TOWNSVILLE PORT EXPANSION PROJECT

Additional Information to the Environmental Impact Statement

TOWNSVILLE PORT EXPANSION PROJECT

SECTION 6

Marine Water Quality

AECOM BMT WBM

6.0 Marine Water Quality

6.1 Introduction

Marine water quality values of the Project area and surrounds are discussed in Chapter B.4 (Marine Water) of the Port Expansion Project (PEP) Environmental Impact Statement (EIS). The Port of Townsville is located in Cleveland Bay, which is bordered by Magnetic Island and the Coral Sea to the north, Cape Pallarenda to the west and Cape Cleveland to the east. Ross River discharges into Cleveland Bay at the Port, with other major river systems feeding in to the north of Cleveland Bay (Bohle River) and the south (Burdekin River). During wet season storm events, these and other smaller river systems deliver sediments and nutrients into Cleveland Bay and other nearshore waters of the Great Barrier Reef lagoon.

Marine water quality is an important environmental asset in the Study Area and surrounds due to the presence of a number of ecological receptors that are sensitive to altered water quality conditions. These sensitive receptors include seagrass meadows, which are located throughout Cleveland Bay, as well as reef communities (including coral) at Middle Reef and Magnetic Island. The Great Barrier Reef Marine Park is adjacent to the Port of Townsville exclusion zone, and supports areas with high ecological values.

Resuspension of existing (predominantly mud) sediments, the majority of which were deposited during the Holocene period, where wave action created high suspended sediment concentrations within shallow nearshore environments of Cleveland Bay (Larcombe *et al.* 1995). Offshore areas of Cleveland Bay, including the waters surrounding Magnetic Island, typically have lower suspended sediment concentrations than nearshore environments, resulting in relatively clear water conditions for most of the time (refer to Section 6.2.8).

A number of submissions were received in response to the EIS that are relevant to marine water quality. Key matters raised from the submission process include:

- adequacy of baseline water quality data and trigger levels
- consideration of ambient turbidity in impact assessment
- adequacy of water quality impact assessment method
- assessment of impacts from maintenance dredging
- oxidisation of potential acid sulfate soils (PASS) in the water column
- perception of ‘green valve’ used in dredging
- water quality and public swimming safety concerns
- natural turbidity of Cleveland Bay.

Responses to these key matters raised in submissions are provided in the following sections.

6.2 Response to Submissions

6.2.1 Adequacy of baseline water quality data and trigger levels

Two submissions questioned the adequacy of the baseline water quality data used to characterise baseline water quality and to set trigger levels for impact assessment. Specifically, the submissions raised the following matters.

- Perception that the baseline data was unrepresentative as a result of periods of maintenance dredging and large rainfall events being included in the analysis of baseline data.
- That the baseline data did not allow seasonality to be considered in determining the impact assessment trigger levels.

In response to the first matter, periods of dredging and an unusually large rainfall event were quarantined from the data prior to analysis. All data was subjected to a quality control process whereby periods of data were quarantined to ensure the data represented baseline conditions. This resulted in a ‘cleaned’ data set with small periods of data quarantined, but still encompassing a 12 month period.

Periods of data were quarantined if the following occurred during the monitoring period:

- obvious signs of sensor bio-fouling
- equipment failure
- periods of dredging
- any unusually large rainfall events (i.e. larger than 1 in 5 year recurrence interval).

This same quality control process was undertaken for the additional 12 months of data collected as discussed below.

In response to the second matter, the EIS acknowledged insufficient existing data to describe seasonal patterns in water quality (due to monitoring data collected over a period of 3-4 months). For this reason, the EIS committed to a 12 month water quality monitoring program in an attempt to characterise seasonality better. This program consisted of continuous water quality data collection over a 12 month period (July 2012 to July 2013) at five sites generally representing sensitive ecological receptor locations that could potentially be indirectly affected by the PEP. The locations of these sites are shown in Figure 6.1 (which also shows the sites where monitoring data was collected in 2008/2009) and include:

- Geoffrey Bay
- Picnic Bay
- Florence Bay
- Virago Shoal
- The Strand.

While the focus of the monitoring was on turbidity and Photosynthically Active Radiation (PAR), other parameters such as water temperature, electrical conductivity and pH were also recorded. Further information in regard to the 12 month baseline water quality monitoring program is provided in Appendix A1 (Additional Field Studies Report).

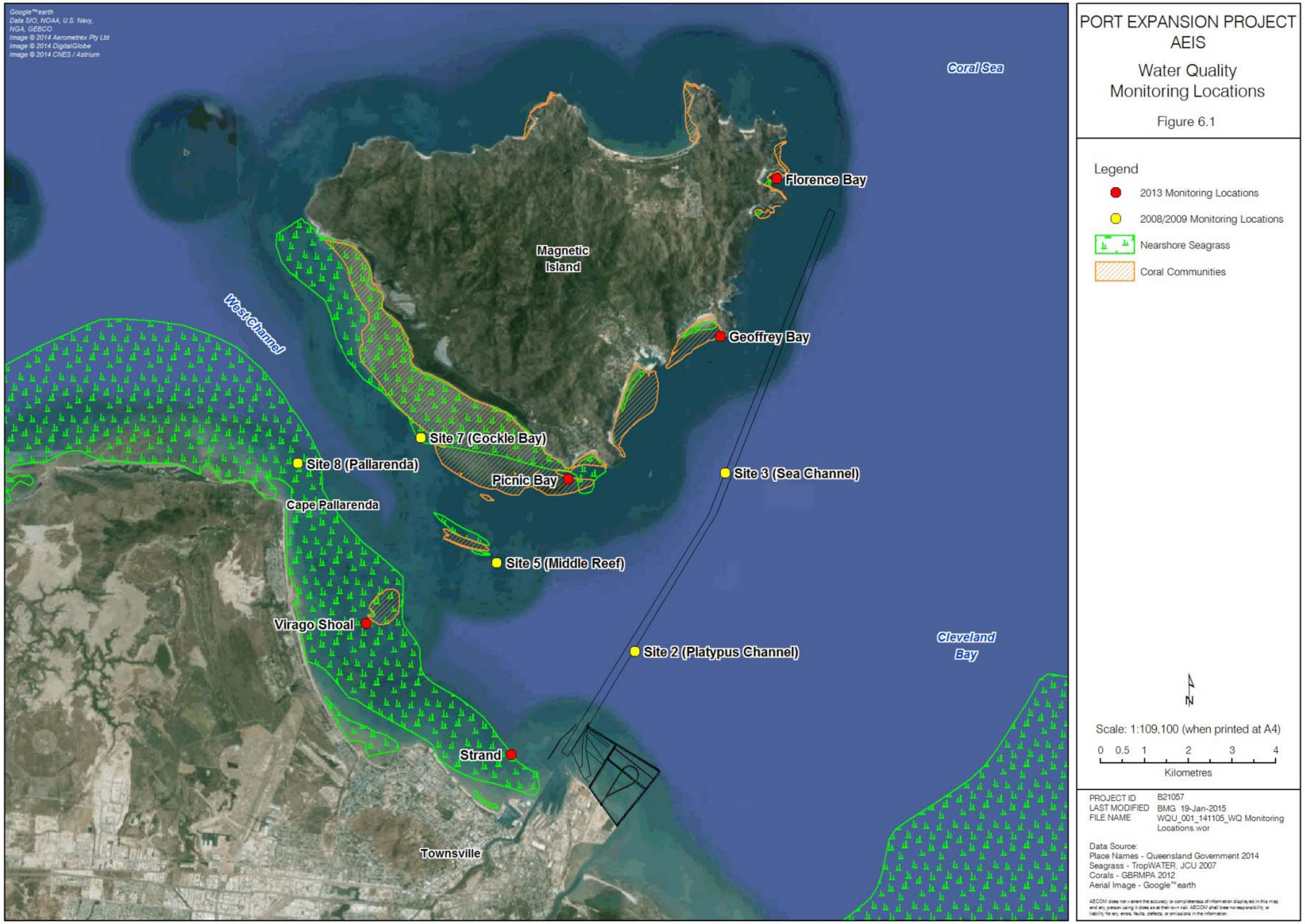

Figure 6.1 Water Quality Monitoring Locations

Using the 12 months of additional baseline data, along with the existing baseline data used in the EIS (i.e. 2008/2009 data), trigger values for assessing potential impacts of the PEP have been revised as part of this AEIS.

To determine if the ambient turbidity baseline data displayed distinct seasonal patterns, the dataset was analysed and it was found that variability is driven primarily by the wind regime (speed and direction), and there were no distinct differences in turbidity between wet and dry seasons. For this reason, the 12 month data set was analysed using 10 day moving windows to account for varying wind conditions. Therefore, seasonality is built into the methodology used to determine the revised trigger levels, which take into consideration the natural variability of water quality throughout the 12 month monitoring period. The methodology and revised trigger levels are discussed in Section 6.3.4.1.

6.2.2 Consideration of ambient turbidity in impact assessment

Three submissions related to the failure to address ambient turbidity in the impact assessment. Specifically, the submissions highlighted that the modelling impact plots are presented as 'above ambient', potentially ignoring the already disturbed nature of the receiving environment.

At the time of the EIS preparation, modelling of ambient conditions was not undertaken due to inadequate data and limitations of the model. However, recent improvements in the model and the availability of the 12 month data set (used to calibrate the model) have enabled ambient conditions to be modelled. As a result, the revised impact assessment in Section 6.3.4.1 takes into consideration ambient turbidity by showing ambient turbidity plots (without dredging) along with dredging impact plots which represent the predicted change in ambient turbidity due to dredging. Further details on how modelled ambient turbidity has now been incorporated into the model are included in Appendix A2 (Modelling Report).

6.2.3 Adequacy of water quality impact assessment method

Seven submissions were related to the water quality impact assessment method used in the EIS. The impact assessment method used in the EIS was based on McArthur *et al.* (2002). The submissions stated that the McArthur *et al.* (2002) method focussed on the 95th percentile of baseline data, thereby only considering acute impacts instead of chronic impacts.

While the McArthur *et al.* (2002) method has been used in a number of major port EIS projects in Queensland and elsewhere in Australia, the EIS noted that the methodology has significant limitations. To (partially) address these limitations, the EIS used the McArthur *et al.* (2002) method to assess acute impacts and 50th percentile (median) plots to assess chronic impacts.

A revised impact assessment methodology has been developed to account for both highly elevated 'acute' sediment concentrations, and chronic, low level changes to suspended sediment concentrations. In the present study, 20th, 50th and 80th percentile values[1] were calculated from baseline data, which were used to develop a set of 'impact threshold values'.

The revised impact assessment used in this AEIS involves the use of 'zones of impact', which are recommended in the GBRMPA Modelling Guidelines and are generally based on environmental assessment guidelines for dredging produced by the WA EPA (2011). The revised impact assessment methodology, including the zones of impact, is discussed further in Section 6.3.4.1.

It is important to note that the 'impact threshold values' were specifically developed to generate 'zones of impact', based on the degree to which dredge plumes (predicted by modelling) deviated from natural variability. These 'impact threshold values' were specifically developed for impact prediction purposes, and have not been developed for setting 'response action levels' for dredge plume monitoring programs. It is the intention that a technical advisory committee will develop action levels for any future dredge plume monitoring program, as outlined in the DMP.

6.2.4 Assessment of impacts from maintenance dredging

240 submissions (includes form letter submissions) related to the maintenance dredging required after the capital dredging has been completed, and that the EIS needs to undertake further assessment of impacts from maintenance dredging. Specifically, submissions were focussed around the following.

- Whether there will be increased maintenance dredging due to the increased length and depth of the shipping channel (coastal processes issue).
- Whether annual maintenance dredging will have a significant impact on sensitive ecological receptors, especially along the Magnetic Island coastline.

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[1] These percentile values have been adopted in the Queensland Water Quality Guidelines for determining whether water quality meets water quality objectives in High Ecological Value (HEV) waters

As discussed further in Section 5.0 (Coastal Processes), the ultimate development of the PEP is predicted to increase the volume of maintenance dredging by approximately 14% with the design refinement, mostly due to the increased channel width. Nevertheless, maintenance dredging impacts are not predicted to differ significantly from current maintenance dredging activities. This is discussed further in Section 6.3.4, which presents the findings of additional modelling of maintenance dredging using the increased volume of material.

While the predicted impacts from maintenance dredging are discussed in Section 6.3.4, further assessment of maintenance dredging was undertaken in 2013 (BMT WBM 2013) and in 2014 (BMT WBM 2014) assuming a slightly shorter dredging program (i.e. as per existing maintenance dredging programs). These assessments involved modelling of typical and worst case maintenance dredging campaigns. The findings from the BMT WBM (2013 and 2014) assessments are summarised as follows.

- Impacts from annual maintenance dredging under different periods were predicted to be negligible, with zones of impact restricted to areas within and immediately adjacent to dredging and placement areas only. The change in turbidity due to dredging at sensitive receptor locations was predicted to remain well within the range of variability in ambient water quality of Cleveland Bay.
- Sensitive ecological receptors in Cleveland Bay, such as seagrass and coral reef habitats along Magnetic Island, were within the predicted 'zone of influence' (detectable plumes but negligible impacts predicted) of maintenance dredging (and associated marine placement at the approved Dredge Material Placement Area), however they were not predicted to be within any zones of low, moderate or high impact (varying levels of potential impacts to sensitive receptors, if present).
- Given the short duration (typically up to five weeks) of maintenance dredging campaigns, the short term nature of dredge plumes and the tolerance of biota to short term increases in turbidity, it was not expected that impact thresholds will be exceeded during maintenance dredging at areas containing sensitive ecological receptors.
- Cumulative impacts from maintenance dredging and placement impacts were assessed and indications were that the relative contribution of dredge sediment to overall sedimentation processes operating in Cleveland Bay are minimal and cumulative impacts on water quality (between years) and marine habitats that are currently in poor (recovering) condition were not expected. Furthermore, maintenance dredging during increased turbidity from flood plumes is not expected to noticeably contribute to impacts on ecosystems due to the flood plumes.
- In terms of resilience, it was acknowledged that there was little information on the tolerances of seagrass during periods of recovery, and it was possible that if seagrass condition was poor in the period leading up to future maintenance dredging campaigns, measurable changes to condition (e.g. reduced growth, loss of carbohydrate) of the more sensitive seagrass species could occur. However, taking into consideration the negligible impacts predicted, the current condition and extent of seagrasses and corals, and the temporary nature of turbid plumes, it was considered that water quality effects resulting from the annual maintenance dredging will not affect longer term recovery of seagrass or corals.
- In regard to regional impacts from resuspension of material from the DMPA, 12 month resuspension modelling indicated that the modelled change in the 95th percentile turbidity (i.e. the turbidity value exceeded 5% of the time, or 18 days in the year) was less than 2 NTU, while the modelled change in the 50th percentile turbidity (representing median or typical turbidity) was less than 0.05 NTU throughout the model domain. This very small change to ambient turbidity is highly unlikely to cause measurable changes to biota or ecosystems.
- In terms of sediment deposition, the change in the 95th percentile deposition rate and the 50th percentile deposition rate will be less than 1 mg/cm2/day and less than 0.01 mg/cm2/day respectively throughout the entire model domain. At sensitive receptor sites within Cleveland Bay, changes in deposition rates will be virtually undetectable. These small changes to sedimentation rates are very small compared to background variability (e.g. 2.9-7.4 mg/cm2/day recorded at Middle Reef) and are highly unlikely to cause adverse effects to sensitive receptors.

These conclusions are supported by previous reactive monitoring undertaken during the 1993 capital dredging campaign (11 week campaign). This dredging campaign was longer than a typical 5 week maintenance dredging campaign, so provides a conservative comparison. The results of the 1993 monitoring program indicated that 'no extreme suspended sediment concentration occurred at any of the Magnetic Island bay sites as a direct result of dredging' and 'given available data, dredge related effects appear to lie within normal variation at seagrass sites in SE Cleveland Bay and the coral systems at Middle Reef' (Larcombe and Ridd 1994).

6.2.5 Oxidisation of potential acid sulfate soils (PASS) in the water column

Five submissions were related to the potential for oxidisation of sediments that contain potential acid sulfate soil (PASS) when placed at sea below the lowest astronomical tides water level. These submissions suggested that placement of this material below lowest astronomical tides could well be within the wave re-suspension zone, bringing the material into contact with 100% oxygenated water and potentially forming low pH conditions.

In response to this, it is generally accepted that dredged material which remains waterlogged in the marine environment will not oxidise (sensu Dear *et al*. 2014). Dear *et al*. 2014 does acknowledge that dissolved oxygen can sometimes be high enough to cause oxidation of submerged sulfidic fines, however this is more relevant to enclosed freshwater bodies such as lakes. In the marine environment, seawater is a natural buffer against the formation of sulphuric acid, and any acidity will be neutralised relatively quickly.

Nevertheless, the revised design now involves placement of all dredged material in reclamation. This will allow appropriate treatment of any acid sulfate soils in a confined area. Furthermore, the reactive monitoring program (in the Dredge Management Plan) will include monitoring of pH during dredging and placement in the reclamation.

6.2.6 Perception of 'green valve' used in dredging

12 submissions were related to the use of a 'green valve' by the Trailer Suction Hopper Dredge (TSHD), and whether this will actually reduce the potential impacts from dredging. Specifically, the submissions stated that the green valve will not change the amount of sediment released, only that the sediment will be released beneath the water surface thereby only reducing visual impacts.

An environmental valve, or 'green valve', is used in the dredging industry to reduce the environmental impact from dredging. While it is correct that the green valve does not reduce the amount of sediment released from a dredge, it does reduce the extent of turbid dredge plumes in the water column and limits the mobility of dredged material.

The overflow from the TSHD consists of water, sediments and air. Without a green valve, the air in the overflow carries the sediment fines to the surface. As a consequence, the sediment fines are dispersed over a much larger area increasing turbidity in the water column. With a green valve (Figure 6.2), the overflow is choked such that a constant fluid level is maintained in the hopper and, as a result, no air is taken down with the overflow water. This results in more sediment taken to the seabed and less sediment suspended in the water column as turbid plumes. The material on the seabed is less likely to become mobilised into areas of sensitive ecological receptors compared to material suspended in the water column.

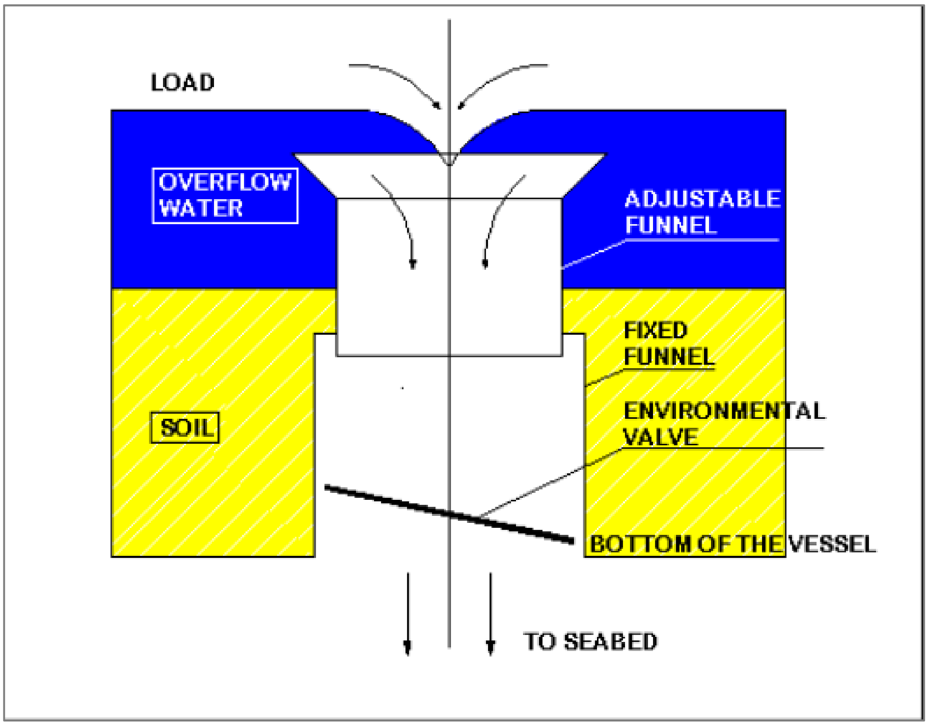

Figure 6.2 Diagram of an Environmental Valve or 'Green Valve'

6.2.7 Water quality and public swimming safety concerns

Picnic Bay Surf Life Saving Club raised the potential change in water quality which could lead to public swimming safety concerns. Specifically, the submission stated that changes to water quality could potentially result in the following:

- increased frequency of toxic algal blooms
- increased jellyfish abundance as a result of higher nutrient level
- changes to shark and crocodile population and behaviour in the area resulting from increased turbidity
- decreased ability to identify dangerous predatory animals and underwater hazards due to increased turbidity.

The predicted changes to water quality as a result of dredging are not expected to be at a level of magnitude which will lead to the above issues. The levels of nutrients and other contaminants in the dredged sediment have been shown to be in low concentrations such that a perceptible increase in these constituents in the water column will be unlikely as a result of dredging (Section B4.4.3.2 and B4.4.3.3 of the EIS). With placement of all dredged material now in reclamation as a result of the design refinement, the risk to changes in water quality are further reduced.

Further to this, while there is predicted to be a short-term increase in turbidity near to the dredging area, the level of increased turbidity will be unlikely to be noticeable at public swimming areas (i.e. increased turbidity may be able to be measured by instrumentation, but not likely to be visually perceptible).

Therefore, the low levels of predicted short-term changes to water quality are expected to have a negligible effect on the safety matters raised in the submission.

6.2.8 Natural turbidity of Cleveland Bay

Six submissions were related to a statement made in the baseline section of the EIS that Cleveland Bay is 'naturally turbid'. The submissions raised that Cleveland Bay (including Magnetic Island and the Strand) have been contaminated by dredge spoil for about 100 years, and the water is turbid with sediment that contains high concentrations of anthropogenic metals and organic contaminants. The submissions also raised that many bays to the north and south of Cleveland Bay are relatively clear water bays (except during cyclonic flooding), indicating that it is more likely that the turbidity of Cleveland Bay is due to historic dredging activities.

While it is accepted that there is some level of anthropogenic sources of turbidity in Cleveland Bay (dredging, port activities and other urban development), the general consensus is that the sediment in Cleveland Bay is predominantly derived from sediments deposited during the Holocene period (e.g. Larcombe and Ridd 1994, and Orpin 1999).

In response to the matter of Cleveland Bay being contaminated with dredged material, water quality monitoring data indicates that while some areas of Cleveland Bay are typically turbid due to resuspension from wind and waves (in particular the nearshore shallow areas), other areas of Cleveland Bay (especially around Magnetic Island and in offshore waters) are typically low turbidity environments for most of the year as a result of regular tidal exchange with less turbid offshore waters.

To illustrate the natural turbidity in Cleveland Bay from resuspension of bed sediments during high wind events, aerial photos are shown in Figure 6.3. These photos were taken on a day when high winds were occurring and had been sustained for a number of days previously. As can be seen, the waters within Cleveland Bay can become naturally turbid during high wind events.

In contrast, Figure 6.4 shows photos of the typical low turbidity experienced year round along the Coast of Magnetic Island. While the turbidity generally increases for short periods of time during high wind events such as that in Figure 6.3, the waters surrounding Magnetic Island are less susceptible to increased turbidity from wind and waves.

This difference in turbidity at various areas within Cleveland Bay is demonstrated in the different water quality threshold values presented in Section 6.3.4, with very low turbidity threshold values for waters surrounding Magnetic Island due to the low turbidity measured in these areas.

Figure 6.3 Natural turbidity in Cleveland Bay from resuspension during high winds – looking toward the Port (top) and looking toward Cape Cleveland (bottom)

Figure 6.4 Typical Low Turbidity Environment at Geoffrey Bay

6.3 Revised Environmental Impact Assessment

6.3.1 Legislation and policy

Since the initial release of the EIS, there have been important legislative changes at both the State and Commonwealth level. A new regulation under the *Great Barrier Reef Marine Park Regulations 1983* (Cth) was introduced on 2 June 2015 which sets out to prevent the placement of capital dredge material in the Marine Park. Specifically, the regulation prevents GBRMPA from granting permission for placement of capital dredge material in the Marine Park.

In addition, the *Sustainable Ports Development Act 2015* (Qld) prevents approval being granted for capital dredging areas that are in the Great Barrier Reef World Heritage Area but outside the Great Barrier Reef Marine Park unless it is for a priority port and in accordance with that port's Master Plan, or if the development is the subject of an EIS process started before the act came into effect. The Port of Townsville is a priority port under the Act and the PEP is the subject of an eligible EIS process.

At the time of preparing the EIS, draft environmental values (EVs) and water quality objectives (WQOs) for the Townsville region had been recently released for public comment. These EVs and WQOs have now been finalised and are included in Schedule 1 of the *Environmental Protection (Water) Policy 2009* in the Ross River Basin and Magnetic Island Plan (Basin No. 118), which was released in late 2013.

Implications from this document include zones of high ecological value around Magnetic Island and the eastern region of Cleveland Bay, resulting in more stringent turbidity and WQOs around Magnetic Island, with WQOs expressed as 20th, 50th and 80th percentiles.

As the PEP impact assessment described below does not rely on assessment against WQOs, this change in WQOs for the study area does not affect the outcomes of the impact assessment in the EIS or in this AEIS.

6.3.2 Design refinement

The design of the Port Expansion Project has been refined in response to submissions and in order to reduce the overall environmental impact and to eliminate the placement of capital dredge material at sea.

The proposed reclamation is now larger (increased from approximately 100 ha to approximately 150 ha), extending further to the north-east in the vicinity of the Ross River channel. The larger reclamation will allow all capital dredging material to be placed onshore rather than at a marine DMPA. Only maintenance dredging material will continue to be placed at the existing marine DMPA as part of the current proposal.

The design refinement also includes widening the Platypus and Sea Channels and a reduction in the proposed deepening of the channels (-12.8m LAT rather than -13.7m LAT). The impacts associated with widening the channels have been fully assessed as part of this AEIS.

The proposed development will take place gradually in stages, reducing the intensity of the development and its associated environmental impacts. Smaller dredging plant are now proposed, which further reduces the potential impact due to suspended sediment plumes and dredged sediment deposition.

The impacts on marine water quality from the design refinement are assessed in Section 6.3.4.1. Due to the change in dredging campaign (equipment and timing) and dredge material placement resulting from the design refinement, the following impacting processes have been reassessed:

- turbid plume impacts to water quality from dredging
- turbid plume impacts from tailwater discharges from the reclamation
- sediment deposition due to settling of suspended sediments in turbid dredge plumes.

6.3.3 Supporting studies

Supporting studies relevant to this section of the AEIS include Appendix A1 (Additional Field Studies Report) and Appendix A2 (Modelling Report).

6.3.4 Revised assessment

6.3.4.1 Impact assessment

Impact assessment methodology – water quality

Conceptual approach

To assess potential impacts to marine water quality and ecologically sensitive areas from the dredging works as part of the revised design, 'zones of impact' were developed using site-specific threshold values. The zones of impact, which are recommended in the GBRMPA Modelling Guidelines and are generally based on environmental assessment guidelines for dredging produced by the WA EPA (2011), include the following.

- Zone of Influence - extent of detectable plume[2], but *no predicted ecological impacts*.
- Zone of Low Impact - water quality *may* be pushed beyond natural variation potentially resulting in sub-lethal impacts to ecological receptors with a nominal recovery time of approximately 6 months.
- Zone of Moderate Impact - water quality *likely* to be pushed beyond natural variation potentially resulting in sub-lethal impacts to ecological receptors and/or mortality with a nominal recovery time up to 24 months.
- Zone of High Impact - water quality will *most likely* be pushed beyond natural variation (excluding extreme weather events) potentially resulting in mortality of ecological receptors with recovery greater than 24 months.

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

The Zone of Low Impact indicates that sub-lethal effects to sensitive ecological receptors are expected to be minor (e.g. stress, but mortality unlikely), and on this basis recovery times are expected to be relatively rapid. The Zone of Moderate Impact indicates possible greater sub-lethal effects or impacts at the colony scale (e.g. seagrass leaf loss, partial colony loss), with longer recovery timeframes therefore expected. Zone of High Impact indicates that a large proportion of seagrass or coral could be lost from the affected area, and on this basis, long timeframes (measured in years) will be expected for full recovery to occur.

Threshold development methodology

To determine the zones of impact, site-specific threshold values were developed using a combination of water quality (turbidity) and biological tolerances methods. This entailed using baseline water quality monitoring data to set initial threshold values. These values were then compared to biological tolerances from literature values as a 'reality check' to confirm that the threshold values are biologically meaningful.

To determine initial impact assessment threshold values, the 12 month baseline water quality monitoring data set (Section 6.2.1) was amalgamated with previous monitoring data (Chapter B.4 (Marine Water Quality) of the EIS). As mentioned in Section 6.2.1, the baseline monitoring data set underwent a quality control process whereby periods of data were quarantined (to remove periods of dredging, bio-fouling and unusually large weather events) to ensure the data represented baseline conditions. The amalgamated baseline data were 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 baseline data were analysed over 30 day periods to give a range of percentile values over different time periods. This method provides a general indication of natural variability around each percentile value and provides context for modelling outputs which show turbidity in a 30 day window (refer to Appendix A2, Modelling Report) . In selecting a 30 day period, it is acknowledged that different species vary greatly in terms of their tolerances to the duration/frequency of exposure to water quality stressors (including turbidity). Based on a review of ecological tolerance data for relevant sensitive receptors (i.e. seagrass and corals), measurable responses to water quality stress by sensitive species typically occur over periods measured in days to weeks (e.g. the seagrass *Halophila ovalis*). The adopted percentile values (20th, 50th, 80th percentile) measured over a 30 day time period are meaningful for assessing changes to sensitive receptors at sub-monthly time-scales. For context, a percentile curve was also calculated based on data collected over the entire monitoring period.

As an example, Figure 6.5 shows the percentile curves for data collected at Virago Shoal. This shows the natural variability measured around the median (50%ile) and other percentile values. The x-axis in Figure 6.5 represents the different percentile values extracted from the rolling 30 day window analysis moving from frequently exceeded on the left to rarely exceeded on the right. The different curves are statistics representing the variability of the percentile analysis results across the different 30 day periods (making up the entire baseline monitoring period). The lower curve represents the least turbid conditions experienced across the monitoring period while the upper curve is conversely the most turbid conditions. The solid green line is the mean of the different 30 day window conditions.

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[2] 'Detectable' plume in terms of detectable by instrumentation deployed in the water column

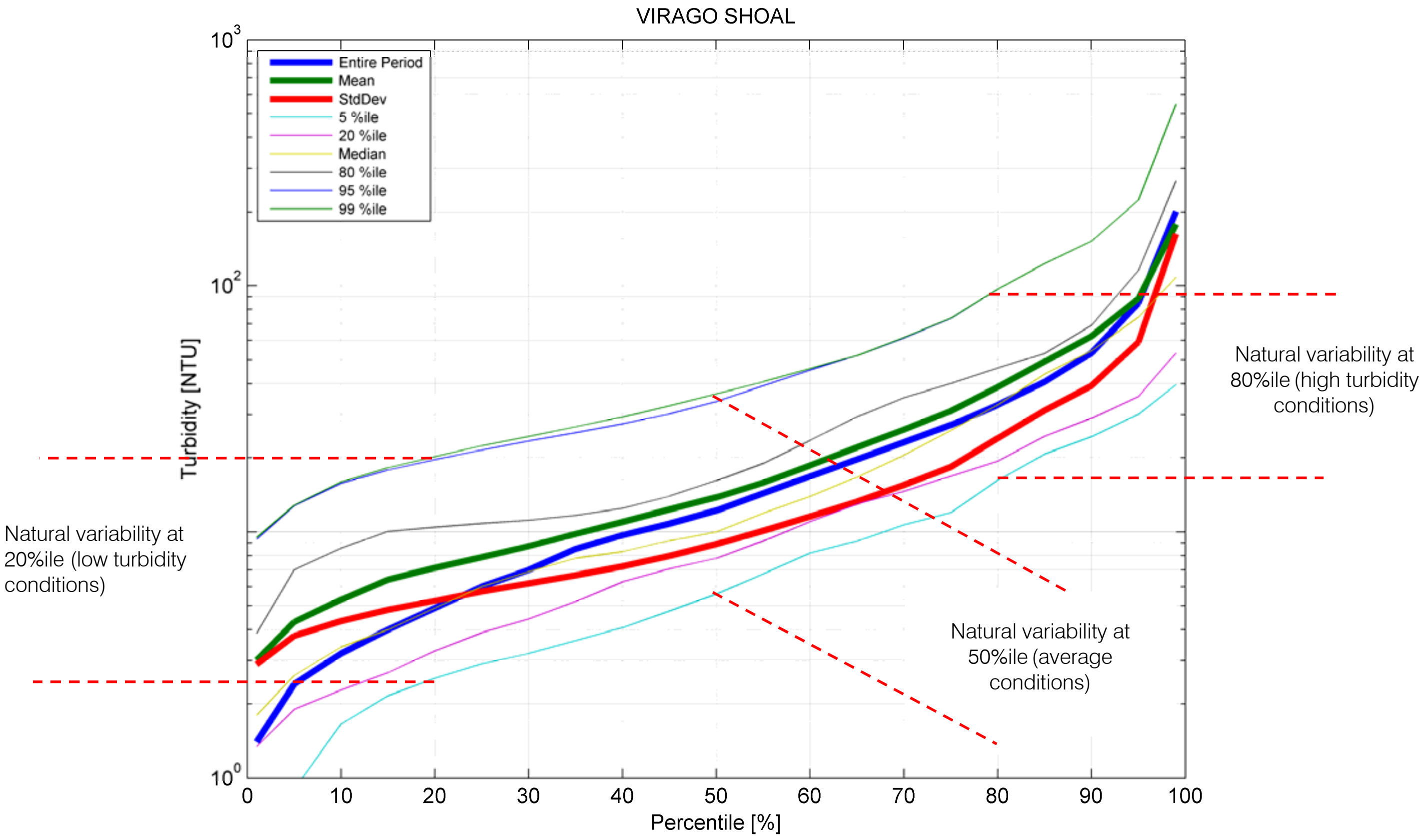


Figure 6.5 Example Summary Analysis of Baseline Data for Virago Shoal

Threshold values were derived from these percentile curves based on the natural variability around the 50th percentile (average conditions), 20th percentile (low turbidity conditions – typically low wind and waves) and the 80th percentile (high turbidity conditions – typically moderate to high wind and waves). The higher percentiles (e.g. 80th percentile) represent less frequent occurrences of higher turbidity which can lead to acute impacts, while the lower percentiles (e.g. 20th and 50th percentiles) represent more frequent occurrences of lower turbidity which can lead to chronic impacts. Therefore, this method considers both acute and chronic impacts.

A description of the threshold values for the zones of impact and how they relate to the natural variability is provided in Table 6.1. The approach used to determine the threshold levels involved using the standard deviation from the natural background mean at each percentile (i.e. 20th, 50th and 80th percentiles). This is conceptually similar to the approach developed by Orpin *et al.* (2004) to assess impacts from construction-related turbidity increases in Nelly Bay in Townsville.

The threshold values for each zone of impact are based on a number of standard deviations from the mean, increasing from the zone of low impact (1-2 standard deviations) up to the zone of high impact (3-5 standard deviations). Initially, the number of standard deviations used for each zone of impact was consistent across all sites. However, after testing against biological thresholds (discussed below) and comparing to other thresholds for corals in low turbidity waters (DHI in Chevron 2010), it was considered more appropriate for the less turbid offshore waters around Magnetic Island to use a different number of standard deviations than the more turbid nearshore waters.

The 'zone of influence' was defined as the extent of detectable plumes due to the proposed dredging. Turbid plumes were assumed to become detectable once they were approximately 20-30% above background conditions (background conditions conservatively assumed to be waters around Magnetic Island). To determine the extent of this zone, the following criteria were used:

- greater than 0.5 NTU above 50th percentile conditions (i.e. 50% of the time)
- greater than 2 NTU above 80th percentile conditions (i.e. 20% of the time)
- greater than 5 NTU above 95th percentile conditions (i.e. 5% of the time).

Benchmarking to biological thresholds

As the key sensitive ecological receptors in Cleveland Bay are hard corals and seagrass, these have been considered in the current assessment.

Numerous laboratory studies have examined the tolerances of hard corals to sediments, however there are several uncertainties regarding the applicability of these data for developing locally-specific thresholds. Potential stress thresholds for some coastal corals were quantified by Cooper *et al.* (2008) using an 18-month data set of water turbidity at Horseshoe Bay on the northern side of Magnetic Island. Based on the analysis of coral bio-indicators for water quality, Cooper *et al.* (2008) concluded that long-term (ca. 2 years as interpreted by McDonald *et al.* 2013) turbidity greater than 3 NTU leads to sub-lethal coral stress while turbidity greater than 5 NTU may represent a threshold for severe stress on corals in shallow areas.

There is a large body of work on the tolerances of some seagrass species to benthic light levels. Relevant tolerance values for seagrass were provided by James Cook University (JCU) and are presented in Table 6.1. The purpose of these biological tolerances is to test the impact zone predictions (discussed further in section below) developed using water quality (turbidity) thresholds, and are not intended to be used for light based thresholds.

Descriptions of water quality threshold values along with biological tolerance values (from the literature) for each zone of impact are presented in Table 6.1.

Table 6.1 Description of Impact Assessment Threshold Values

Zone of Impact	Water Quality (Turbidity)	Biological Tolerances (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 for nearshore areas, and five standard deviations for offshore areas. ▪ Durations of excess turbidity based on 20%, 50% and 80% of dredge period (Table 6.2 and Table 6.3).	▪ LR# for Zostera (4.5-12 mol/m^2/day rolling 2 week average) is not met for more than 6 weeks during the growing season (July-Dec). ▪ LR for *Halophila ovalis* (2.8-4.4 mol/m^2/day)## is not met for more than 21 days during the growing season (July-Dec). ▪ Resulting in total loss of seagrass and no recovery within 12 months (reliant on new recruitment).
Zone of Moderate Impact	▪ Excess turbidity likely to push total turbidity beyond natural variation. ▪ Threshold value = excess turbidity greater than two standard deviations from the natural background mean for nearshore areas, and three standard deviations for offshore areas. ▪ Durations of excess turbidity based on 20%, 50% and 80% of dredge period (Table 6.2 and Table 6.3).	▪ LR for Zostera (4.5-12 mol/m^2/day rolling 2 week average) is not met for 3-6 weeks during the growing season (July-Dec). ▪ LR for *Halophila ovalis* (2.8-4.4 mol/m^2/day) is not met for 15-21 days during the growing season (July-Dec). ▪ Resulting in declines in seagrass but some recovery within one month.
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 for nearshore areas, and two standard deviations for offshore areas. ▪ Durations of excess turbidity based on 20%, 50% and 80% of dredge period (Table 6.2 and Table 6.3).	▪ LR for Zostera (4.5-12 mol/m^2/day rolling 2 week average) is not met for 7-21 consecutive days during the growing season (July-Dec). ▪ LR for *Halophila ovalis* (2.8-4.4 mol/m^2/day) is not met for 7-14 consecutive days during the growing season (July-Dec). ▪ Management action can avoid declines in seagrass cover.
Zone of Influence	▪ Extent of detectable plumes. ▪ Dredging related turbidity exceeds 0.5 NTU for 50% of the time, 2 NTU for 20% of the time, and/or 5 NTU for 5% of the time (Table 6.2 and Table 6.3).	▪ LR for Zostera (4.5-12 mol/m^2/day rolling 2 week average) is not met for <7 consecutive days during the growing season (July-Dec). ▪ LR for *Halophila ovalis* (2.8-4.4 mol/m^2/day) is not met for <7 consecutive days during the growing season (July-Dec).

Notes:
LR = Light Requirement
Collier *et al* 2009 lab experiments found significant loss of *Halophila ovalis* after 14 days below LR and based on lab experiments determined a light requirement of 4.4 mol/m^2/day. JCU work in Gladstone also noted declines of *Halophila ovalis* in shaded treatments within 2 weeks

The output from the analysis of data was turbidity (NTU) impact assessment threshold values for each impact zone at each monitoring site. These values represent turbidity above background levels, and are included in Table 6.2 for offshore waters and Table 6.3 for nearshore waters. Importantly to note is that the threshold values presented in Table 6.2 and Table 6.3 have been used for impact assessment purposes only, and are not proposed as trigger values during dredging. Turbidity trigger values during dredging will be developed following further monitoring prior to commencement of the dredging campaign, as per Appendix B1 (Dredge Management Plan).

Benchmarking to other studies

As mentioned, threshold values for offshore waters around Magnetic Island are based on a higher number of standard deviations than the more turbid nearshore waters due to the much lower natural turbidity in the offshore areas. These offshore threshold values are comparable to thresholds developed by DHI in Chevron (2010) for corals in low turbidity waters, as follows:

- Zone of total mortality (high impact) = 80th percentile turbidity threshold of 13 NTU (converted from TSS of 25 mg/L).
- Zone of partial mortality (low to moderate impact) = 50th percentile value of 2.5 NTU, and 80th percentile value of 5 NTU.

Development of impact zones

To delineate the zones of impact, the site-specific impact threshold values were interpolated spatially across the study area using GIS mapping software to produce 3-dimensional threshold grids. These threshold grids were then analysed against the 3-dimensional model output grids. This produced impact zone maps which indicate areas where modelled turbidity is higher than the relevant impact threshold value.

Table 6.2 Turbidity Threshold Values (Above Background) for Impact Assessment Purposes – Magnetic Island and Offshore Waters

Impact Zone	Description	Method	Percentile	Percentile Descriptor (Duration of excess turbidity per month of dredging)	Picnic Bay	Geoffrey Bay	Florence Bay	Cockle Bay	Sea Channel
					Turbidity Threshold Values (NTU) – *above background*				
Zone of High Impact	Excess turbidity *most likely* pushes total turbidity beyond natural variation	5 x standard deviations from 20%ile mean	20%ile	Exceeded 80% of the time (24 days per month of dredging)	3	3	3	6	3
		5 x standard deviations from 50%ile mean	50%ile	Exceeded 50% of the time (15 days per month of dredging)	5	5	5	9	8
		5 x standard deviations from 80%ile mean	80%ile	Exceeded 20% of the time (6 days per month of dredging)	12	10	18	13	25
Zone of Moderate Impact	Excess turbidity *likely* to push total turbidity beyond natural variation	3 x standard deviations from 20%ile mean	20%ile	Exceeded 80% of the time (24 days per month of dredging)	2	2	2	3	2
		3 x standard deviations from 50%ile mean	50%ile	Exceeded 50% of the time (15 days per month of dredging)	3	3	3	5	5
		3 x standard deviations from 80%ile mean	80%ile	Exceeded 20% of the time (6 days per month of dredging)	7	6	11	8	15
Zone of Low Impact	Excess turbidity *may* push total turbidity beyond natural variation	2 x standard deviations from 20%ile mean	20%ile	Exceeded 80% of the time (24 days per month of dredging)	1	1	1	2	1
		2 x standard deviations from 50%ile mean	50%ile	Exceeded 50% of the time (15 days per month of dredging)	2	2	2	4	3
		2 x standard deviations from 80%ile mean	80%ile	Exceeded 20% of the time (6 days per month of dredging)	5	4	7	5	10
Zone of Influence	Full extent of detectable plumes (including resuspension)	Dredging related turbidity exceeds 0.5 NTU	50%ile	Exceeded 50% of the time (15 days per month of dredging)	0.5				
		Dredging related turbidity exceeds 2 NTU	80%ile	Exceeded 20% of the time (6 days per month of dredging)	2				
		Dredging related turbidity exceeds 5 NTU	95%ile	Exceeded 5% of the time (1.5 days per month of dredging)	5				

Table 6.3 Turbidity Threshold Values (Above Background) for Impact Assessment Purposes – Nearshore Waters

Impact Zone	Description	Method	Percentile	Percentile Descriptor (Duration of excess turbidity per month of dredging)	Strand	Virago Shoal	Platypus Channel	Middle Reef	Cape Pallarenda
					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 20%ile mean	20%ile	Exceeded 80% of the time (24 days per month of dredging)	12	16	19	5	3
		3 x standard deviations from 50%ile mean	50%ile	Exceeded 50% of the time (15 days per month of dredging)	17	27	43	9	11
		3 x standard deviations from 80%ile mean	80%ile	Exceeded 20% of the time (6 days per month of dredging)	50	72	91	21	49
Zone of Moderate Impact	Excess turbidity *likely* to push total turbidity beyond natural variation	2 x standard deviations from 20%ile mean	20%ile	Exceeded 80% of the time (24 days per month of dredging)	8	11	12	3	2
		2 x standard deviations from 50%ile mean	50%ile	Exceeded 50% of the time (15 days per month of dredging)	12	18	29	6	8
		2 x standard deviations from 80%ile mean	80%ile	Exceeded 20% of the time (6 days per month of dredging)	33	48	60	14	33
Zone of Low Impact	Excess turbidity *may* push total turbidity beyond natural variation	1 x standard deviation from 20%ile mean	20%ile	Exceeded 80% of the time (24 days per month of dredging)	4	5	6	2	1
		1 x standard deviation from 50%ile mean	50%ile	Exceeded 50% of the time (15 days per month of dredging)	6	9	14	3	4
		1 x standard deviation from 80%ile mean	80%ile	Exceeded 20% of the time (6 days per month of dredging)	17	24	30	7	16
Zone of Influence	Full extent of detectable plumes (including resuspension)	Dredging related turbidity exceeds 0.5 NTU	50%ile	Exceeded 50% of the time (15 days per month of dredging)	0.5				
		Dredging related turbidity exceeds 2 NTU	80%ile	Exceeded 20% of the time (6 days per month of dredging)	2				
		Dredging related turbidity exceeds 5 NTU	95%ile	Exceeded 5% of the time (1.5 days per month of dredging)	5				

Testing of impact zones

In consultation with researchers from James Cook University, a method was developed to test whether the zones of impact developed using water quality (turbidity) thresholds in Table 6.2 and Table 6.3 are biologically meaningful. This method involved applying the turbidity thresholds to periods where actual benthic PAR monitoring data and surface PAR monitoring data coincided for three monitoring sites known to previously contain seagrass. The locations of these monitoring sites are shown in Figure 6.1 and include the following:

- Geoffrey Bay – offshore waters around Magnetic Island
- Virago Shoal – nearshore waters
- The Strand – nearshore waters.

The aim of undertaking this analysis was to assess the benthic PAR available to these seagrass areas if additional turbidity as per the turbidity impact thresholds was added to the measured PAR data. To achieve this, the time series benthic PAR was converted to time series turbidity using a light attenuation/turbidity correlation developed for each monitoring site. Once the additional turbidity was added onto this time series it was converted back to benthic PAR using the same light attenuation/turbidity correlations.

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

The 50th percentile threshold values for Geoffrey Bay, Virago Shoal and The Strand were used as this allowed a relatively simple addition of excess turbidity to the time series PAR data.

Two week rolling averages of the derived benthic PAR data for each of the three monitoring sites are presented in Figure 6.6, which also shows baseline monitoring data (actual recorded data). Note that the monitoring periods at each site are different depending on the availability of data at each site.

The results were compared to the biological tolerances for *Halophila ovalis* in Table 6.1 noting (i) this is one of the most sensitive species to light reductions; and (ii) this is one of the most abundant species found at the monitoring locations (average water depth of 2-4m). The results indicate that:

- Using the high impact zone threshold values, there will be extended periods under ambient conditions at Virago Shoal and the Strand when benthic PAR will fall below the *Halophila ovalis* light requirement for longer than 3 weeks. On this basis, it will be predicted that turbidity in this zone will result in the total loss of seagrass (as expected of this zone). At Geoffrey Bay, benthic PAR will be below the light requirement for up to 2 weeks, resulting in more moderate impacts. This indicates the offshore threshold values are on the conservative side.
- Using the moderate impact zone threshold values, there will be short periods (1-2 weeks) when benthic PAR will be below the *Halophila ovalis* light requirement at all three sites, but PAR will remain mostly within the light requirement range.
- Using the low impact zone threshold values, benthic PAR will remain mostly within the light requirement range, with only a few very brief periods (up to one week) when benthic PAR will be below the *Halophila ovalis* light requirement.
- The zone of influence (no predicted impacts) will be in the range between the baseline and the low impact zone threshold. As indicated in Figure 6.6, benthic PAR in this range will remain above the light requirement for most of the simulated period.

Therefore, based on this analysis, the zones of impact derived using the turbidity threshold values in Table 6.2 and Table 6.3 are considered to be suitable for impact assessment purposes.

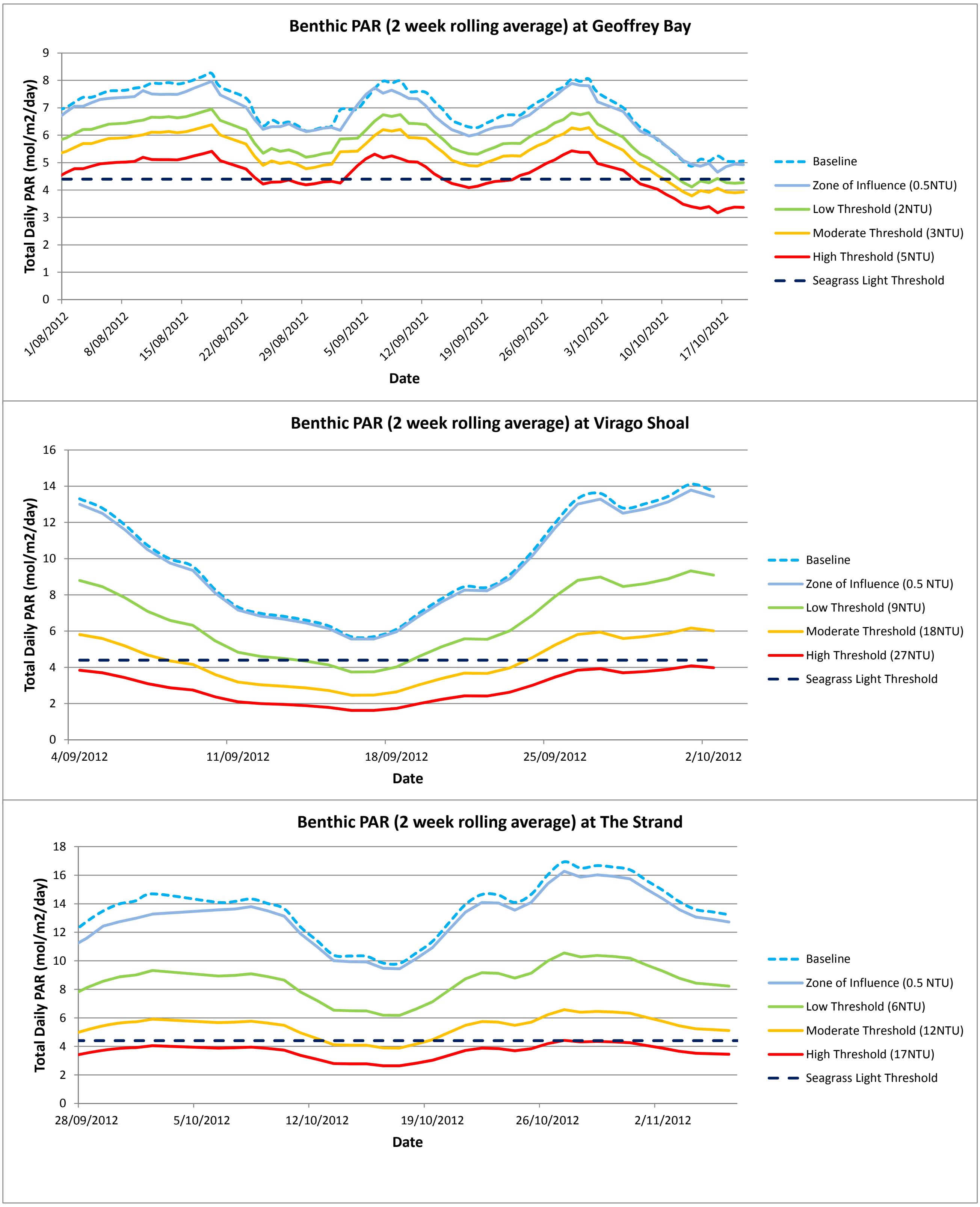


Figure 6.6 Total Daily PAR (mol/m²/day as 2 week rolling average) at Seagrass Monitoring Sites (Geoffrey Bay, Virago Shoal and the Strand) showing Baseline (actual monitoring data) and Addition of Impact Zone Threshold Values (note that scales differ between each figure)

Impact assessment methodology – sediment deposition

Sediment deposition impact thresholds should ideally:

- take into account ambient background conditions at the site
- be based on the tolerance limits of resident biota, and incorporate different levels of ecosystem stress
- use consistent methods, and have similar underlying assumptions as modelling with regard to deposition and erosion processes.

Tolerance limits

Tolerance limits vary greatly among species, as outlined in reviews by Erftemeijer *et al*. (2012) for corals, and Erftemeijer *et al*. (2006) for seagrass. In general terms many corals tend to be more sensitive to sediment deposition than seagrasses (Erftemeijer *et al*. 2006; 2012). On this basis, adopting thresholds that protect corals should protect most seagrass species, particularly those found in turbid depositional environments as occur in Cleveland Bay.

GBRMPA (2010) recommends sedimentation trigger values of 3 mg/cm^2/day (mean annual) and 15 mg/cm^2/day (daily maximum). GBRMPA (2010) indicates that the trigger value has low confidence, but has been developed to mitigate “excessive coral recruit mortality and includes an uncertainty factor for higher organic content or small grain sizes”.

GBRMPA (2010) suggests that this trigger value may not necessarily apply to all environments, and that “experimental evidence suggests that 10 mg/cm^2/day sedimentation is valid in areas with coarse calcareous sediments, but trigger levels need to be lower where sediments are largely of terrigenous origin, of small grain size or of high organic content (De’ath and Fabricius 2008).”This is further considered below with regard to ambient environmental conditions in Cleveland Bay.

Gilmour *et al*. (2006) calculated preliminary estimates of different loads and durations likely to cause increasing levels of impacts to corals. Gilmour *et al*. (2006) cautions that the estimates are based on very limited data from their investigation area (the Pilbara) and other regions, and that levels will need to be refined and corrected through further research. The curves shown in Figure 6.7 apply to relatively tolerant coral taxa in nearshore reef systems in the Pilbara, which can have high background sedimentation rates as occurs in Cleveland Bay. These curves were assessed in the benchmarking exercise of the indicative thresholds developed for the purposes of this impact assessment.

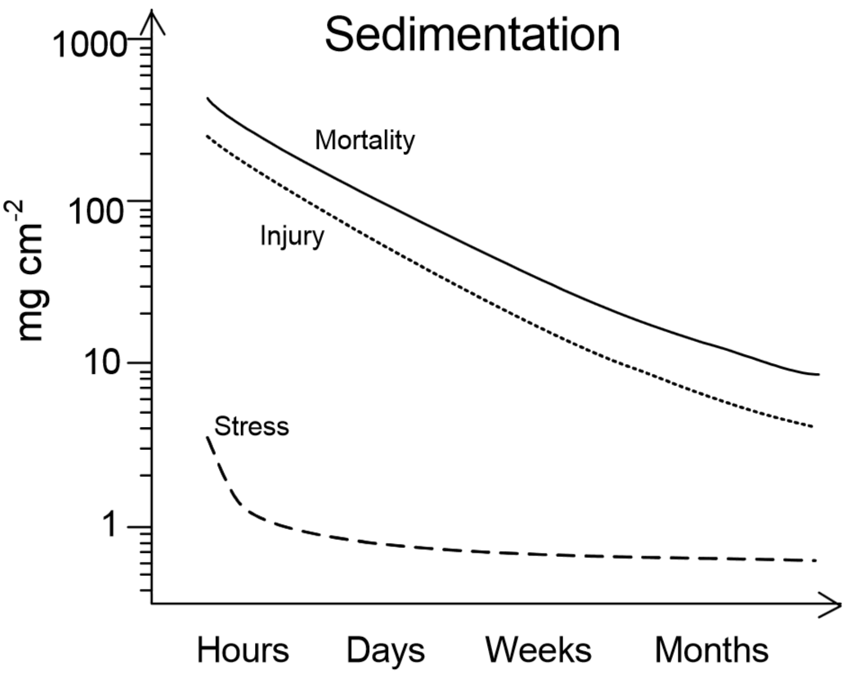


Figure 6.7 Preliminary estimates of loads and durations of sediment likely to cause impacts to corals in north-west Australia (Source: Gilmour *et al* 2006)

Ambient deposition measurements

As discussed in the EIS, sediment deposition rates vary great over time and spatially in response to wind and wave re-suspension of the seabed and environmental conditions at the receptor site. The measurement method is also important. Baseline sediment trap data collected from Middle Reef recorded sedimentation rate of 270 g/m^2/day or 27 mg/cm^2/day (Larcombe *et al*. 1994), whereas sedimentation rates recorded at fringing reefs of Magnetic Island varied between 26 to 3640 g/m^2/day (2.6 – 364 mg/cm^2/day) (Mapstone *et al*. 1992 in Larcombe and Ridd 1994). These studies were made using sediment tubes that alter hydrodynamics and significantly impede sediment resuspension. Browne *et al*. (2012) measured seasonal variations in sedimentation at Middle Reef and Paluma Shoals (located in Halifax Bay), and used a sampling device that allowed for natural resuspension of sediments. At Middle Reef, mean sedimentation rates varied among sites from 30 to 74 g/m^2/day (3-7.4 mg/cm^2/day), which were far lower than measured by Larcombe *et al*. 1994 using sedimentation tubes.

The lowest seasonal average sediment deposition value measured by Browne *et al*. (2012) at Middle Reef (3 mg/cm^2/day) was equivalent to the annual average guideline value of GBRMPA (2010) but less than the daily maximum guideline value of 15 mg/cm^2/day. It is important to note that the methods to measure sedimentation rates by Browne *et al*. (2012) and those used to calculate guideline values are unlikely to provide consistent results, and caution is therefore required when comparing values.

Adopted thresholds

Indicative impact thresholds were developed to assess potential risks of sediment deposition impacts to corals and seagrass. Similar to the water quality thresholds discussed previously, sediment deposition thresholds were scaled to take into account impact duration and intensity (i.e. 95th percentile equivalent to 1.5 days per month, 50th percentile equivalent to 15 days per month), and benchmarked to:

- GBRMPA (2010) guidelines
- Gilmour *et al*. (2006) sedimentation loads, as shown in Figure 6.7
- impact thresholds adopted by DHI (in Chevron 2010) for a dredging project in north west Australia, as shown in Table 6.5.

It is important to note that GBRMPA (2010) guidelines and Gilmour *et al*. (2006) are based on total sediment deposition levels, whereas impact thresholds adopted by DHI (in Chevron 2010) are for 'excess' sediment resulting from dredging (i.e. above background sedimentation levels) and reportedly take into account the tolerance limits of corals and seagrass found in their investigation area (North West Australia). As the modelling in the present study also reports 'excess' sediment resulting from dredging, a level of conservatism was adopted for the indicative impact thresholds.

The indicative impact thresholds were developed for impact assessment reporting purposes, i.e. prediction of potential impacts of one to two month dredging campaign. These threshold values are presented in Table 6.4. As mentioned previously, it is important to note that methods to measure sedimentation rates are varied and can produce different results. It is unknown what types of sedimentation sampling devices were used to develop the guideline values in Table 6.4. It is therefore recommended that any future monitoring program should establish trigger values based on locally specific field measurement data, and should not rely on the indicative impact thresholds adopted in the present study.

Note that while particle size of dredged sediments has been taken into account by the model, there is insufficient existing data to develop different impact thresholds for different sediment types.

Table 6.4 Impact thresholds for sediment deposition (above background)

Impact Zone	50%ile i.e. 15 days per month (mg/cm^2/day)	95%ile i.e. 1.5 days per month (mg/cm^2/day)	Notes

Zone of High Impact	>20.0	>200	▪ Similar to DHIs most conservative Zone of Mortality threshold of >20 mg/cm^2/day averaged over 14 days
			▪ More conservative (50th percentile) or similar to (95th percentile)'mortality' thresholds in Gilmour *et al*. (2006):
			  ▪ days (>200 mg/cm^2)
			  ▪ weeks (>70-80 mg/cm^2)

Zone of Moderate Impact	10.0-20.0	100-200	▪ 50%ile (medium term impact) > or = GBRMPA (2010) daily max values (15 mg/cm^2/day)
			▪ Similar to DHIs most conservative Zone of Partial Mortality thresholds for corals = 5-20 mg/cm^2/day averaged over 14 days
			▪ Upper bounds approximates 'injury' thresholds in Gilmour *et al*. (2006):
			  ▪ days (~>100 mg/cm^2)
			  ▪ weeks (~>20 mg/cm^2)

Impact Zone	50%ile i.e. 15 days per month ($mg/cm^2/day$)	95%ile i.e. 1.5 days per month ($mg/cm^2/day$)	Notes
Zone of Low Impact	1.5-10	15-100	▪ Upper bound of 95%ile value (short term acute impact) > daily max value of GBRMPA (2010), i.e. 15 mg/cm2/day ▪ 50%ile (medium term impact) within range of GBRMPA (2010) mean annual and daily max values (3-15 $mg/cm^2/day$)
Zone of Influence	0.5-1.5	5.0-15	▪ Upper bound of 95%ile value (short term acute impact) = daily max value of GBRMPA (2010), i.e. 15 $mg/cm^2/day$ ▪ 50%ile (medium term impact) below GBRMPA (2010) mean annual and daily max values (3-15 $mg/cm^2/day$) ▪ Similar to DHIs most conservative ZOI thresholds for corals = 1-5 $mg/cm^2/day$ averaged over 14 days

Table 6.5 DHI (in Chevron 2010) Impact Zone Thresholds (Above Background)

a) Coral – transitional periods

Zones	Definitions
Zone of Total Mortality	• Sedimentation > 0.2 $kg/m^2/day$ (> 7.0 mm/14day*)
Zone of Partial Mortality	• Sedimentation 0.05 – 0.2 $kg/m^2/day$ (1.7 – 7.0 mm/14day*)
Zone of Influence	• Sedimentation 0.01 – 0.05 $kg/m^2/day$ (0.3 – 1.7 mm/14day*)
No Impact	• Sedimentation < 0.01 $kg/m^2/day$ (< 0.3 mm/14day*)

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

b) Coral summer-winter

Zones	Definitions
Zone of Total Mortality	• Sedimentation > 0.5 $kg/m^2/day$ (> 17.5 mm/14day*)
Zone of Partial Mortality	• Sedimentation 0.1 – 0.5 $kg/m^2/day$ (3.5 – 17.5 mm/14day*)
Zone of Influence	• Sedimentation 0.025 – 0.1 $kg/m^2/day$ (0.9 – 3.5 mm/14day*)
No Impact	• Sedimentation < 0.025 $kg/m^2/day$ (< 0.9 mm/14day*)

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

c) Seagrass – transitional periods

Zones	Definitions
Zone of Total Mortality	• Sedimentation > 0.7 $kg/m^2/day$ (> 25 mm/14day*)
Zone of Partial Mortality	• Sedimentation 0.2 – 0.7 $kg/m^2/day$ (7 – 25 mm/14day*)
Zone of Influence	• Sedimentation 0.03 – 0.2 $kg/m^2/day$ (1 – 7 mm/14day*)
No Impact	• Sedimentation < 0.03 $kg/m^2/day$ (< 1 mm/14day*)

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

d) Seagrass – summer-winter

Zones	Definitions
Zone of Total Mortality	• Sedimentation > 1 $kg/m^2/day$ (> 35 mm/14day*)
Zone of Partial Mortality	• Sedimentation 0.3 – 1 $kg/m^2/day$ (10 – 35 mm/14day*)
Zone of Influence	• Sedimentation 0.04 – 0.3 $kg/m^2/day$ (1.5 – 10 mm/14day*)
No Impact	• Sedimentation < 0.04 $kg/m^2/day$ (< 1.5 mm/14day*)

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

Note that the units for sedimentation can be expressed as either kg/m2/day or mg/cm2/day, as shown in the above tables. The difference between the units is two orders of magnitude – e.g. 0.2 kg/m2/day is equal to 20 mg/cm2/day.

Revised impact assessment

The following impact assessment assumes that no mitigation measures, such as constraints on overflow, are implemented (i.e. unmitigated case).

The assessment considers both the ‘Expected Case’ and likely ‘Worst Case’ as per GBRMPA modelling guidelines. Modelling was undertaken to simulate dredging during five different 30 day periods during different seasons and the results were aggregated to determine likely impacts. The ‘Expected Case’ impacts were determined on the basis of the average turbidity and deposition percentiles at each location over the five different modelling periods. The ‘Worst

Case' impacts were determined on the basis of the maximum turbidity and deposition percentiles at each location from all of the five modelling periods. Further description of this is included in Appendix A2 (Modelling Report).

Stage 1 dredging

Stage 1 will be undertaken over a 4.5 year period and consists of the following.

- Construction of temporary perimeter revetment structures to capture any soft sediments and subsequent construction of revetment structures including removal of soft sediments (0.3 million m^3) under retaining wall structures along the perimeter of the proposed interim reclamation area. This will be carried out by a mechanical dredger and relocated to temporary bund areas within the existing reclamation area.
- Widening the Platypus Channel on its western side (a new width of 180 m at the outer harbour, tapering to 135 m at its northern end), and widening the Sea Channel on its eastern side (for 135 m at the southern end to 120 m at its northern end). The soft marine sediments and dense clayey sands will be dredged by TSHD (dredge volume of 1.5 million m^3). The stiff, very stiff and hard clays will be dredged by a mechanical dredger (dredge volume of 2.4 million m^3).
- The dredging of Berth 12 by mechanical dredger (dredge volume of 1.4 million m^3).
- Total dredge volume of approximately 5.6 million m^3.
- All dredge material to be placed in the reclamation.
- Duration of dredging for Stage 1 estimated as follows:
  - construction of temporary revetment structures including placement of soft material – 12 months
  - channel widening by TSHD – 4 months
  - channel widening by mechanical dredger – 2.3 years
  - Berth 12 – 15 months
  - total duration of Stage 1 ~ 4.5 years.

For the purposes of the AEIS, it was assumed that a small TSHD (hopper capacity of approximately ~ 3,000 m^3) would complete the TSHD dredging. Previously in the EIS, it was assumed a medium sized TSHD would be used.

The following percentile contour plots, sourced from Appendix A2 (Modelling Report), show depth averaged dredging-related turbidity above background levels for the TSHD dredging for the Expected Case (Figure 6.8) and the Worst Case (Figure 6.9). The mechanical dredging plots, which show very minimal dredge plumes, are presented in Appendix A2 (Modelling Report).

Note that the scales used on the plots differ between the 50th and 95th percentiles to reflect ambient turbidity during these varying conditions. Plots shown are based on the following percentile values:

- 50th percentile plot - typical (median) turbidity levels, which occur 50% of the time
- 95th percentile plot - infrequent periods (occurring 5% of the time) of high turbidity.

For context, percentile contour plots showing modelled ambient turbidity (without dredging) during 50th and 95th percentile conditions are provided in the Appendix A2 (Modelling Report).

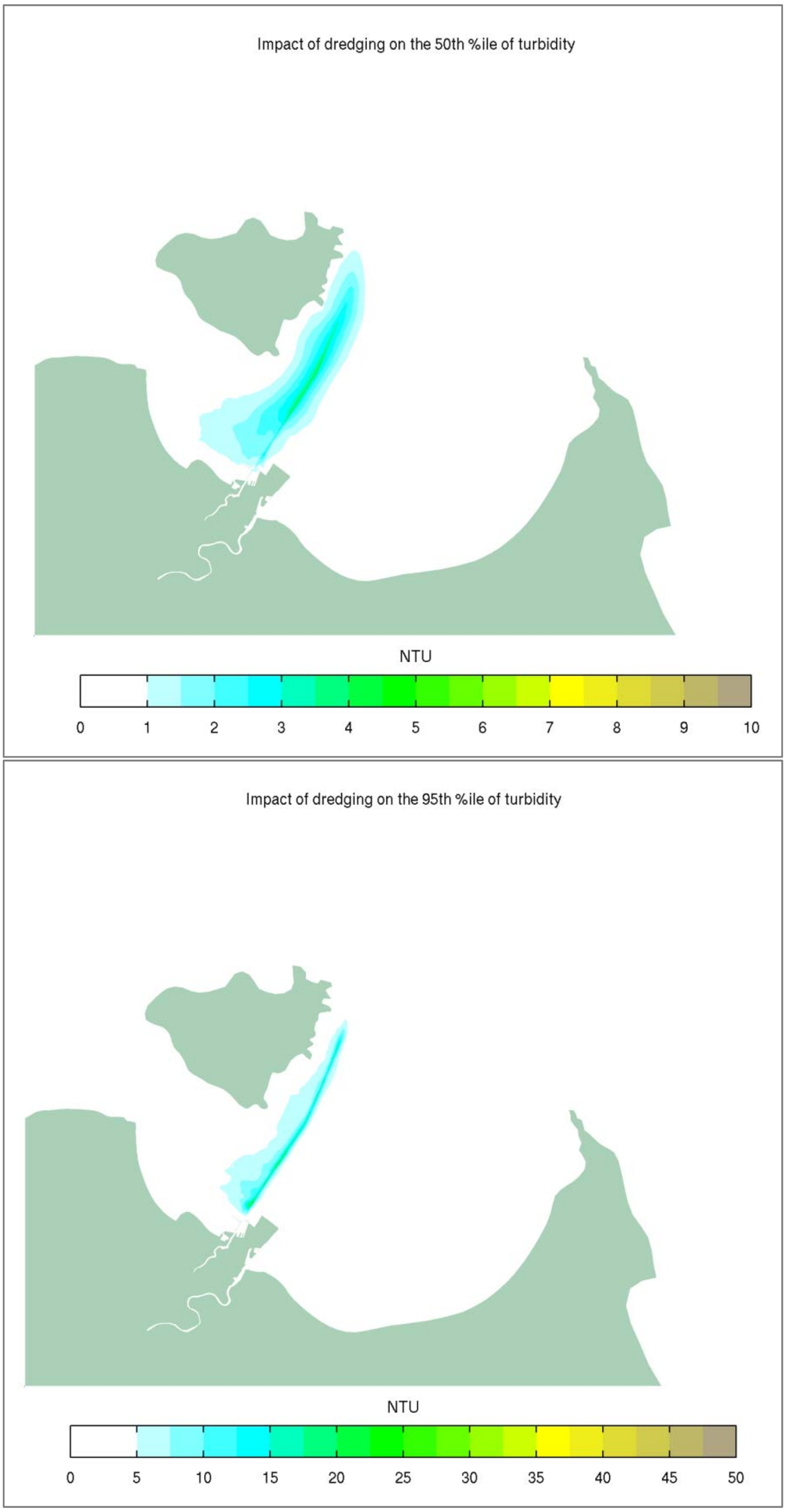


Figure 6.8 Impact of Dredging on the 50th Percentile (top) and the 95th Percentile (bottom) – Stage 1 (Widening) by TSHD – Expected Case (note that scales differ between the two figures)

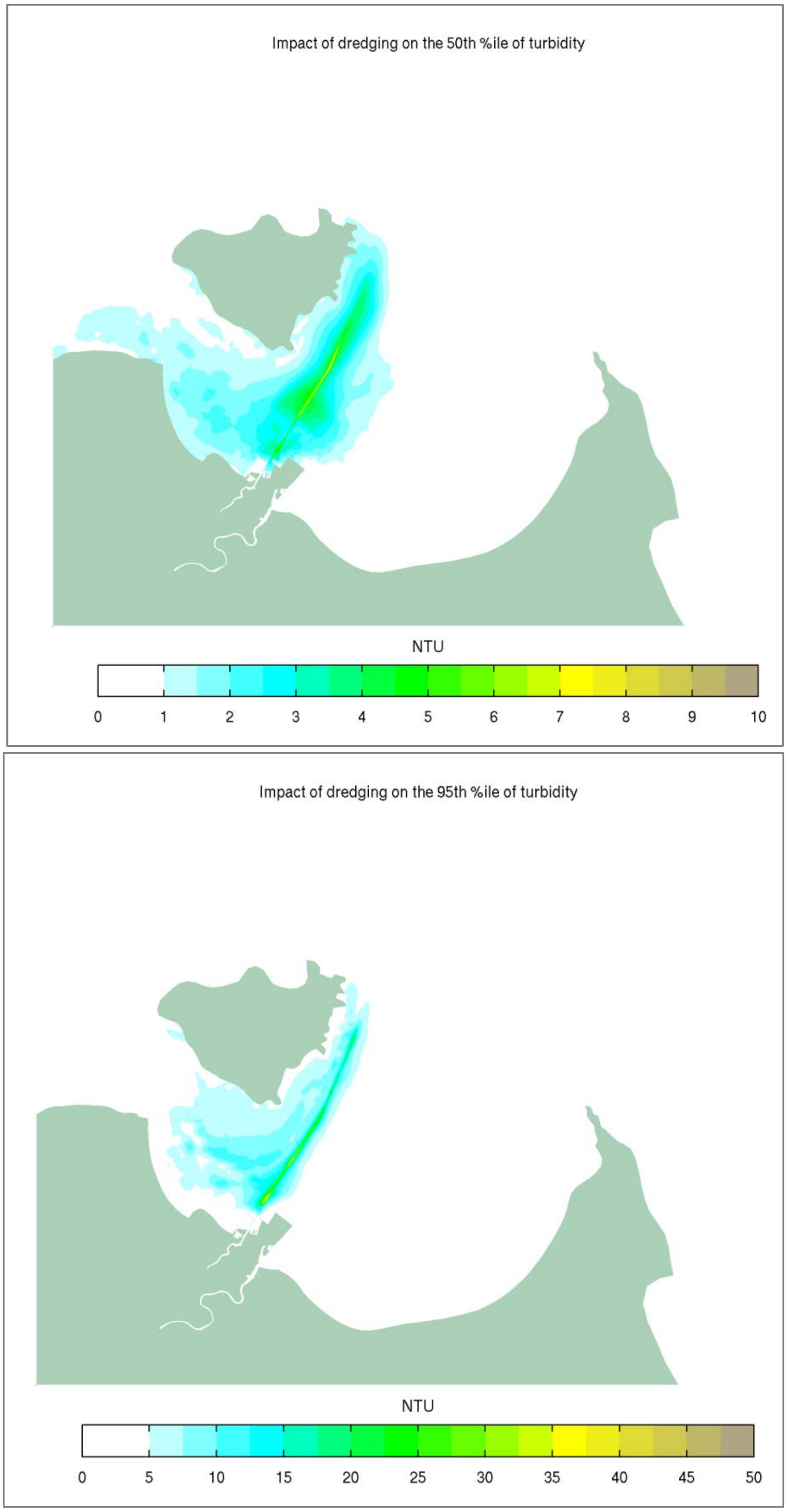


Figure 6.9 Impact of Dredging on the 50th Percentile (top) and the 95th Percentile (bottom) – Stage 1 (Widening) by TSHD – Worst Case (note that scales differ between the two figures)

The impact significance of these results is interpreted using zones of impact as described previously. Note that model outputs from both the TSHD dredging and the mechanical dredging were combined (as both types of dredging will likely be undertaken concurrently) for the purposes of the zone of impact assessment.

The impact zone maps for Stage 1 dredging for the Expected Case and the Worst Case are shown in Figure 6.10 and Figure 6.11 respectively, and indicate the following.

- For the Expected Case, the zone of influence (detectable plumes but negligible impacts predicted) extends to the eastern Magnetic Island Coastline and through West Channel past Middle Reef. There is a zone of low impact (potential low level sub-lethal impacts to sensitive receptors, if present) extending out from the dredge channel by approximately 1 km each side of the channel. However, this zone does not extend to areas of sensitive ecological receptors.
- For the Worst Case, the zone of influence extends further west along the mainland coastline and around the north-eastern corner of Magnetic Island. The zone of low impact extends to the eastern Magnetic Island coastline between Geoffrey Bay and Florence Bay/Gowrie Bay on the north-eastern coast. These areas are known to contain corals and seagrass. There is also a relatively small zone of moderate impact (moderate sub-lethal impacts/small scale mortality of sensitive receptors, if present) located near the channel bend where the junction of the Platypus Channel and the Sea Channel. This zone is limited to the channel and areas directly adjacent.
- The impact zones are concentrated around the outer section of the Platypus Channel and the inner section of the Sea Channel. This is likely due to the volume of material and material type being dredged in these areas, and the lower impact thresholds in the offshore waters. While dredge plumes are predicted to occur in nearshore areas (including inner Platypus Channel), they are not predicted to cause impacts due to the naturally elevated turbidity (and hence impact threshold values) in these nearshore areas.

Based on areas of low impact predicted to occur along the coastline of Magnetic Island during the Worst Case scenario, *minor* impacts are predicted from Stage 1 dredging.

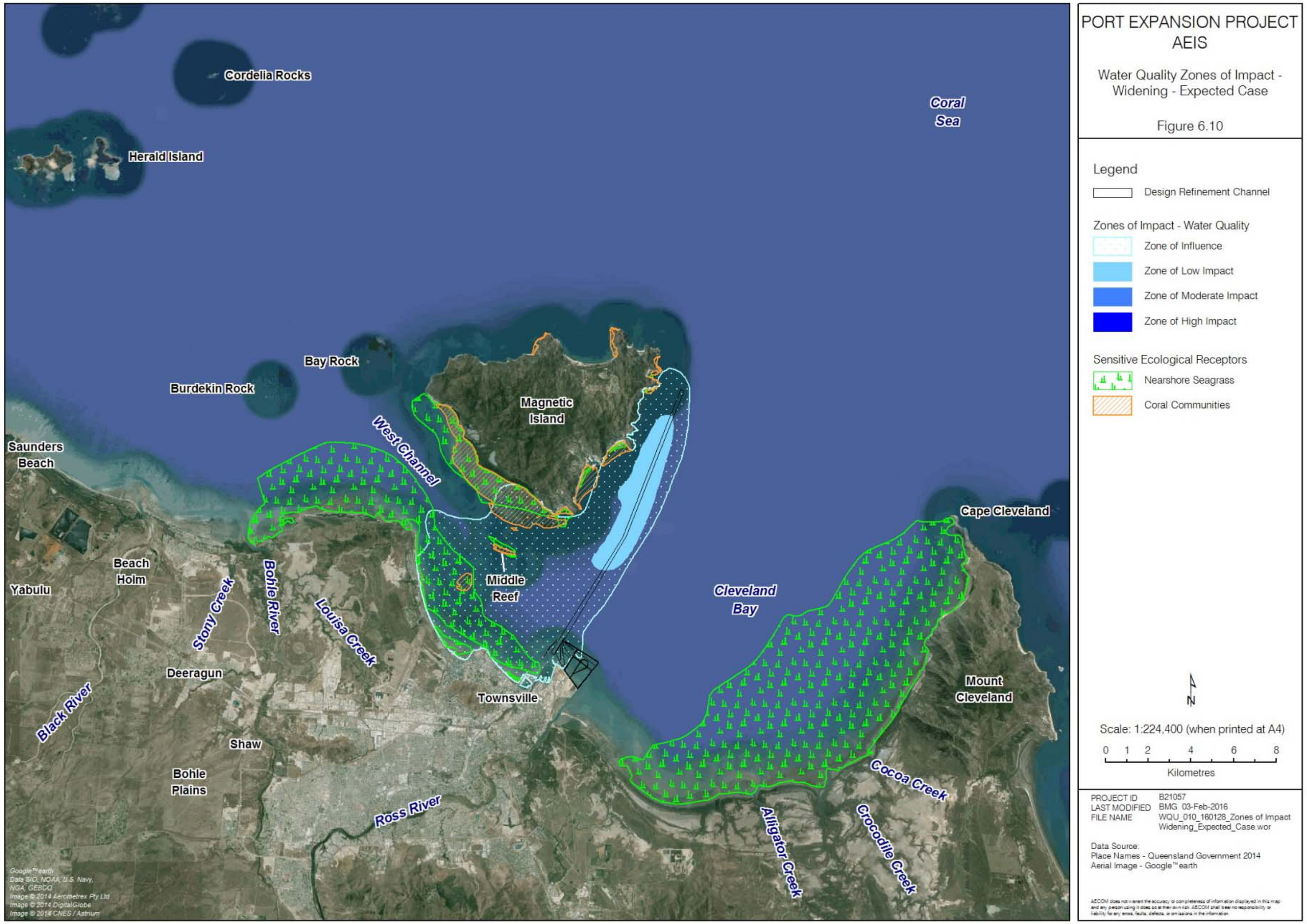


Figure 6.10 Water Quality Zones of Impact – Stage 1 (Widening) - Expected Case

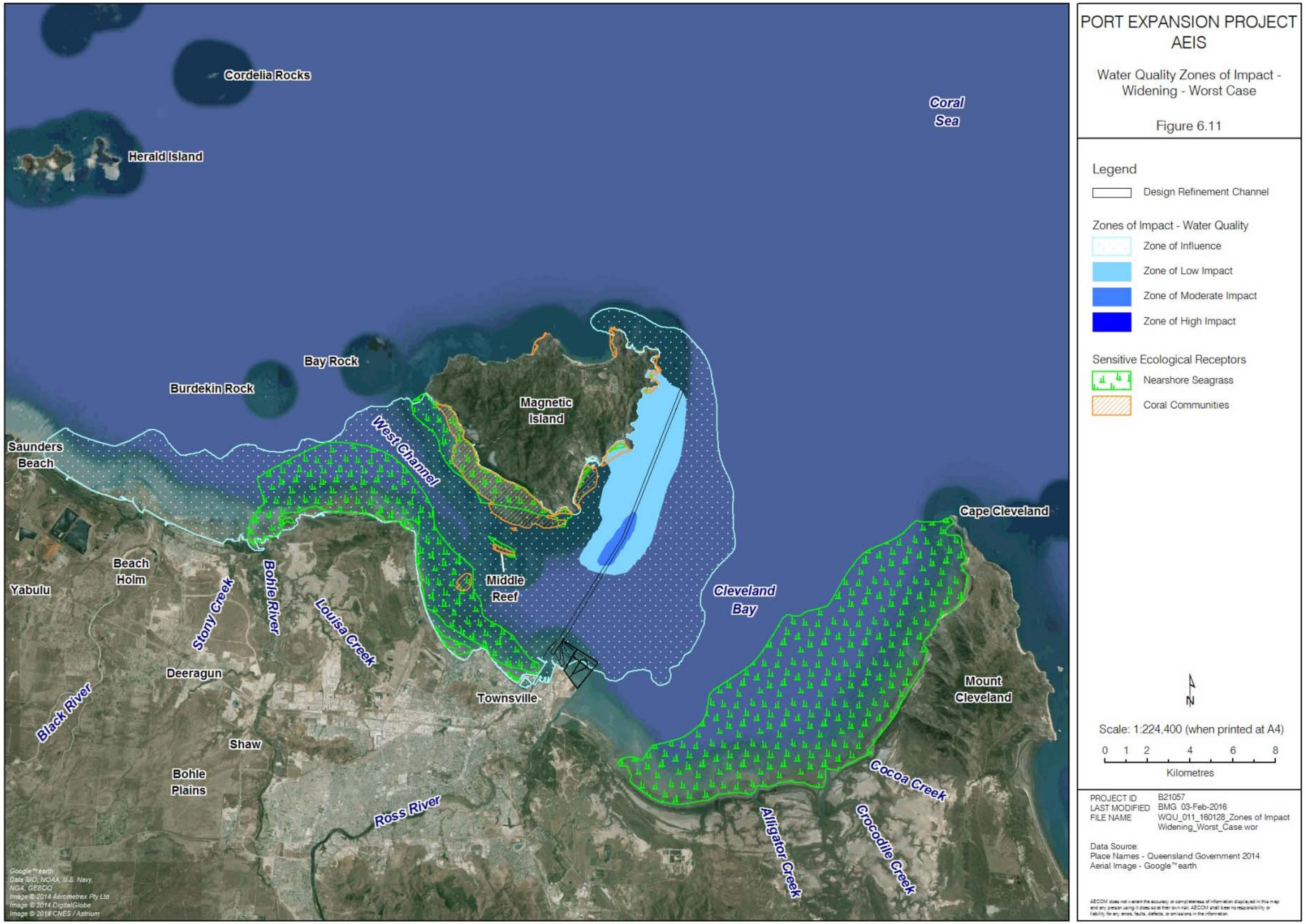


Figure 6.11 Water Quality Zones of Impact – Stage 1 (Widening) - Worst Case

Stage 2 dredging

Stage 2 involves dredging berths 14, 15 and 16 in the outer harbour (3.6 million m^3), as well as soft sediments under the footprint of the final reclamation bunds and breakwater (0.2 million m^3). The total dredge volume is expected to be 3.8 million m^3 and be undertaken over a duration of 4.5 years by a mechanical dredger as follows:

- reclamation works – 12 months
- Berths 14, 15 and 16 ~ 3.5 years
- total ~ 4.5 years.

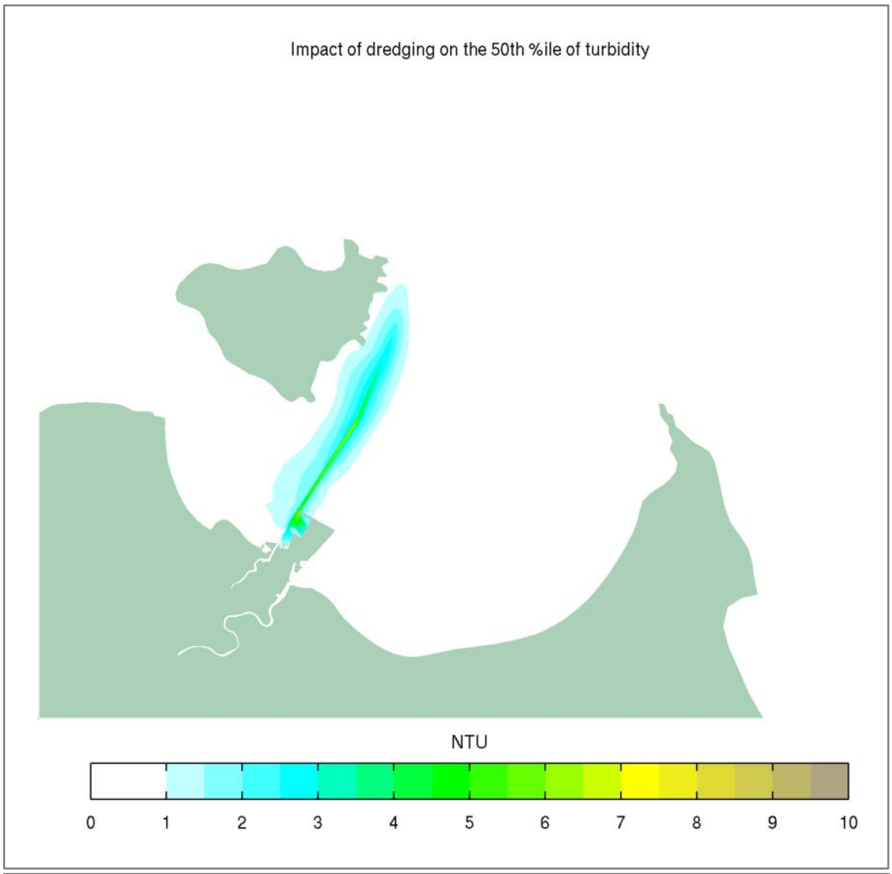
Modelling plots in Appendix A2 (Modelling Report) indicate that turbid dredge plumes from dredging during Stage 2 are limited to the outer harbour area, and do not disperse over a wide area (i.e. do not disperse near any sensitive ecological receptors). Therefore, *negligible* impacts are predicted from Stage 2 dredging.

Stage 3 dredging

Stage 3 dredging will be undertaken over a 2.5 year period and consists of the following:

- Deepening of the Platypus Channel and the Sea Channel to a Navigation Design Depth of -12.8m LAT. The total dredge volume is expected to be 2 million m^3, with the soft marine sediments and dense clayey sands will be dredged by TSHD (dredge volume of 0.7 million m^3), and the stiff, very stiff and hard clays will be dredged by a mechanical dredger (dredge volume of 1.3 million m^3).
- The dredging of the berth pockets for Berths 17 and 18 by a mechanical dredger (0.08 million m^3).
- Duration of dredging is:
  - channel deepening by TSHD – 8 weeks
  - channel deepening by mechanical Dredger – 2.2 years
  - Berths 17 and 18 – 5 weeks
  - total ~ 2.5 years.

The following percentile contour plots show depth averaged dredging-related turbidity above background levels for the TSHD dredging for the Expected Case (Figure 6.12) and the Worst Case (Figure 6.13) during Stage 3 dredging. The mechanical dredging plots, which show very minimal dredge plumes, are presented in Appendix A2 (Modelling Report).



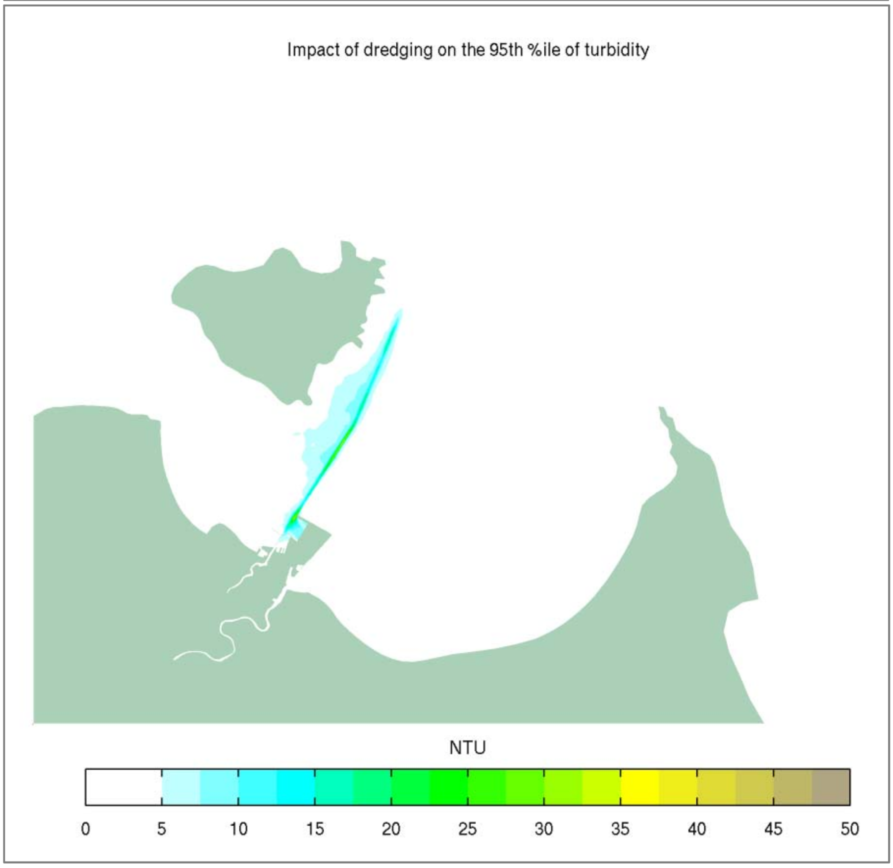
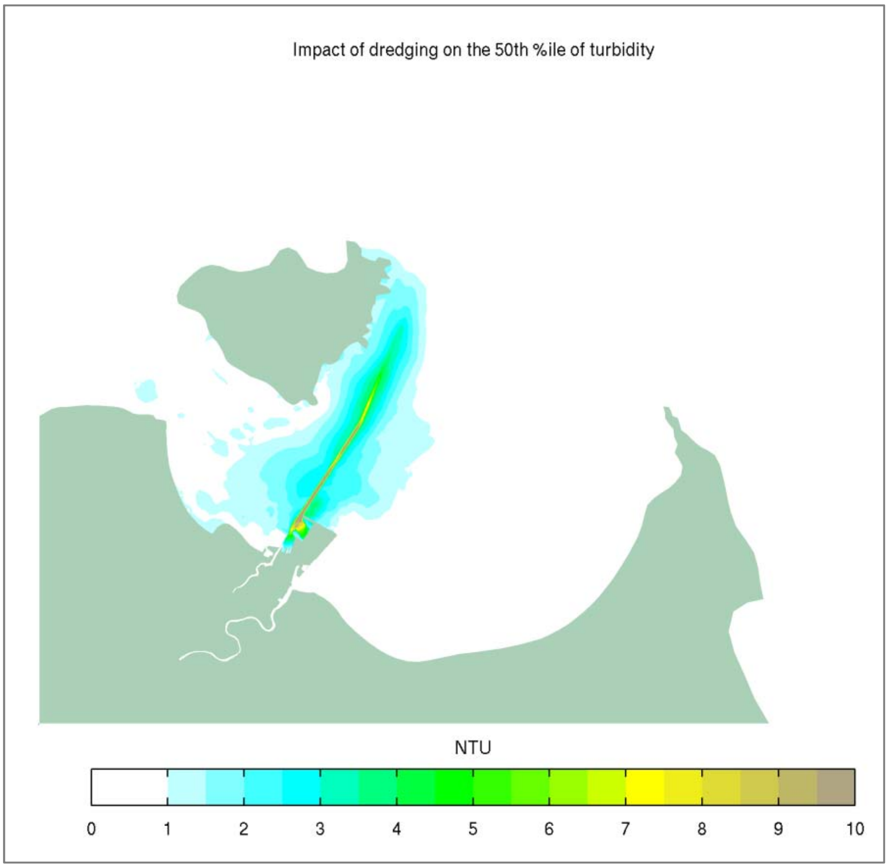


Figure 6.12 Impact of Dredging on the 50th Percentile (top) and the 95th Percentile (bottom) – Stage 3 (Deepening) by TSHD – Expected Case (note that scales differ between the two figures)



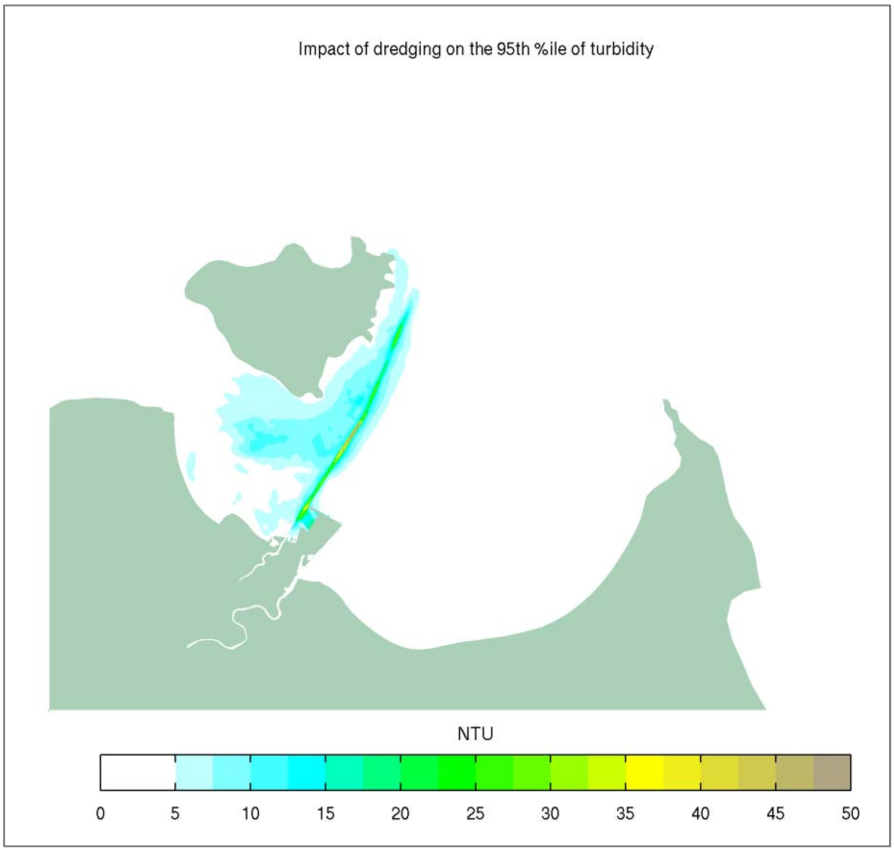


Figure 6.13 Impact of Dredging on the 50th Percentile (top) and the 95th Percentile (bottom) – Stage 3 (Deepening) by TSHD – Worst Case (note that scales differ between the two figures)

The significance of these results is interpreted using zones of impact as described previously. Note that the model outputs from both the TSHD dredging and the mechanical dredging were combined (as both types of dredging will likely be undertaken concurrently) for the purposes of the zone of impact assessment.

The impact zone maps for Stage 3 dredging for the Expected Case and the Worst Case are shown in Figure 6.14 and Figure 6.15 respectively. These figures indicate that the zones of impact for Stage 3 (deepening) are very similar to Stage 1 (widening), with a zone of low impact extending to the north-eastern coast of Magnetic Island under the Worst Case scenario. This similarity is due to the use of similar dredging campaigns (equipment and dredge material type) for both stages.

Based on areas of low impact predicted to occur along the coastline of Magnetic Island during the Worst Case scenario, *minor* impacts are predicted from Stage 3 dredging.

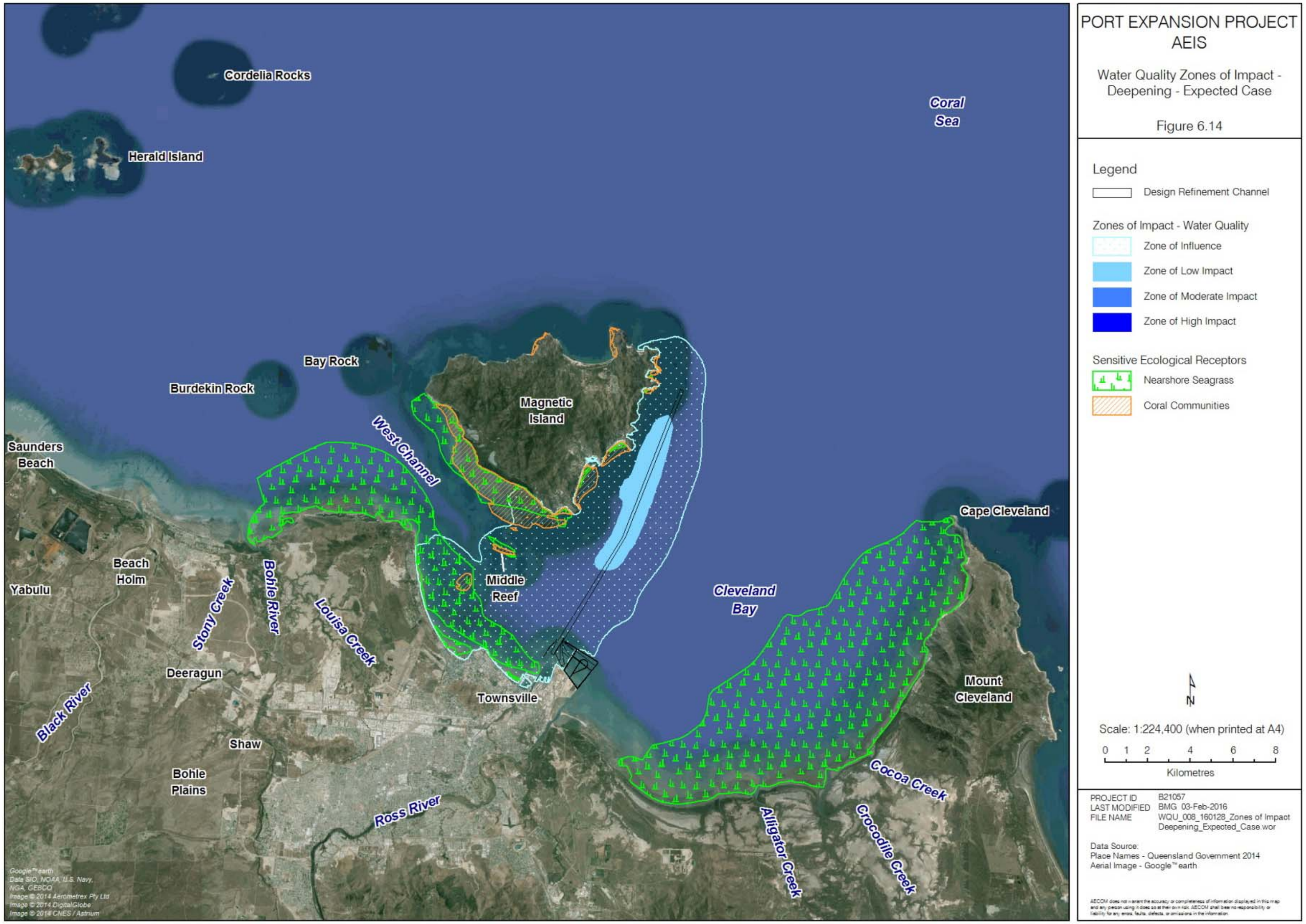


Figure 6.14 Water Quality Zones of Impact – Stage 3 (Deepening) – Expected Case

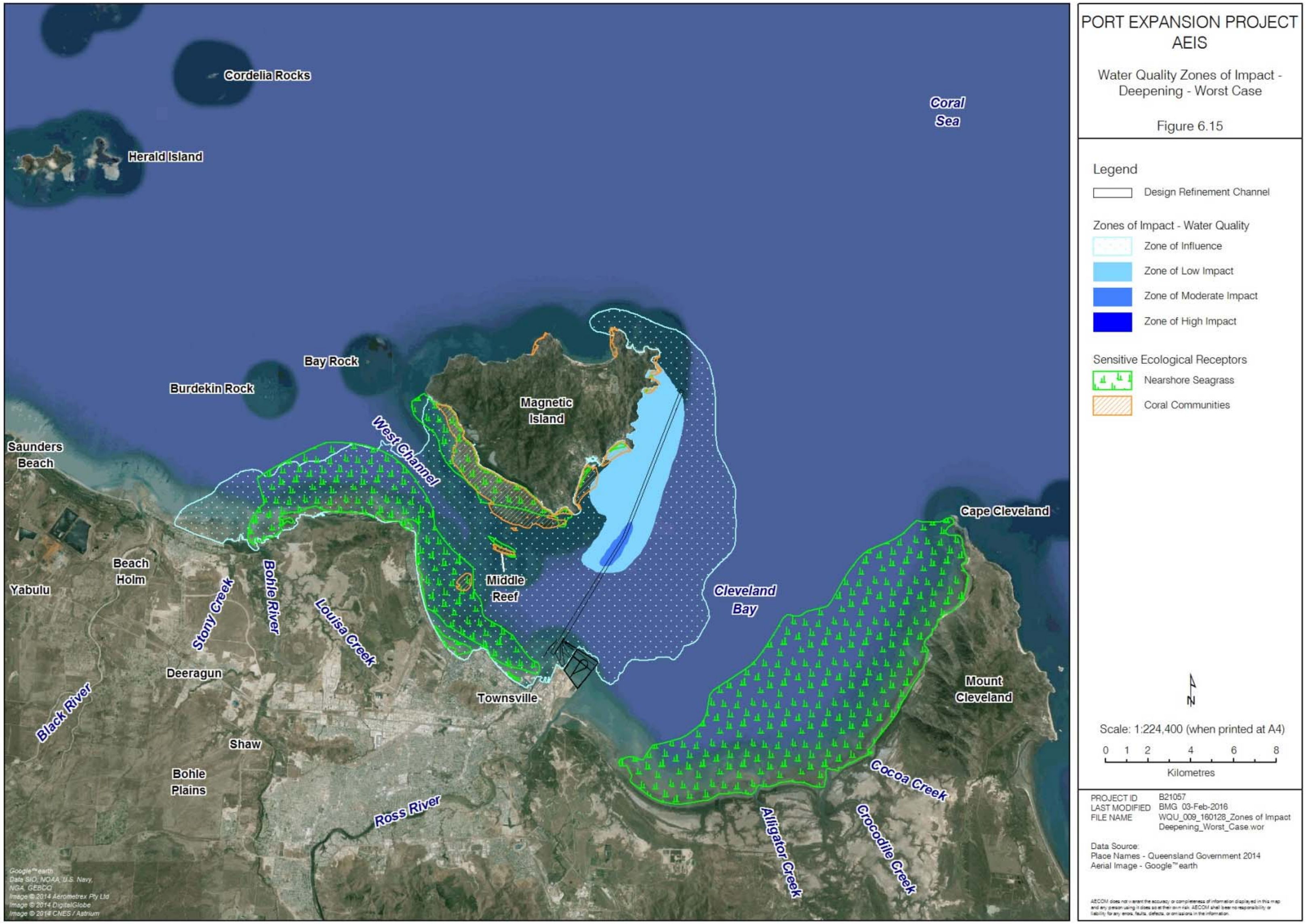


Figure 6.15 Water Quality Zones of Impact – Stage 3 (Deepening) – Worst Case

Sediment deposition

While the previous section assessed impacts to water quality from suspended sediments in the water column as a result of turbid dredge plumes, this section assesses the potential impacts in terms of sediment deposition from the settlement of these suspended sediments.

Resuspension of sediments was also simulated during the modelling period, i.e. the sediment deposition results indicate the final location of settled sediment particles at the end of the modelling period, and each particle may have been re-deposited a number of times over the modelling period due to resuspension.

Sediment deposition percentile contour plots are presented in Appendix A2 (Modelling Report). The impact significance of the sediment deposition results is interpreted using similar zones of impact to water quality. These sediment deposition zones of impact are described in in the impact assessment methodology section.

The impact zone maps for sediment deposition for the Expected Case and the Worst Case are shown in Figure 6.16 to Figure 6.19, and indicate the following.

- There is a zone of high impact (i.e. 50th percentile deposition rates of >20 mg/cm2/day, and/or 95th percentile deposition rates of >200 mg/cm2/day) predicted to occur during the Worst Case scenario for Stage 3 (deepening) only. However, this zone of high impact is limited to the area of dredging in the outer harbour (Figure 6.19).
- During the Worst Case scenarios for both stages, there are zones of moderate impact (i.e. 50th percentile deposition rates of 10-20 mg/cm2/day, and/or 95th percentile deposition rates of 100-200 mg/cm2/day) predicted to occur along the Platypus Channel and areas directly adjacent to the channel. The zone of moderate impact is predicted to be slightly larger during Stage 3 (deepening), however does not extend to areas of sensitive ecological receptors.
- Sediment deposition during Stage 1 (widening) and Stage 3 (deepening) will be predicted to result in similar zones of low impact (i.e. 50th percentile deposition rates of 1.5-10 mg/cm2/day, and/or 95th percentile deposition rates of 15-100 mg/cm2/day) in the channel and adjacent areas. These zones extend close to the Magnetic Island coastline during the Worst Case Scenario, but do not extend into areas of sensitive ecological receptors.

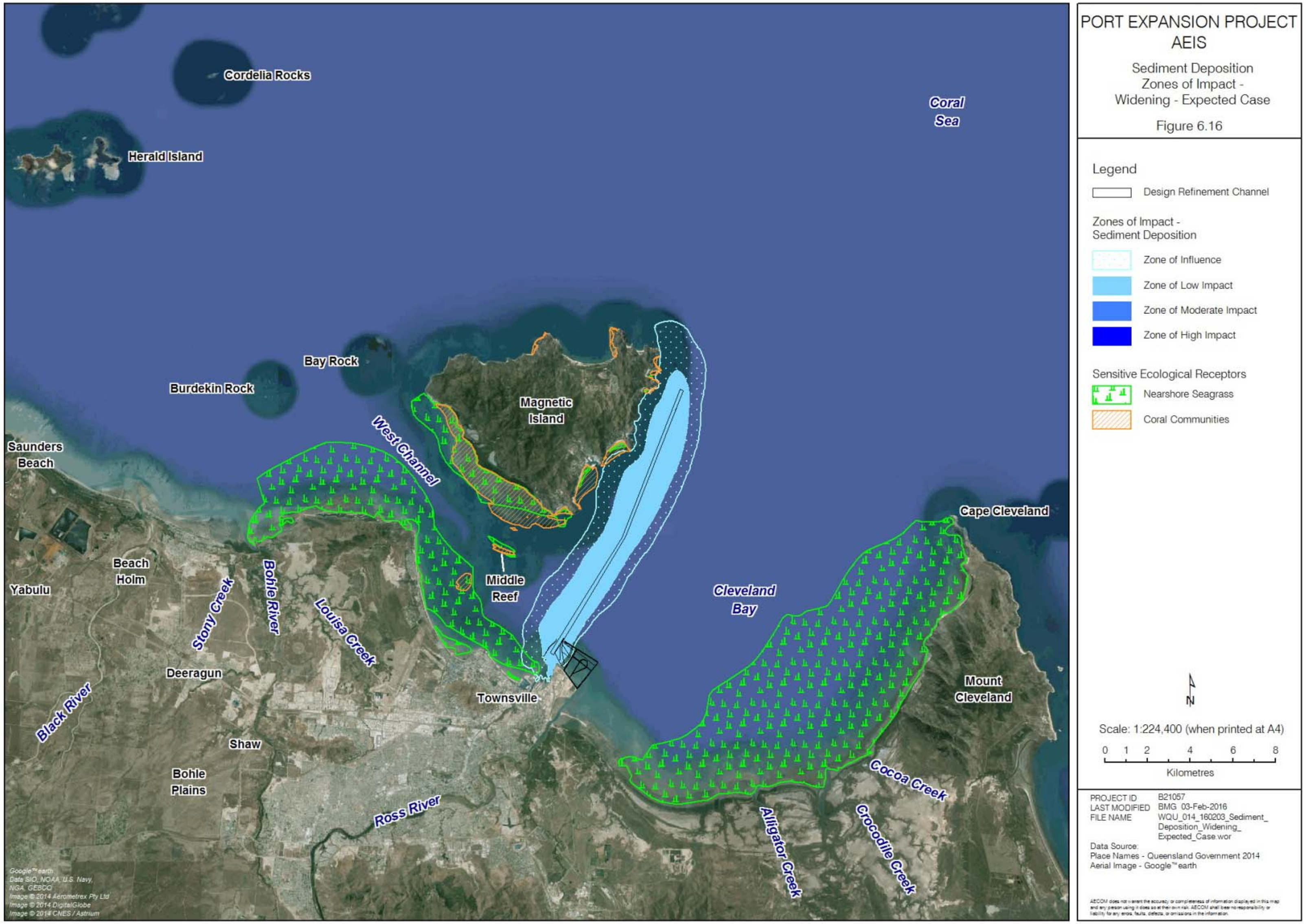


Figure 6.16 Sediment Deposition Zones of Impact – Stage 1 (Widening) – Expected Case

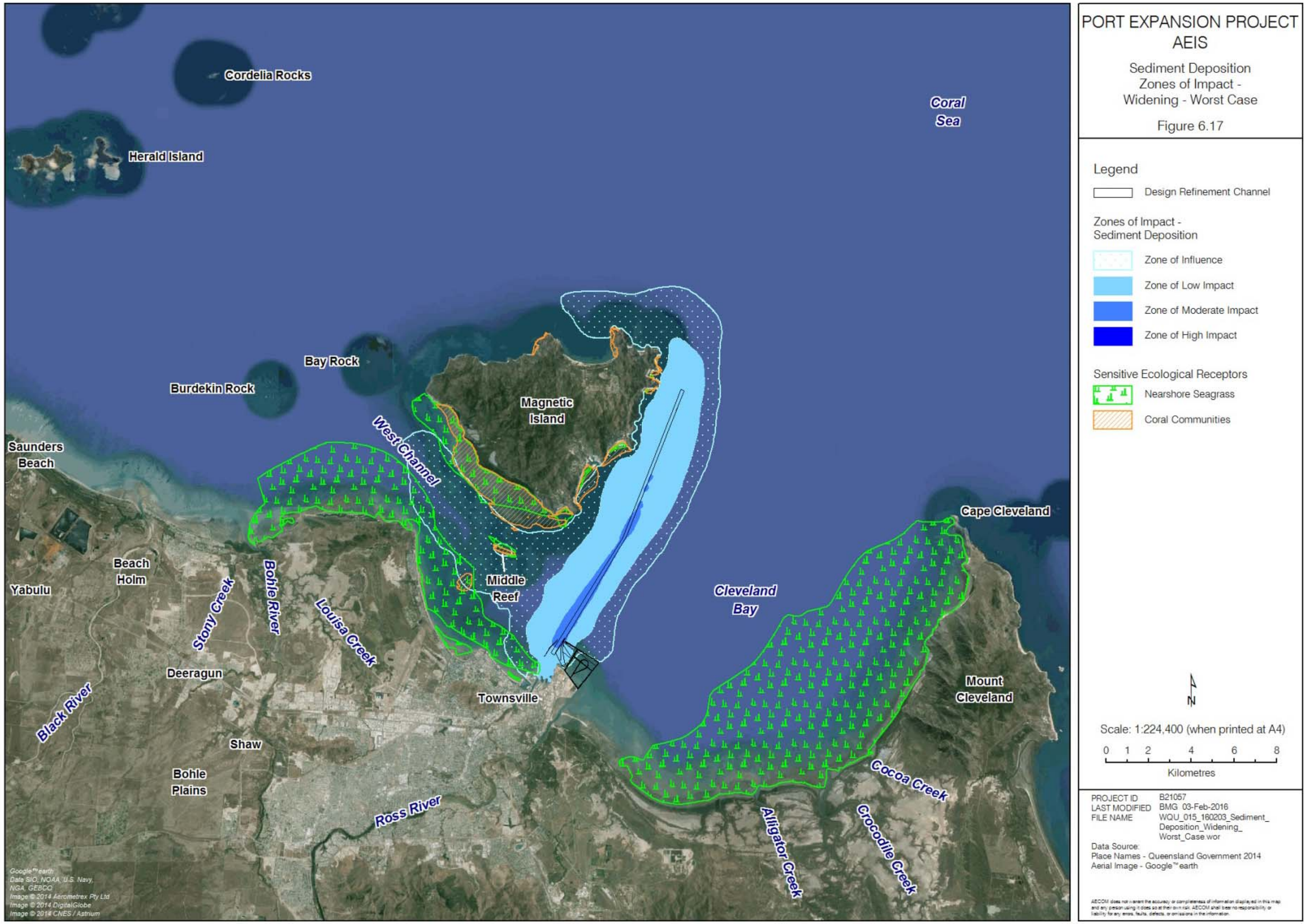


Figure 6.17 Sediment Deposition Zones of Impact – Stage 1 (Widening) – Worst Case

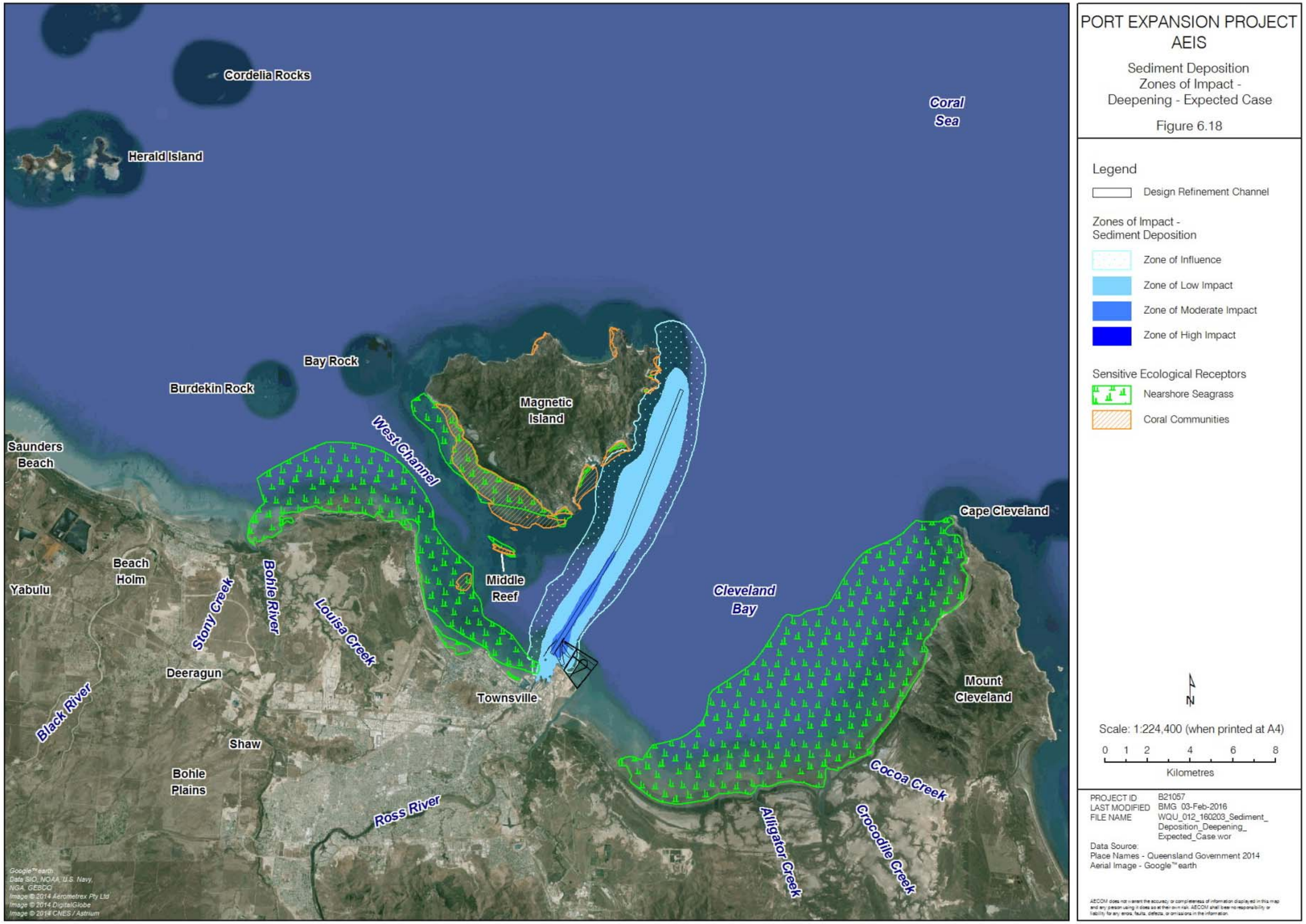


Figure 6.18 Sediment Deposition Zones of Impact – Stage 3 (Deepening) – Expected Case

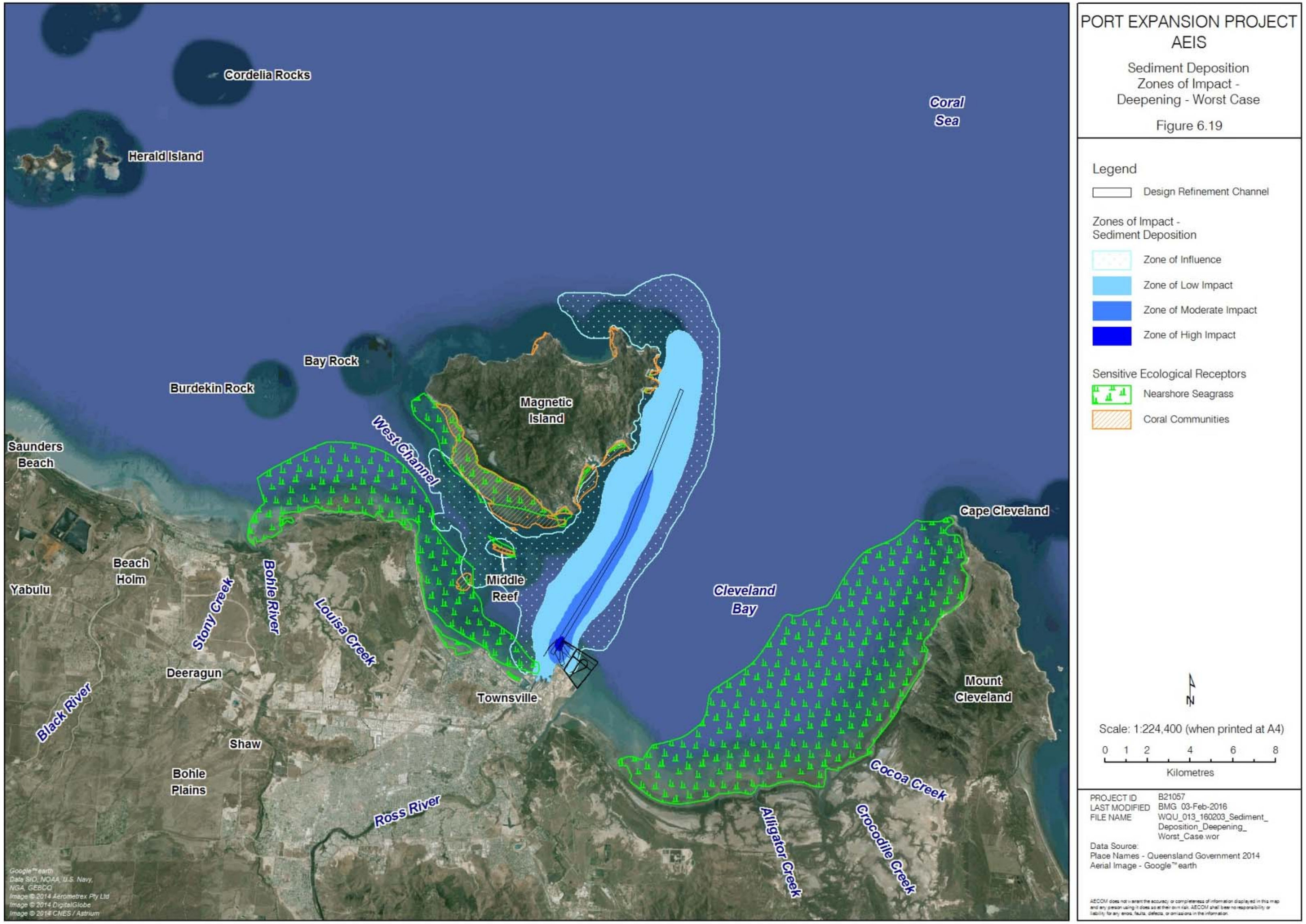


Figure 6.19 Sediment Deposition Zones of Impact – Stage 3 (Deepening) – Worst Case

Maintenance dredging

As discussed further in Section 5.0 (Coastal Processes), the ultimate development of the PEP is predicted to increase the volume of maintenance dredging by approximately 14% with the design refinement, mostly due to the increased channel width. This section presents the findings of additional modelling of maintenance dredging using the increased volume of material.

A maintenance dredging campaign was modelled assuming an additional 14% of maintenance dredge material. The model results were assessed using the water quality zones of impact methodology, with results presented in Figure 6.20. These results indicate the following.

- There will be a zone of influence (detectable plumes but negligible impacts predicted) along the channel areas extending to the west past Middle Reef, and also in the marine DMPA. The only zone of impact is a zone of low impact predicted to occur in a relatively localised area near the channel bend.
- The impacts predicted from the slightly increased maintenance dredging campaign are similar to previous assessments of maintenance dredging undertaken in 2013 (BMT WBM 2013) and in 2014 (BMT WBM 2014). These assessments involved modelling of typical and worst case maintenance dredging campaigns, and found that impacts from annual maintenance dredging under different periods are predicted to be negligible, with zones of impact restricted to areas within and immediately adjacent to dredging and placement areas only. The change in turbidity due to dredging at sensitive receptor locations is predicted to remain well within the range of variability in ambient water quality of Cleveland Bay.
- These previous studies also concluded cumulative impacts from maintenance dredging and placement impacts have been assessed and indications are that the relative contribution of dredge sediment to overall sedimentation processes operating in Cleveland Bay are minimal and cumulative impacts on water quality (between years) and marine habitats that are currently in poor (recovering) condition are not expected. Furthermore, maintenance dredging during increased turbidity from flood plumes will not be expected to noticeably contribute to impacts on ecosystems due to the flood plumes.

Therefore, based on the above finding, it is concluded that negligible impacts are predicted from maintenance dredging.

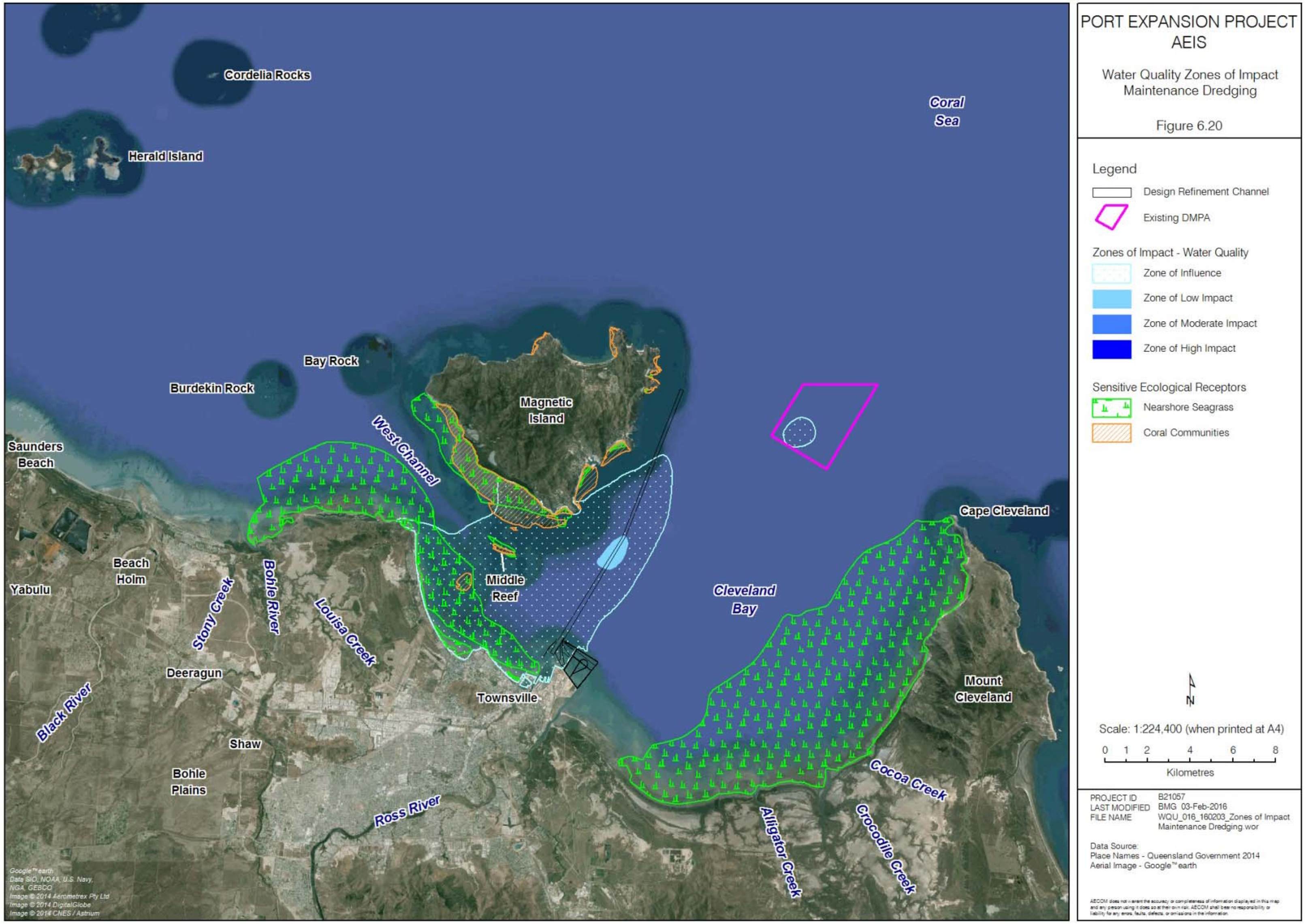


Figure 6.20 Water Quality Zones of Impact – Maintenance Dredging

Tailwater impacts

As dredge material is placed into reclamation, the supernatant water (i.e. excess water overlaying the dredge material) will be discharged from the south-eastern corner of the reclamation into the mouth of the Ross River (Figure 6.21).

To assess the potential impacts from tailwater discharges, tailwater from the reclamation during dredging was simulated in all modelling scenarios. The results indicated that the suspended sediments discharged in the tailwater will be negligible relative to the receiving environment. There were minimal turbidity plumes which were localised near the tailwater discharge location in the percentile contour plots (Appendix A2), and the magnitude of these turbidity plumes was too low to show up in any of the zones of impact figures presented above.

Therefore, based on this, it is concluded that *negligible* impacts are predicted from tailwater discharges from the reclamation during dredging works.

Figure 6.21 Tailwater Discharge Location from the Reclamation Area

Summary of findings

The revised impact assessment indicates that the largest impact from dredging operations is predicted to occur during the channel widening (Stage 1) and channel deepening (Stage 3) of the Platypus and Sea Channels when dredging is undertaken by a TSHD. Turbid dredge plumes from dredging during Stage 2 will be limited to the outer harbour area, and will not disperse over a wide area (i.e. do not disperse near any sensitive ecological receptors).

Dredging by the mechanical dredger is predicted to produce insignificant turbid dredge plumes relative to the TSHD dredging.

Impact assessment using 'zones of impact' indicates that during Stages 1 and 2, the coastal waters along the north-eastern coast of Magnetic Island are predicted to fall within the zone of low impact (potential low level sub-lethal impacts of sensitive receptors, if present) during the Worst Case scenario only. During the Expected Case, all zones of impact will be limited to the channel and adjacent areas where sensitive ecological receptors are not known to occur. Note that these findings relate to the unmitigated dredging case.

Zones of moderate impact (moderate sub-lethal impacts/small scale mortality of sensitive receptors, if present) are predicted to occur during the Worst Case scenario only, and in localised areas near to the channel bend where sensitive ecological receptors are not known to occur.

Sediment deposition during Stage 1 and Stage 3 will be predicted to result in zones of low impact extending close to the Magnetic Island coastline but not into areas of sensitive ecological receptors.

Based on these assessments, *minor* impacts (as defined in the EIS) are expected during dredging works due to low level of potential impacts to water quality (and sensitive ecological receptors) along the coastal waters of Magnetic Island. Due to the likelihood (possible) of these minor impacts occurring, the risk rating is considered to be *low*. Despite the low risk rating, these impacts can be further mitigated with measures discussed in the following section.

As discussed further in the Cumulative Impacts section (Section 25.0), the above impact predictions should be considered in the context of the condition of sensitive ecological receptors (e.g. seagrass and corals) prior to dredging. If the condition is poor and resilience is low, the impacts may be greater than predicted. To address this, the Dredge Management Plan (DMP) includes a requirement to assess the condition of seagrass and corals in areas likely to be affected by dredging, prior to commencement of dredging and development of trigger levels by the Technical Advisory Committee (TAC).

6.3.4.2 Mitigation measures

The mitigation measures which were specified in the EIS still remain relevant and are to be implemented as part of the capital dredging campaign.

If the mitigation measures described above and in the DMP are implemented, the residual risk rating to marine water quality is considered to be *low*.

6.3.5 Summary

The following table summarises the revised impact assessment based on the design refinement, including a revised risk rating, additional mitigation measures required, and a revised residual (mitigated) risk rating.

Table 6.6 Assessment Summary Table – Marine Water Quality

Element	Primary Impacting Process	Updated Risk Rating			Mitigation Measures	Mitigated Risk Rating
		Magnitude	Likelihood of impact	Risk Rating		
Dredging	Generation of turbid plumes - *TSHD*	Local Scale: Minor Dredging of the outer harbour and Sea/Platypus Channels will create turbid plumes, with zones of low impact predicted to occur along the north-eastern coast of Magnetic Island during the Worst Case Scenario only, and a zone of moderate impact in the immediate vicinity of the dredge.	Likely	Medium	Implement standard mitigation measures as per the DMP. Implement additional mitigation measures, including development and implementation of a Reactive Monitoring Program (RMP) with appropriate triggers and corrective actions.	Low
		Broader Scale: Minor While turbid plumes at the dredge site and surrounds are expected, the plume will disperse the further away from the impacting area and is unlikely to impact on the broader values. Zones of impact largely located near the dredged channel area.	Unlikely	Low	As above	Low
	Generation of turbid plumes – *mechanical dredge*	Local Scale: Negligible Dredging of the outer harbour and Sea/Platypus Channels will create very minor turbid plumes in the immediate vicinity of the dredge.	Likely	Low	Implement standard mitigation measures as per the DMP.	Low
		Broader Scale: Negligible Turbid plumes are unlikely to impact on the broader values.	Unlikely	Low	As above	Low
	Mobilisation of contaminants into the water column	Local Scale: Minor Dredging of the outer harbour and Sea/Platypus Channels may mobilise nutrients/heavy metals into the water column potentially affecting water quality near sensitive habitats.	Possible	Low	Further sediment quality testing prior to dredging.	Low
		Broader Scale: Negligible Unlikely to impact on the broader values.	Unlikely	Negligible	Nil	Negligible

Element	Primary Impacting Process	Updated Risk Rating			Mitigation Measures	Mitigated Risk Rating
		Magnitude	Likelihood of impact	Risk Rating		
Reclamation	Generation of turbid plumes	Local Scale: Minor Discharge of tailwater will create turbid plumes potentially resulting in localised zones of impact immediately adjacent to the tailwater discharge point.	Possible	Low	Management of tailwater discharge quality through the implementation of a tailwater management plan. Use of appropriately designed sedimentation pond to reduce TSS. Implementation of best management sediment and erosion control plans.	Low
		Broader Scale: Negligible The turbid plumes from the tailwater will disperse and be unlikely to impact on the broader values.	Unlikely	Negligible	As above	Negligible
	Mobilisation of contaminants into the water column	Local Scale: Minor Discharge of tailwater may mobilise nutrients/heavy metals into the water column potentially affecting water quality near sensitive habitats.	Possible	Low	Management of tailwater discharge quality through the implementation of a tailwater management plan.	Low
		Broader Scale: Negligible Any contaminants in plumes from the tailwater will disperse and be unlikely to impact on the broader values.	Unlikely	Negligible	Nil	Negligible
	Discharge of acidic tailwater from acid sulfate soil (ASS) in reclamation	Local Scale: Minor Discharge of acidic tailwater due to presence of ASS in reclamation ponds may adversely impact sensitive ecological receptors in the vicinity of the tailwater release.	Likely	Medium	Manage ASS in accordance with the ASS Management Plan. Management of tailwater discharge quality through the implementation of tailwater management plan.	Low
		Broader Scale: Negligible The acidic tailwater will be diluted in the broader receiving waters and be unlikely to impact on the broader values.	Unlikely	Negligible	As above	Negligible

6.4 Conclusion

With the design refinement and the refined impact assessment methodology, it is predicted that during the Worst Case scenario only, zones of low impact will extend from the dredge area to waters adjacent to the north-eastern coast of Magnetic Island, where sensitive ecological receptors are known to occur. It is predicted these zones of impact can be mitigated through the implementation of various mitigation measures, including a reactive monitoring program (RMP) to validate impact assessment findings and monitor key thresholds for impacts as a trigger for corrective actions.

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