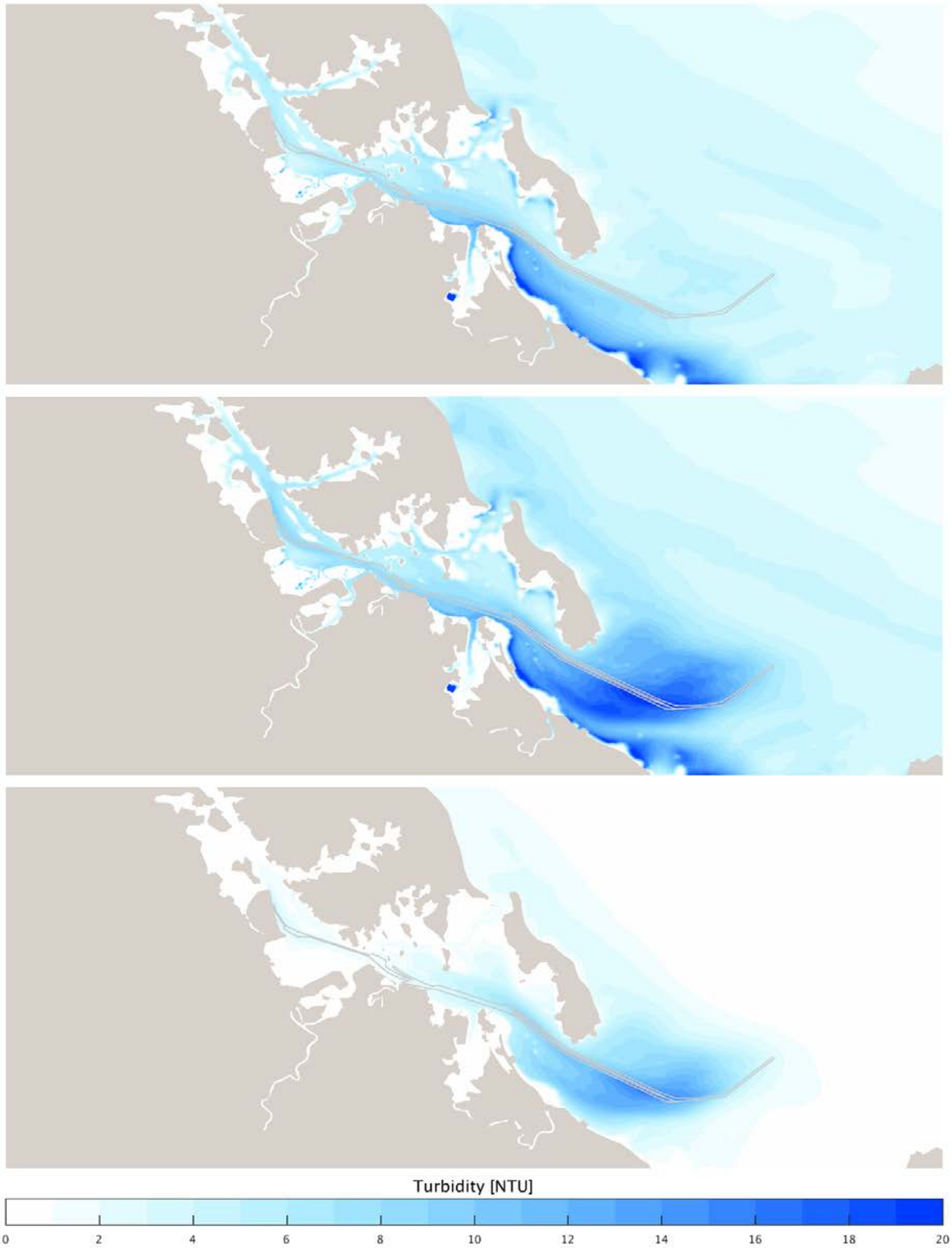


Figure 8.19 **50th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) overall dredging campaign**

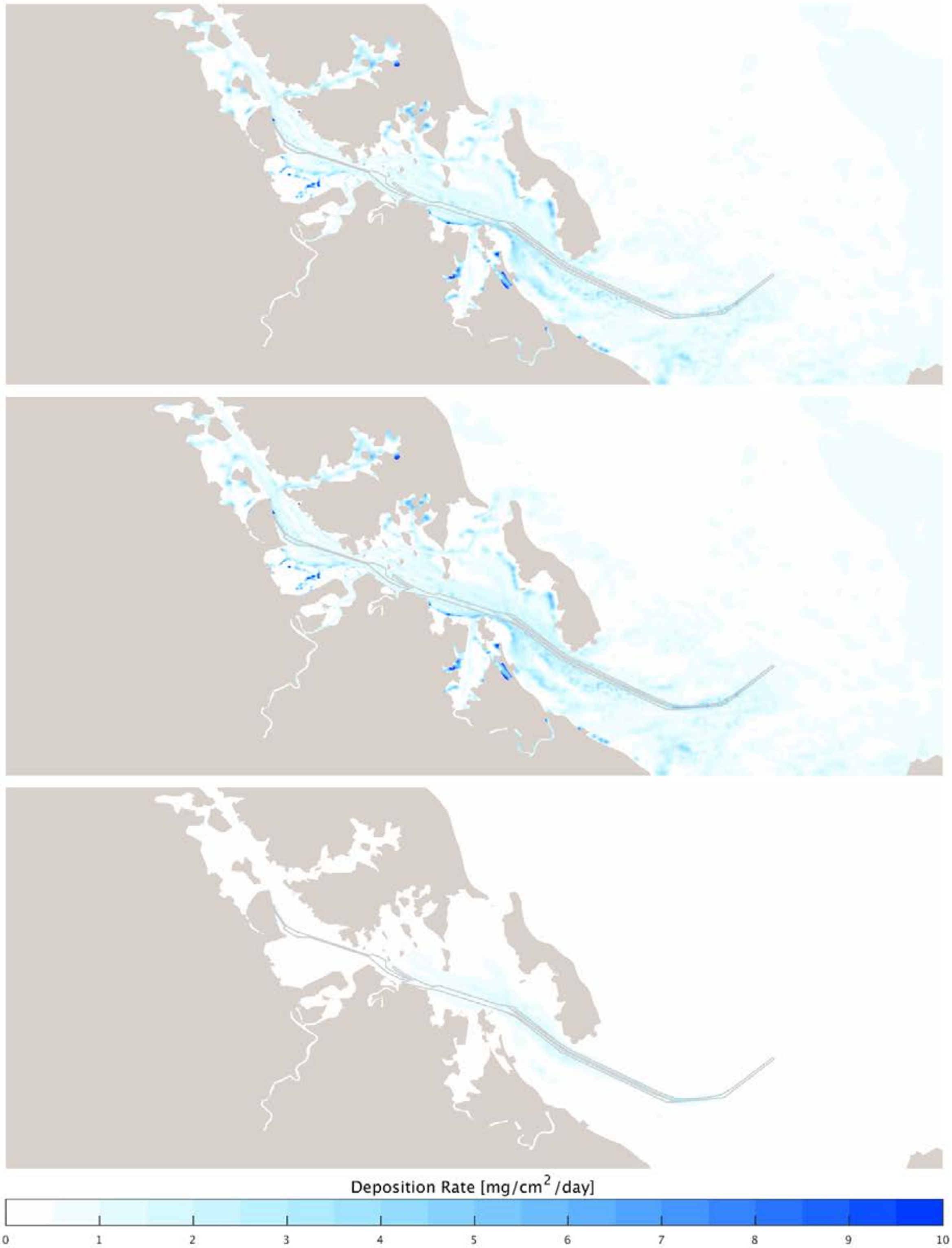


Figure 8.20 **95th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) overall dredging campaign**

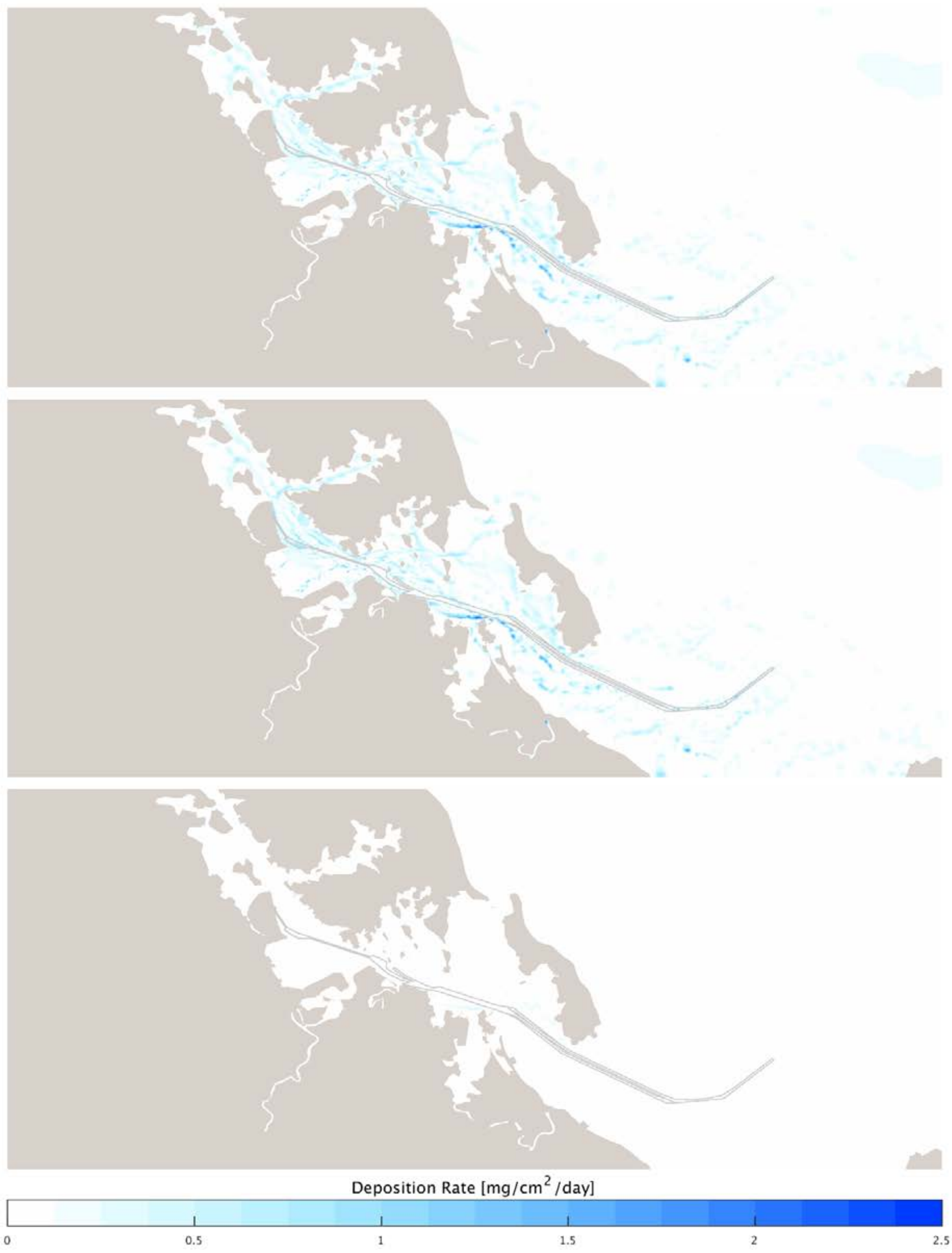


Figure 8.21 **50th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) overall dredging campaign**

It is important to note that the colours used to demonstrate the changes in the turbidity for the 95th percentile and 50th percentile plots use different scales, therefore the specific colour used in the figures do not represent the same level of turbidity for every modelled scenario (i.e. each figure needs to be interpreted with respect to the specific NTU scale colours given at the bottom of each figure).

The modelling results indicate that some short term impacts to turbidity levels (refer Figure 8.18) are expected throughout the Port area, with the highest increases in areas outside the Port where wave activity can resuspend existing sediment and dredged sediment after initial deposition. It is important to note that the ambient (background) turbidity level is high throughout the study area (refer top panel in Figure 8.18). The modelling results indicate minor sustained impacts (refer Figure 8.19) to the turbidity level within the Port, and higher sustained (but temporary) effects in the vicinity of the area to be dredged and further offshore (due to resuspension activity).

Modelling results also indicated a short term increase (refer Figure 8.20) in the deposition rate in a number of areas within the Port and also along the coastline to the north. With some minor sustained (but temporary) increases in the deposition rate are noted within the Port, with larger increases in the outer part of the shipping channel (refer Figure 8.21).

Zones of impact

Figure 8.8 indicates that the zone of influence (i.e. extent of detectable plumes but no ecological impact) extends from the dredging area northwards along the coastline adjacent to Facing Island and Curtis Island. The zone of influence is larger in the offshore area due to less turbid ambient conditions in this area (i.e. plumes are easier to detect above background).

At the areas to be dredged, the zone of high impact is within the immediate vicinity of the channel duplication dredging area and extends approximately 1km in a northwest direction of the Gatcombe Channel and approximately 2km southeast from the Golding Cutting Channel. The zone of high impact also extends 6 to 7km in both east and west directions from the Golding Cutting Channel (refer Figure 8.8).

The zone of low impact extends northwards along the coastline of Facing Island and into the central part of the Port. The largest impact is expected to occur immediately within and adjacent to the Gatcombe and Golding Cutting Channels (refer Figure 8.8).

It should be noted that the zones of impact only relates to potential impacts from suspended sediment in the water column.

To minimise potential water quality impacts during dredging activities the mitigation measures provided in Section 8.7 and the Project Environmental Monitoring Procedure will be implemented. The implementation of the adaptive strategies contained within the Procedure will ensure that the water quality of the Port and the outer harbour area is within acceptable levels to protect the marine flora and fauna values within the Project's zones of impact and zone of influence.

8.6.6.2 Worst case scenario

The 'worst case' assessment of potential impacts to turbidity and deposition rate was derived by calculating the highest modelled change in the turbidity and deposition rate percentiles over all of the 14-day assessment windows throughout the dredging campaign.

The top panel of Figure 8.22 shows the ambient (background) 95^{th} percentile turbidity throughout the model domain over the 14 day simulation period. The middle panel shows the total (ambient plus dredging) 95^{th} percentile turbidity throughout the model domain over the simulation period. The bottom panel shows the change in the 95^{th} percentile turbidity due to the dredging activity (indicating the impact to the turbidity level for 0.7 days out of the 14 day assessment window). The modelling results indicate a higher level of short term turbidity impacts in the outer parts of the shipping channel (than the 'expected case') and in some areas within the Port due to the high levels of resuspension of dredged sediment.

The top panel of Figure 8.23 shows the ambient 50th percentile turbidity throughout the model domain over the 14 day simulation period. The middle panel shows the total (ambient plus dredging) 50th percentile turbidity throughout the model domain over the simulation period. The bottom panel shows the change in the 50th percentile turbidity due to the dredging activity (indicating the impact to the turbidity level for 7 days out of the 14 day assessment window). The modelling results a higher sustained (but temporary) impact to turbidity levels in the vicinity of the dredging operation (relative to the 'expected case').

The top panel of Figure 8.24 shows the ambient 95th percentile deposition rate throughout the model domain. The middle panel shows the total (ambient plus dredging) 95th percentile deposition rate throughout the model domain. The bottom panel shows the change in the 95th percentile deposition rate due to the dredging activity (indicating the impact to the deposition rate for 0.7 days out of the 14 day assessment window). The modelling results indicate a short term increase in the deposition rate in a number of areas within the Port and also along the coastline to the north.

The top panel of Figure 8.25 shows the ambient 50th percentile deposition rate throughout the model domain. The middle panel shows the total (ambient plus dredging) 50th percentile deposition rate throughout the model domain. The bottom panel shows the change in the 50th percentile deposition rate due to the dredging activity (indicating the impact to the deposition rate for 7 days out of the 14 day assessment window). Some minor sustained (but temporary) increases in the deposition rate are noted within the Port.

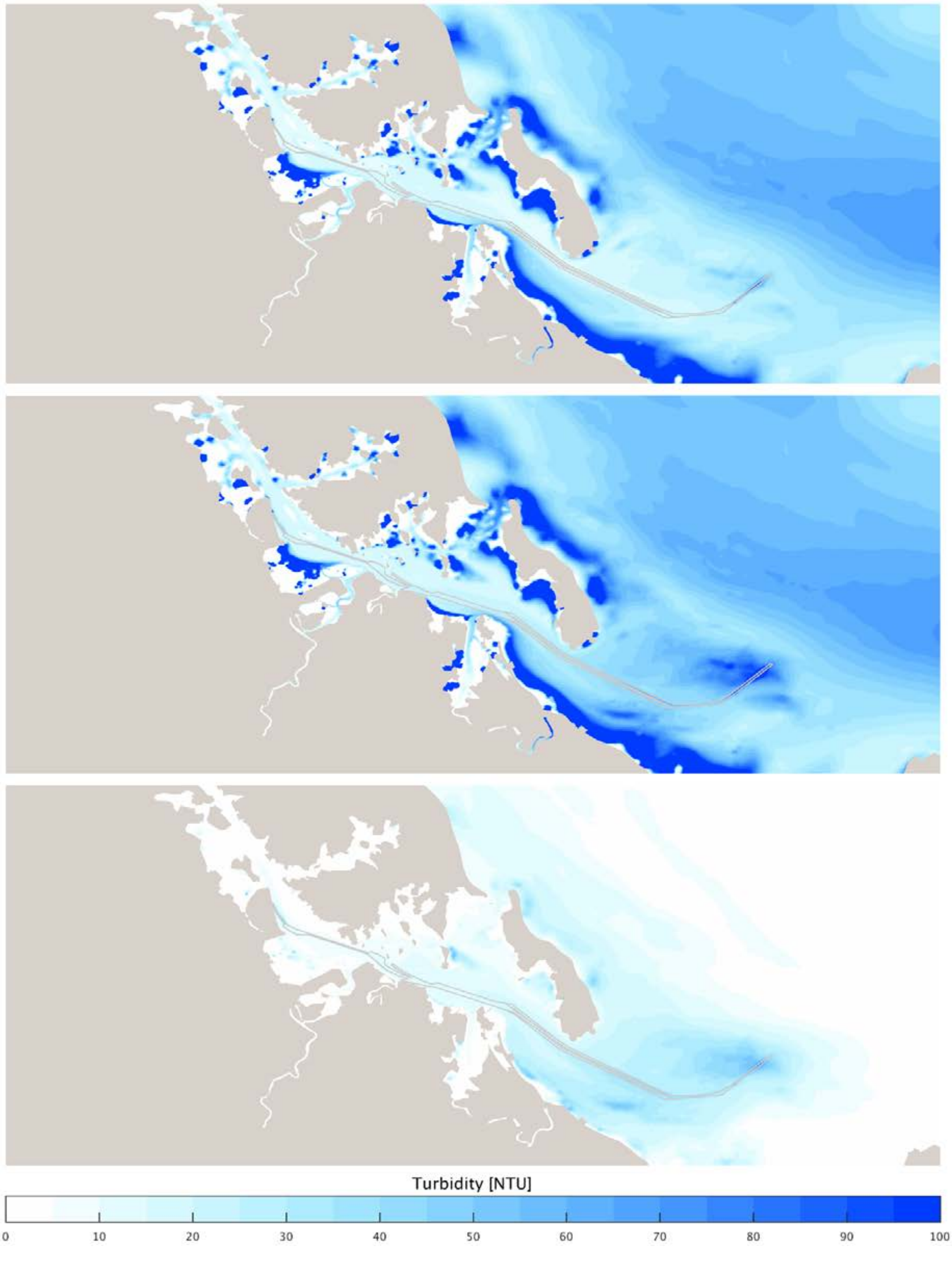


Figure 8.22 **95th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) 'worst case' simulation**

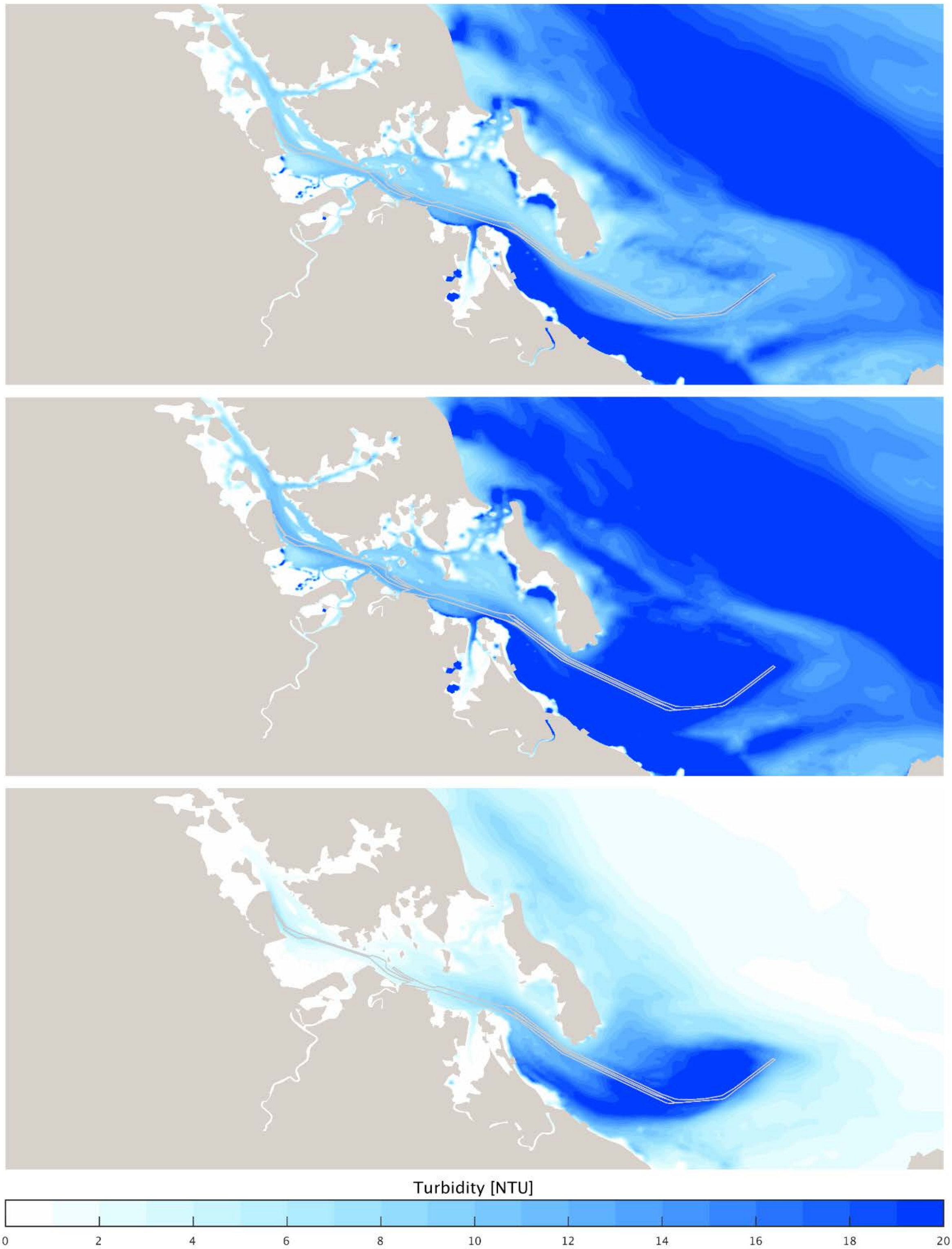


Figure 8.23 50th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) 'worst case' simulation

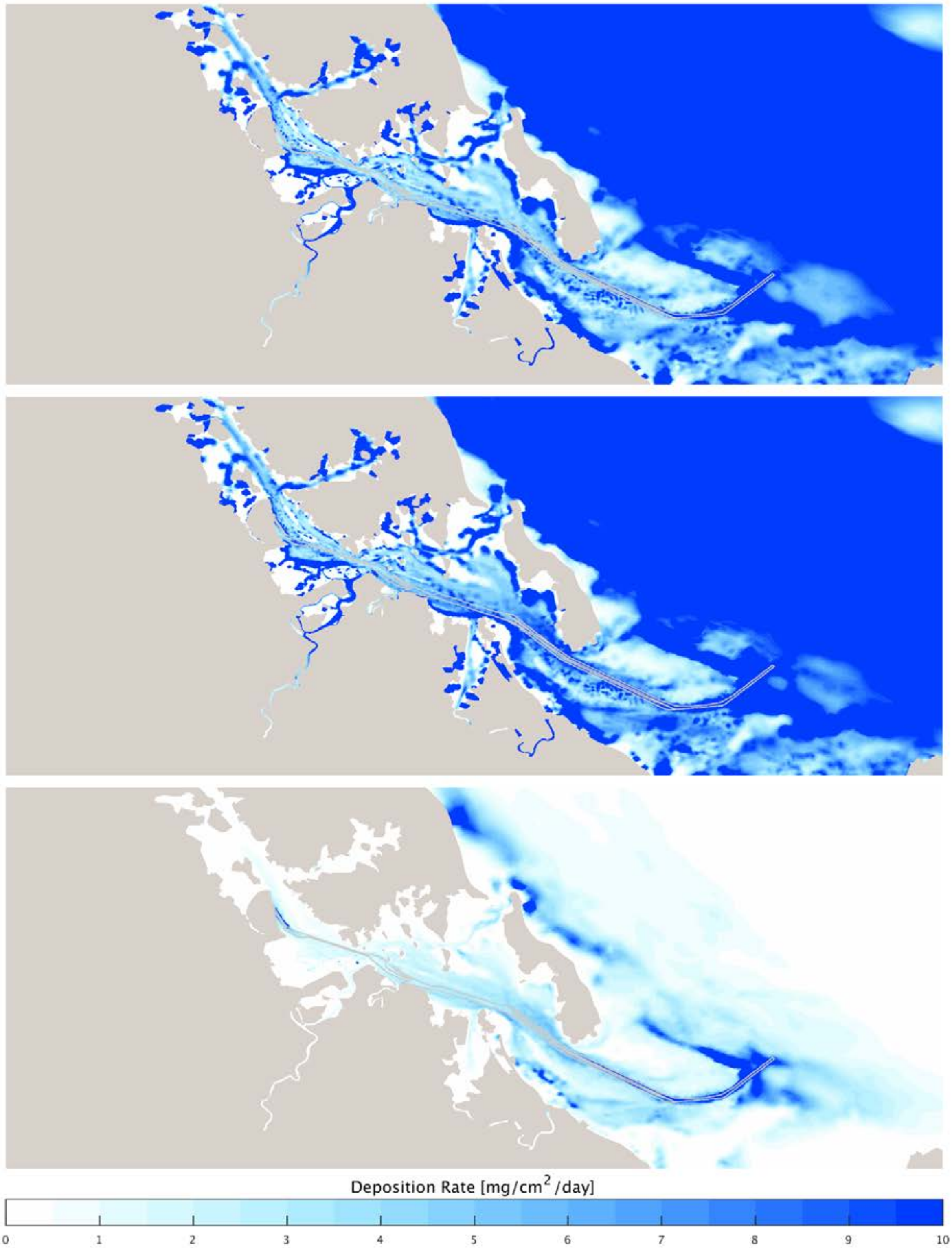


Figure 8.24 **95th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) ‘worst case’ simulation**

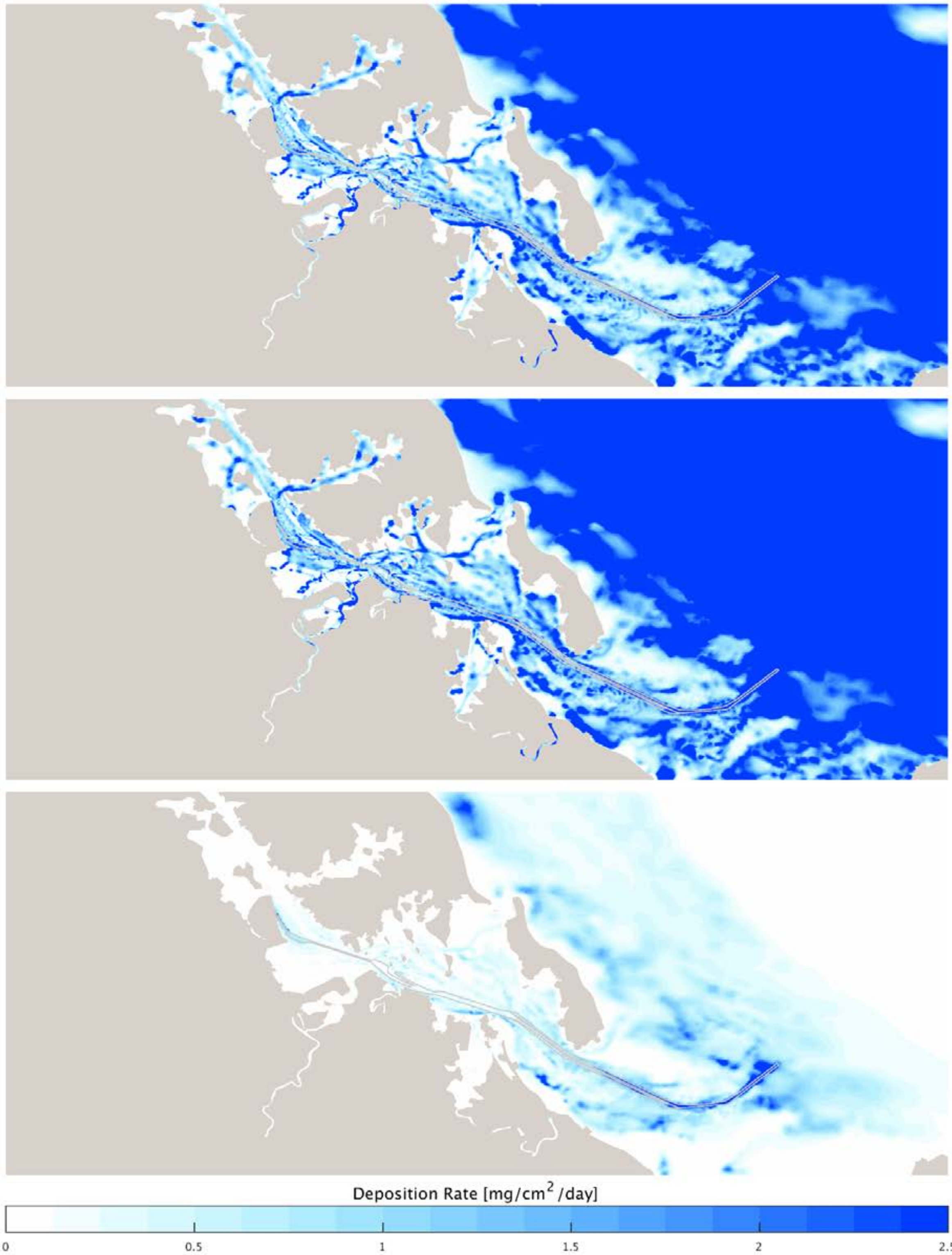


Figure 8.25 50th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) 'worst case' simulation

8.6.6.3 Cumulative case dredging scenario (maintenance dredging)

The model looked at the cumulative dredging (combining the capital dredging campaign with a Port-wide maintenance dredging campaign (i.e. 260,000m^3)) for short term impacts (refer Figure 8.26) and sustained impacts (refer Figure 8.27). The modelled impacts show that cumulative turbidity is not significantly higher than the capital dredging only case (refer Section 8.6.6.1)

The analysis of the deposition rate percentiles for the maintenance dredging cumulative case (combining the capital dredging campaign with a Port-wide maintenance dredging campaign) is presented in Figure 8.28 (short term impacts) and Figure 8.29 (sustained impacts). The modelled short term impact to the deposition rate is higher than the ‘capital dredging only’ case at the offshore East Banks DMPA (maintenance dredged material only), in the vicinity of the WBE reclamation area and in certain areas within the estuary. The sustained (but temporary) impact to the deposition rate is higher than the ‘capital dredging only’ case in offshore areas (due to resuspension from the East Banks DMPA) and Jacobs Channel area.

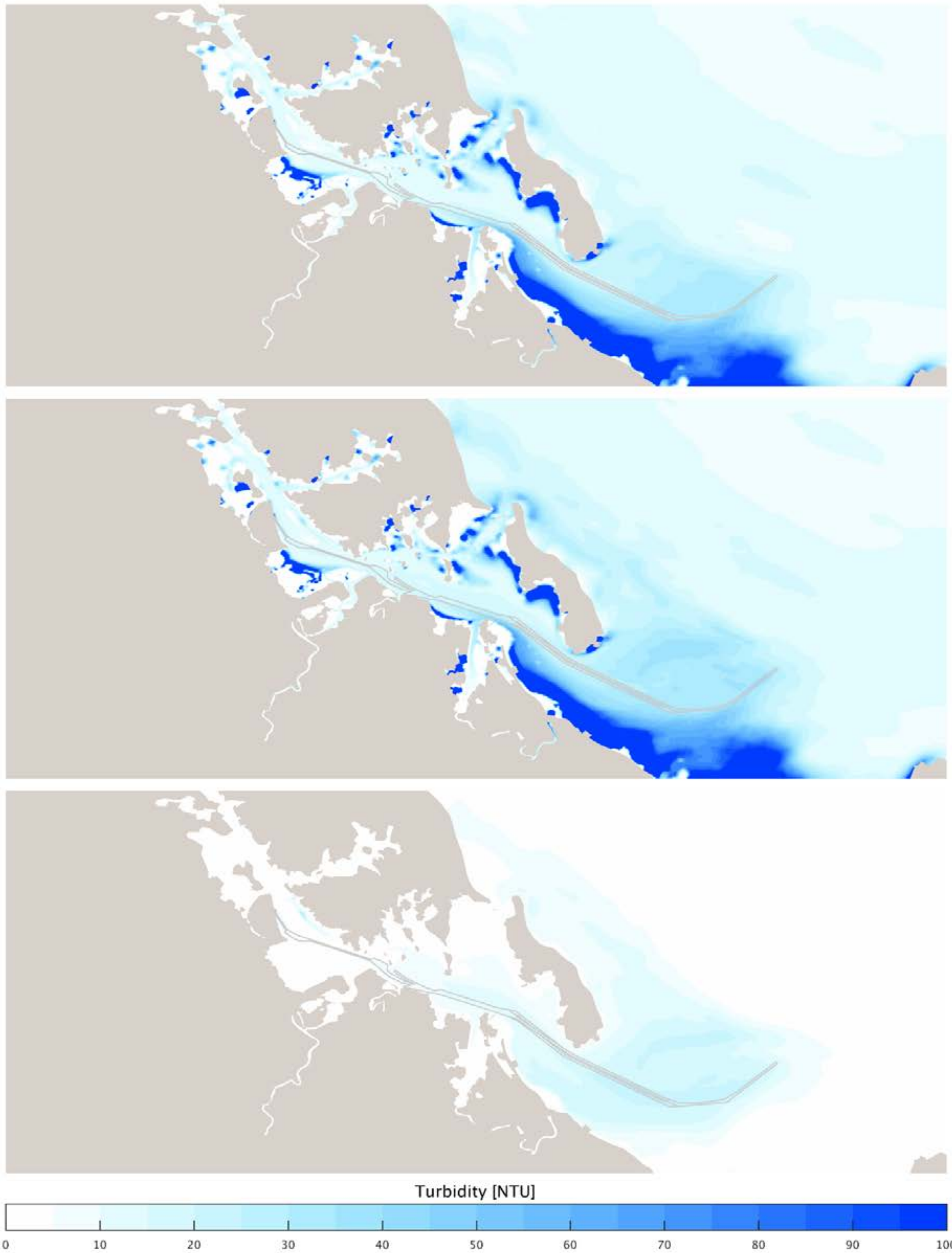


Figure 8.26 **95th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) maintenance dredging cumulative case**

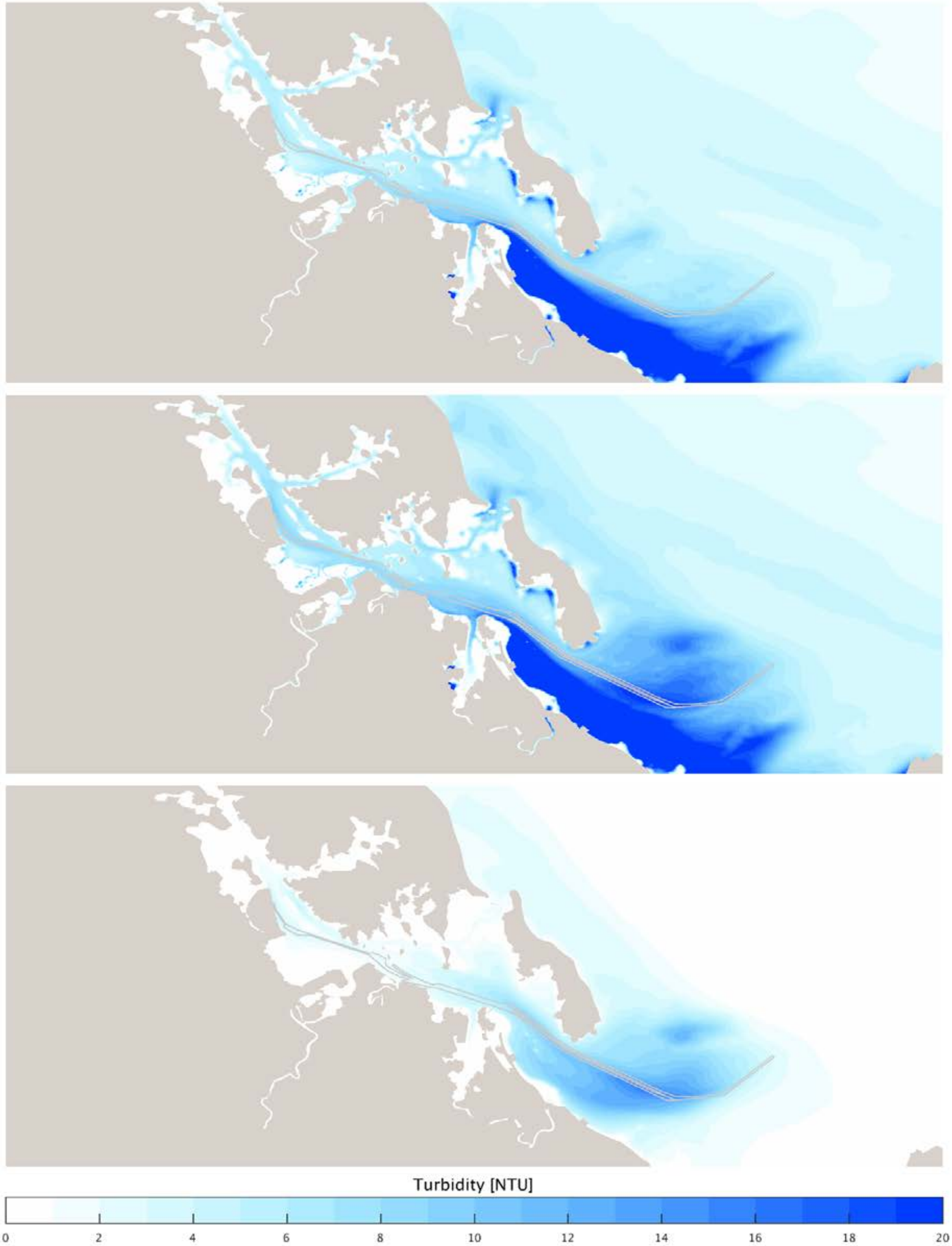


Figure 8.27 **50th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) maintenance dredging cumulative case**

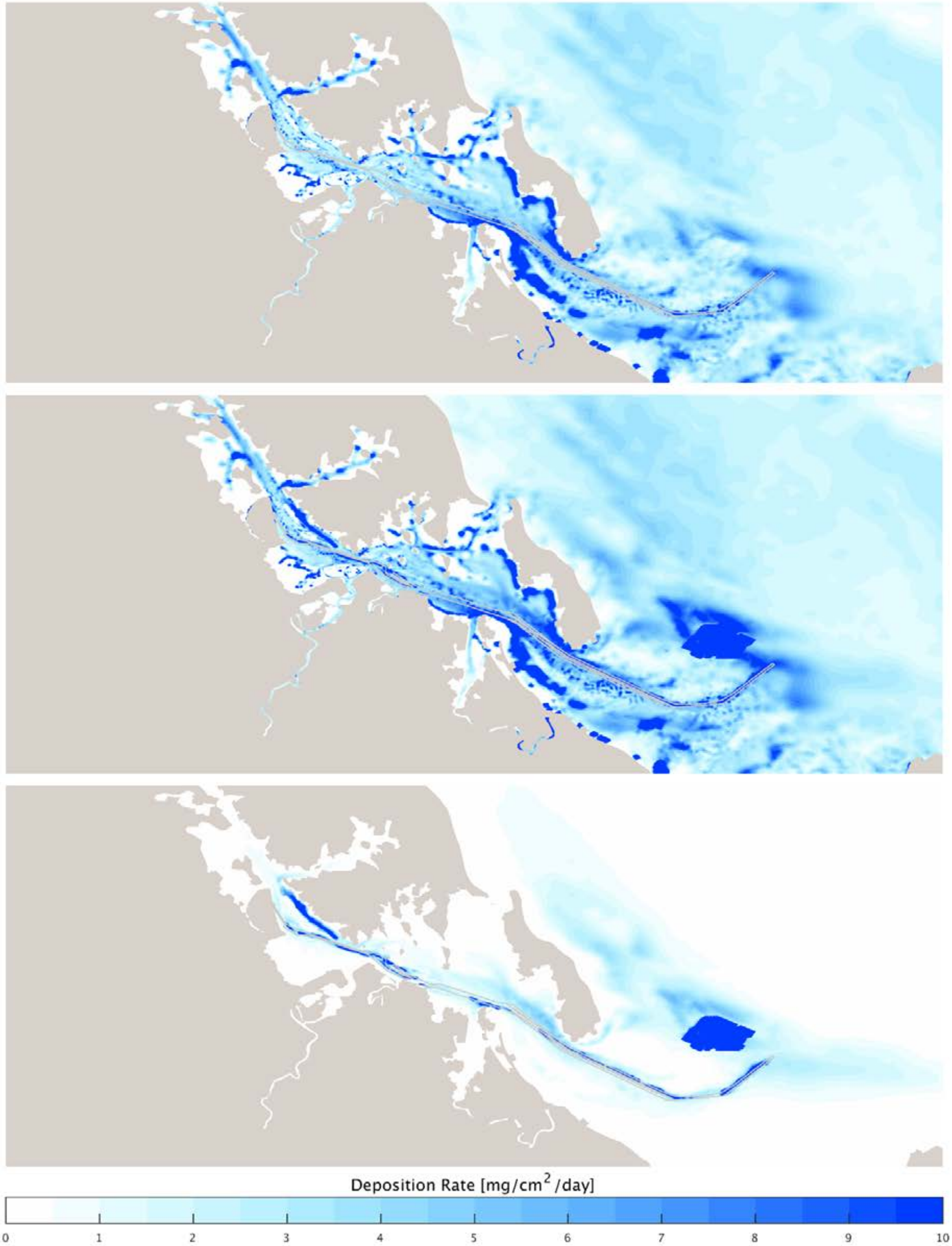


Figure 8.28 **95th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) maintenance dredging cumulative case**

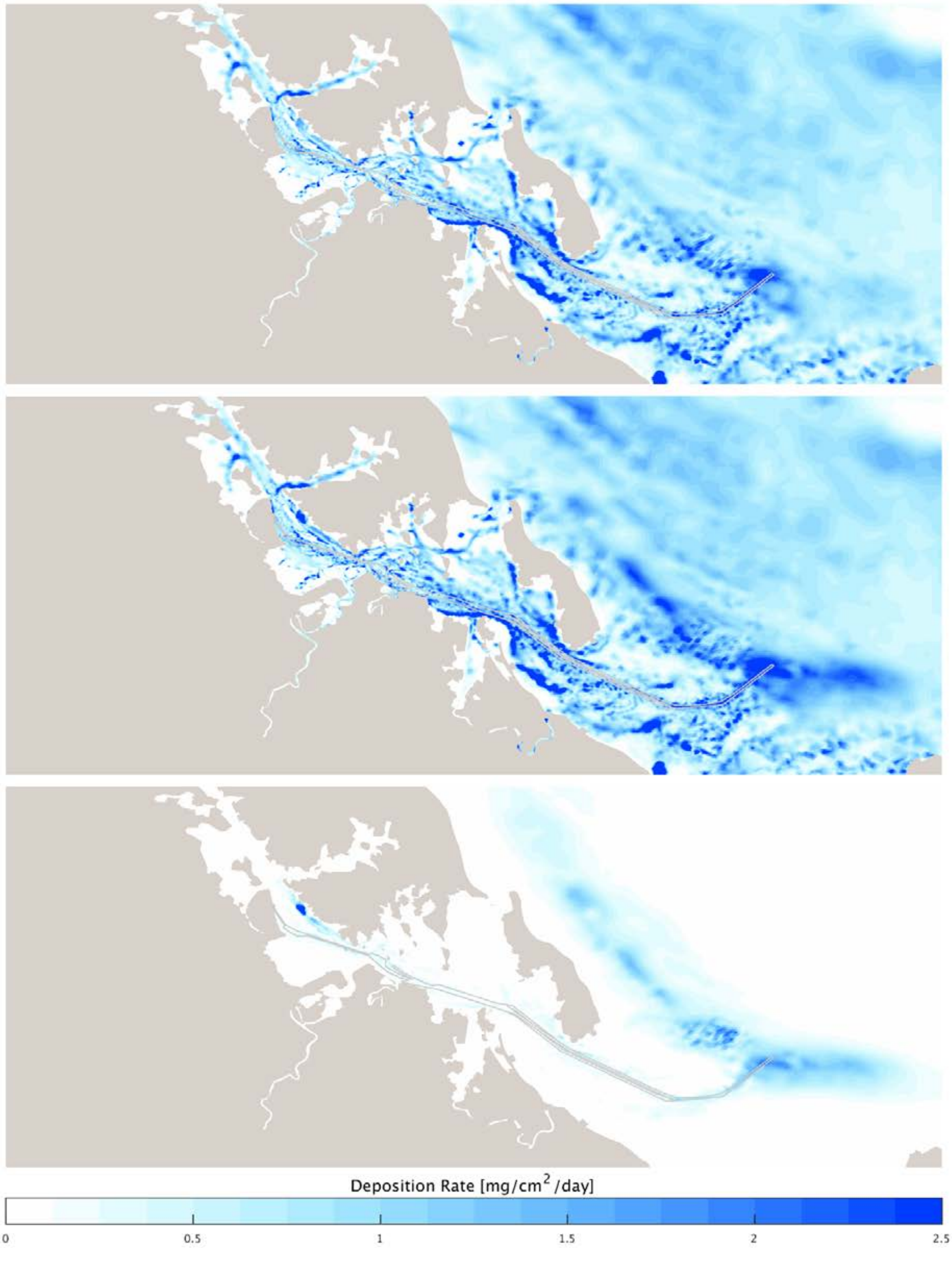


Figure 8.29 **50th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) maintenance dredging cumulative case**

8.6.6.4 Cumulative case dredging scenario (flood event scenario)

The overall impact on turbidity percentiles for the flood cumulative case (combining the capital dredging campaign with the 2013 flood event) is presented in Figure 8.30 (short term impacts) and Figure 8.31 (sustained impacts). The modelled impacts to the turbidity percentiles are higher than the 'capital dredging only' case (Section 8.6.6.1) within and adjacent to the entrances of the Calliope and Boyne Rivers, due to the influence of flood-related plumes.

The overall impact on deposition rate percentiles for the flood cumulative case (combining the capital dredging campaign with the 2013 flood event) is presented in Figure 8.32 (short term impacts) and Figure 8.33 (sustained impacts). The modelled short term impact to deposition rate is higher than the 'capital dredging only' case (Section 8.6.6.1) within several areas dispersed throughout the estuary, but the sustained (temporary) increase in the deposition rate is relatively small.

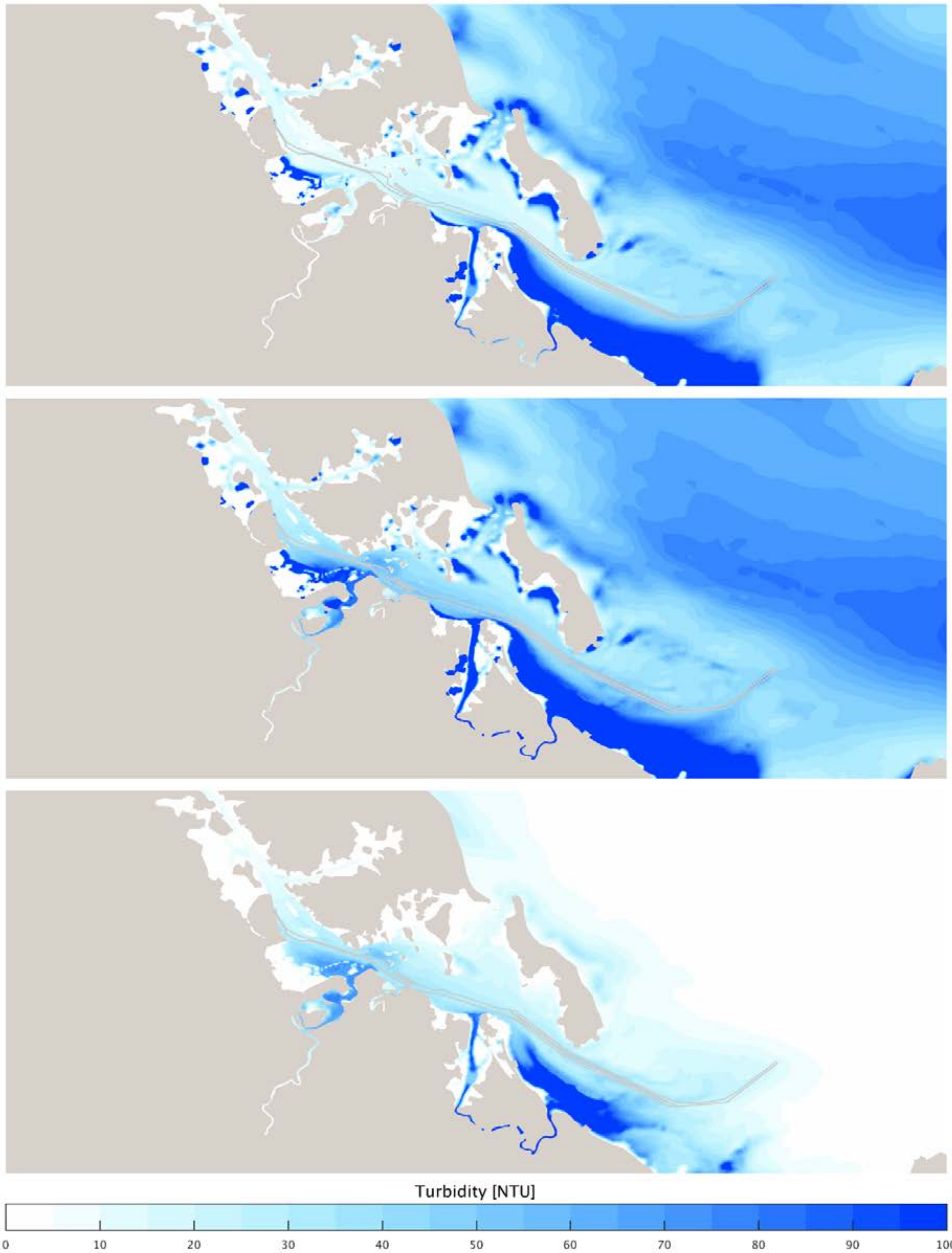


Figure 8.30 **95th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) flood event cumulative case**

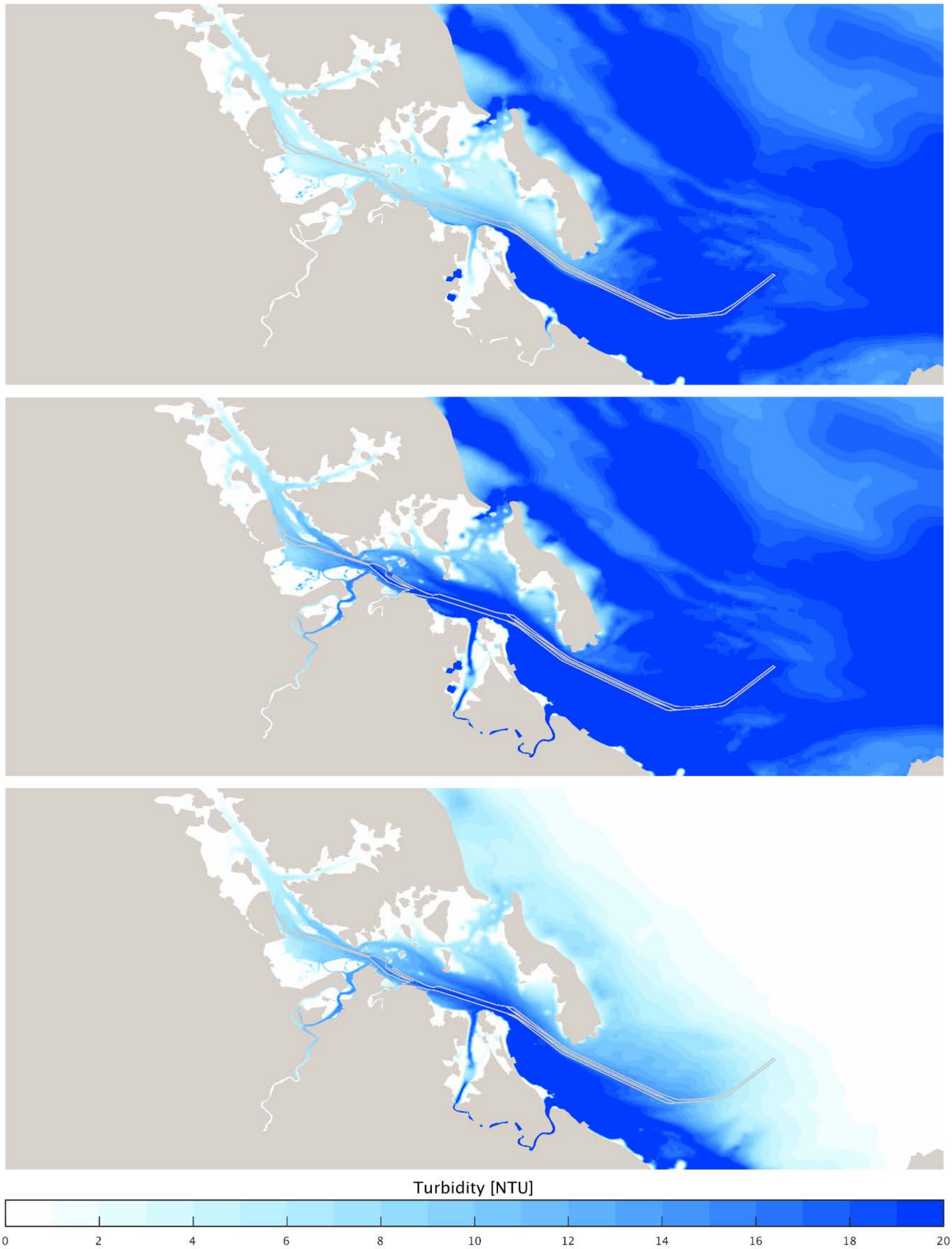


Figure 8.31 **50th percentile of the depth averaged turbidity ambient (top), total (middle) and impact of dredging (bottom) flood event cumulative case**

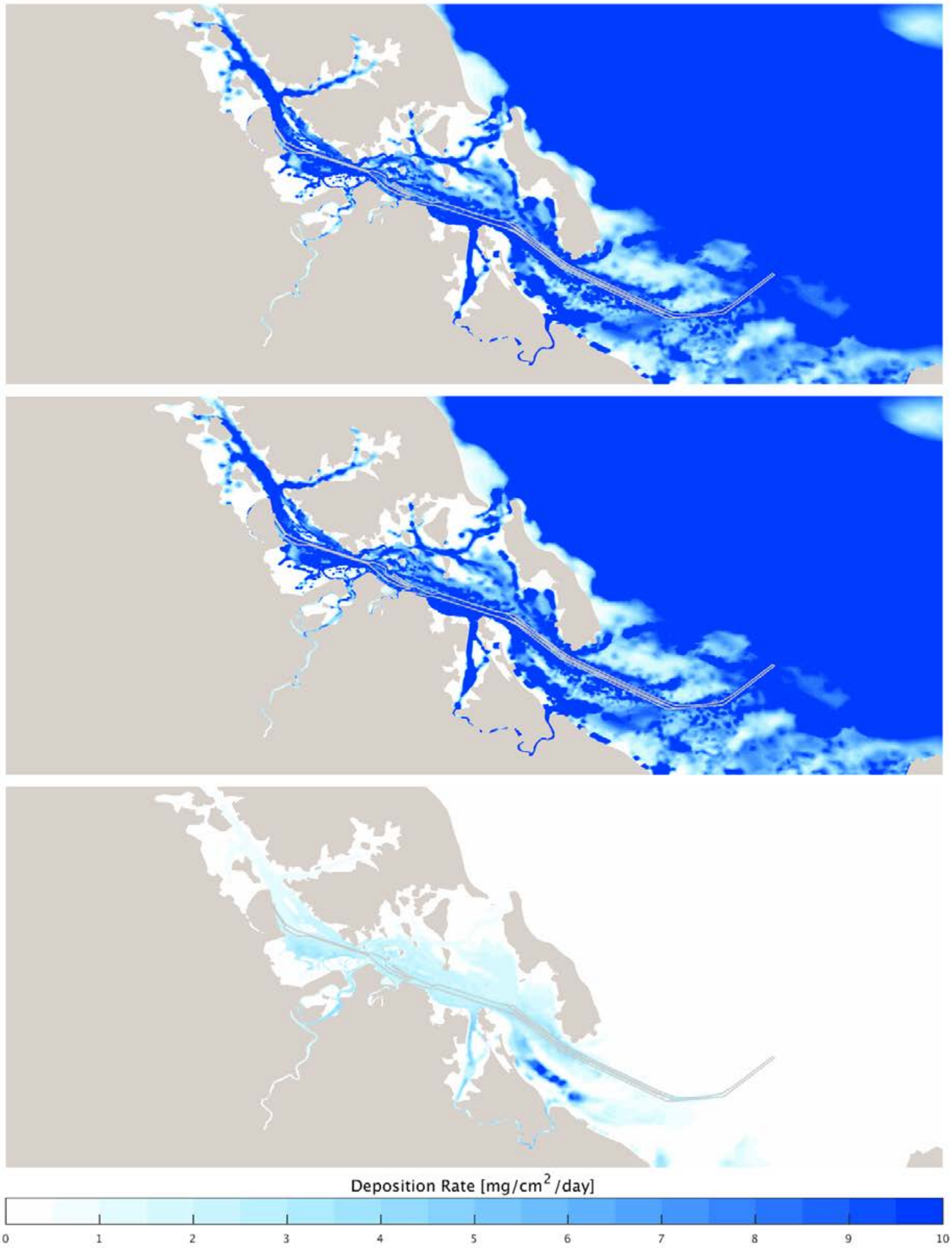


Figure 8.32 95th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) flood event cumulative case

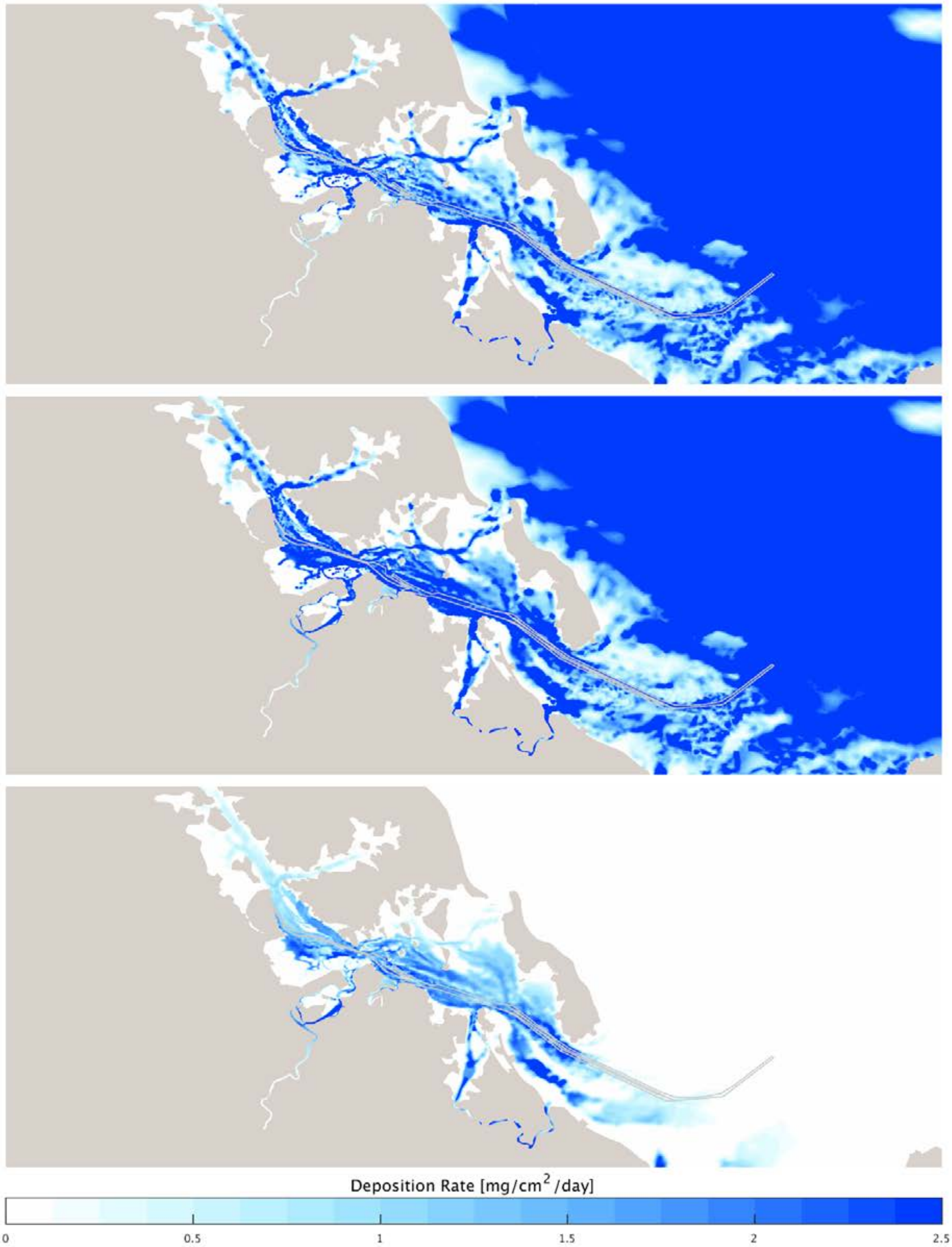


Figure 8.33 50th percentile of the deposition rate ambient (top), total (middle) and impact of dredging (bottom) flood event cumulative case

8.6.6.5 Potential impacts on water quality from sediment quality and elutriate release during dredging and dewatering

Dredging within the Gatcombe and Golding Cutting shipping channels will be undertaken by a TSHD with dredged material transferred to the BUF for unloading and placement of the dredged material into the WB and WBE reclamation areas. As such, there is potential for sediment resuspension and absorption of contaminants, including nutrients and metals, back into the water column during the following activities:

- Direct disturbance of sediment by the dredger head of the TSHD (and CSD during the short period of initial dredging works)
- Overflow dredging by the barges, where excess water (containing some suspended sediments) is drained from the barges and released back into the marine waters
- Propwash from the TSHD
- Release of water from the Project licenced discharge point as part of the dewatering process within the WB and WBE reclamation areas.

The potential impacts from the release of contaminants into the receiving environment during dredging and dewatering include contamination of marine water, toxicity to marine and/or intertidal flora and fauna, increased algal blooms and public health risks.

Sediments within the dredged material are deemed ‘clean’ under NAGD (2009), as detailed in Chapter 6 (sediment quality). Naturally occurring metals/metalloids, nutrients and PASS are present within the sediments and have the potential to be mobilised in the water column during dredging and dewatering activities (refer Chapter 5 (topography, geology and soil)). However, the low levels of potential contaminants within the dredged material is within NAGD (2009) guidelines and as such is unlikely to pose any significant risk to water quality and the receiving environment.

To ensure that sediment quality does not impact water quality, management measures will be implemented, including measures detailed in Section 8.7, the ASSMP and the Project Environmental Monitoring Procedure.

Discharge from the Project licenced discharge point will comply with the water release limits as detailed in Table 8.16.

Table 8.16 Dredge decant water release limits from the Project licenced discharge point

Quality characteristics	Release limits		Monitoring frequency
	Minimum	Maximum	
TSS		100 mg/L	Monthly or weekly during discharge events
pH	6.5	9.0	Hourly[1]
DO		100% sat[2]	Monthly or weekly during discharge events
Ammonia (nitrogen) (at a pH of 8)		910[6] µg/L[2]	Monthly or daily if pH is outside release limits
pH	6.5	9.0	Hourly[1]
Aluminium		0.5 µg/L[3]	Monthly or daily if pH is outside release limits
Arsenic (III) (filtered)		2.3 µg/L[3]	Monthly or daily if pH is outside release limits
Arsenic (V) (filtered)		4.5 µg/L[3]	Monthly or daily if pH is outside release limits
Cadmium (filtered)		0.7 µg/L[5]	Monthly or daily if pH is outside release limits
Chromium (VI) (filtered)		4.4 µg/L[4]	Monthly or daily if pH is outside release limits
Copper (filtered)		1.3 µg/L[4]	Monthly or daily if pH is outside release limits
Lead (filtered)		4.4 µg/L[4]	Monthly or daily if pH is outside release limits

Quality characteristics	Release limits		Monitoring frequency
	Minimum	Maximum	
Manganese (filtered)		80 µg/L[3]	Monthly or daily if pH is outside release limits
Mercury (filtered)		0.1 µg/L[5]	Monthly or daily if pH is outside release limits
Nickel (filtered)		7.0 µg/L[5]	Monthly or daily if pH is outside release limits
Silver (filtered)		1.4 µg/L[4]	Monthly or daily if pH is outside release limits
Zinc (filtered)		15 µg/L[4]	Monthly or daily if pH is outside release limits
TPH		10 mg/L	Monthly

Table notes:

1 While pH is to be sampled hourly, limits apply to pH as a 6 hour rolling average
2 Source: Table 2A MD2421 Western Basin, 80th percentile (DEHP 2014)
3 Source: Low reliability trigger value, Section 8.3.7 (ANZECC 2000 V2)
4 Source: ANZECC trigger values for marine waters 95th percentile (ANZECC 2000 V2)
5 Source: ANZECC trigger values for marine waters 99th percentile (ANZECC 2000 V2)
6 refer to table 8.3.7 of the ANZECC guidelines if pH differs from 8

8.6.7 Removal and installation of navigational aids

Existing navigational aids will need to be removed and/or relocated and new navigational aids installed. The impact to water quality during the removal and installation will be minimal and localised. Although there may be a small amount of sediment disturbed during this process it is expected to be negligible and result in no impact to water quality.

Other potential water quality impacts include oil spills from vessels undertaking the work. Contamination from hydrocarbons or other toxicants on board the vessel has the potential to occur if accidentally released into marine environment. These contaminants may pose a risk to marine flora and fauna, however these kinds of spills are unlikely.

Waste disposal from vessels also has the potential to pose a risk if not undertaken correctly. Plastics and other packaging pose a risk to marine fauna. Waste disposal management will be implemented as part of the Project EMP. Chapter 9 (nature conservation) provides additional information on potential impacts to marine flora and fauna.

8.6.8 Stabilisation and maintenance activities

Following the completion of the Project dredging and the stabilisation of the WB and WBE reclamation areas, maintenance activities will occur on the reclamation areas which have the potential to impact on the adjoining marine water quality. There is the potential for hydrocarbon spills, airborne contaminants from exposed materials entering the water column and solid waste such as packaging materials from vehicles and plant operation in the areas. There is also the potential for soil erosion and runoff from the reclamation areas, although the potential risk is low given the minor scale and nature of the maintenance activities.

As discussed in Chapter 11 (climate and climate change assessment) of the EIS, climate change may potentially result in an increased frequency of severe tropical cyclones in the region, with an associated increase in extreme wave climate and storm surge water levels. This may lead to overtopping of marine structures and inundation of the WB and WBE reclamation areas (without adequate mitigation). This in turn could result in the uncontrolled release of sediment into the marine environment.

The potential for introduced contaminants from maintenance activities on the WB and WBE reclamation areas presents a minor impact.

Once the WBE reclamation area is operational all stormwater will be captured within the large stormwater pond located onsite to manage stormwater quality runoff from the final surface. There will be no licence discharge points within the WB and WBE reclamation areas post dredging. Section 2.10 provides further design features and principles of the final WBE reclamation area.

Mitigation of these potential impacts will be addressed by compliance with the Project EMP.

8.6.9 Maintenance dredging

Maintenance dredging will be required to ensure that the shipping channels, swing basins and berths remain at the required depths. Volumes of material to be dredged and frequency of maintenance dredging is detailed in Chapter 2 (Project description). Disposal of this material will be in accordance with Commonwealth and State Government requirements and approvals.

The impacts of maintenance dredging will be similar to current Port maintenance dredging and significantly less than those predicted from the Project capital dredging works. Compared to capital dredging, much smaller volumes of material are involved in maintenance dredging and the timeframes over which dredging will occur will be shorter.

8.6.10 Operation of the duplicated shipping channels

A description of the potential future increases in shipping movements post the duplication of the channels is provided in Section 1.4. The projected increase in industrial trade demand and vessel movements are likely to be dominated by coal, alumina, cement, petroleum, aluminium and agricultural resources.

It is important to note that while the Project will facilitate an improvement in the existing and future vessel movement efficiency, and a reduction in the likelihood of vessel incident risk, the duplication of the Gatcombe and Golding Cutting Channels will not have any direct influence on increasing commercial vessel movement numbers within the Port.

The loading and unloading of these imports and exports is controlled and managed by existing environmental licences held by operators. However, other sources have the potential introduce contaminants that may have an impact on water quality, including:

- Ballast water
- Antifouling systems
- Black water and grey water release
- Other wastewater
- Airborne contaminants from exposed materials (e.g. bulk product) entering the water column
- Solid waste such as packaging materials.

Ballast water, antifouling and wastewater are regulated by the conventions and legislation below which vessels operating in Australia need to comply with.

8.6.10.1 International obligations

- *Convention for the Prevention of Pollution from Ships 1973* (MARPOL)
- *Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (London Convention) 1972*
- *Convention on the Control of Harmful Antifouling Systems on Ships (IMO-AFS Convention) 2001*
- *Convention for the Control and Management of Ship's Ballast Water and Sediments 2004*.

8.6.10.2 Commonwealth legislation

- *Quarantine Act 1908* for management of introduced pests in ballast water, managed by the AQIS
- *Australian Ballast Water Management Regulations* (Version 7) (Commonwealth Government 2017)
- *Environment Protection (Sea Dumping) Act 1981*.

8.6.10.3 State legislation, policy and guidelines

- *Port Procedures and Information for Shipping – Gladstone* (DTMR 2018)
- *Environmental Protection (Waste Management) Regulation 2000* and EPP (Water)
- *Transport Operations (Marine Pollution) Act 1995 and Transport Operations (Marine Pollution) Regulation 2008*
- *Maritime Safety Queensland Act 2002*
- *Pollution prevention for ships required documents* (Queensland Government 2010a)
- *Port of Gladstone – First-Strike Oil Spill Response Plan* (DTMR 2017c)

The potential for introduced contaminants from increased shipping presents a 'minor' impact. Mitigation of these potential impacts will be addressed by compliance with the above legislation administered by the above authorities.

8.7 Mitigation measures

The Project is located within the Port of Gladstone and the GBRWHA. As detailed in Section 8.6, a number of potential impacts to water quality have been identified during the construction and maintenance phases of the Project. The mitigation measures below will be implemented to minimise the potential for Project activities to impact on water quality conditions within the Port and outer harbour areas. The Dredging EMP and the Project EMP summarises the management and mitigation measures for all aspects of the Project (refer Appendix Q1 and Q2, respectively). The Project Environmental Monitoring Procedure details specific adaptive management and mitigation measures to manage water quality during the Project (refer Appendix Q3).

8.7.1 General

The following measures will be implemented to manage the potential Project impacts associated with water quality:

- No construction activities are initiated prior to obtaining DoEE and DES approval of the Project EMP, Dredging EMP and Project Environmental Monitoring Procedure
- All activities will comply with the approved Project EMP, Dredging EMP and Project Environmental Monitoring Procedure to minimise impacts on water quality, associated with the health of marine flora and fauna values
- No exceedance of the seagrass time to impact light threshold levels as specified in the Project Environmental Monitoring Procedure
- Compliance with all Commonwealth and State Government approval conditions and Project management plans relevant to the Project works
- Achieve the performance criteria outlined in the Project EMP and Dredging EMP
- An appropriate response is implemented where monitoring determines that the water quality trigger levels have been exceeded or seagrass light thresholds is found to be compromised by Project activities
- All wastewater will be adequately contained and treated before being discharged into the receiving waters, including gross pollutant and sediment removal. All reasonable and practicable measures will be implemented to prevent pollution resulting from silt runoff, oil and grease spills from machinery, concrete truck washout and the like.

8.7.2 Establishment of the Western Basin Expansion reclamation area and barge unloading facility

As a minimum, the controls below will be implemented to manage water quality during the construction of the WBE reclamation area and BUF.

- The detailed design phase of the WBE reclamation area bund wall and BUF will adopt the following into the design and construction methodology process and construction specification:
  - Industry best practice
  - Lining of the inner face of the bund wall of the WBE reclamation area and BUF bund walls with geotextile fabric to reduce the migration of fines through the bund walls
  - Geotextile materials designed to filter sediment will be:
    - Placed on the inner bund wall material and then be overlaid and secured by core material
    - Keyed into the rock armour material to prevent slippage and deformation from occurring prior to placement of the core material
    - Laid on the bund wall such that no wrinkles, gaps, folds or deformations occur in the material, with all joints sewn to create seams and to conform to the requirements of Australian Standards 3706: Geotextiles – Methods of Test. Overlaps in the fabric should be directed vertically down the slope of the armour material.
  - Use of internal cells and adjustable weir boxes within the WBE reclamation area to allow retention of dredged tailwaters and settling of suspended solids
  - Incorporate the findings and recommendations of the independent review of the WBDDP bund water performance (refer Appendix D)
  - Incorporate the findings of the Project EIS geotechnical investigations and additional geotechnical investigation will be undertaken for the WBE reclamation area and BUF during the detailed design phase of the Project
  - Stormwater management system to form part of the detailed design of WBE reclamation area and BUF, which will include drainage systems and stormwater treatment measures to manage runoff and minimise discharge of sediment laden and turbid waters into Port Curtis
  - Groundwater modelling and piping investigation to be undertaken during the detailed design phase of the Project. The findings of the modelling and investigation will be incorporated into the design and construction methodology and specification.
- Core material (up to 300mm) and dredged material to be used against the outer bund wall geotextile material
- Removal of fines < 20mm from bund materials prior to placement
- Maximum unarmoured length of 50m will be maintained during construction
- Sufficient armoured material will be held in reserve for placement in the event of a storm or approaching cyclone
- Implement the Project Environmental Monitoring Procedure to manage potential impacts on water quality

Dewatering discharge from the WB and WBE reclamation areas will comply with the licenced conditions and be managed in accordance with the Project Environmental Monitoring Procedure for water quality. Appropriate design and construction of bund, including:

- All reasonable and practicable measures will be implemented to prevent pollution resulting from silt runoff, oil and grease spills from machinery, concrete truck washout and the like

- No refuelling or maintenance of construction equipment will occur on the site, nor will equipment be parked at the site for a significant time, reducing the potential for significant spills of oils and fuels to occur
- No waste, other than reclamation decant water, is to be released into the marine environment or adjacent vegetation communities
- Spill kits for land and water based spills (including hydrocarbon absorbent booms) will be kept at the site and personnel trained in their use. Emergency response procedures will be established.
- Adherence to waste management controls identified in the Project EMP
- Monitoring and management of any material that is displaced above LAT will be undertake in accordance with the ASSMP
- All construction equipment will undergo regular maintenance and pre-start inspections. Equipment and vehicles will not be parked at the site for a significant time
- Powered Mobile Equipment (PME) will be suitable and rated for the task and kept in good working order
- A PME preventative maintenance regime will be implemented.

8.7.3 Dredging activities

As a minimum, the controls below will be implemented to manage water quality during dredging.

- Implement an approved Dredging EMP and Project Environmental Monitoring Procedure during all dredging works
- Where practical scheduling the timing of dredging to reduce the potential likelihood for turbid plumes to impact on sensitive receptors such as avoiding the late spring and early summer periods (together with other less extreme summer periods), which represent key periods for seagrass growth and resilience building
- Dredging operations to be undertaken during suitable conditions (i.e. within the operational parameters of the dredger, for example not during high energy situations such as storm surges). If the BoM issues a severe weather warning, dredging works within the affected area to cease.
- Dredger and work boats sailing routes to be optimised to reduce the generation of propeller wash
- Ensure the dredger operates within approved dredging footprint at all times
- The TSHD and barges will carry out adaptive management measures depending on results of water quality monitoring (i.e. reduce overflow, move location, etc.)
- Decant water will be treated in decanting ponds constructed at the WBE reclamation area. All decant water will be treated to meet the water quality limits outlined in the ERA 16 approval and Project Environmental Monitoring Procedure prior to being released at the licensed discharge points.
- No decant water is to be discharged prior to water monitoring in accordance with the Project Environmental Monitoring Procedure and the ASSMP. If required, lime dosing of decant water within the WB and WBE reclamation areas in accordance with the ASSMP.
- In the event that discharge occurs, or is likely to occur, at other than the approved and monitored discharge point, dredging will stop
- Overflow levels to be raised to the highest allowable point during sailing from the channel duplication area to be dredged to the BUF to ensure spillage of sediment is reduced
- The barges to be fitted with 'green valves' in the overflow pipe to control the amount of air contained in the excess water in order to reduce turbidity. Overflow discharge to be managed using a computer-based management system to prevent excessive overflow discharge.

- Below keel discharge of tailwaters to be via an anti-turbidity control valve. Vessel to have on-board systems for determining the density of dredged material (or solid to water ratio).
- Turbidity minimising equipment will be serviced and inspected appropriately by the dredging contractor. Vessel log books will be maintained by the dredging contractor and are available for viewing by GPC.
- Prepare and finalise a dredging contractors' Ballast Water Management Plan in accordance with the Australian Ballast Water Management Requirements (Version 6) (Commonwealth Government 2016). The management plan will include contingency measures that include, but are not limited to:
  - Immediate notification to DAF (Biosecurity Queensland), DAWR, DES and MSQ
  - Follow any directions or notices given by a regulator in relation to marine pests
  - Corrective actions (i.e. immediate investigation strategies, holding the balance of ballast on board, transferring the balance between tanks, examining ship to shore transfer options, etc.)
  - Consequential reporting/liaison requirements.

8.7.4 Removal and installation of navigational aids

To manage potential water quality impacts during the removal and installation of navigational aids, this activity will be undertaken in accordance with the relevant legislative approval conditions, the Project EMP and best practice management.

8.7.5 Stabilisation and maintenance activities in the reclamation area

As a minimum, the controls below will be implemented to manage potential water quality impacts during the stabilisation and maintenance activities on the reclamation area.

- No contaminants will be released from site to any waters, beds, or banks of any waters (including groundwater) unless authorised
- Progressive installation of stormwater management measures on the final Project reclamation surface as it is completed
- At the completion of filling of the reclamation area, the retention of a large stormwater pond to manage stormwater quality runoff from the final surface
- Progressive capping and revegetation of the reclamation surface to manage stormwater quality
- No refuelling or maintenance of equipment will occur on the site, nor will equipment be parked at the site for a significant time, reducing the potential for significant spills of oils and fuels to occur
- No waste, other than reclamation decant water, is to be released into the marine environment or adjacent vegetation communities
- Spill kits for land and water based spills will be kept at the site and personnel trained in their use. Emergency response procedures will be implemented
- Best practice management will be implemented throughout the maintenance phase, by implementing the Project EMP, GPC maintenance procedures and guidelines, and complying with all relevant Commonwealth and State legislation and approval conditions.

8.7.6 Established duplicated shipping channels

As a minimum, the controls below will be implemented to manage potential water quality impacts during the operation of the duplicated shipping channels.

- Vessels will comply with the *Quarantine Act 1906* for management of introduced pests in ballast waters, managed by the AQIS

- Vessels will comply with the International Convention on the Control of Harmful Antifouling systems on Ships, managed by MSQ
- Waste management during operation will be implemented in accordance with the relevant legislative approval conditions and best practice management
- Loading and unloading of materials at facilities will be undertaken in accordance with individual operational licences and permits.

8.7.7 Maintenance dredging

As a minimum, the controls below will be implemented to manage potential water quality impacts during maintenance dredging.

- GPC will obtain all required permits for maintenance dredging and will implement mitigation measures
- Maintenance dredging operations occur in compliance with applicable Commonwealth and State legislative requirements, as well as the Port of Gladstone Maintenance Dredging EMP (#879363) and the Long Term Monitoring and Management Plan for Sea Disposal (#1071543) (LTMMP)
- A water quality monitoring program will be undertaken throughout maintenance dredging activities, to ensure that WQOs are achieved
- Preparation and implementation of a sediment SAP to determine suitability of maintenance dredged material for marine placement
- Any contaminated material detected in future testing will be assessed and investigated to determine suitability and management options under the NAGD (2009) and the sea dumping permit process.

8.8 Monitoring, reporting and corrective actions

Compliance with legislation, environmental standards and relevant management plans will be demonstrated through the implementation of water quality monitoring and reporting strategies throughout the Project, as detailed below.

- Undertake water quality monitoring, reporting and implement corrective action in accordance with the Project Environmental Monitoring Procedure
- GPC will report monitoring results to DoEE and DES as per permit requirements
- Regular internal and external third party audits will be conducted for the duration of the Project works, to ensure that:
  - Mitigation measures are being implemented effectively
  - Relevant performance criteria is being achieved
  - Activities are compliant with regulatory and Project-specific requirements
  - Any non-conformances are recorded and appropriate corrective actions are implemented
- All records and associated permits will be provided to the relevant authority upon request and/or at the completion of Project activities
- Complaints and incidents will be monitored throughout the Project activities, and corrective actions will be determined by the incident or complaint investigation
- Maintenance and/or corrective actions will be scheduled as required for equipment issues
- Records/logs of dredging and dredged material placement activities will be maintained in accordance with relevant permit and legislative requirements

- Regular auditing will be undertaken to confirm that Project activities are carried out in accordance with the defined requirements set out in the Dredging EMP, Project Environmental Monitoring Procedure and the Project EMP.
- Regular visual monitoring of turbid plumes during rock placement as part of the WBE reclamation area bund wall construction
- Weekly reports (as appropriate) will be completed for the duration of the Project activities
- Pre-start inspections on construction equipment to identify potential leaks
- Emergency response procedure will be prepared prior to the commencement of construction as part of the environmental management plans and the GPC EMS
- A non-compliance report will be filled out if any non-conformances are found
- In the event of an environmental incident, effective emergency response measures will be quickly implemented to ensure environmental harm for the event is minimised and feedback is issued to all parties involved in the works.

8.9 Risk assessment

8.9.1 Methodology

To assess and appropriately manage the potential water quality risks to EVs as a result of Project activities, a risk assessment process has been implemented. The risk assessment methodology adopted is based on principles outlined in the:

- AS/NZS ISO 31000:2009 Risk management – Principles and guidelines
- HB 203:2012 Handbook: Managing environment-related risk.

The risk assessment identifies and assesses the potential water quality risks to EVs/receptors for both the establishment of the reclamation area, dredging activities, installing navigational aids and maintenance activities on the reclamation area.

The purpose of this risk assessment is to identify potential impacts to EVs/receptors, prioritise environmental management actions and mitigation measures, and to inform the Project decision making process.

The risk management framework incorporates the Australian/New Zealand Standard for Risk Management (AS/NZS 4360:2004) and contains quantitative scales to define the **likelihood** of the potential impact occurrence and the **consequence** of the potential impact should it occur.

An overview of the interaction between Project activities (drivers/stressors), sensitive values/receptors and the risk impact assessment process is provided in Figure 8.34.

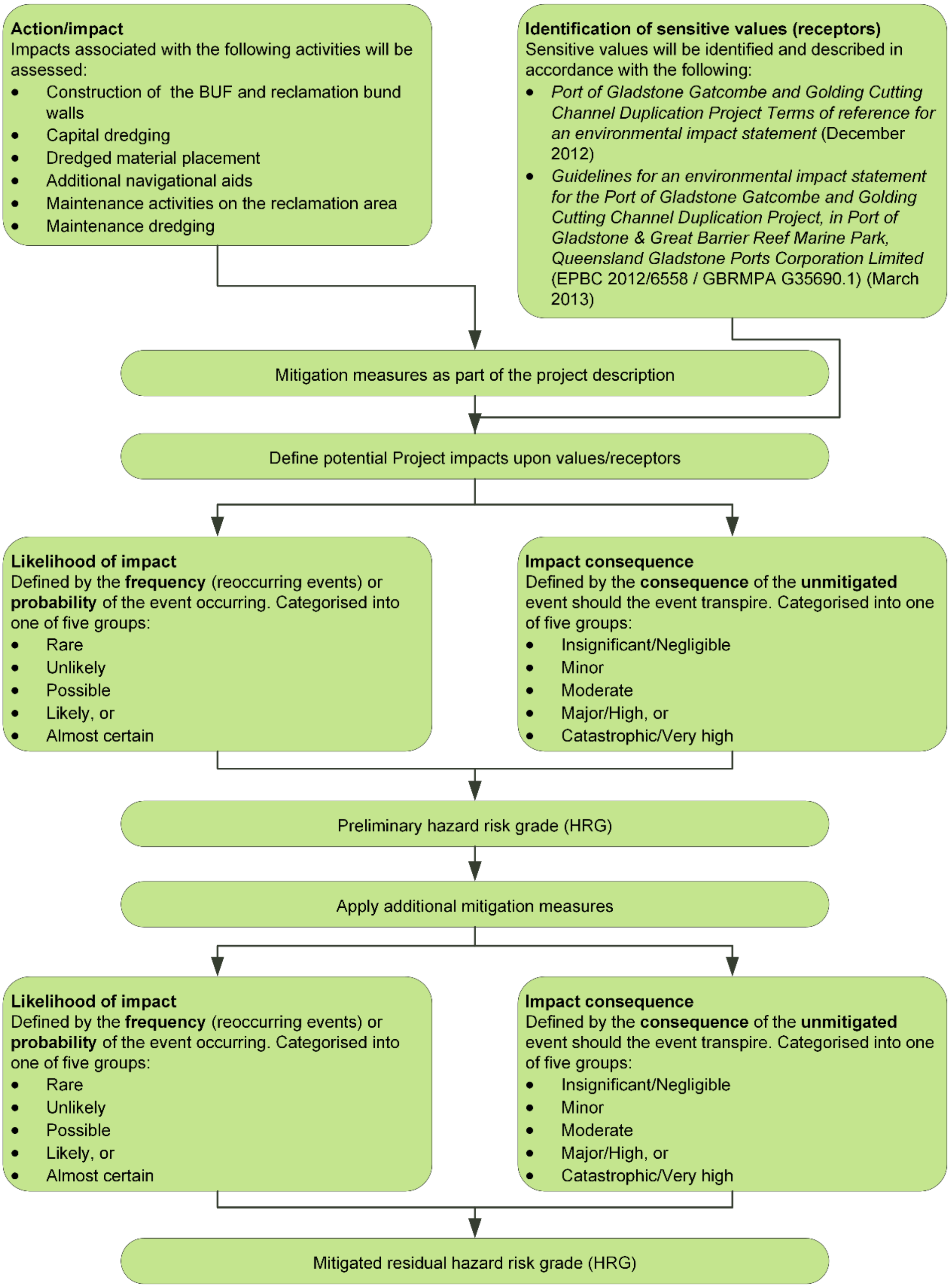


Figure 8.34 Risk assessment framework

Criteria used to rank the **likelihood** and **consequence** of potential impacts are provided in Table 8.17 and Table 8.18, respectively.

Table 8.17 **Environmental (ecosystem), public perception and financial consequence category definitions (adapted from GBRMPA 2009)**

Description	Definition/quantification[1]		
	Environmental*	Public perception	Financial
Negligible (Insignificant)	No impact or, if impact is present, then not to an extent that would draw concern from a reasonable person No impact on the overall condition of the ecosystem	No media attention	Financial losses up to $500,000
Low (Minor)	Impact is present but not to the extent that it would impair the overall condition of the ecosystem, sensitive population or community in the long term	Individual complaints	Financial loss from $500,001 to $5 million
Moderate	Impact is present at either a local or wider level Recovery periods of 5 to 10 years likely	Negative regional media attention and region group campaign	Financial loss from $6 million to $50 million
High (Major)	Impact is significant at either a local or wider level or to a sensitive population or community Recovery periods of 11 to 20 years are likely	Negative national media attention and national campaign	Financial loss from $51 million to $100 million
Very high (Catastrophic)	Impact is clearly affecting the nature of the ecosystem over a wide area **or** impact is catastrophic and possibly irreversible over a small area or to a sensitive population or community Recovery periods of greater than 21 years likely **or** condition of an affected part of the ecosystem irretrievably compromised	Negative and extensive national media attention and national campaigns	Financial loss in excess of $100 million

Table notes:

1 Quantification of impacts should use the impact with the greatest magnitude in order to determine the consequence category

* MNES protected under the provisions of the EPBC Act the *Matters of National Environmental Significance – Significant Impact Guidelines 1.1 – Environmental Protection and Biodiversity Conservation Act 1999* (DoE 2013b) are to be used to determine the consequence category

Table 8.18 **Likelihood category definitions (adapted from GBRMPA 2009)**

Description	Frequency	Probability
Rare	Expected to occur once or more over a timeframe greater than 101 years	0-5% chance of occurring
Unlikely	Expected to occur once or more in the period of 11 to 100 years	6-30% chance of occurring
Possible	Expected to occur once or more in the period of 1 to 10 years	31-70% chance of occurring
Likely	Expected to occur once or many times in a year (e.g. 1 to 250 days per year)	71-95% chance of occurring
Almost certain	Expected to occur more or less continuously throughout a year (e.g. more than 250 days per year)	96-100% chance of occurring

Once the likelihood and the consequence has been defined, determination of the HRG of the potential hazard will be determined through the use of a five by five matrix (refer Table 8.19).

Table 8.19 Hazard risk assessment matrix (adapted from GBRMPA 2009)

Likelihood	Consequence rating				
	Negligible (insignificant)	Low (minor)	Moderate	High (major)	Very high (catastrophic)
Rare	Low	Low	Medium	Medium	Medium
Unlikely	Low	Low	Medium	Medium	High
Possible	Low	Medium	High	High	Extreme
Likely	Medium	Medium	High	High	Extreme
Almost certain	Medium	Medium	High	Extreme	Extreme

Table note:

Hazard risk categories identified in Table 8.19 are defined in Table 8.20

Table 8.20 Risk definitions and actions associated with hazard risk categories (adapted from GBRMPA 2009)

Hazard risk category	Hazard risk grade definition
Low	These risks should be recorded, monitored and controlled. Activities with unmitigated environmental risks that are graded above this level should be avoided.
Medium	Mitigation actions to reduce the likelihood and consequences to be identified and appropriate actions (if possible) to be identified and implemented.
High	If uncontrolled, a risk event at this level may have a significant residual adverse impact on MNES, MSES, GBRWHA and/or social/cultural heritage values. Mitigating actions need to be very reliable and should be approved and monitored in an ongoing manner.
Extreme	Activities with unmitigated risks at this level should be avoided. Nature and scale of the significant residual adverse impact is wide spread across a number of MNES and GBRWHA values.

The implementation of mitigation measures (refer Section 8.7), will result in the water quality risks to human health and EVs being generally assessed as low to medium (refer Table 8.21).

Table 8.21 Potential water quality impacts and risk assessment ratings

Potential impact	Project activity					Preliminary HRG			Post mitigation HRG		
	Reclamation area and BUF establishment	Dredging	Navigational aids	Demobilisation	Maintenance	Likelihood	Consequence	HRG	Likelihood	Consequence	HRG
Establishment of Western Basin Expansion reclamation area and BUF											
Increased turbidity and sedimentation in adjoining marine areas through construction of the bund walls and BUF	✓					Likely	Moderate	High	Unlikely	Moderate	Medium
Increased turbidity through changes in hydrodynamics	✓					Possible	Moderate	High	Possible	Low	Medium
Potential mobilisation of contaminants into the water column through construction of the bund wall and BUF	✓					Possible	Moderate	High	Unlikely	Moderate	Medium
Potential release of contaminants into the water column through construction operations (e.g. hydrocarbon spills)	✓					Unlikely	High	Medium	Rare	High	Medium
Changes to water quality from PASS lowering the pH	✓					Possible	Moderate	High	Unlikely	Moderate	Medium
Sedimentation within adjacent environments as a result of erosion within the reclamation area	✓					Possible	low	Medium	Unlikely	Low	Low
Erosion and sedimentation in adjoining marine areas due to the establishment of the reclamation area and BUF	✓					Likely	Low	Medium	Likely	Low	Medium
Dredging activities and dewatering											
Increased turbidity and sedimentation; and potential mobilisation of contaminants through dredging operations and equipment		✓				Likely	High	High	Unlikely	High	Medium
Increased turbidity and potential mobilisation of contaminants through dewatering within the reclamation areas		✓				Likely	Moderate	High	Unlikely	Moderate	Medium
Changes to water quality from PASS lowering the pH		✓				Possible	Moderate	High	Unlikely	Moderate	Medium

Potential impact	Project activity					Preliminary HRG			Post mitigation HRG		
	Reclamation area and BUF establishment	Dredging	Navigational aids	Demobilisation	Maintenance	Likelihood	Consequence	HRG	Likelihood	Consequence	HRG
Sedimentation within adjacent environments as a result of erosion within the reclamation areas		✓				Possible	low	Medium	Unlikely	Low	Low
Introduction of contaminants and PASS from the dredged sediments into the reclamation areas		✓				Possible	Moderate	High	Unlikely	Moderate	Medium
Removal of existing navigational aids and installation of relocated and new navigational aids											
Localised, short term increases in turbidity			✓			Likely	Low	Medium	Unlikely	Low	Low
Potential release of contaminants into the water column			✓			Possible	Moderate	High	Unlikely	Moderate	Medium
Maintenance activities on the reclamation area											
Potential release of contaminants into the water column through maintenance activities (i.e. hydrocarbon spills)					✓	Possible	High	High	Unlikely	High	Medium
Contamination of surface water and/or groundwater due to spills from site compound storage of hydrocarbons and other potential contaminants					✓	Possible	High	High	Unlikely	High	Medium
Operation of the duplicated shipping channels											
Potential release of contaminants into the water column through shipping operations and vessel movements					✓	Possible	High	High	Unlikely	High	
Permanent change in hydrodynamics due to duplicated channels					✓	Unlikely	Low	Low	Unlikely	Low	Low
Maintenance dredging											
Short term increases in turbidity		✓									

8.10 Summary

An assessment of background water quality conditions within Port Curtis showed that the condition of water quality is strongly correlated with tidal state and associated bedload resuspension. The Port has naturally high turbidity during large spring tides, which generate strong tidal currents eroding and resuspending fine sediments. The water quality of Port Curtis is heavily influenced by weather extremes, particularly turbidity and conductivity when turbid freshwater reaches Port Curtis via the Calliope River and Boyne River.

The waters of Port Curtis are generally well mixed both vertically and horizontally. It is a well-connected estuary which allows dissolved material to be dispersed evenly, although material does not as readily leave the estuary to the offshore environment. Hydrodynamic studies have found that the Port has a reduced flushing time which may contribute to some metals bioaccumulating in Port Curtis biota. Trace metals distributions are found in Port Curtis and are present in suspended sediments and benthic sediments in low concentrations.

The results of the Project EIS baseline water quality monitoring program found that surface turbidity was significantly higher at inshore sites than at offshore sites with the highest turbidity results recorded during spring tides. At the offshore sites, only marginal differences were evident between benthic and surface temperature, conductivity, pH and DO, indicating the offshore water column was generally well-mixed, similar to the inshore sites. Many variables were found to influence the benthic light climate at monitoring sites, including the daily light integral, turbidity and water depth. BPAR results also showed significant seasonal variation.

The Project coastal processes and hydrodynamics modelling results indicate that water level impacts will be negligible. Velocity impacts will be moderate in channels adjacent to the WBE reclamation area, but small in the vicinity of the deepened shipping channels. Wave climate impacts will be limited to the immediate vicinity of the WBE reclamation area. Sedimentation impacts will be most significant adjacent to the WBE reclamation area, but there will also be a slight increase in overall annual maintenance dredging requirements. The deepening of the shipping channels is not likely to cause any change to the projected impacts of climate change and SLR in the Project impact areas.

The model was used to simulate the full dredging program and the expected impacts to the turbidity percentiles and deposition rates due to dredging were assessed. The model indicates that increases to the turbidity and deposition rate statistics are expected near the WBE reclamation area and BUF and in the vicinity of the TSHD operating in the Gatcombe and Golding Cutting Channels.

An assessment of the potential impacts to water quality associated with the Project found the main impacts to be increased turbidity and sedimentation, and the potential release of contaminants. These changes to water quality conditions have the potential to result in impacts to other aspects of the local environment. This includes potential impacts on sensitive ecological receptors such as seagrass meadows, coral reef communities, marine flora and fauna as well as other environmental and recreational values.

The low levels of potential contaminants within the dredged material is within NAGD (2009) guidelines and as such is unlikely to pose any significant risk to water quality and the receiving environment.

Other potential Project impacts to water quality include:

- The establishment of the reclamation area bund wall and BUF has the potential to result in localised turbidity, sedimentation and contaminant releases into the adjoining marine waters. The bund wall and BUF will create localised hydrodynamic changes which will impact on sedimentation and erosion.
- The installation and removal of navigational aids has the potential to create localised turbidity and the release of minor amounts of contaminants into the adjoining marine waters.
- Maintenance activities on the reclamation area have the potential for introduced contaminants to enter marine waters

- Maintenance dredging water quality impacts will be similar to current Port maintenance dredging and significantly less than those predicted from the Project capital dredging works. Compared to capital dredging, much smaller volumes of material are involved in maintenance dredging and the timeframes over which dredging will occur will be shorter.
- The duplicated channels will have a relatively minor impact on the hydrodynamics within the outer harbour.

The implementation of mitigation measures, as detailed in Section 8.7, the Project EMP, the Dredging EMP, ASSMP and the adaptive management strategies in the Project Environmental Monitoring Procedure, will result in the water quality risks to human health and EVs being generally assessed as low to medium.