Port of Gladstone
Gatcombe and Golding Cutting
Channel Duplication Project

Environmental Impact Statement

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6

Sediment quality

Contents

6 Sediment quality

6.1 Chapter purpose

This chapter details the marine sediment quality within the Project footprint and the surrounding sediments within Port Curtis. Baseline sediment quality data has been sourced from previous investigations as well as the geochemical investigations undertaken for the Project EIS.

The implementation reports for the geochemical investigation are provided in:

- Appendix E4 (Sampling and Analysis Plan (SAP) Implementation Report (area to be dredged))
- Appendix E5 (Geochemical Sediment Characterisation Plan Implementation Report (DMPAs))
- Appendix E6 (SAP Implementation Report – Barge access channel).

This chapter has a focus on the potential for Project activities to disturb marine sediments and release contaminants into the receiving environment. The potential environmental impacts from sediment quality on environmental values are provided in the relevant EIS environmental aspect chapters, including:

- Potential water quality impacts (refer Chapter 8)
- Potential ecology and MNES impacts (refer Chapter 9).

6.2 Methodology

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

- Review of the Commonwealth and State legislation, policy and guidelines relevant to sediment quality for the pre-construction, construction and operational phases of the Project
- Review of previous sediment investigations in Port Curtis to inform the design of the sediment sampling and the analysis plan
- Completion of a geochemical investigation into the sediment quality of material to be dredged from the Gatcombe and Golding Cutting channel duplication and the barge access channel, as well as the existing sediment quality at the WBE reclamation area
- Assessment of the potential impacts and risks associated with sediment quality for the following activities:
  - WBE reclamation area bund wall and BUF construction
  - 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 transfer of dredged material through the BUF
  - Stabilisation and maintenance activities at the WB and WBE reclamation areas
- Identification of management and monitoring measures to minimise impacts from sediment quality.

6.3 Legislative and policy context

6.3.1 Environment Protection (Sea Dumping) Act 1981

The Sea Dumping Act aims to protect the waters surrounding Australia's coastlines from wastes and pollution dumped at sea. The Sea Dumping Act regulates the loading and dredged material placement at sea and fulfils Australia's international obligations under the London Protocol to prevent marine pollution.

The Sea Dumping Act is administered by the DoEE and applies to all vessels, aircraft and platforms in Australian waters, and to all Australian vessels and aircrafts in any part of the sea.

Under the Act, a Sea Dumping Permit is required for all sea dumping activities, including the placement of dredged material. Given that the Project dredged material is being beneficially reused within the WB and WBE reclamation areas, a sea dumping permit under the Sea Dumping Act is not required from the DoEE, although a permit will be required for the placement of future maintenance material within the East Banks DMPA. Approval for the placement of maintenance material will be sought separately as part of GPC's Port wide maintenance dredging operations.

6.3.2 National Assessment Guidelines for Dredging 2009

The objective of the NAGD is to apply a regulatory framework for the assessment of the impacts of dredged material loading and dredged material placement and, when offshore dredged material placement is permitted, that impacts are managed responsibly and effectively under the Sea Dumping Act.

While designed for assessing offshore placement of sediments, NAGD (2009) provides the most stringent guidelines for assessing marine sediments. As such, these guidelines were used to assess the contamination status of sediments to be dredged and the ambient condition of the WBE reclamation area.

6.3.3 National Environment Protection Council Act 1994

The *National Environment Protection (Assessment of Site Contamination) Measure 1999 (Amendment 1, 2013)* (NEPM 2013) was developed under the *National Environment Protection Council Act 1994* (Cth) to establish a nationally consistent approach to the assessment of site contamination. This will ensure best practice environmental management is employed by regulators, site assessors, environmental auditors, landowners, developers and industry.

6.4 Description of environmental values

6.4.1 Background

The Gladstone region contains the city of Gladstone and a variety of coastal and hinterland townships, including Boyne Island/Tannum Sands, Yarwun, Targinnie, Miriam Vale and Calliope. Industries within the region include pastoral, agricultural and processing and manufacturing. Major processing and manufacturing industries located within the Gladstone region are summarised in Table 6.1. Potential pollutant sources in the Port of Gladstone and the associated contaminants are listed in Table 6.2.

Table 6.1 Major industries in the Gladstone region

Industry name	Industry type
Queensland Alumina Limited	Alumina refinery
Rio Tinto Aluminium Yarwun	Alumina refinery
Boyne Smelters Limited	Aluminium smelter
Cement Australia	Cement and clinker plant

Industry name	Industry type
NRG – NRG Gladstone Operating Services Pty Ltd	Coal fired power plant
Auckland Point Terminal	Wharves – bulk trades, grain, petroleum products, containers and break bulk products
RG Tanna Coal Terminal	Coal terminal
Wiggins Island Coal Terminal	Coal terminal
Australia Pacific LNG	LNG facility
Gladstone LNG	LNG facility
Queensland Curtis LNG	LNG facility
Queensland Energy Resources Pty Ltd	Oil shale miner and medium shale oil and naphtha plant
Orica Australia Pty Ltd	Sodium cyanide, ammonium nitrate and chlorine plant

Source: Updated from GHD (2012)

Table 6.2 Potential pollutant sources and contaminants of concern in the Port of Gladstone

Industry	Potential pollutant sources	Associated contaminants of concern
Shipping	Hydrocarbons (fuels and oils)	Total recoverable hydrocarbons (TRH) Benzene, toluene, ethylbenzene, xylene (BTEX)
	Anti-fouling paints	Polycyclic aromatic hydrocarbons (PAH) Organotins Copper
	Spillage of product during import and export (e.g. bauxite, coal, clinker, alumina)	Heavy metals PAHs TRH BTEX
Natural geology	Metals and metalloids	Metals and metalloids (including arsenic, manganese, nickel, silver and zinc)
Industrial discharges	Intentional and/or unintentional waste products discharged from nearby industries	Heavy metals PAHs TRH Polychlorinated biphenyls (PCB)
Landfills	Metals and other leachates – few likely in Gladstone as only small inactive landfills present close to the coast	Heavy metals
Agriculture and horticulture	Herbicides, pesticides and fertilisers – however it should be noted that agriculture/horticulture has reduced in the Gladstone area in recent years	Pesticides Ammonia Nutrients
Stormwater	Urban stormwater discharges	Heavy metals PAHs TRH BTEX
Sewage treatment plants	Secondary treated water re-used at local industrial sites	Heavy metals

Source: GHD (2012)

Capital dredging works in the Port of Gladstone, and subsequent placement of dredged material, has been occurring since the late 1890s to support major project development and port industry expansion. Substantial capital dredging occurred in the 1960s for the Auckland Point and Barney Point berths, and Port and entrance channels.

Reclamation areas previously established within Gladstone using predominantly dredged material include:

- Auckland Point to Barney Point (Port Central)
- Clinton Estate west of Auckland Inlet, includes Marina and Spinnaker Parklands and RG Tanna Coal Terminal
- Fisherman's Landing
- Wiggins Island intertidal reclamation areas
- Fisherman's Landing Expansion and WB reclamation area.

6.4.2 Previous investigations

For the past 25 years, all dredged material within Port Curtis has been sampled and analysed for contamination to determine the suitability for its intended placement location. More recently, extensive geotechnical and geochemical investigation have been undertaken within Port Curtis to support the various LNG projects, the WICT Project, and Clinton Vessel Interaction Project and the WBDDP.

Previous sampling programs conducted within the Port of Gladstone are illustrated in Figure 6.1 and include:

- Metal Concentrations in the Waters and Sediments of Port Curtis (Angel et a. 2012)
- Contaminants in Port Curtis: screening level risk assessment (Apte et al. 2005)
- Maintenance dredging of the shipping channels, swing basins and berths (WBM 1996; WBM 2000; GHD 2006; BMT WBM 2012)
- Western Basin Dredging and Disposal Project (GHD 2009).

Previous investigations have identified that while Gladstone is an urban and industrial area, there are relatively few incidences of sediments with elevated contaminant results. Vicente-Beckett et al. (2006) demonstrated that anthropogenic influenced sediments are likely to only occur in the top 0.28m and below this depth, any elevated levels of metals are likely to be natural occurring and relate to the geology of the region.

The occurrence of naturally elevated levels of some metals was also demonstrated by Connell Hatch (2006), who reported elevated concentration of silver at depths below 6m within the sediments tested offshore of Port Curtis. Investigations by Apte et al. (2005), Apte et al. (2006) and Vicente-Beckett et al. (2006) reported elevated concentrations of arsenic, chromium and nickel at depth in Port Curtis sediments, which were determined to be derived from natural geology rather than from an anthropogenic source.

The QCLNG Jetty Optimisation Study (Geocoastal Australia 2009) investigated the sediment composition in Port Curtis and determined a strong relationship between sediments containing arsenic and the residual and weathering products of the Wandilla Formation of Curtis Island.

The Queensland Government investigated sediment quality at Port Curtis in September/October 2011 and in February/March 2012 (DERM 2011; EHP 2012). The investigation identified elevated arsenic, mercury, manganese and nickel in select samples, although the 95% UCL for all metals/metalloids was below the relevant guideline values and consistent with concentrations from previous investigations (EHP 2012).

Previous investigations have also identified elevated concentrations of manganese throughout Port Curtis with no clear pattern of distribution. Manganese has been recorded as occurring within Port Curtis as early as 1606 when the Portuguese explorer Pedro Fernández de Quirós allegedly described the Port Curtis strandline as being strewn with 'black heavy pebbles'. Cardinal Moran, in his book 'Discovery of Australia by de Quiros in the Year 1606', went on further to clarify that locally these were referred to in the Port Curtis area as "manganese bubbles" (Aurecon 2010).

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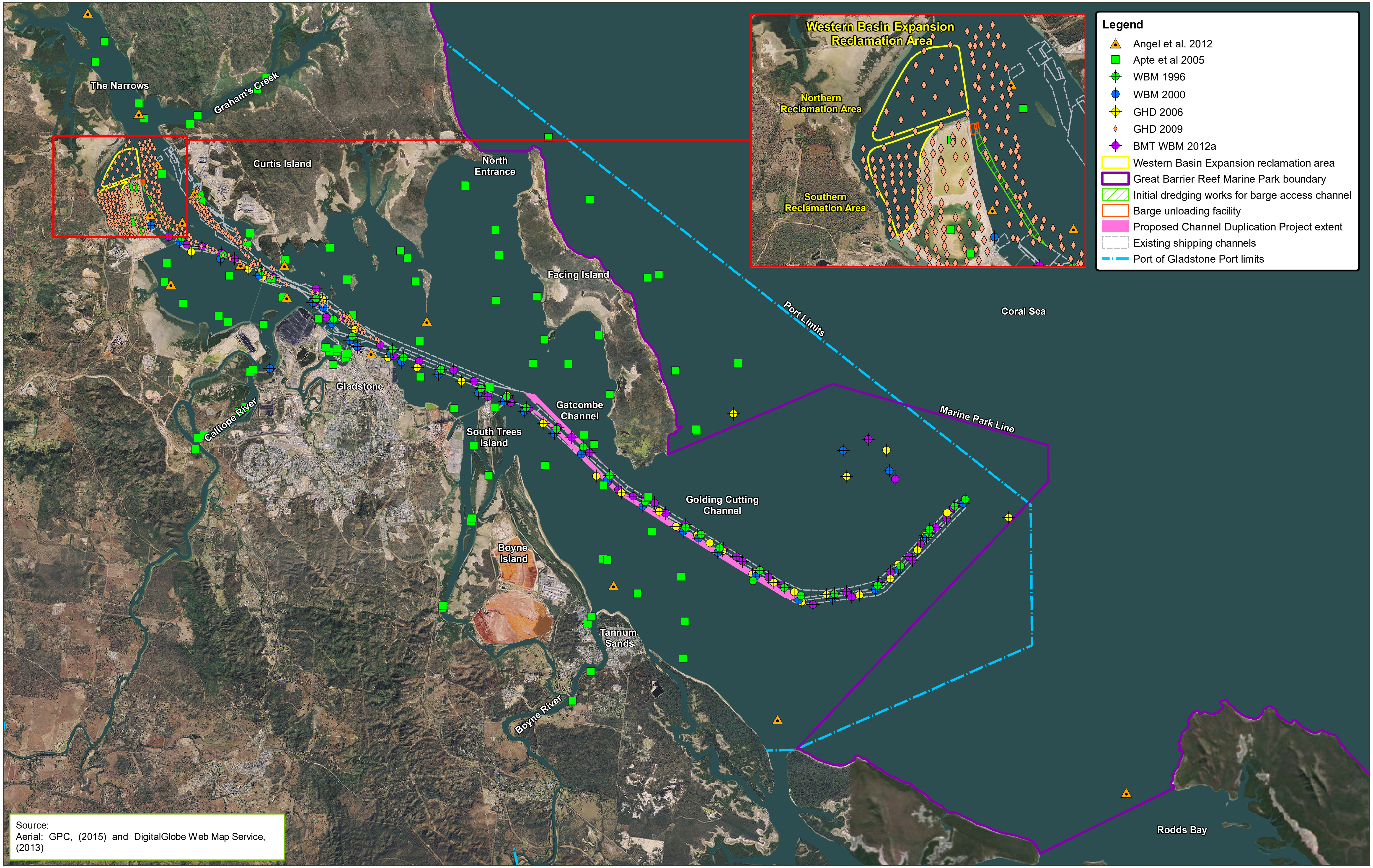

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Figure 6.1: Previous sampling programs conducted within the Port of Gladstone

In addition, six separate areas of manganese mineralisation are located within the Gladstone area with the most significant of which being the historic Mount Millar manganese mine which opened in 1895 and operated intermittently until 1916 and then from 1958 to 1960. Manganese was also historically mined from 1882 to 1900 at Auckland Hill, adjacent to Port Curtis (GPC 2012). The rocky face of Auckland Hill is a remnant of this manganese mining and quarrying.

More recently, Angel et al. (2010) investigated dissolved metal levels in Port Curtis and concluded that nickel and manganese are likely to be released by natural processes such as reduction of manganese (hydr)oxides and leaching by the lower sediment and water pH. Anastasi and Wilson (2010) also examined Port Curtis as a case study in reviewing manganese in subtropical estuaries and stated that naturally occurring manganese concentrations have been recorded in marine sediments with values up to 9,000 milligrams per kilogram (mg/kg).

Angel et al. (2012) determined that metal concentrations were generally greater in fine sediments, as these particles have a higher surface to volume ratio. The study identified elevated arsenic and manganese concentrations that were likely to be from geological formations rather than anthropogenic sources (Angel et al. 2012). The study concluded that there was no evidence of contaminant 'hot spots', such as where dredging had previously occurred.

Contaminants of concern that have been identified during previous investigations in Port Curtis at elevated concentrations include:

- Metals and metalloids (especially, arsenic, manganese, nickel and zinc)
- PAHs
- Organotin compounds.

6.4.3 Sediment investigation methodology

6.4.3.1 General

A description of the methodology employed during the geochemical investigation for the marine sediment is provided in Appendix E4 (SAP Implementation Report (area to be dredged)), Appendix E5 (Geochemical Sediment Characterisation Plan Implementation Report (DMPAs)) and Appendix E6 (SAP Implementation Report – Barge access channel).

While four potential new DMPAs were investigated during the geochemical investigation, only one has progressed to the impact assessment stage of the EIS; the WBE reclamation area.

The geochemical investigation was undertaken between 2 February and 28 February 2015 with additional sampling undertaken from 9 March to 4 May 2015 during the Project geotechnical investigations.

An additional geochemical investigation for the barge access channel was undertaken between 12 February and 15 February 2018. It should be noted that since completion of the geochemical investigations for the Project, the area to be dredged for the barge access channel has been reduced and the alignment shifted. To supplement the results from the geochemical investigation undertaken in February 2018, an assessment of previous investigations within the revised barge access channel was conducted. Eight previous boreholes were identified to have been drilled within the barge access channel during the WBDDP (GHD 2009).

6.4.3.2 Sample locations

The sampling locations (with an accuracy of ±10m) are illustrated in Figure 6.2, Figure 6.3 and Figure 6.4.

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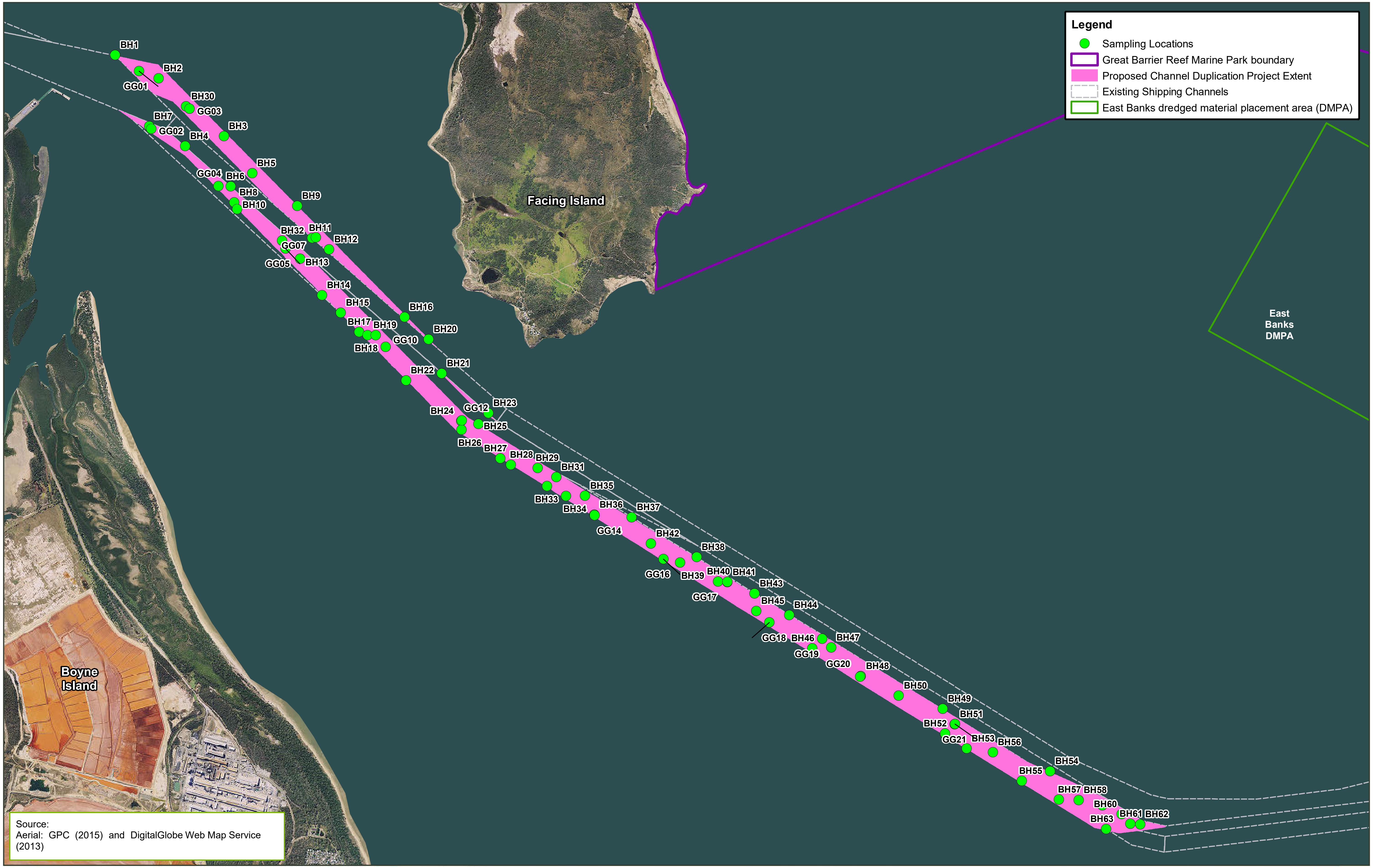

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Figure 6.2: Sampling locations within the area to be dredged

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Source:
Aerial: GPC (2015) and DigitalGlobe Web Map Service (2013)
Previous sampling locations: GHD (2009)

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Figure 6.3: Sampling locations within the barge access channel

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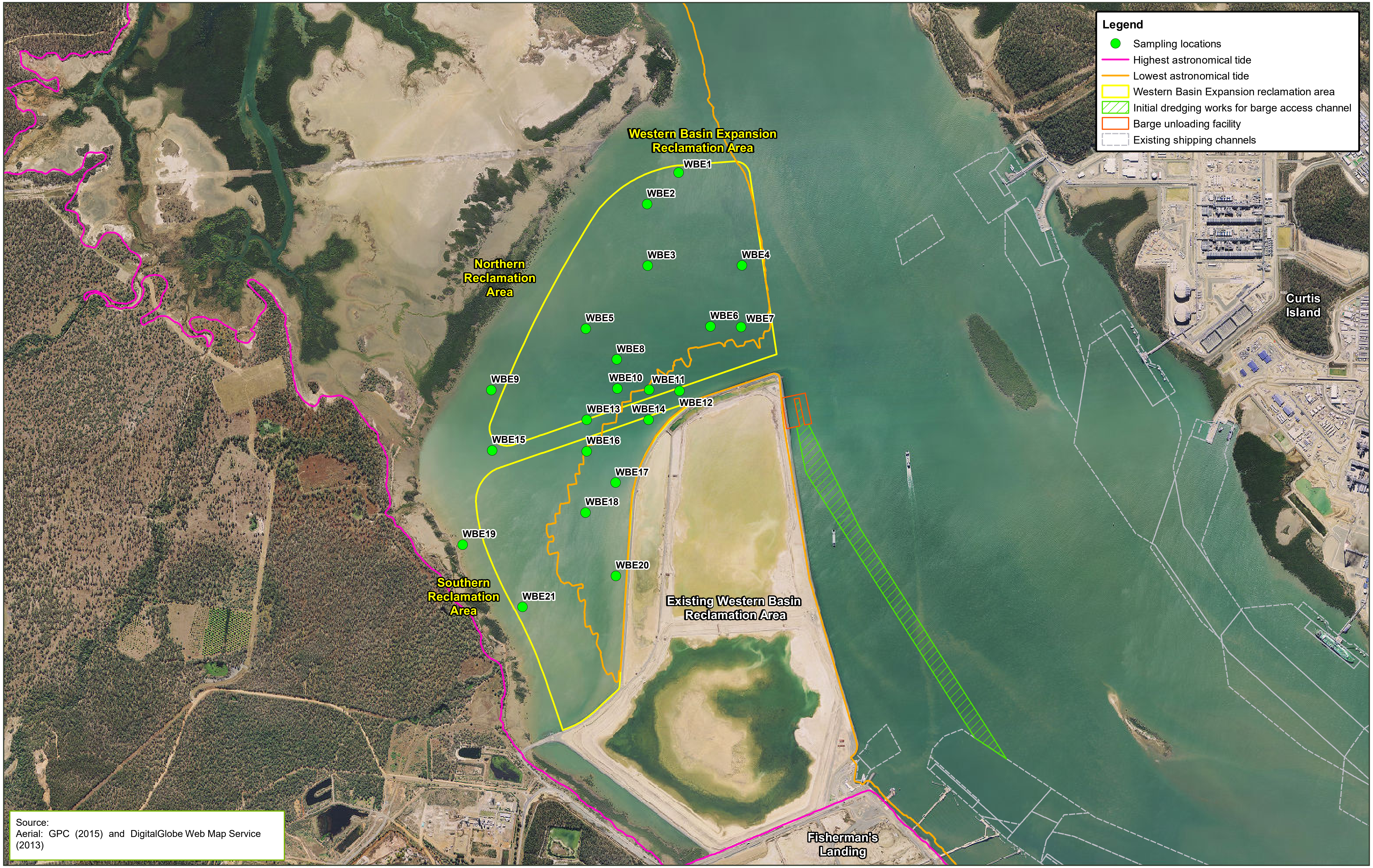

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Coordinate system: GDA_1994_MGA_Zone_56

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Figure 6.4: Sampling locations within Western Basin Expansion reclamation area

The following boreholes were assessed during the investigation:

- Area to be dredged:
  - Sixty three boreholes
  - Fifteen boreholes (geotechnical)
- Barge access channel:
  - Thirteen boreholes (Project investigation)
  - Eight grab samples (Project investigation)
  - Eight boreholes (from WBDDP (GHD 2009))
- WBE reclamation area:
  - Twenty one boreholes.

6.4.3.3 Sample collection

The number of sampling locations was calculated in accordance with NAGD (2009), based on the volume of *potentially contaminated* dredge material. *Potentially contaminated* material is sediment that is contiguous with an area of known contamination, or sediment that has been exposed to known contamination sources (NAGD 2009). It does not include the volume of underlying natural geographic materials which are, except for a boundary layer, expected to be uncontaminated. It is generally unnecessary to sample (for chemical analysis) consolidated natural geological materials underlying the surface sediments (NAGD 2009).

Although previous studies undertaken within Port Curtis indicated that anthropogenic influenced sediments are likely to only occur in the top 0.28m (Vicente-Beckett et al. 2006), the top 0.5m was regarded *potentially contaminated*, as a conservative measure, in calculating the number of sampling locations (i.e. increasing the number of sample locations required under NAGD). However, sediment samples were collected along the full length of each core, either to the depth of dredging or until refusal (whichever was met first).

Sampling within the proposed channel duplication area to be dredged was undertaken to full depth of sediment that has the potential to be contaminated from anthropogenic influences (i.e. top 0.28m). Sediment samples collected within the area to be dredged were required to comply with the following:

- Up to 17.1m LAT, or
- Until vibrocore drilling refusal (due to encountering consolidated natural geological materials (e.g. rock, dense sands/gravels or stiff to very stiff clays)), whichever is met first, and
- Where refusal of the vibrocore occurred, additional attempts were undertaken by lifting the vibrocore rig and placing it down again (in an adjacent location). Up to a total of three attempts were undertaken in each location to reach -17.1m LAT. Where refusal occurred during all three attempts, a sample of the surficial sediment (up to 0.28m below sediment surface level) was taken using a grab sampler.

Grab sampling was undertaken where refusal occurred at the surface of the seabed and no sample was retrieved from the vibrocore barrel.

The proposed dredging depth in the channel duplication area is -16.1m LAT. Current depths of the seabed in the proposed dredging area range from approximately -7.5m LAT to -16.6m LAT (i.e. the material to be dredged has a thicknesses that ranges from approximately 0.5m to 9.4m), and as such sampling undertaken by this investigation provides sufficient characterisation of material proposed to be dredged.

A good representation of *potentially contaminated* sediment that lies above the consolidated natural geology material was collected within the area to be dredged, given approximately 93.6% of sampling locations were drilled to depths greater than 0.3m. While only 42.3% of the sampling locations were drilled below 1.0m, due to refusal on consolidated natural geological materials, this is expected within high energy environments such as the exposed outer channel. It is considered likely that the looser sediments found elsewhere in Port Curtis (up to approximately 1.0m) are of a limited thickness within the Gatcombe and Golding Cutting bypass channels and, in some areas, not present (depending on exposure).

Sampling within the barge access channel was undertaken using a vibrocorer for 13 sampling locations to below the depth of dredging (-7.0m LAT for the barge access channel) or until vibrocore drilling refusal. A grab sampler was used to collect sediment at eight sampling locations. Ten of the sampling locations (BH01 to BH10) from the geochemical investigation remain relevant to the revised barge access channel and are supplemented with results from eight previous sediment sampling locations collected during the WBDDP (GHD 2009). Seabed depths in the proposed barge access channel area to be dredged range from approximately -4m LAT to -9.2m LAT, and the material to be dredged has a thicknesses that ranges from approximately 0m to 1.3m. Samples were collected from 0.5m intervals along each borehole, which were terminated at depths ranging from 1.4m to 5.5m below the seabed, and as such sampling undertaken by the Project and previous investigations provides sufficient characterisation of material proposed to be dredged.

Sampling within the WBE reclamation area was undertaken to full depth of sediment that has the potential to be contaminated and is considered to have potential to interact with the dredged material. This was considered to be the top 1.0m of sediment or until vibrocore drilling refusal due to encountering consolidated natural geological materials. This was achieved in approximately 95.2% of sampling locations within the WBE reclamation area.

An Aurecon environmental scientist determined the suitability of each sediment core following collection, based on the following:

- No loss of surface sediments
- No major loss or disturbance of sediments at depth
- Target depth was achieved or refusal at rock, dense sands/gravels or stiff clay.

Where vibrocoring collected insufficient sediment, grab sampling was employed to collect surface sediment. In some cases, multiple grabs were collected to capture sufficient sediment for laboratory analysis.

During the geochemical investigations, a vibrocorer, operated by Seas Offshore aboard the vessel 'Shackleton', was used to collect the sediment cores at each location. For coarse or firm sediment, or for sampling in the 3m to 6m depth range, vibrocoring is recommended by NAGD (2009). Samples were collected from 0.5m intervals until the maximum depth of refusal (whichever occurred first).

During the geotechnical investigation, the 'Ocean Driller II' jack-up barge was utilised. Grab samples were collected from approximately 1.0m intervals along the core to a depth of 4.0m.

The findings of each of the SAP Implementation Reports undertaken for this Project, are consistent with investigations undertaken in the Port of Gladstone, both spatially and temporally.

6.4.3.4 Sample analysis

Samples were analysed for the following contaminants:

- Metals and metalloids
- Organotins
- TRH
- Benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN)
- PAHs
- PCBs
- Organochlorine pesticides (OCP) and organophosphate pesticides (OPP)
- Dioxins and furans
- Total organic carbon (TOC)
- Nitrogen (speciated)
- Phosphorus
- Particle sizing (assessed in Chapter 7 (coastal processes and hydrodynamics))
- Acid sulfate soils (assessed in Chapter 5 (topography, geology and soils))

6.5 Results

6.5.1 Summary

Results were compared against summary sediment guidelines in the geochemical implementation reports, with a summary provided in Section 6.5.2. As the dredged material will be placed within the WB and WBE reclamation areas, the geochemical results have also been compared against terrestrial guideline values (refer Section 6.5.3).

Summary tables of the geochemical sediment results, as well as the full laboratory results, and a full description of the quality assurance and quality control (QA/QC) procedures employed during the geochemical investigation are provided in Appendix E4 (SAP Implementation Report (area to be dredged)), Appendix E5 (Geochemical Sediment Characterisation Plan Implementation Report (DMPAs)) and Appendix E6 (SAP Implementation Report – Barge access channel).

6.5.2 Sediment

The assessment of Project geochemical data was undertaken in a staged process. This was to comply with NAGD (2009), where a contaminant does not have a screening level and to account for placement of dredged material in a reclamation area. The sediment investigation framework staged process included:

- A compliance assessment undertaken for potential contaminants of concern, where guideline values exist under NAGD (2009)
- Where no guideline values exist under NAGD (e.g. iron), a comparison against locally derived reference values and other locally derived reference data was undertaken. This is in compliance with the NAGD (2009) requirement that where contaminants are identified for which there are no screening levels, these contaminant concentrations should be compared against regional ambient baseline levels. This methodology was adopted from the Gladstone Healthy Harbour Partnership (GHHP) report card assessments and used background sediment quality data from numerous geochemical investigations in the harbour over the past 20 years.
- A comparison against terrestrial background values, such as the Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (both background and Environmental Investigation Levels (EIL)), Australasian Institute of Mining & Metallurgy (2011) (background range) and the Dutch Intervention Levels (for dioxins) (Ministry of Housing, Spatial Planning and the Environment 2000) was undertaken.

Further detail is provided in the SAP Implementation Report (area to be dredged) (Appendix E4), Sediment Characterisation Plan Implementation Report (DMPAs) (Appendix E5) and SAP Implementation Report – Barge access channel (Appendix E6).

Table 6.3 outlines the NAGD (2009) guideline values adopted for sediment quality during the geochemical investigation.

Table 6.3 Sediment quality guidelines

Chemical	Units	NAGD (2009) screening level[1]	NAGD (2009) high level[1]
Metals and metalloids			
Aluminium	mg/kg	-	-
Iron	mg/kg	-	-
Antimony	mg/kg	2	25
Arsenic	mg/kg	20	70
Cadmium	mg/kg	1.5	10
Chromium	mg/kg	80	370
Cobalt	mg/kg	-	-
Copper	mg/kg	65	270
Lead	mg/kg	50	220
Mercury	mg/kg	0.15	1
Manganese	mg/kg	-	-
Nickel	mg/kg	21	52
Selenium	mg/kg	-	-
Silver	mg/kg	1.0	3.7 (4.0)
Vanadium	mg/kg	-	-
Zinc	mg/kg	200	410
Organometallics[2]			
Tributyltin	µg Sn/kg	9	70
Organics[2]			
Total TRH	mg/kg	550 (280)	- (550)
Total PCB	µg/kg	23 (34)	- (280)
Total PAH	µg/kg	10,000	45,000-50,000 (50,000)
DDD	µg/kg	2 (3.5)	20 (9.0)
DDE	µg/kg	2.2 (1.4)	27 (7.0)
Total DDT	µg/kg	1.6 (1.2)	46 (5.0)
Dieldrin	µg/kg	280 (2.8)	270 e/ 620 (7.0)
Chlordane	µg/kg	0.5 (4.5)	6 (9.0)
Lindane	µg/kg	0.32 (0.9)	1.0 (1.4)
Endrin	µg/kg	10 (2.7)	120 e/ 220 (60)
Dioxins	µg/kg	-	-
Inorganics			
Ammonia as N	mg/kg	- (4)	- (4.5)

Table notes:

µg Sn/kg = micrograms tin per kilogram µg/kg = micrograms per kilogram
DDD = dichlorodiphenyldichloroethane DDT = dichlorodiphenyltrichloroethane DDE = dichlorodiphenyldichloroethylene
1 Values provided in brackets represent revised sediment quality values as provided in Simpson et al. (2013)
2 For comparison to revised sediment quality values (Simpson et al. 2013), concentrations were normalised to 1.0% total organic carbon

Contaminant concentrations were assessed against the guideline values outlined in Table 6.3 using the 95% UCL, calculated with ProUCL Version 5.0 (US EPA 2013). Where no analytical values of a contaminant were reported over the NAGD practical quantification limit (PQL), statistical calculations were not undertaken. In some cases, where less than three values were above PQL for the respective contaminant, the maximum recorded value was used instead of the 95% UCL for a conservative comparison against NAGD (2009) screening levels. Analytical values reported below the detection limit were set to one-half of the laboratory PQL as per NAGD (2009).

6.5.2.1 Metals/metalloids

This section provides a summary of metals/metalloids detected within the Project footprint sediments.

- The 95% UCL of all metals and metalloids for all horizon samples across the Project footprint were below the NAGD (2009) screening levels
- Metals with no NAGD (2009) screening level values were compared against locally derived reference values and other locally derived reference data (equivalent to the NAGD (2009) term - regional ambient baseline levels) was undertaken. Concentrations of aluminium, iron, cobalt, selenium and vanadium across the Project footprint were consistent with the reference values derived during previous investigations.
- The 95% UCLs for arsenic were below the NAGD (2009) screening level of 20mg/kg across the Project footprint. Samples were generally below the screening level, with the exception of:
  - Five samples within the area to be dredged (95% UCL of 9.74mg/kg)
  - Two samples within the barge access channel (95% UCL of 11mg/kg)
  - One sample within the barge access channel from previous sampling (95% UCL off 11.4mg/kg)
  - Four samples within the WBE reclamation area (95% UCL of 14.64mg/kg)
- Chromium was recorded in a single sample collected at depth within the area to be dredged at a concentration above the NAGD (2009) screening level of 80mg/kg. The 95% UCL for chromium (17.53mg/kg) was significantly lower than the NAGD (2009) screening level.
- The 95% UCLs for copper were below the NAGD (2009) screening level of 65mg/kg across the Project footprint. Samples were generally below the screening level, with the exception of:
  - One sample within the barge access channel from previous sampling (95% UCL of 31.3mg/kg)
- Manganese is ubiquitous both spatially and at depth within Port Curtis, with 37 samples at 24 locations within the area to be dredged reporting manganese concentration over the Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland (EPA 1998) 500mg/kg EIL. It is evident that the highest manganese concentrations are found naturally at depth with the following 95% UCLs:
  - Manganese (< 1.0 depth): 494.3mg/kg (from 110 samples)
  - Manganese (> 1.0 depth): 823.2mg/kg (from 47 samples)
  - Manganese (combined depths): 469.8mg/kg (from 157 samples)
- Within the barge access channel, manganese was reported above the adopted EIL of 500mg/kg in 20 samples across 11 locations, with a 95% UCL of 926.1mg/kg
- Within the barge access channel, manganese from previous sampling was reported above the adopted EIL of 500mg/kg in three samples, with a 95% UCL of 330mg/kg
- Within WBE reclamation area, manganese was not detected above the adopted EIL of 500mg/kg in any samples

- The 95% UCLs for nickel were below the NAGD (2009) screening level of 21mg/kg across the Project footprint. Samples were generally below the screening level, with the exception of:
  - Nine samples within the area to be dredged (95% UCL of 11.98mg/kg)
  - Three samples within the barge access channel (95% UCL of 13.14mg/kg)
  - Two samples within the barge access channel from previous sampling (95% UCL of 13.1mg/kg).

6.5.2.2 Nutrients

Total kjeldahl nitrogen (TKN) accounted for all total nitrogen measured in all samples across the Project footprint. Sediments within the WBE reclamation area were determined to be more nutrient rich than the Gatcombe and Golding Cutting shipping channels, and the barge access channel.

- TKN:
  - Concentrations within the area to be dredged ranged between 30mg/kg and 480mg/kg with a median concentration of 160mg/kg
  - Concentrations within the barge access channel ranged between 60mg/kg and 1,120mg/kg with a median concentration of 460mg/kg
  - Concentrations within the barge access channel from previous sampling ranged between 110mg/kg and 1,120mg/kg with a median concentration of 360mg/kg
  - Concentrations within WBE reclamation area ranged from 100mg/kg to 1,470mg/kg with a median of 570mg/kg
- Total phosphorus:
  - Concentrations within the area to be dredged ranged between 92mg/kg and 474mg/kg with a median concentration of 217mg/kg
  - Concentrations within the barge access channel ranged between 84mg/kg and 680mg/kg with a median concentration of 281mg/kg
  - Concentrations within the barge access channel from previous sampling ranged between 68mg/kg and 2,830mg/kg with a median concentration of 261mg/kg
  - Concentrations within WBE reclamation area ranged from 61mg/kg to 550mg/kg with a median of 166mg/kg.

Ammonia as N was compared against the Simpson et al. (2013) screening level of 4.0mg/kg. Within the area to be dredged, ammonia as N exceeded this screening level in 15 samples, although the 95% UCL was below the Simpson et al. (2013) screening level. Within the WBE reclamation area, ammonia as N exceeded the Simpson et al. (2013) screening level on 33 occasions with a 95% UCL of 7.41mg/kg. Within the barge access channel, ammonia as N exceeded the Simpson et al. (2013) screening level:

- Project investigation: in 90% of samples collected, with a 95% UCL of 46.85mg/kg
- Previous sampling (GHD 2009): in 76% of samples collected, with a 95% UCL of 16.1mg/kg.

Sediments comprising higher silt/clay content and total organic carbon, such as those within the WBE reclamation area and barge access channel, typically contain higher concentrations of ammonia as N, compared with sediments with higher proportions of coarse material.

6.5.2.3 Organic compounds

A summary of organic compounds detected within the Project footprint sediments is provided below.

- Tributyltin was detected at an elevated concentration in a single sample within the area to be dredged, although this sample was below the NAGD (2009) screening level. Tributyltin was not detected within the barge access channel or WBE reclamation area.
- No concentrations of PCB, OCP, OPP or BTEX were detected above the NAGD (2009) PQL or laboratory limit of reporting (LOR) across the Project footprint
- TRH was detected in low concentrations on across the Project footprint, although all samples from the Gatcombe and Golding Cutting shipping channels, and barge access channel were below the NAGD (2009) screening level
- Within the WBE reclamation area, the NAGD (2009) screening level for TRH (>C_{10}-C_{40}) was exceeded on ten occasions with a 95% UCL of 927.6mg/kg (adjusted to 1.0% TOC). The maximum concentration was 3,950mg/kg (adjusted to 1.0% TOC) at a depth of 0.5 to 1.0m at WBE11, and is a one-off hydrocarbon hotspot of unknown origin.
- PAHs were detected in low concentrations across the Project footprint, although all samples were below the NAGD (2009) screening levels, with elevated concentrations in six samples within the area to be dredged, 35 samples within the barge access channel, and nine samples within the WBE reclamation area.

6.5.2.4 Dioxins

NAGD (2009) does not provide screening levels for dioxins. The Canadian sediment quality guidelines were adopted, which provide for dioxins in marine (freshwater and marine) environments with an interim sediment quality guideline (ISQG) value of 0.85 picogram toxic equivalent per gram (pg TEQ/g) and a probably effect level (PEL) of 21.5pg TEQ/g (Canadian Council of Ministers of the Environment 1999).

During this investigation, 33 sediment samples were collected across the Project footprint and analysed for dioxins. The summary dioxin results are:

- February 2015 investigation in the area to be dredged and the WBE reclamation area:
  - Minimum: 0.04pg TEQ/g
  - Median: 0.355pg TEQ/g
  - Maximum: 2.89pg TEQ/g
- February 2018 investigation in the barge access channel:
  - Minimum: 0.1pg TEQ/g
  - Median: 0.99pg TEQ/g
  - Maximum: 2.43pg TEQ/g.

All dioxin concentrations are significantly below the PEL, while the median concentration is below the ISQG, indicating that dioxins within the sediments of Port Curtis are unlikely to result in adverse biological effects.

However, given dredged material will be placed in the WB and WBE reclamation areas, it is considered more appropriate to compare the results to the Dutch Intervention Levels for dioxins (1,000pg/g) (Ministry of Housing, Spatial Planning and the Environment 2000). As the median concentration (and maximum) are several orders of magnitude below the Dutch Intervention Level, no risk is anticipated from dioxins to future site users of the reclamation.

In addition, dioxin concentrations were considered similar to previous results collected by the former EHP (2012) in Port Curtis and were typical of marine sediments around Australia when compared with the National Dioxins Program (Müller et al. 2004).

6.5.2.5 Sediment results summary

Results from the geochemical investigation of the channel duplication area to be dredged have demonstrated that the sediment from the area to be dredged is **clean** as per NAGD (2009) and is therefore chemically suitable for placement within the WB and WBE reclamation areas.

Results from the geochemical investigation of the barge access channel (including previous sampling during the WBDDP) have demonstrated that the sediment from the barge access channel is **clean** as per NAGD (2009) and is therefore chemically suitable for placement within the WB reclamation area.

Results from the DMPA geochemical investigation have demonstrated that the sediments from the WBE reclamation area have low concentrations of metals throughout the sediment profile, and despite the exceedances of NAGD (2009) screening levels for some contaminants in some samples, overall, the sediment is considered **clean** as per NAGD (2009).

Given the sediments from the Project areas to be dredged and WBE reclamation area are all **clean** as per NAGD (2009), the WB and WBE reclamation areas are considered to be chemically suitable to receive dredged material from the Project areas to be dredged.

6.5.3 Terrestrial

6.5.3.1 Introduction

Results from the areas to be dredged geochemical investigations have been compared to terrestrial soil guidelines (National Environmental Protection Measure (NEPM) 2013) as dredged material will be beneficially reused for reclamation, for which the future land use is likely to be port-related industrial. NEPM (2013) does not provide a guideline value for dioxins, as such, the Dutch Intervention Levels for dioxins were adopted. Section 6.5.2.4 provides a summary of dioxins and the comparison against adopted guideline values.

6.5.3.2 Risk assessment criteria

The specific assessment criteria adopted for the dredged material are presented in Table 6.4. Results were compared against commercial/industrial levels (health investigation level (HIL)/health screening level (HSL) D). While the proposed land use for the future reclamation area will be industrial, results have also been compared against the residential land use criteria (HIL/HSL A), as a conservative approach and as the most sensitive future land use.

Due to the heterogeneous nature of the sediment, in those instances where the relevant assessment criteria is dependent on sediment type (e.g. clay, silt or sand), the most conservative value (i.e. lowest accepted contaminant concentration) has been adopted.

Table 6.4 Selected assessment criteria

Term	Definition	Reference	Contaminant
Human health risk assessment criteria			
NEPM (2013) HIL (D)	HILs for commercial/industrial setting	NEPM (2013)	Heavy metals, OCPs, OPPs, herbicides, PAHs and PCBs
NEPM (2013) HSL (D)	Vapour HSL for commercial/industrial setting	NEPM (2013)	Petroleum hydrocarbons (BTEX, TRH and naphthalene)
Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) (HSL) (D)	Direct contact HSLs for commercial/industrial setting	Friebel and Nadebaum (2011)	Petroleum hydrocarbons (BTEX and TRH)

Term	Definition	Reference	Contaminant
Dutch Intervention Levels	Intervention levels for contaminants	Ministry of Housing, Spatial Planning and the Environment (2000)	Dioxins
NEPM (2013) HIL (A)	HILs for residential land use with garden/accessible soil	NEPM (2013)	Heavy metals, OCPs, OPPs, herbicides, PAHs and PCBs
NEPM (2013) HSL (A)	Vapour HSL for residential land use with garden/accessible soil	NEPM (2013)	Petroleum hydrocarbons (BTEX, TRH and naphthalene)
CRC CARE (HSL) (A)	Direct contact HSLs for residential land use with garden/accessible soil	Friebel and Nadebaum (2011)	Petroleum hydrocarbons (BTEX and TRH)
Environmental risk assessment criteria			
NEPM (2013) EIL	EIL for urban residential and open public spaces	NEPM (2013)	Arsenic, naphthalene, zinc, copper, chromium III, nickel and lead
NEPM (2013) ESL	Ecological screening level (ESL)	NEPM (2013)	Petroleum hydrocarbons (BTEX, TRH and benzo(a)pyrene)

6.5.3.3 Results

A summary of the geochemical results above PQL or laboratory LOR, showing comparisons to relevant health and environment assessment criteria identified in Section 6.5.3.2 is provided in Table 6.5.

No contaminants were detected above the recreational/open space or commercial/industrial guideline levels.

Contaminant concentrations were detected above the more conservative residential (with gardens/accessible soils). These values are highlighted in bold, along with the corresponding assessment criteria in Table 6.5.

Sampling locations where site assessment criteria have been exceeded are illustrated in Figure 6.5 and Figure 6.6.

Previous sampling within the barge access channel during the WBDDP (GHD 2009) did not identify any contaminants above the investigation levels for human health for any land use. One sediment sample contained a copper concentration above the EIL of 130mg/kg, although the 95% UCL for copper was significantly below this guideline level.

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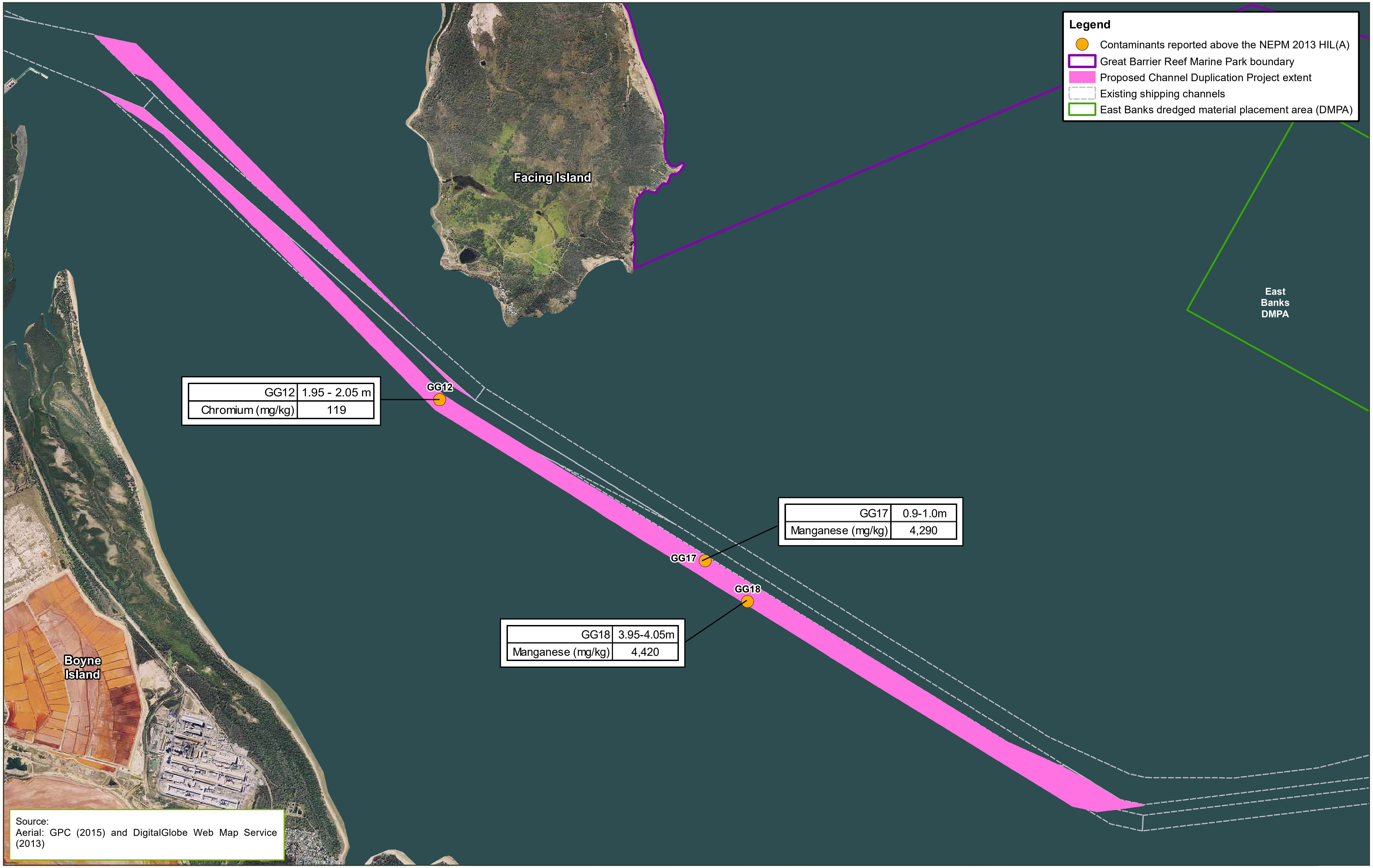

Metres
0 500 1,000

Date: 22/03/2018 Version: 4 Job No: 237374
Coordinate system: GDA_1994_MGA_Zone_56

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Map by: RZ

Gatcombe and Golding Cutting Channel Duplication Project

Figure 6.5: Contaminants reported above NEPM 2013 HIL (A) within the area to be dredged

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BH11	0.0 - 0.5 m
Manganese (mg/kg)	5,510

Metres
0 255 510

Date: 29/01/2019 Version: 1 Job No: 237374

Coordinate system: GDA_1994_MGA_Zone_56

Map by: RB P:\GIS\Projects\237374_GPC_Channel_Duplication_EIS\237374_EIS_216.mxd 29/01/2019 14:12

Gatcombe and Golding Cutting Channel Duplication Project

Figure 6.6: Contaminants reported above the NEPM 2013 HIL(A) within the barge access channel

Table 6.5 Summary of area to be dredged geochemical results compared with terrestrial human health and environment risk assessment criteria

Analytes (mg/kg)	Metals/metalloids											Organics						
	Arsenic	Cadmium	Chromium	Copper	Cobalt	Lead	Manganese	Nickel	Selenium	Zinc	Mercury	Naphthalene	Benzo(a) pyrene	Total PAHs	TRH >C_{10}-C_{16}	TRH >C_{16}-C_{34}	TRH >C_{34}-C_{40}	TRH >C_{10}-C_{40}
NEPM 2013 HIL/HSL (D)	3,000	900	3,600	240,000	4,000	1,500	60,000	6,000	10,000	400,000	730		40	4,000	1,000[3]	3,500[3]	10,000[3]	
CRC CARE HSL (D)												11,000			20,000	27,000	38,000	
NEPM 2013 HIL/HSL (C)	300	90	300	17,000	300	600	19,000	1,200	1,200	30,000	80		3	300	1,000[3]	2,500[3]	10,000[3]	
NEPM 2013 HIL/HSL (A)	100	20	**100**	6,000	100	300	**3,800**	400	200	7,400	40	3[4]	3	300	110			
CRC CARE HSL (A)												1,400			3,300	4,500	6,300	
NEPM 2013 EIL/ESL	50		150	130		270		110		300		10[5]	0.7		120	300	2,800	
Samples collected	157	157	157	157	157	157	157	157	157	157	157	95	95	95	97	97	97	97
Number of detects	152	5	157	157	157	155	157	157	156	157	58	1	1	6	2	44	1	44
Minimum	<1.0	<0.1	3.8	2.8	2.2	<1.0	32	1.9	<0.1	7.1	<0.01	-	-	-	-	<3	-	<3
Maximum	31.4	0.6	**119**	53	84.3	25.3	**4,420**	26.9	5.2	84.5	0.1	0.005	0.006	0.046	0.2	14	5	19
Mean	8.017	0.0561	16.28	16.55	10.71	6.415	412.1	9.901	0.92	30.52	0.0108	-	-	0.0049	-	4.25	-	4.3
Median	7.755	0.2	13.9	12.7	7.9	4.8	271	7.1	0.6	24.8	0.02	-	-	<0.004	-	3.0	-	3.0
Standard deviation	4.941	0.0471	11.27	11.84	9.748	4.473	584	5.981	0.937	17.08	0.0115	-	-	0.0051	-	2.22	-	2.49
95% UCL[1]	9.736	0.0623	17.53	20.67	14.1	7.325	469.8	11.98	1.246	36.46	0.0148	0.005	0.006	0.0058	0.2	4.63	5	4.72
Number of exceedances[2]	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-

Table notes:

1 Where less than three values were above the laboratory LOR or PQL, the maximum value was used instead of the 95% UCL for a conservative comparison against guideline value
2 Refers to exceedances over the adopted guideline value.
3 Management limits for hydrocarbon limits, using coarse soil texture.
4 Naphthalene soil HSL for vapour intrusion.
5 Naphthalene EIL for areas of ecological significance.
Bold indicates an exceedance of the corresponding guideline

Table 6.6 Summary of barge access channel geochemical results compared with terrestrial human health and environment risk assessment criteria

Analytes (mg/kg)	Metals/metalloids											Organics					
	Arsenic	Cadmium	Chromium	Copper	Cobalt	Lead	Manganese	Nickel	Selenium	Zinc	Mercury	Naphthalene	Total PAHs	TRH >C_{10}-C_{16}	TRH >C_{16}-C_{34}	TRH >C_{34}-C_{40}	TRH >C_{10}-C_{40}
NEPM 2013 HIL/HSL (D)	3,000	900	3,600	240,000	4,000	1,500	60,000	6,000	10,000	400,000	730		4,000	1,000[3]	3,500[3]	10,000[3]	
CRC CARE HSL (D)												11,000		20,000	27,000	38,000	
NEPM 2013 HIL/HSL (C)	300	90	300	17,000	300	600	19,000	1,200	1,200	30,000	80		300	1,000[3]	2,500[3]	10,000[3]	
NEPM 2013 HIL/HSL (A)	100	20	100	6,000	100	300	**3,800**	400	200	7,400	40	3[4]	300	110			
CRC CARE HSL (A)												1,400		3,300	4,500	6,300	
NEPM 2013 EIL/ESL	50		150	130		270		110		300		10[5]		120	300	2,800	
Samples collected	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
Number of detects	63	0	63	63	63	63	63	63	63	63	46	1	19	1	30	2	30
Minimum	1.39	<0.1	4.9	4.9	4.7	2	36	3.7	<0.1	13.4	<0.01	-	<0.004	-	<3	-	<3
Maximum	23.1	<0.1	29.5	57.9	66.7	20.3	**5,510**	32.8	2	72.5	0.06	0.3	0.11	3.0	17	8	25
Mean	10.12	<0.1	18.78	21.25	15.10	7.45	538.60	11.99	0.38	37.94	0.019	-	0.0228	-	5.433	-	6.0
Median	9.61	<0.1	20.6	21.70	12.8	8	383	11.5	0.3	37.9	0.02	-	0.01	-	5.0	-	5.0
Standard deviation	4.13	0	6.13	10.00	10.36	2.95	705.7	5.43	0.25	11.42	0.010	-	0.0275	-	2.763	-	4.315
95% UCL[1]	11	-	20.8	23.38	20.84	8.084	926.1	13.14	0.441	40.37	0.0218	0.3	0.05	3.0	4.698	8	7.339
Number of exceedances[2]	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-

Table notes:

1 Where less than three values were above the laboratory LOR or PQL, the maximum value was used instead of the 95% UCL for a conservative comparison against guideline value

2 Refers to exceedances over the adopted guideline value.

3 Management limits for hydrocarbon limits, using coarse soil texture.

4 Naphthalene soil HSL for vapour intrusion.

5 Naphthalene EIL for areas of ecological significance.

Bold indicates an exceedance of the corresponding guideline

6.5.3.4 Human health risk assessment

HILs were developed for a broad range of metals and organic substances, for assessing human health risk via all relevant pathways of exposure. HILs and HSLs are the concentrations of a contaminant above which further appropriate investigation and evaluation is required (NEPM 2013). Investigation and screening levels area intended by NEPM (2013) as a tool for assessing existing contamination and to trigger consideration of an appropriate site specific risk based approach or implementation of appropriate risk management options when they are exceeded.

Initial findings

A total of 265 sediment samples collected from the Project footprint were analysed with results screened against the human health risk assessment criteria listed in Table 6.4. Exceedances are summarised in Table 6.5 and Table 6.6.

Sediment samples that exceeded the selected assessment criteria are presented in Table 6.7.

Table 6.7 Soil contaminant exceedances for human health risk assessment

Contaminant	Screening criteria	No. of exceedances	Samples
Chromium	NEPM 2013 HIL (A)	1 of 220	GG12 1.95-2.05m (Gatcombe and Golding Cutting shipping channels).
Manganese	NEPM 2013 HIL (A)	3 of 220	GG17 0.9-1.0m (Gatcombe and Golding Cutting shipping channels). GG18 3.95-4.05m (Gatcombe and Golding Cutting shipping channels) BH11 0.0-0.5 (barge access channel)

When compared with the human health risk assessment criteria for low density residential land use, elevated concentrations of chromium and manganese were detected within isolated samples. The source of these elevated concentrations is likely from the geological formations of Port Curtis, given the depth of the samples, below the depth of potential anthropogenic influence of 0.28m (Vicente-Beckett et al. 2006).

Statistical analysis

Where samples have exceeded selected screening criteria, statistical analysis has been undertaken in accordance with the NEPM (2013) guidance, which states that for a site to be considered uncontaminated, the following must be met, based on meeting the QA/QC requirements:

- The 95% UCL for the sampling area must be below the acceptable limit
- The standard deviation of the results must be less than 50% of the criterion
- No single value may exceed 250% of the criteria.

Table 6.8 presents a summary of results for manganese and chromium.

Table 6.8 Statistical analysis of contaminants in exceedance of the relevant assessment criteria

Contaminant	Assessment criteria (mg/kg)	250% of assessment criteria (mg/kg)	95% UCL (mg/kg)	Standard deviation (mg/kg)	Maximum concentration (mg/kg)
Gatcombe and Golding Cutting shipping channels					
Chromium	100	250	17.53	11.27	119
Manganese	3,800	9,500	469.8	584	4,420
Barge access channel					
Manganese	3,800	9,500	926.1	705.7	5,510

The statistical analysis was passed for both chromium and manganese, and therefore the presence of these contaminants is not considered to present a significant risk to human health for the most sensitive residential land use (the most conservative guideline values).

In addition, the proposed land use will be port-related industrial, rather than low-density residential. The HILs for commercial/industrial (e.g. shops, offices, factories and industrial sites) (D) are higher than the residential land use guidelines, as follows:

- HIL (D):
  - Chromium: 3,600mg/kg
  - Manganese: 60,000mg/kg.

For a port-related industrial land uses, contaminants in all samples are below these human health risk assessment criteria.

6.5.3.5 Environmental risk assessment

An environmental risk assessment is a risk based process which assesses the risk posed to terrestrial ecosystems from adverse effects of contaminants in soil. EILs were developed to be used as part of the environmental risk assessment process. The aim whilst developing the EILs was so that varying levels of protection could be provided to ecological receptors, with the level of protection dependent on the land use and whether the contaminant in question biomagnifies (NEPM 2013). There are two types of ecological values: generic and site-specific.

For this investigation, site-specific EILs were calculated using the EIL Calculation Spreadsheet, developed by CSIRO for the National Environment Protection Council (NEPC) and are provided in Table 6.5. Results were screened against the environmental risk assessment criteria.

Previous sampling within the barge access channel during the WBDDP (GHD 2009) detected one sediment sample with a copper concentration above the EIL of 130mg/kg, although the 95% UCL for copper was significantly below this guideline level.

There were no other contaminants identified at concentrations exceeding the environmental risk assessment.

6.6 Potential impacts

6.6.1 Bund wall and barge unloading facility construction

Construction of the bund wall for the WBE reclamation area and part of the BUF will involve placement of core material and rock armour. As this material is placed to establish the reclamation area and BUF, there is potential for the resuspension of soft sediment, including contaminant resuspension, and absorption back into the water column. However, results from the geochemical investigation within the proposed WBE reclamation area indicate that contaminant concentrations comply with the NAGD (2009) screening levels. As such, it is considered that the remobilisation of these sediments into the water column during bund wall and BUF construction will not result in the introduction of contaminants.

The potential environmental impacts from the placement of the bund wall material are provided in the relevant EIS environment aspect chapter, including:

- Potential water quality impacts (refer Chapter 8)
- Potential ecological and MNES impacts (refer Chapter 9).

6.6.2 Dredging activities

Dredging within the Gatcombe and Golding Cutting shipping channels will be undertaken by a TSHD which will load the dredged material into four barges which will transport the material to the BUF adjacent to the existing WB reclamation area, to be unloaded using large excavators into trucks for placement within the WB and WBE reclamation areas. As such, there is potential for sediment resuspension and absorption of contaminants back into the water column during the following activities:

- Direct disturbance by the dredger head of the TSHD
- Overflow dredging from the barges, where excess water (containing some suspended sediments) is drained from the barge and released back into the marine waters.

However, sediments within the dredged material are deemed ‘clean’ under NAGD (2009). Although naturally occurring metals/metalloids are present within the sediments, Project activities may mobilise these adsorbed metals into the water column, however, it is unlikely that these contaminants will pose any significant risk to the receiving environment given the low concentrations present, and that turbidity generated during dredging activities will be managed by implementing the Dredging EMP and Procedure (refer Appendix Q1 and Q3, respectively).

Eggleton and Thomas from the United Kingdom Centre for Environment, Fisheries and Aquaculture Science undertook research in 2004 and prepared ‘A review of factors affecting the release and bioavailability of contaminants during sediment during sediment disturbance events’. A summary of the findings that are relevant to this Project and potential risks are provided below.

- There is negligible mobilisation of metals in locations that have only minor changes in the redox potential and pH. The Project ASS investigation has indicated that there is a low presence of ASS in the material to be dredged and there is also sufficient self neutralising capacity within the sediment to neutralise any acid generated. Therefore, pH changes of the ocean water are not expected to occur as part of this Project.
- Any released Fe and Mn are rapidly precipitated and deposited as insoluble oxides/hydroxides, to which other newly released metals can become adsorbed to, at varying rates
- During the placement of dredged material, only a small percentage of the total material remains in suspension, with the majority going directly to the bottom of the water column
- Pieters et al. (2002) observed low contaminant mobilisation during dredging, although metal mobility changed during each dredging technique and was different for every contaminant examined

- Van den Berg et al. (2001) and De Groote et al. (1998) also observed low mobilisation of metal contaminants into the dissolved phase during dredging, which was thought to be due to the rapid scavenging of sulfide liberated metals by newly formed Fe and Mn oxides/hydroxides.

Water sampling was undertaken by DES, as part of monitoring during dredging activities for the WBDDP in the Port of Gladstone from September 2011 to January 2013. A review was undertaken on the total and filtered manganese data as a potential contaminant of concern, due to the concentrations observed in the natural sediments within the material proposed to be dredged. A total of 561 sets of paired data were reviewed, where both total manganese concentrations (unfiltered water sample) and dissolved manganese (filtered water sample) concentrations were analysed by a laboratory. The unfiltered water sample includes both manganese dissolved in the water, as well as the manganese either adhered to sediment, or manganese that forms part of the sediment matrix (i.e. the suspended solids). On average, 62% of total manganese identified in the samples was found to be in the solid phase (adhered to or part of sediment/suspended solids matrix). On average 38% of total manganese was in the dissolved fraction.

Similar water sampling was undertaken by GPC as part of the WBDDP from November 2011 to November 2013. A total of 578 sets of paired data from 25 monitoring rounds were reviewed, where both total manganese concentrations (unfiltered water sample) and dissolved manganese (filtered water sample) concentrations were analysed by a laboratory. This monitoring identified a similar trend, with on average, 61% of total manganese identified in the samples was found to be in the solid phase (adhered to or part of sediment/suspended solids matrix). On average 39% of total manganese was in the dissolved fraction.

Based on this water quality monitoring data (total and dissolved metals data), potential risks from metals/metalloids potentially disturbed during dredging activities (already low due to concentrations being below NAGD guidance) will be effectively managed through management of turbidity by implementing the Dredging EMP and Procedure (refer Appendix Q1 and Q3, respectively).

The *National Environment Protection Measures (Assessment of Site Contamination) 2013, Schedule B5a, Guideline on Ecological Risk Assessment* adopts the ‘added risk approach’. This approach assumes that availability (and toxicity) of background concentrations of a potential contaminant to organisms is either zero or sufficiently close to zero, such that there is no risk to the surrounding ecosystems. It also assumes that the naturally occurring background concentrations have resulted in ecosystems evolving to survive in these conditions, or evolving to require those concentrations to fulfil micronutrient requirements.

In adopting the NEPM ‘added risk approach’, any concentrations of metals/metalloids identified in the sediment (below the potentially anthropogenically influenced layer of 0.28m) will not have an adverse effect on the surrounding ecosystems.

Potential risks associated with contaminants in the sediment proposed to be dredged have been assessed and managed, through:

- Geochemical sampling and assessment of contaminants undertaken in the sediment that is potentially anthropogenically influenced (the top 0.28m) at every sampling location.
- Geochemical results were compared against NAGD guidance for offshore disposal in a marine environment, as well as onshore re-use in a terrestrial environment through comparison against NEMP screening criteria. The sediment is suitable for both offshore disposal and onshore terrestrial re-use.
- The sediments to dredged under the Project sampling locations are natural material which may contain naturally occurring elevated metal concentrations (e.g. Mn, Ni). However, these metals are present in the natural material as a result of the sediment parent rock material. Adopting the NEPM ‘added risk approach’, any concentrations of metals/metalloids identified in the sediment (below the potentially anthropogenically influenced layer of 0.28m) will not have an adverse effect on the surrounding ecosystems.

- Monitoring data from both DES and GPC as part of the WBDDP indicates metals/metalloids are predominantly associated with sediments (on average 62% are either adhered to sediment or form part of the matrix) and are stable (i.e. unlikely to be made available within the water column).

The Project Environmental Monitoring Procedure will be implemented to manage dewatering impacts within the WB and WBE reclamation areas, including licenced metal water quality discharge limits (refer Appendix Q3

The potential impacts from the release of contaminants into the receiving environment during dredging are provided in the relevant EIS environmental aspect chapter, including:

- Potential water quality impacts (refer Chapter 8)
- Potential ecological and MNES impacts (refer Chapter 9).

6.6.3 Placement of dredged material

Placement of dredged material within the WB and WBE reclamation areas from the barges has the potential to resuspend contaminants from the sediment and remobilise contaminants to migrate into the WB and WBE reclamation areas. This has the potential to impact on the quality of the decant water to be released into Port Curtis from the reclamation areas via licenced discharge points.

In addition, the concentration of nutrient heavy sediments at the WB and WBE reclamation areas may result in algal blooms through the discharge of nutrient heavy water to the Port. The intertidal channel to the northwest of the WBE reclamation area where reduced flushing occurs will be most affected by an increase in metal/metalloid and nutrient concentrations.

There is potential for the dredged material to produce a nuisance odour from high concentrations of ammonia or the formation of hydrogen sulfide (H_2S) in PASS material. The potential impacts related to odour from placement of dredged material at the WB and WBE reclamation areas are provided in the potential Project impacts on air quality (refer Chapter 12).

The potential impacts from the release of contaminants into the receiving environment from the WB and WBE reclamation areas are provided in the relevant EIS environmental aspect chapter, including:

- Potential water quality impacts (refer Chapter 8)
- Potential ecological and MNES impacts (refer Chapter 9).

6.6.4 Installation of navigational aids

The removal of existing navigational aids will involve a barge and pile extractor while new or relocated navigational aids will be installed using a pile hammer to drive the pile until design depth is reached. While sediments are likely to be resuspended during this process, the works will be confined to small areas only and temporary, taking up to 12 days per navigational aid. While sediment sampling was not conducted in these locations, the impact on the receiving environment from sediment resuspension is likely to be minimal.

6.6.5 Stabilisation and final Project landform

During stabilisation and maintenance activities, there is potential for excavation activities to occur to install below ground infrastructure or to create the final design surface level. These excavation activities may expose construction workers to contaminants within the sediment. In addition, the final use of the reclamation area will be port-related industrial. Given the 95% UCL of contaminant concentrations are below HIL (A), the sediment quality of the dredged material is suitable for excavation activities and will not result in any impacts to construction workers.

Sediment runoff from within the WB and WBE reclamation areas will be directed towards a series of stormwater and polishing ponds, which will be monitored regularly to prevent any accumulation of metals/metalloids and other potential contaminants. The stormwater and polishing ponds will be constructed internal to the outer bund wall to allow fine material to settle from the tailwaters. Once settled, water from these ponds will be discharged from the licenced point into Port Curtis. Clean stormwater will be directed away from the ponds and discharged directly into Port Curtis to reduce the quantity of stormwater requiring management. The final pond configuration and design will be undertaken during the detailed design phase of the Project.

The potential impacts from the release of contaminants into the receiving environment are provided in the relevant EIS environmental aspect chapter, including:

- Potential water quality impacts (refer Chapter 8)
- Potential ecological and MNES impacts (refer Chapter 9).

The potential Project sediment quality impact will be managed by implementing mitigation measures (refer Section 6.7).

6.7 Mitigation measures

6.7.1 Bund wall and barge unloading facility construction

The potential creation of a ‘mud wave’ during bund wall construction may resuspend unconsolidated materials within the WBE reclamation area, however geochemical investigation at the WBE reclamation area concluded that the sediments are unlikely to contain contaminants above the NAGD (2009) screening criteria. As such, mitigation measures to manage sediment quality during construction of the bund wall are not considered to be required. Mitigation measures relating to the oxidation of PASS material through the potential creation of a ‘mud wave’ are outlined in topography, geology and soils mitigation measures (refer Chapter 5).

The rock obtained from the Yarwun/Targinnie quarry area for the construction of the bund walls will be screened at the quarry site to remove the fine fraction (< 20mm) to reduce the likelihood of turbid plumes from bund wall construction.

6.7.2 Dredging activities

The geochemical investigation within the areas to be dredged concluded that the sediments are unlikely to contain contaminants above the NAGD (2009) screening criteria and as such, are suitable for placement within the WB and WBE reclamation areas.

However, during dredging activities, appropriate management procedures will be implemented, such as ensuring the barges are not overloaded to avoid dredged material from spilling over the sides of the vessels and the dredgers are maintained in good condition to ensure sediment laden water is not discharged back into marine waters.

Trigger values for toxicants (e.g. metals/metalloids) and turbidity will be applied to assess the ongoing water quality within Port Curtis, as described in Chapter 8 (water quality). Should these trigger values be exceeded, management measures will be implemented, including amending the dredging methodology, such as the dredging location or timing of dredging as related to tides, to allow the water quality to return to the national range and within the EPP (Water) water quality objectives (WQOs).

6.7.3 Placement of dredged material

The geochemical investigation within the areas to be dredged concluded that the dredged material is unlikely to contain contaminants above the NEPM (2013) EILs and HILs, and as such, is suitable for placement within the WB and WBE reclamation areas, and is suitable for any land use.

However, monitoring of decant water for contaminants will occur on an ongoing basis to ensure that licenced discharges into Port Curtis comply with the release limits provided in Table 6.9. Further details on the monitoring of decant water are provided in Chapter 8 (water quality) and Appendix Q3.

Table 6.9 Dredging decant water release limits

Quality characteristics	Release limit maximum	Monitoring frequency
Ammonia (nitrogen) (at a pH of 8)	910 µg/L	Monthly or daily if pH is outside release limits
Cadmium (filtered)	0.7[1] µg/L	Monthly or daily if pH is outside release limits
Chromium (filtered)	4.4[1] µg/L	Monthly or daily if pH is outside release limits
Copper (filtered)	1.3[1] µg/L	Monthly or daily if pH is outside release limits
Lead (filtered)	4.4[1] µg/L	Monthly or daily if pH is outside release limits
Manganese (filtered)	80[1] µg/L	Monthly or daily if pH is outside release limits
Mercury (filtered)	0.1[1] µg/L	Monthly or daily if pH is outside release limits
Nickel (filtered)	7.0[1] µg/L	Monthly or daily if pH is outside release limits
Silver (filtered)	1.4[1] µg/L	Monthly or daily if pH is outside release limits
Zinc (filtered)	15[1] µg/L	Monthly or daily if pH is outside release limits

Table notes:
µg/L = micrograms per litre
1 These maximums are trigger values only, requiring interpretation in respect of historical sediment analysis data when exceeded.

In addition, the inner face of the bund walls will be lined with geotextile material to minimise the migration of dredged material fines into the marine waters of Port Curtis during reclamation and dewatering.

It is considered that any nuisance odour formed during placement of dredged material will be temporary in nature and have no discernible impact on residential properties. Mitigation measures related to odour are provided in the air quality and greenhouse gas assessment (refer Chapter 12).

6.7.4 Installation of navigational aids

Given the removal and installation of navigational aids is temporary in nature and confined to small areas only, the impact on the receiving environment from sediment resuspension is likely to be minimal. As such, mitigation measures related to sediment quality are not required.

6.7.5 Stabilisation and final Project landform

The geochemical investigation determined that the dredged material is suitable for any land uses and as such, there is no risk to human health during stabilisation and maintenance activities.

Stormwater runoff and decant water will be captured and discharged from the licenced point into Port Curtis. Monitoring of this water will be undertaken to ensure compliance with the release limits identified in Table 6.9.

6.8 Risk assessment

6.8.1 Methodology

To assess and appropriately manage the potential sediment quality risks to environmental values as a result of Project activities, a risk assessment process has been implemented (herein referred to as 'risk assessment'). 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 sediment quality impact risks to environmental values/receptors for both the establishment of the reclamation area, dredging activities, installing navigational aids and stabilisation and maintenance activities at the WB and WBE reclamation areas.

The purpose of this risk assessment is to identify potential impacts to environmental values/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 6.7.

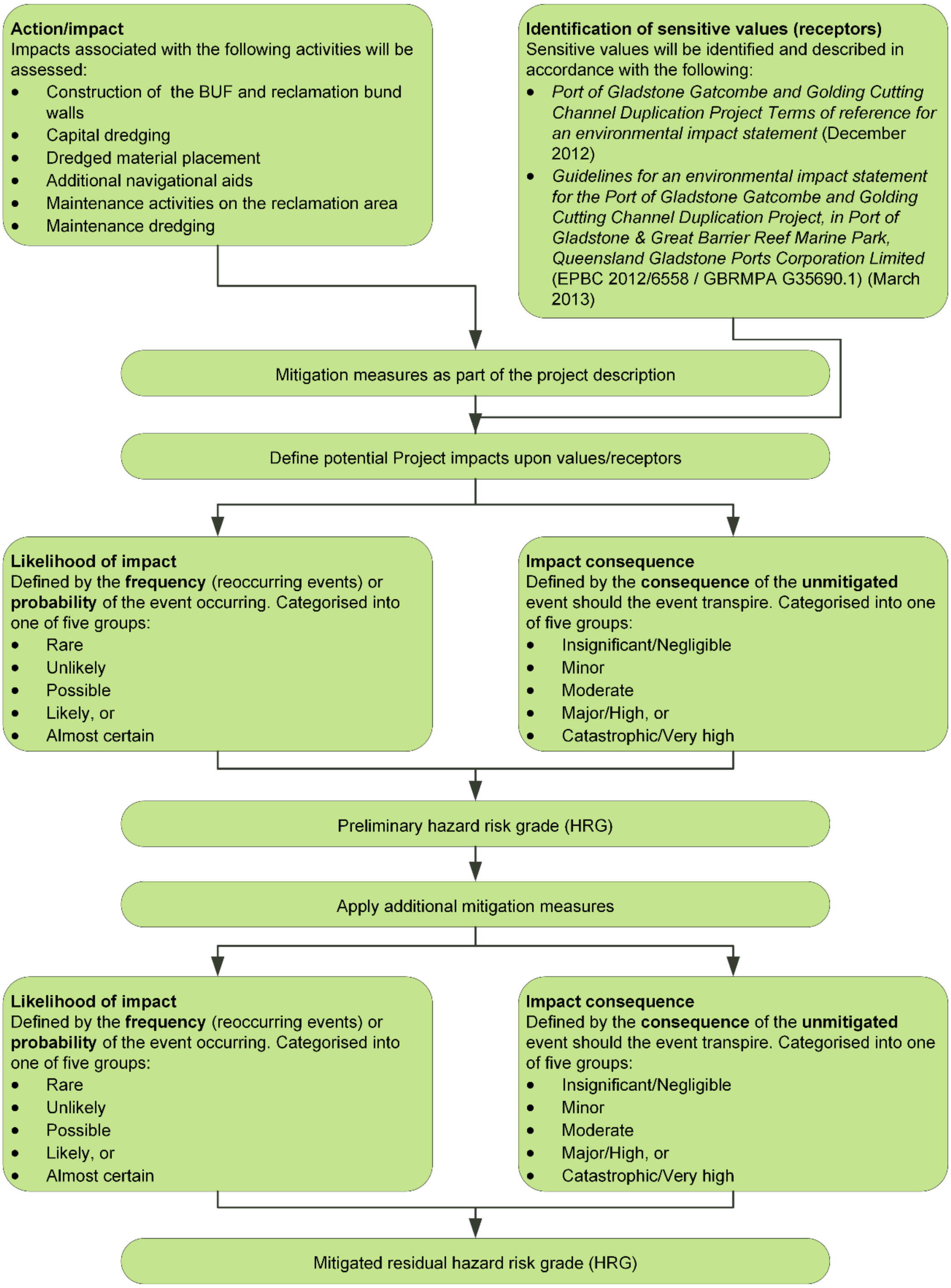

Figure 6.7 **Risk assessment framework**

Criteria used to rank the **likelihood** and **consequence** of potential impacts are provided in Table 6.10 and Table 6.11, respectively.

Table 6.10 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

* For Matters of National Environmental Significance (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 6.11 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 6.12).

Table 6.12 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 6.12 are defined in Table 6.13

Table 6.13 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.

6.8.2 Summary of risk assessment.

The potential sediment quality impacts risk assessment is summarised in Table 6.14.

The implementation of mitigation measures (refer Section 6.7) will result in the potential impacts being generally assessed as a low risk.

Table 6.14 Potential sediment quality impacts and risk assessment ratings

Potential impact	Project phase: Reclamation area and BUF establishment	Dredging	Navigational aids	Demobilisation	Maintenance	Preliminary HRG: Likelihood	Consequence	HRG	Post mitigation HRG: Likelihood	Consequence	HRG
Resuspension of sediment and mobilisation of contaminants during bund wall and BUF construction											
▪ Contamination of marine water ▪ Toxicity to marine and/or intertidal flora and fauna ▪ Public health risks	✓					Unlikely	Low	Low	Unlikely	Low	Low
Resuspension of sediment and mobilisation of contaminants during dredging activities											
▪ Contamination of marine water ▪ Toxicity to marine and/or intertidal flora and fauna ▪ Public health risks		✓	✓			Likely	Low	Medium	Unlikely	Low	Low
Resuspension of sediment and mobilisation of contaminants during unloading and placement of dredged materials											
▪ Contamination of marine water ▪ Toxicity to marine and/or intertidal flora and fauna ▪ Increased algal blooms ▪ Public health risks		✓				Likely	Low	Medium	Unlikely	Low	Low
Dewatering of reclamation area											
▪ Contamination of marine water ▪ Toxicity to marine and/or intertidal flora and fauna ▪ Increased algal blooms ▪ Public health risks		✓			✓	Likely	Low	Medium	Unlikely	Low	Low

Potential impact	Project phase					Preliminary HRG			Post mitigation HRG		
	Reclamation area and BUF establishment	Dredging	Navigational aids	Demobilisation	Maintenance	Likelihood	Consequence	HRG	Likelihood	Consequence	HRG
Exposure during stabilisation and maintenance activities of the reclamation area											
- Health risks to construction workers - Public health risks - Odours					✓	Possible	Negligible	Low	Unlikely	Negligible	Low

6.9 Summary

The geochemical investigations demonstrated that the dredged material within the Gatcombe and Golding Cutting shipping channels, and the barge access channel are clean in accordance with NAGD (2009) and are chemically suitable for placement within a reclamation area. In addition, sediment results from the WBE reclamation area are also considered clean in accordance with NAGD (2009) and is chemically suitable to receive the dredged material.

Sediment results from the dredged material indicate that the material is suitable for a future land use of port-related industrial.

There is potential for minor impacts related to the resuspension of sediment and mobilisation of contaminants during bund wall and BUF construction, dredging activities, unloading and placement of dredged material. A range of mitigation measures are proposed to manage potential impacts from sediment quality and are incorporated into the Project EMP and Dredging EMP. With these measures effectively implemented, the residual sediment quality risks to human health and environmental values from Project activities are assessed as being low.