16. MARINE WATER QUALITY AND SEDIMENT

This chapter describes the characteristics of marine water and sediment in the study area, assesses the potential impacts of the project on these values and describes the measures Arrow Energy will implement through design, construction and operations to manage impacts on marine water and sediment quality.

This chapter is based upon the findings of the marine water quality impact assessment completed by BMT WBM Pty Ltd (Appendix 8, Coastal Processes, Marine Water Quality, Hydrodynamics and Legislation Assessment) and the water and sediment quality baseline study conducted by Central Queensland University (Appendix 12, Marine and Estuarine Ecology Impact Assessment).

The objectives for marine water quality and sediment quality have been developed based on relevant legislative context with the aim of protecting existing values, and are described in Box 16.1.

Box 16.1 Objectives: Marine water quality and sediment

- To avoid and reduce potential adverse effects on marine water and sediment quality resulting from the project during design, construction and operation.
- To achieve project water quality and sediment quality objectives during construction and operations.
- To identify mitigation strategies to reduce any adverse effects on water quality and sediment quality environmental values to an acceptable level.

Impacts on hydrology and surface water quality are described in Chapter 13, Surface Water Hydrology and Water Quality. Impacts on marine and estuarine ecology are addressed in Chapter 19, Marine and Estuarine Ecology.

16.1 Legislative Context and Standards

This section describes relevant Commonwealth and state legislation, policies, plans and guidelines that are designed to protect the environmental values of both the marine and estuarine environment within Port Curtis.

16.1.1 Commonwealth Legislation

The following Commonwealth legislation, guidelines and plans are relevant to managing impacts on marine water quality and sediment through all project phases:

- *Great Barrier Reef Marine Park Act 1975* (Cwlth). The act promotes and enforces the protection and conservation of the environment, biodiversity and heritage values of the Great Barrier Reef region. The project area is not located within the boundaries of the Great Barrier Reef Marine Park (GBRMP), although project-related impacts could potentially extend into the marine park (see Figure 1.1). Subordinate to the act is the Great Barrier Reef Marine Park Zoning Plan 2003 (GBRMPA, 2003). This plan is the primary planning instrument for the conservation and management of the marine park. It takes account of the world heritage values of the marine park and the principles of ecologically sustainable development. This plan works in conjunction with other management instruments to protect and conserve the biodiversity of the Great Barrier Reef ecosystem within a network of protected zones, while providing opportunities for the ecologically sustainable use of (and access to) the Great Barrier Reef region by current and future generations.

- Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ, 2000). The guidelines provide recommended concentration limits and descriptive statements for physical stressors and toxicants in water and sediment to protect associated environmental values.

16.1.2 State Legislation

State legislation, plans, policies and guidelines relevant to the construction and operation phases of the project, in relation to marine water quality and sedimentation include:

- *Environmental Protection Act 1994* (Qld). The act allows for ecologically sustainable development while protecting Queensland's environment. Environmentally relevant activities are regulated under the act, and environmental assessment procedures are outlined. Subordinate to the act are:
  - Environmental Protection (Water) Policy 2009. The principle behind this policy is to identify environmental values and management goals for Queensland waters by specifying water quality guidelines and water quality objectives designed to enhance or protect the environmental values.
  - State Planning Policy 4/10: Healthy Waters 2010. The objective of this policy is to ensure the developments are planned, designed, constructed and operated to manage stormwater and wastewater in ways that help protect environmental values for waterbodies specified in the Environmental Protection (Water) Policy 2009. Meeting these objectives means that corresponding environmental values and uses for waterbodies will be protected.
- *Coastal Protection and Management Act 1995* (Qld). This act provides for the protection, conservation, rehabilitation and management of coastal resources and biological diversity, primarily through coastal management plans. The aim is to achieve ecologically sustainable management through broad coastal management outcomes and principles and policies. Relevant statutory instruments include:
  - State Coastal Management Plan 2001 (DERM, 2002a), which describes the various types of coastal resources and their values, and the pressures placed on these resources. The objective of the plan is to maintain water quality in the coastal zone at a standard that protects and maintains coastal ecosystems and their ability to support human use.
  - Curtis Coast Regional Coastal Management Plan 2003 (EPA, 2003), which outlines how the coastal zone in the Curtis Coast region is to be managed within the policy framework created by the State Coastal Management Plan. The Curtis Coast Regional Coastal Management Plan has the force of law to guide relevant decisions by state and local governments and the Planning and Environment Court, as a statutory instrument under the Coastal Protection and Management Act. The state government must consider the Curtis Coast Regional Coastal Management Plan when making relevant decisions about coastal management in the Curtis Coast region.
- *Fisheries Act 1994* (Qld). This act has been implemented to provide for a balanced approach to the protection, use and management of fish habitats and fisheries resources in ways that are ecologically sustainable, ensuring that there is equal access to the resources by commercial, recreational and Indigenous fishers.
- *Sustainable Planning Act 2009* (Qld). Formerly known as the *Integrated Planning Act 1999*, this act was implemented in December 2009 and is designed to coordinate planning at the local, regional and state levels within Queensland. The act assists in managing the process by

which development takes place while managing the effects of development on the environment. Any dredging activities will require approval under this act and under the Coastal Protection and Management Act.

- Queensland Water Quality Guidelines (DERM, 2009b). The guidelines provide regulatory values tailored to different Queensland regions and water types, and identify a framework and process for developing and applying more locally specific guidelines for waters in Queensland.
- State Planning Policy 2/02: Planning and Managing Development of Acid Sulfate Soils 2002. This policy sets out the state's interests concerning development and works involving potential disturbance of acid sulfate soils in coastal areas.

16.2 Assessment Method

This section describes the marine water and sediment impact assessment study method, which has applied the significance assessment method. The legislation described above has been used to establish marine water and sediment quality criteria for the project. The criteria provide context in the characterisation of existing conditions in the impact assessment study area. The study area is shown in Figure 16.1 and encompasses all marine waters that may be impacted by project activities, including Port Curtis and the mouth of the Calliope River.

While no direct impacts on marine sediment quality are expected, it is nonetheless important to characterise marine sediment that will be disturbed during dredging activities. Plumes of suspended sediments will directly affect marine water quality.

The assessment of impacts has been made within the context of the existing quality of marine water and sediment in Port Curtis. If existing conditions change due to natural or third-party activities, project impacts will be reassessed.

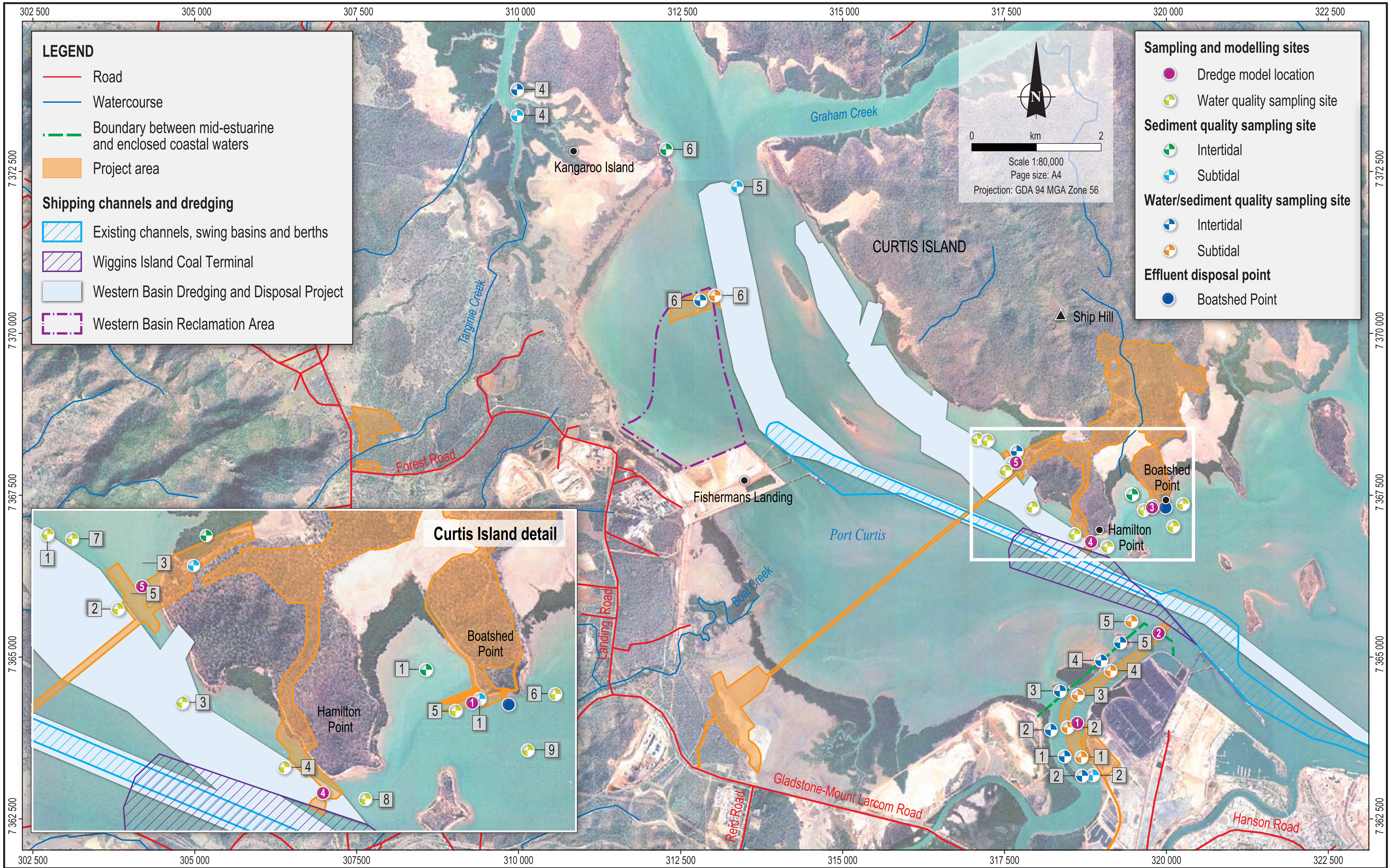
16.2.1 Baseline Method

This section describes the methods used to characterise existing water and sediment quality in the study area.

Water Quality

Existing water quality in the study area was characterised via a desktop review of previous studies in Port Curtis and water sampling events conducted by Central Queensland University in March 2010 and February 2011 as follows:

- Water samples collected on 10 March 2010 coincided with spring tides when water quality is likely to be most affected by water currents, which are strongest during this period. The water sampling campaign collected samples at six locations (water quality sampling sites 1 to 6) in the vicinity of the project marine infrastructure at Curtis Island as shown in Figure 16.1.
- Two water samples (one at the surface and one immediately above the seafloor) were collected at each sampling site during low, mid and high tide, i.e., a total of 36 water samples were collected. Water samples were analysed for nutrient and physicochemical compounds, including filterable reactive phosphorus (i.e., orthophosphate), nitrate and nitrite, total organic carbon as nitrogen and phosphorus species, total nitrogen and total phosphorus.
- In situ measurements of temperature, conductivity (and salinity), turbidity, chlorophyll *a* and dissolved oxygen were made with a water quality probe at each sampling site over the entire water column (i.e., from the surface to the seafloor).



Source:
Place names, roads and watercourses from DME.
Water quality sampling site locations from BMT WBM and GHD. Sediment and water/sediment sampling locations from CQU.
Dredge model locations from BMT WBM. Effluent discharge point from Arrow Energy.
Project area from Coffey Environments.
Western Basin Dredging Master Plan and Disposal Project from Gladstone Ports Corporation. Imagery from SPOT (2004-2007).

coffey environments

Date: 13.12.2011
MXD: 7033CA_07_GIS228_v1_2
File Name: 7033_07_F16.01_GIS_GL

Arrow Energy
Arrow LNG Plant

arrow energy go further

Marine water and sediment quality sampling sites

Figure No: 16.1

- An additional suite of water samples was collected in February 2011 as part of a sediment quality sampling campaign performed by Central Queensland University (see Figure 16.1). Water samples were collected in the Calliope River (water and sediment sampling sites 1 to 5) and offshore mainland launch site 4N (water and sediment sampling site 6). These samples were analysed for physicochemical parameters (i.e., temperature, conductivity, dissolved oxygen, pH and turbidity).

Water sampling and dissolved metals and metalloids analyses performed in 2009 for the Western Basin Dredging and Disposal (WBDD) Project EIS (GHD, 2009b) were used to characterise conditions in the vicinity of the project marine infrastructure on Curtis Island. Water sample sites are shown on Figure 16.1 as water quality sampling sites 7, 8 and 9 and were analysed for mercury, iron, silver, aluminium, arsenic, cadmium, chromium, copper, manganese, nickel, lead, antimony, barium, beryllium, cobalt and vanadium. Four sampling campaigns were undertaken in May, June, July and August 2009 by specialist consultants GHD at each of the three sampling sites.

Sediment Quality

A similar approach was taken for the characterisation of existing sediment quality in the study area, where a desktop review of previous studies was supported by two sediment sampling campaigns by Central Queensland University; the first in May 2010 and the second in February 2011. A van-Veen grab sampler was used to collect sediment samples from the 13 sampling sites (sediment sampling sites 1 to 7 and water and sediment sampling sites 1 to 6) shown in Figure 16.1.

Five replicate intertidal and subtidal sediment samples were collected at each site and analysed for particle size distribution and carbon content. Sediment samples collected during the February 2011 campaign at water/sediment sampling sites 1 to 6 were also analysed for the following parameters:

- Organochloride (OC) and organophosphate (OP) pesticides.
- Polynuclear aromatic hydrocarbon (PAH).
- Metals: aluminium, arsenic, chromium, cadmium, cobalt, copper, iron, manganese, nickel, lead, selenium and zinc.

16.2.2 Impact Assessment

The major impacts on water quality and sediment during construction will be due to the formation of suspended sediment during dredging. It is anticipated that dredged material will be placed in the Western Basin Reclamation Area. During the early stages of reclamation activities, decant water will be formed when dredged material (consisting of solids and seawater) placed in the Western Basin Reclamation Area settles and separates into solid material (to form the reclamation area) and decant water which must be disposed of. The decant water will be discharged to Port Curtis. It will contain some suspended sediments that did not settle out and will instead form plumes in Port Curtis. The decant water may also contain contaminants released to the water from dredged sediments. As reclamation activities progress, and the Western Basin Reclamation Area is filled, dredged material will be placed above ground level and water will drain through placed material prior to being discharged to Port Curtis. This process will likely capture much of the suspended sediment that would have discharged to Port Curtis during the early phases of reclamation. It is during the latter stages of reclamation that material dredged for the Arrow LNG Plant will be placed in the Western Basin Reclamation Area. Impacts associated with discharge of decant water have been addressed in the WBDD Project EIS (GHD, 2009b), and are therefore not discussed in this EIS.

During construction of the feed gas pipeline Port Curtis tunnel crossing, it may be necessary to dewater some of the spoil material placed in the mainland tunnel spoil disposal area, specifically the top 2 m of sediments excavated at the site (see Figure 7.4). Spoil may contain acid sulfate soils. Any excess water will be discharged to Port Curtis and may include sediments containing contaminants, which will form plumes in the water column and affect water quality and sediment. Impacts on marine water quality may also arise from the release of acid sulfate soils from the mainland tunnel spoil disposal site into marine water if these soils are not managed correctly. Management of acid sulfate soils is addressed in Chapter 12, Land Contamination and Acid Sulfate Soils.

During phase 1 construction of the LNG plant, it will be necessary to discharge treated sewage generated at the construction camp to Port Curtis via an outfall at Boatshed Point.

Other minor impacts on water quality and sediment that may occur during construction include the formation of suspended sediment plumes during piling activities at marine infrastructure, suspension of sediment by propeller wash as vessels navigate shallow water and discharge to Port Curtis of water used during hydrostatic testing of the integrity of the feed gas pipeline and LNG storage tanks. These impacts are expected to be relatively minor compared to impacts that will occur during dredging and therefore have not been assessed.

During operations, impacts on water quality and sediment will occur from the discharge of waste streams from the LNG plant site into Port Curtis. These waste streams include brine from the reverse osmosis plant, demineralisation plant effluent, clean stormwater runoff and, during exceptional conditions such as major rainfall events, treated effluent.

The impacts on marine water and sediment from abstracting water from Port Curtis are negligible. The volume of water abstracted is insignificant when compared to the total volume moving past the pipe inlet over a tidal cycle, and these impacts are not discussed further. This includes abstraction of seawater to supply to the reverse osmosis plant, for hydrostatic testing and construction camp effluent treatment.

At the time of preparation of this EIS, the Gladstone Area Water Board was investigating the feasibility of constructing a water supply pipeline and sewerage main to Curtis Island. If this infrastructure is built, Arrow Energy may source all freshwater and dispose of all waste streams via these services. Impacts described in this chapter associated with providing potable water and sewage treatment at the LNG plant site would therefore not occur.

In addition to these impacts, accidental discharge of small volumes of hazardous substances (e.g., diesel fuel, oils, solvents, paints and hydraulic fluids) from vessels may occur during construction and operation, and cause local contamination in the receiving waters.

Computer modelling used to assess impacts from dredging activities during construction and effluent discharge during operations is described below. Impacts from large-scale accidental spills are discussed in Chapter 29, Hazard and Risk.

Dredging during Construction

Advection-dispersion modelling was used to predict impacts during dredging at four of the five potential dredge sites (described in Table 16.1 and shown in Figure 16.1). Modelling was not performed at launch site 4N due to the very small volume of dredge material relative to the other dredge sites.

Table 16.1 Dredge model sites

Dredge Model Site	Dredge Location	Maximum Dredge Volume (m^3)
1	Launch site 1	900,000
2		
3	Boatshed Point MOF and personnel jetty[*]	50,000
4	Hamilton Point South MOF and personnel jetty[*]	50,000
5	LNG jetty	120,000
		Total dredge model volume: 1,120,000[a]

[*]Dredging will occur at the Boatshed Point MOF and the personnel jetty, or at the Hamilton Point South MOF and personnel jetty, but not at both sites. The total maximum volume of material dredged is therefore estimated to be 1,070,000 m^3.

The following assumptions were made in the model:

- Dredging will occur 24 hours per day for a two-month period.
- Worst-case dredge volumes were used and are outlined in Table 16.1. At launch site 1, two dredge model locations were modelled – one immediately offshore launch site 1 and one at the northern extent of the dredge site – to simulate conditions at the northern and southern extents of the dredge site.
- Dredging will occur using a cutter suction dredger with the same configuration as in the WBDD Project EIS (GHD, 2009b), i.e., the dredger will excavate 500 m^3/hour of material from the seafloor and is assumed to lose 4 kg/s of dredged material to the surrounding seawater. Resulting plumes of suspended sediment will have a concentration of 96 kg/m^3 at the dredger cutter head.
- Immediately after plume formation at the cutter head, 100% of suspended material smaller than 159 µm in diameter (i.e., fine sand and silt) will remain in the water column and slowly settle to the seafloor as it is transported away by water currents. All of the coarser material (gravels and coarse sand) will immediately fall to the seafloor at the dredger cutter head.

Effluent Discharge during Operations

Hydrodynamic modelling was conducted to estimate the dispersion of effluent from the proposed outfall located approximately 50 m offshore from the eastern tip of Boatshed Point at a depth of approximately 12 m (see Figure 16.1). The effluent will consist of a brine solution produced in the reverse osmosis plant, demineralisation plant effluent, clean stormwater runoff and, during exceptional conditions such as excessive wet weather, treated wastewater from the effluent treatment plant (beyond design capacity). Three discharge scenarios were modelled to estimate impacts from differing combinations of effluent discharge. Modelling scenarios and effluent characteristics are shown in Table 16.2 and are based on the LNG plant configuration producing the greatest volume of discharge, i.e., when the LNG plant will be operating all four LNG trains.

Modelling scenarios 2 and 3 include cooling tower blowdown waste streams (which, although required at the time of modelling, are no longer included in the design). Additionally, ongoing plant design means the project water balance has changed and is now lower than when modelling occurred. Cooling tower blowdown waste streams and the original higher water balance have been retained in the assessment to provide a conservative estimate of impacts.

Table 16.2 Port Curtis effluent discharge: model scenarios and assumptions

Parameter	Discharge Model Scenario		
	Scenario 1	Scenario 2	Scenario 3
Effluent source			
Reverse osmosis plant brine	✓	✓	✓
Cooling tower blowdown		✓	✓
Demineralisation plant effluent		✓	✓
Clean stormwater runoff		✓	✓
Effluent treatment plant wastewater			✓
Effluent characteristics			
Salinity (parts per thousand (ppt))	56.70	50.94	44.42
Temperature (°C)	30	30	30
Density (kg/m^3)	1,038.1	1,033.8	1,028.8
Discharge rate (m^3/d)	3,816	4,248	4,871
pH[a]	n/a	n/a	6.5 to 8.5
Turbidity (NTU)*	n/a	n/a	<2
Thermo-tolerant coliform (coliform forming units per 100 mL)*	n/a	n/a	<10
Chlorine after 30 minutes (mg/L)[a]	n/a	n/a	1

n/a – Not applicable.
* Values are sourced from ARMCANZ/ANZECC/NHMRC (2000) and apply to the effluent treatment plant waste stream only.

All modelling scenarios assumed that the discharge pipeline will be fitted with a three-port diffuser at the outfall location, resulting in a discharge velocity of between 2 and 3 m/s. Water velocities at the point of discharge for slack water, tenth, fiftieth and ninetieth percentile velocities for both ebb and flood tidal conditions were used to model the behaviour and fate of effluent dispersion.

Characteristics of the receiving water used in the model were based on data collected during the water sampling event on 10 March 2010 and were:

- Temperature: 25.90°C.
- Salinity: 32.20 ppt.
- Density: 1,021.0 kg/m^3.

Environmental Values

The Queensland Environmental Protection (Water) Policy 2009 (EPP (Water)) defines marine water environmental values to be enhanced or protected. The qualities of the marine environment relevant to the project are those that are conducive to:

- Protecting the biological integrity of aquatic ecosystems.
- The suitability of the water for:
  - Producing foods for human consumption.
  - Primary recreational use (e.g., diving, swimming, surfing etc.).
  - Secondary recreational use (e.g., boating and fishing).
  - Visual recreational use (i.e., viewing but not contacting the water).
- Cultural and spiritual values of the water (i.e., aesthetic, historical, scientific, social or other significance to current and future generations).

The environmental values described above are consistent with those set out in the State Coastal Management Plan (DERM, 2002a) and the Curtis Coast Regional Coastal Management Plan 2003 (EPA, 2003) and fulfil the intent of the Great Barrier Reef Marine Park Act (i.e., the management and protection of the natural and cultural heritage values of the marine park).

Marine Water and Sediment Quality Criteria

Marine water quality criteria used in the assessment aim to protect the environmental values described above i.e., environmental values are protected if measures for all water quality criteria are not exceeded. The criteria are derived from those set out in the Queensland Water Quality Guidelines (DERM, 2009b) and the ANZECC/ARMCANZ (2000) guidelines.

Under the Queensland water quality guidelines, waters within Port Curtis are classified as 'Enclosed Coastal Waters' and the Calliope River is defined as 'Mid-Estuarine' for the majority of its tidal section (see Figure 16.1). Water quality criteria are provided in Table 16.3 and vary depending on the water body type. Where the Queensland water quality guidelines do not provide guidance values, the ANZECC/ARMCANZ (2000) guidelines were used.

From a regulatory standpoint (ANZECC/ARMCANZ, 2000; EPP(Water)), the establishment of a mixing zone is allowed where water quality criteria can be exceeded within this mixing zone, provided compliance with water quality criteria is achieved beyond this zone.

The Queensland (DERM, 2002a) and the ANZECC/ARMCANZ (2000) guidelines were developed specifically for protecting the biological integrity of aquatic ecosystems. Protection of this environmental value requires application of the most stringent water quality criteria and, if these criteria are met, all other environmental values will also be protected.

In some instances, no guidelines are specified for a contaminant of interest (i.e., iron, aluminium, arsenic and manganese). This generally reflects an absence of adequate scientific data and information for that contaminant such that the Queensland (DERM, 2002a) and ANZECC/ARMCANZ (2000) guidelines are unable to provide a guidance value.

The environmental values described for marine water quality have been adopted for marine sediment quality, as the quality of sediment can directly affect water quality. Therefore, the values placed on marine waters serve the same purpose as those that apply to marine sediments.

Table 16.3 Marine water quality criteria

Parameter	Target			Source
	Unit	Port Curtis (Enclosed Coastal Waters	Calliope River (Mid-estuarine Waters)	
Physicochemical and Nutrients				
Ammonia nitrogen	µg/L	8	10	Queensland Water Quality Guidelines
Oxidised nitrogen	µg/L	3	10	
Organic nitrogen	µg/L	180	260	
Total nitrogen	µg/L	200	300	
Filterable reactive phosphorous	µg/L	6	8	
Total phosphorous	µg/L	20	25	
Chlorophyll *a*	µg/L	2	4	

Table 16.3 Marine water quality criteria (cont'd)

Parameter	Target			Source
	Unit	Port Curtis (Enclosed Coastal Waters	Calliope River (Mid-estuarine Waters)	
Physicochemical and Nutrients (cont'd)				
Dissolved oxygen	% saturation - lower limit	90	85	Queensland Water Quality Guidelines
	% saturation - upper limit	100	100	
Turbidity	NTU	6	8	
Light penetration	Secchi depth in metres	1.5	1	
Suspended solids	mg/L	15	20	
pH	Lower limit	8	7	
	Upper limit	8.4	8.4	
Metals				
Mercury	µg/L	0.1	0.1	ANZECC/ARMCANZ (2000) guidelines[a]*
Silver	µg/L	1.4	1.4	
Cadmium	µg/L	0.7	0.7	
Chromium	µg/L	4.4	4.4	
Copper	µg/L	1.3	1.3	
Nickel	µg/L	7.0	7.0	
Lead	µg/L	4.4	4.4	
Zinc	µg/L	15	15	
Cobalt	µg/L	1	1	
Vanadium	µg/L	100	100	

[*] Slightly to moderately disturbed marine waters.

The National Assessment Guidelines for Dredging (DEWHA, 2009a) set out the regulatory framework for assessing impacts from dredging and offshore disposal. Given that all dredged material will be placed in the Western Basin Reclamation Area (see Figure 16.1), these guidelines are not relevant to this assessment. Instead, the Queensland water quality guidelines have been referred to in determining appropriate project sediment quality assessment criteria. They, in turn, refer to the ANZECC/ARMCANZ (2000) guidelines, which set out interim sediment quality guidelines. These guidelines have been adopted for this assessment and are provided in Table 16.4.

Table 16.4 Sediment quality criteria

Parameter	Target[*]	
	Unit	Value
Metals and Metalloids		
Arsenic	mg/kg dry weight	20
Cadmium	mg/kg dry weight	1.5
Chromium	mg/kg dry weight	80
Copper	mg/kg dry weight	65
Nickel	mg/kg dry weight	21

Table 16.4 Sediment quality criteria (cont'd)

Parameter	Target*	
	Unit	Value
Metals and Metalloids (cont'd)		
Lead	mg/kg dry weight	50
Zinc	mg/kg dry weight	200
Organometallics		
Tributyltin (TBT)	µg Sn/kg dry weight	5
Organics		
Napthalene		
Total polycyclic aromatic hydrocarbon (PAH)	µg/kg dry weight	4,000
Total polychlorinated biphenyl (PCB)	µg/kg dry weight	23
Herbicides and Organochloride (OC) and Organophosphate (OP) Pesticides		
Total dichlorodiphenyltrichloroethane (DDT)	µg/kg dry weight	1.6
Chlordane	µg/kg dry weight	0.5
Dieldrin	µg/kg dry weight	0.02
Endrin	µg/kg dry weight	0.02
Lindane	µg/kg dry weight	0.32

* Targets are for interim sediment quality guideline low trigger values (ANZECC/ARMCANZ, 2000).

16.2.3 Significance Assessment Method

This section describes the approach used to assess impacts on environmental values as they relate to the marine water quality and sediment quality criteria. The significance approach has been adopted as set out in Chapter 9, Impact Assessment Method.

The sensitivity of environmental values has been defined through five key elements as follows:

- Conservation status.
- Intactness.
- Uniqueness or rarity.
- Resilience to change.
- Replacement potential.

The criteria for determining the sensitivity of an environmental value are defined in Table 16.5.

The criteria used for assessing the magnitude of an impact are geographical extent, duration and severity of each impact. The criteria for determining the magnitudes of an impact are provided in Table 16.6.

Table 16.5 Sensitivity of water quality and sediment quality environmental values

Sensitivity	Description
Very high	An environmental value in a site or area that has international environmental significance (e.g., World Heritage listing). An environmental value that is entirely undisturbed by existing developments (i.e., intact). An environmental value that is unique or rare. An environmental value that is very sensitive to change (i.e., very easily disturbed or interrupted). An environmental value that serves a function that cannot be replaced or substituted.
High	An environmental value in a site or area that has national environmental significance (e.g., national wetland of significance, core habitat for nationally listed species, area supports greater than 1% of a national population of a species, the Great Barrier Reef Marine Park). An environmental value that is mostly undisturbed by existing developments (i.e., mostly intact). An environmental value that is rare. An environmental value that is sensitive to change (i.e., easily disturbed or interrupted). An environmental value that serves a function that is difficult to replace or find elsewhere.
Medium	An environmental value in a site or area that has state environmental significance (e.g., national park, high ecological value waters, state marine park conservation zone). An environmental value that is somewhat undisturbed by existing developments (i.e., partly intact). An environmental value that is somewhat rare. An environmental value that is somewhat sensitive to change, (i.e., can be disturbed or interrupted). An environmental value that serves a function that is not easily replaced or found elsewhere.
Low	An environmental value in a site or area with regional or local significance. An environmental value that is somewhat disturbed by existing developments (i.e., not intact). An environmental value that is not very rare. An environmental value that is not sensitive to change (i.e., is not easily disturbed or interrupted). An environmental value that serves a function that can be replaced or found elsewhere.
Negligible	An environmental value in a site or area with limited or no significance (e.g., already degraded). An environmental value that has been totally disturbed by existing developments (i.e., not intact at all). An environmental value that is not rare at all. An environmental value that is totally insensitive to change, (i.e., cannot be disturbed or interrupted). An environmental value that serves a function that is easily replaced or found elsewhere.

Table 16.6 Magnitude of water quality and sediment quality impacts

Magnitude of Impact	Description
Very high	A long-term (greater than 12 months) or irreversible change in water quality and/or sediment quality greater than 70% of existing conditions over an area spanning more than 10 km.
High	A long-term (greater than 12 months) change in water quality and/or sediment quality greater than 50% of existing conditions over an area spanning more than 1 km.
Medium	A medium-term (between 6 and 12 months) change in water quality and/or sediment quality greater than 30% of existing conditions over an area spanning more than 100 m.
Low	A short-term (less than 6 months) change in water quality and/or sediment quality less than 10% of existing conditions over an area spanning less than 100 m.
Negligible	Undetectable or insignificant changes to water quality and/or sediment quality.

The significance of an impact on an environmental value is determined by the sensitivity of the value itself and the magnitude of the change it experiences, as displayed in Table 16.7.

Table 16.7 Significance of water quality and sediment quality impacts

	Sensitivity of Environmental Value				
Magnitude of impact	**Very High**	**High**	**Medium**	**Low**	**Negligible**
Very High	Major	Major	High	Moderate	Minor
High	Major	High	Moderate	Moderate	Minor
Medium	High	Moderate	Moderate	Minor	Negligible
Low	Moderate	Moderate	Minor	Minor	Negligible
Negligible	Minor	Minor	Negligible	Negligible	Negligible

16.3 Existing Environment and Environmental Values

The section describes existing marine water and sediment quality in the study area in the context of relevant guidelines.

16.3.1 Setting

Port Curtis is located directly offshore the city of Gladstone within the greater Port of Gladstone (see Figure 1.2). The region includes areas of high conservation values: Curtis Island and the majority of Port Curtis are within the Great Barrier Reef World Heritage Area, and adjacent to the Great Barrier Reef Marine Park (see Figure 16.1). Port Curtis is also listed as a nationally important wetland in Queensland (DSEWPC, 2011b).

Port Curtis is connected to the Coral Sea via South Channel to the south of Facing Island, North Channel between Facing and Curtis islands. The Narrows, which extend some 40 km to the northwest, separate Curtis Island from the mainland.

The Calliope River drains into Port Curtis, as do the Boyne River, Boat Creek and Auckland and South Trees inlets. To the south are the connected waterways of Colosseum Inlet, Seven Mile Creek and Rodds Bay. Northwards, Grahams Creek and a number of smaller tributaries discharge to The Narrows (Water Resource (Calliope River Basin) Plan 2006) (see Figure 1.1).

The Gladstone region is subject to periodic flooding (also see Chapter 13, Surface Water Hydrology and Water Quality). The last major flood occurred over the period December 2011 to January 2011, when large volumes of fresh water and sediment (and potentially contaminants) were transported into Port Curtis via the river systems.

The marine and estuarine environments of Port Curtis are characterised by extensive intertidal areas, a tidal range of greater than 4 m and substantial tidal currents. Freshwater inflow from the many rivers and creeks that discharge to Port Curtis also influence the marine environment. High natural levels of turbidity and suspended sediments in Port Curtis are maintained by strong tidal currents that flush the numerous tributary creeks and rivers that discharge to the port and resuspend seafloor sediments.

16.3.2 Water Quality

A large amount of baseline marine water quality data has been collected in Port Curtis for other studies and projects in the study area, including EISs for other LNG projects and the WBDD Project. This data, along with data collected specifically for this project, is described here.

Desktop Study

The characteristics of the estuarine waters (the transitional zone between freshwater river environments and marine waters) within Port Curtis are generally closer to seawater than to freshwater riverine conditions. Salinity is often only slightly below that of oceanic seawater (35.5 ppt) and can sometimes be higher. In the northern parts of Port Curtis, salinities are higher than the surrounding coastal waters; this is likely due to the effects of evaporation and restricted water circulation in these more sheltered areas.

Salinity, temperature and pH do not vary greatly with depth in the open parts of Port Curtis, due largely to the mixing effects of water currents over the entire water column. In the shallow mangrove-lined upper estuaries, lower pH and higher turbidity occur due to higher nutrient loads and more sheltered conditions at these locations.

Water clarity is generally poor with visibility less than 2 m. Turbidity generally increases with depth and tidal velocity, most likely due to resuspension of seafloor sediment.

Sewage outfalls along with nitrogen discharges from industrial point sources and natural diffuse nitrogen sources affect water quality in Port Curtis. Nonetheless, nutrient and total organic carbon concentrations, and biochemical oxygen demand, are generally low and indicative of high quality estuarine water. Chlorophyll *a* concentrations, an indicator of phytoplankton growth and hence primary productivity, are low.

Port Curtis exhibits some evidence of elevated metals concentrations. The Narrows region contains the highest concentrations of dissolved copper and nickel. The Fitzroy River is a known source of dissolved metals, in particular elevated nickel concentrations, which are discharged from the river to the coastal region. These metals inputs, along with industrial and other anthropogenic discharges from unidentified sources in The Narrows, contribute to the trace metal distributions within The Narrows and Port Curtis.

Although there are no established ANZECC/ARMCANZ (2000) guidelines for aluminium and iron, concentrations of these metals in Port Curtis can be significantly higher than those for oceanic seawater. Concentrations of other major elements (e.g., manganese, fluoride, boron) in Port Curtis appear to be consistent with concentrations present in oceanic seawater. Inner Port Curtis sites have higher copper concentrations than oceanic reference sites. Concentrations of other metals do not appear to be elevated above typical seawater concentrations or ANZECC/ARMCANZ (2000) guidelines.

Water Sampling Campaigns

This section summarises the results from the water quality sampling event carried out on 10 March 2010 by Central Queensland University (see Appendix 12) for sampling sites 1 to 6in the vicinity of project infrastructure on Curtis Island. . The results of this sampling are summarised in Tables 16.8 and Table 16.9. These results are representative of conditions on the day during which sampling occurred, and should be interpreted as such.

Table 16.8 Marine water quality sampling sites 1 to 6: physicochemical parameters – March 2010 sampling

Parameter	Number of Samples	Minimum	Maximum	Mean	Water Quality Criteria	Number of Exceedences
Temperature (^{o}C)	36	25.7	26.2	25.9	n/a	n/a
Conductivity (mS/cm)	36	47.2	50.5	48.9	n/a	n/a
Salinity (ppt)	36	30.6	33.1	31.9	n/a	n/a
pH	36	8.0	8.2	8.1	8 to 8.4	0
Turbidity (NTU)	36	12.4	150.2	57.4	6	18
Chlorophyll *a* (ug/L)	36	2.0	6.9	3.9	2	17
Dissolved oxygen (%)*	36	87.9	97.3	93.6	90-100	4
Dissolved oxygen (mg/L)	36	6.0	6.6	6.4	n/a	n/a

n/a – Not applicable or no guideline applied.

* Dissolved oxygen guidelines are set for percent of saturated value due to temperature-dependence of dissolved oxygen in the water column.

Table 16.9 Marine water quality sampling sites 1 to 6: nutrients – March 2010 sampling

Parameter	Number of Samples	Units	Minimum	Maximum	Mean	Water Quality Criteria	Number of Exceedences
Top of Water Column							
Ammonia nitrogen	36	µg/L as N	6.0	11.0	8.2	8	7
Filterable reactive phosphorus	36	µg/L as P	2.0	12.0	3.5	6	0
Oxidised nitrogen	36	µg/L as N	13.0	25.0	17.4	3[a]	18
Total organic carbon[b]	36	µg/L as C	2,500.0	9,100.0	4,405.6	n/a	n/a
Total nitrogen	36	µg/L as N	220.0	770.0	436.7	200	18
Total phosphorus	36	µg/L as P	33.0	140.0	75.0	20	18
Bottom of Water Column							
Ammonia nitrogen	36	µg/L as N	5.0	12.0	7.9	8	14
Filterable reactive phosphorus	36	µg/L as P	2.0	4.0	2.8	6	0
Oxidised nitrogen	36	µg/L as N	13.0	19.0	15.7	3[a]	18
Total organic carbon[b]	36	µg/L as C	2,400.0	3,400.0	2,966.7	n/a	n/a
Total nitrogen	36	µg/L as N	220.0	450.0	301.7	200	18
Total phosphorus	36	µg/L as P	17.0	85.0	37.7	20	16

[a] Combined value for NO_2 and NO_3.

[b] As nitrogenous and phosphoric organic carbonaceous species.

n/a = No objective.

The results of metals and metalloid analysis in water quality sampling undertaken for the WBDD Project EIS (GHD, 2009a) are summarised in Table 16.10.

Table 16.10 Marine water quality sampling sites 7 to 9: metals and metalloids

Parameter (µg/L)	Number of Samples	Minimum	Maximum	Mean	Water Quality Criteria	Number of Exceedences
Mercury	12	0.05	0.05	0.05	0.1	0
Iron	12	2.50	6.00	2.82	n/a	0
Silver	12	0.05	0.10	0.05	1.4	0
Aluminium	12	5.00	140.00	17.73	n/a	0
Arsenic	12	0.60	1.90	1.17	n/a	0
Cadmium	12	0.10	1.70	0.25	0.7	1
Chromium	12	0.25	0.25	0.25	4.4	0
Copper	12	0.50	1.00	0.55	1.3	0
Manganese	12	0.25	3.00	1.18	n/a	0
Nickel	12	0.25	0.90	0.38	7.0	0
Lead	12	0.10	0.10	0.10	4.4	0
Antimony	12	0.25	0.25	0.25	n/a	0
Barium	12	6.00	10.00	7.64	n/a	0
Beryllium	12	0.05	0.05	0.05	n/a	0
Cobalt	12	0.10	0.10	0.10	1	0
Vanadium	12	0.60	2.90	1.39	100	0

Results below detection limit were assumed to be half of the detection limit for statistical analysis purposes.
n/a = No objective.

Key findings for existing water quality in the vicinity of the project sites, based on the project-specific sampling carried out by Central Queensland University and other studies (including for the WBDD EIS) are as follows:

- Turbidity tends to increase with depth and is highest during low tides at all locations apart from sampling site 6, where turbidity is highest at mid tide. The water quality criteria for turbidity was exceeded by at least a factor of two at all sampling sites.
- Nutrient concentrations tend to behave similarly to turbidity, and increase as tides decrease.
- Temperature, pH and salinity are relatively uniform across the entire water column and do not change as tidal conditions change. This is indicative of a well-mixed, high-energy environment.
- Dissolved oxygen was generally within the water quality criteria guideline range of 90 to 100%; however, during low tide, dissolved oxygen concentrations fell slightly below this range at sampling sites 1, 2, 3 and 4.
- Concentrations of oxidised nitrogen throughout the water column are at least four times higher than water quality criteria.
- Total phosphorus exceeds water quality criteria at all locations at the water surface and at most locations at the seafloor, apart from sampling sites 2 and 4 during high tide. Filterable reactive phosphorus results did not exceed water quality criteria at any sampling sites.
- Chlorophyll *a*, a measure of phytoplankton population density, exceeds water quality criteria at all sampling sites with the exception of sampling site 5 at high tide.

- Total nitrogen exceeds water quality criteria at all sampling sites, and ammonia nitrogen exceeds water quality criteria at a number of sampling sites, most likely due to anthropogenic inputs (e.g., sewage outfalls).
- Filtered metals concentrations (see Table 16.10) were often below detection limits but, when present, they were at concentrations lower than the water quality criteria.

When compared to the greater Port Curtis area, water quality in the vicinity of the Curtis Island project infrastructure is generally good, although turbidity is naturally elevated due to sediment resuspension by tidal currents. The area is indicative of a high energy environment, with hydrodynamics dominated by strong tidal currents, resulting in a well mixed water column.

There is some evidence of elevated metal concentrations in Port Curtis, but not immediately offshore of Curtis Island project infrastructure. Measured nutrient values during the 2010 sampling event were higher than typical measurements in Port Curtis, but it is not possible to define the reasons for this.

Results for analyses performed on water samples collected in the Calliope River (water/sediment sampling sites 1 to 5) and offshore mainland launch site 4N (water/sediment sampling site 6) are summarised in Table 16.11 and show that:

- Water quality criteria for dissolved oxygen and pH are not exceeded in the Calliope River but are exceeded at water/sediment sampling site 6.
- Turbidity at all sites does not comply with the water quality criteria and is at least three times higher than the water quality criteria.

Table 16.11 Marine water quality (water and sediment sampling sites 1 to 6): physicochemical parameters – February 2011 sampling

Parameter	Calliope River						Port Curtis	
	Water/Sediment Sampling Site					Water Quality Criteria	Water/Sediment Sampling Site	Water Quality Criteria
	1	2	3	4	5		6	
Temperature (°C)	29.0	29.1	29.1	29.0	29.0	n/a	28.7	n/a
Conductivity (mS/cm)	34.0	34.1	34.2	34.4	34.6	n/a	32.6	n/a
Dissolved oxygen (%)	88.0	87.2	87.2	87.7	87.8	85 to 100	***87.7***	90 to 100
pH	7.7	7.7	7.7	7.8	7.8	7 to 8.4	***7.6***	8 to 8.4
Turbidity (NTU)	***34.5***	***35.9***	***36.1***	***31.6***	***39.5***	8	***32.2***	6

n/a – Not applicable or no guideline applied.

Bold, italicised values indicate exceedences of water quality criteria, or in the case of pH and dissolved oxygen, values outside the guideline ranges.

16.3.3 Sediment Quality

This section describes existing sediment quality in the project area and is based on results of a desktop study and two sampling events – the first in May 2010 and the second in February 2011.

Desktop Study

Various studies of sediment quality have been undertaken in Port Curtis to gain an understanding of different contaminants (including metals, pesticides and polyaromatic hydrocarbons (PAHs)) that may be present.

The Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management has conducted research into contaminants in sediment and contaminant pathways in Port Curtis (Apte et al., 2005). The centre performed an initial screening level risk assessment study in 2005 and concluded that the contaminants of concern in Port Curtis sediments were arsenic, tributyltin (TBT) and naphthalene. Further studies undertaken by the centre indicate that the sources of arsenic and napthalene are most likely natural. The centre predicted that concentrations of TBT in Port Curtis sediments will most likely reduce over time as a result of the ban in the use of this anti-fouling agent.

Apte et al. (2005) found that chromium and nickel concentrations in Port Curtis were comparable to control site (i.e., sites not affected by anthropomorphic activities) concentrations, which is an indication of naturally elevated levels of these particular metals in Port Curtis.

Sediment sampling was performed adjacent to the Fishermans Landing wharves and along Targinie Channel (between Fishermans Landing and Hamilton Point) for the Fishermans Landing Northern Expansion Project EIS (GHD, 2009c). Samples were analysed for a range of contaminants (metals, PAHs, TBT, PCBs, pesticides and organic carbon). Results show that the concentrations of metals, PCBs, PAHs, pesticides and TBT were below the ANZECC/ARMCANZ (2000) guidelines (i.e., the project sediment quality criteria) trigger values, although arsenic exceeded the guidelines on two occasions.

An extensive sediment sampling program was carried out for the WBDD Project EIS (GHD, 2009a). Sampling focused on areas to be dredged as part of this project. Results of this sampling are summarised below:

- Low concentrations of anthropogenic contaminants and naturally occurring compounds were found in a few samples.
- A number of samples showed that arsenic, cadmium and copper levels exceeded the sediment quality guidelines in areas to be dredged during the WBDD Project.
- Benzene, toluene, ethylbenzene, and xylenes (BTEX), total petroleum hydrocarbons and individual PAH concentrations were below the sediment quality guidelines, as were concentrations of PCBs and PAHs.
- Concentrations of herbicides, OC and OP pesticides in all samples were below laboratory detection limits.
- Oxidised nitrogen was not present in over half the samples.

No apparent trend was found in the location or depth of the occurrence of metals in sediments. The WBDD Project EIS (GHD, 2009a) concluded that this indicates the presence of metals may be naturally occurring, i.e., metals were found to occur at depths that have not been influenced by anthropogenic activities.

Sediment Sampling Campaign

Two sediment sampling campaigns were conducted by Queensland Central University in Port Curtis and the Calliope River. The first sampling campaign in May 2010 collected sediment samples from seven sites in the study area (sediment sampling sites 1 to 7). The February 2011 campaign collected an additional six samples (water and sediment sampling sites 1 to 6) (see Figure 16.1). Results are as follows:

- PAH, OC and OP pesticides in all samples were below laboratory detection limits.
- Organic carbon content was generally below 2% at sediment sample sites 1 to 7, but were higher at water/sediment sampling sites 1 to 5 along the Calliope River and water/sediment sampling site 6 at mainland launch site 4N, where organic carbon content reached 11%.
- Intertidal sediments at sediment sampling sites 1 to 5 were generally composed of 60 to 90% silts and mud and 20 to 40% sands and gravels. The distribution of sediment sizes was the same for the subtidal sediments at sediment sampling sites 1 to 3, but sediment sampling sites 4 and 5 in the mouth of the Calliope River were composed of up to 80% sands and gravels.
- Intertidal sites along the Calliope River were composed of 30 to 60% silts and muds, and subtidal sites were almost entirely composed of sand and coarser materials.
- Metals concentrations for all water/sediment sampling sites are summarised in Table 16.12. Results show that metal concentrations did not exceed sediment quality criteria in the Calliope River.

Analysis results indicate that, at the locations to be dredged for the project, sediment quality criteria are not exceeded.

Table 16.12 Marine sediment quality (water/sediment sampling sites 1 to 6): metals and metalloids

Parameter (µg/L Dry Weight)	Number of Samples	Minimum	Maximum	Mean	Sediment Quality Criteria (µg/L Dry Weight)	Number of Exceedences
Aluminium	12	2,692.00	17,449.00	8,887.83	n/a	n/a
Arsenic	12	2.20	14.30	7.02	20	0
Cadmium	9	0.01	0.05	0.02	1.5	0
Chromium	12	5.60	22.40	13.97	80	0
Copper	12	3.10	29.40	12.29	65	0
Cobalt	12	4.00	32.30	10.68	n/a	n/a
Nickel	12	3.20	15.20	8.93	21	0
Lead	12	1.20	7.50	4.55	50	0
Zinc	12	9.10	69.00	33.05	200	0
Manganese	12	138.00	517.00	259.83	n/a	n/a
Iron	12	6,517.00	39,558.00	19,039.92	n/a	n/a
Selenium	12	0.05	0.05	0.05	n/a	n/a

Results below detection limit were assumed to be half of the detection limit for statistical analysis purposes.
n/a – Not applicable or no guideline applied.

16.3.4 Sensitivity of Environmental Values

The water quality and sediment environmental values of Port Curtis are somewhat disturbed by human activity and naturally occurring conditions. The values are not particularly unique and occur in similar settings along the coast of Queensland. The port does have regional significance. The overall sensitivity ranking for environmental values in Port Curtis is **low**.

The same assessment approach was applied to the Calliope River, which is regionally significant but somewhat disturbed. Conditions in the river are not very rare and are similar to estuaries along the east coast of Queensland. Based on existing conditions, the overall sensitivity of the water quality and sediment environmental values in the Calliope River is **low**.

16.4 Issues and Potential Impacts

This section describes impacts on marine water and sediment quality. A summary of the predicted significance of impacts from all impacts is provided at the end of this section.

Major accidental spillages of hydrocarbons and hazardous materials to Port Curtis, either directly from vessels or via surface runoff from terrestrial spills, have the potential to cause significant harm to water quality and sediment. These incidents can occur during construction and operations, and management measures associated with these events are described in Chapter 29, Hazard and Risk.

16.4.1 Construction

Impacts on marine water and sediment during construction include the following:

- Dredging at the mainland launch site, Curtis Island LNG jetty and Curtis Island MOF and personnel jetty will cause plumes of suspended sediment to form in the water column at the dredger cutter head.
- The large number of vessel movements during construction means small amounts of some substances (e.g., diesel fuel, oils, solvents, paints and hydraulic fluids) may be spilled on deck and subsequently washed overboard during rainfall events or rough seas. This will result in local contamination of receiving waters.
- Pile driving during the construction of the mainland launch site, MOF and LNG jetty may disturb seafloor sediments and cause plumes of suspended sediment to form in the water column. Impacts on water quality and sediment from these activities are minor in comparison to dredging activities and are not discussed further.
- Dewatering of tunnel spoil (which may include acid sulfate soils) during construction of the feed gas pipeline Port Curtis tunnel crossing will require excess water to be discharged to Port Curtis at the tunnel launch site. This water may contain contaminated sediments, which will impact on marine water quality and sediments.
- Disturbance of acid sulfate soils at the proposed mainland tunnel entrance may cause these soils to be transported to the marine environment during rainfall events or during high tides if these soils are not managed correctly. Avoidance, mitigation and management measures regarding acid sulfate soils are discussed in Chapter 12, Land Contamination and Acid Sulfate Soils.
- Discharge of hydrostatic test water to Port Curtis may impact marine water quality and sediments, particularly if biocides or oxygen scavengers are added to the water during testing.
- Discharge of treated sewage generated at the construction camp into Port Curtis offshore of Boatshed Point may impact water quality by releasing nutrients and pathogenic organisms to the environment.
- Propeller wash from vessels navigating shallow waters may disturb seafloor sediments and cause plumes of suspended sediment to form. Compared to impacts from dredging, impacts from propeller wash are negligible and are not discussed further.

Dredging

The following locations will require dredging to support the construction and operation of project marine facilities:

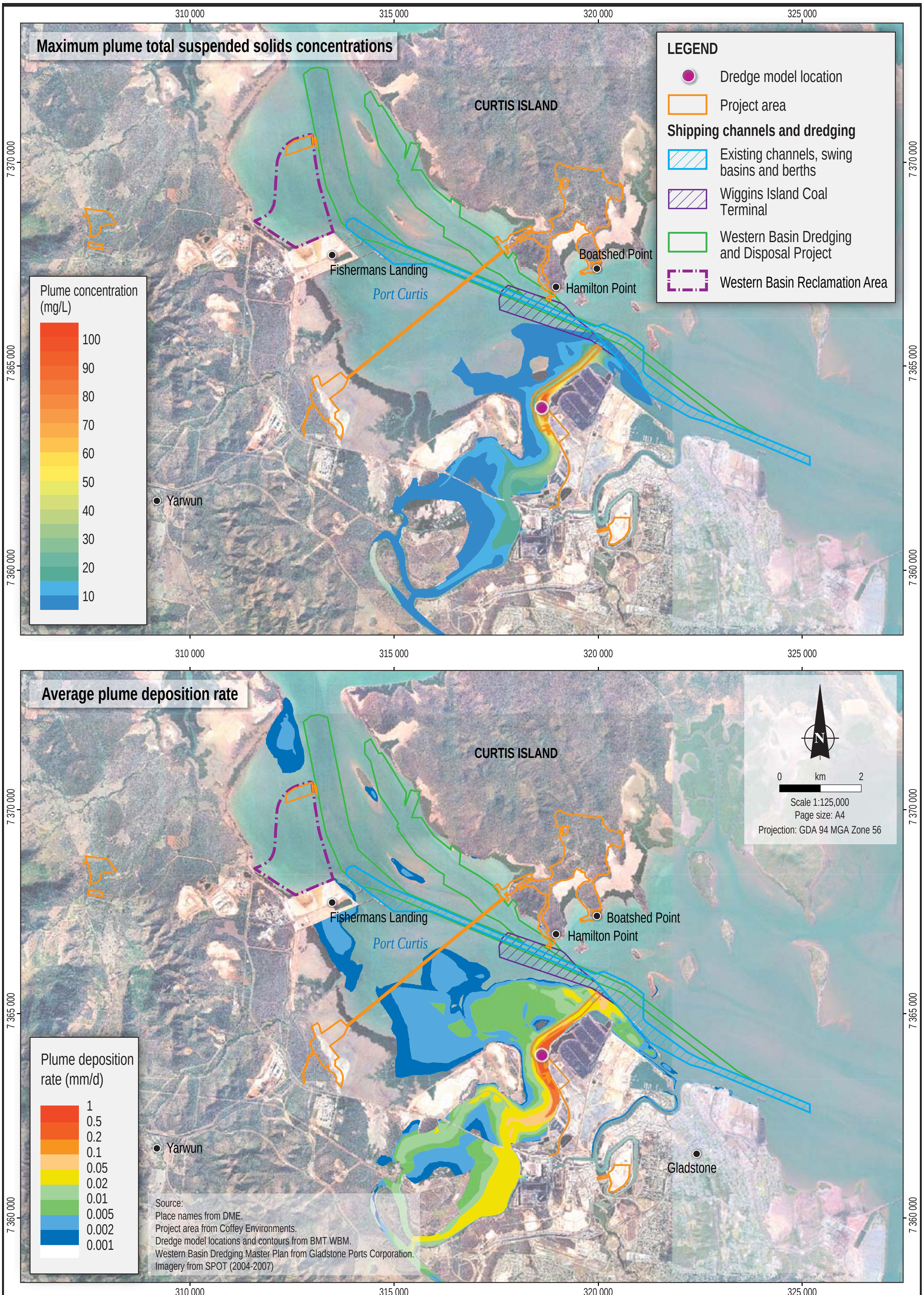
- Mainland launch site, which will be located at one of two sites under consideration as follows:
  - Launch site 1, located in the Calliope River. At most, 900,000 m^3 of material will be dredged at this site; it is expected to take between three and four weeks of effective dredging to complete.
  - Launch site 4N. At most, 2,500 m^3 of material will be dredged at this site over a period of less than one week.
- MOF and personnel jetty. Three options for the location of the MOF and personnel jetty are being considered; however, only two locations will require dredging by the project (as the third location, Hamilton Point North will be dredged by a third party) as follows:
  - Boatshed Point MOF and personnel jetty. Worst-case dredge volumes estimated for this site are 50,000 m^3 and it will take between one and two weeks of effective dredging to complete.
  - Hamilton Point South MOF and personnel jetty. The maximum (worst-case) dredge volume at this site is 50,000 m^3. It is expected to take between one and two weeks of effective dredging to complete.
- LNG jetty. This will require a maximum of 120,000 m^3 of seafloor sediment to be removed and it will be completed in two to three weeks of effective dredging to complete.

Dredging activities will result in plumes of suspended sediment forming in the water column and subsequent deposition of material on the seafloor. Modelled project impacts resulting from plume formation and dredge plume deposition are shown in:

- Figure 16.2 for dredge model site 1 at launch site 1.
- Figure 16.3 for dredge model site 2 at launch site 1.
- Figure 16.4 for dredge model site 3 at Boatshed Point MOF and personnel jetty.
- Figure 16.5 for dredge model site 4 at Hamilton Point South MOF and personnel jetty.
- Figure 16.6 for dredge model site 5 at the LNG jetty.

In general, modelling shows that suspended sediment concentrations build up over the first two weeks of dredging, and then reach a dynamic equilibrium when sediment plumes are governed by the tidal cycle. In areas close to the sediment sources, concentrations are highest during neap tides when water currents, and therefore the potential for plume dispersion, are lowest. In areas further away from dredging activities, plume concentrations are typically highest during spring tides when the water movements are great enough to transport suspended sediment to those locations. Maximum total suspended solids (TSS) concentrations are generally high (greater than 100 mg/L) at the dredge site and decrease with distance from these locations.

The assessment is based on the formation of plumes of suspended sediment in the water column as analysis of metals in sediments and all other parameters show that results are below assessment criteria.



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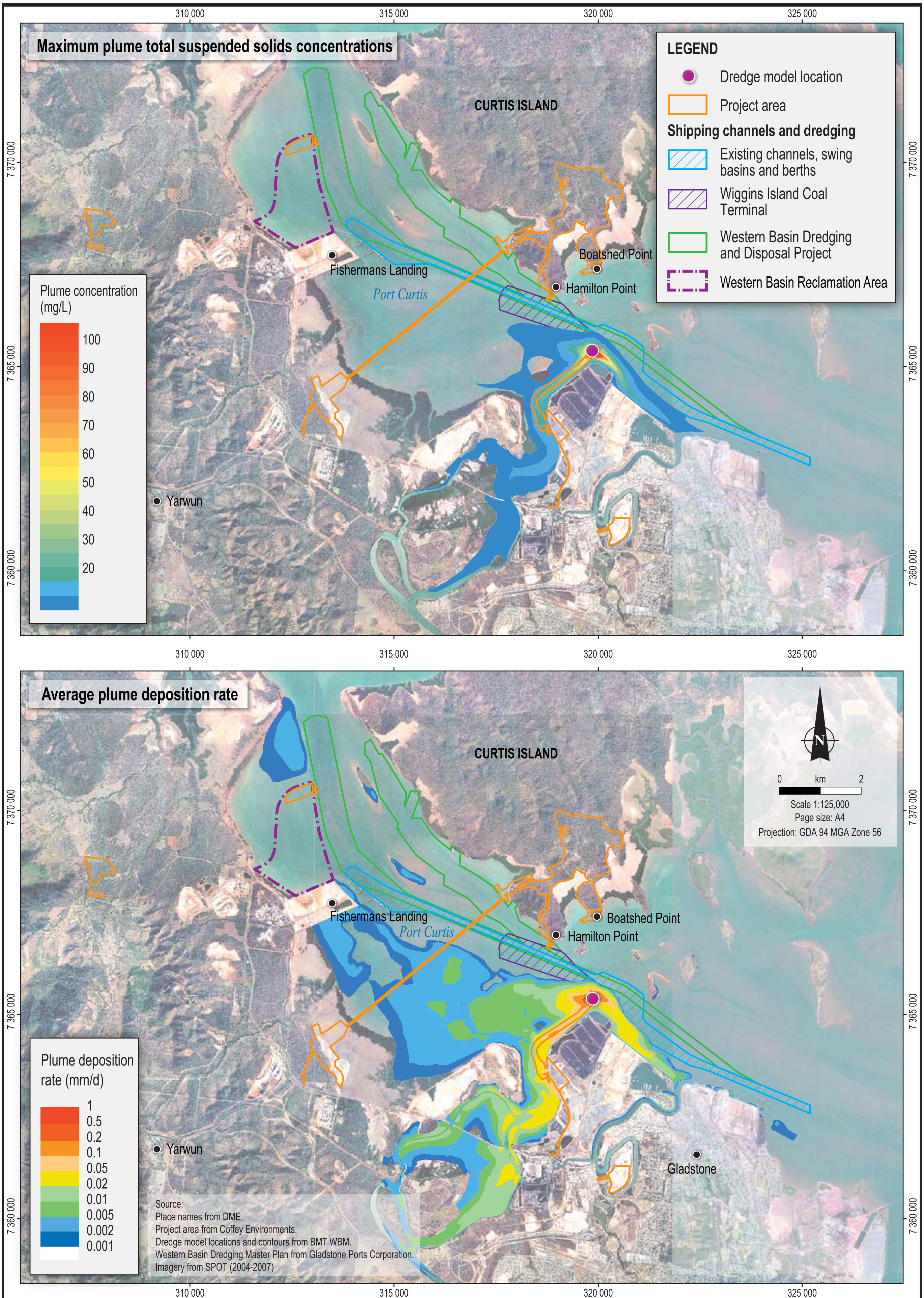

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Arrow Energy

Arrow LNG Plant

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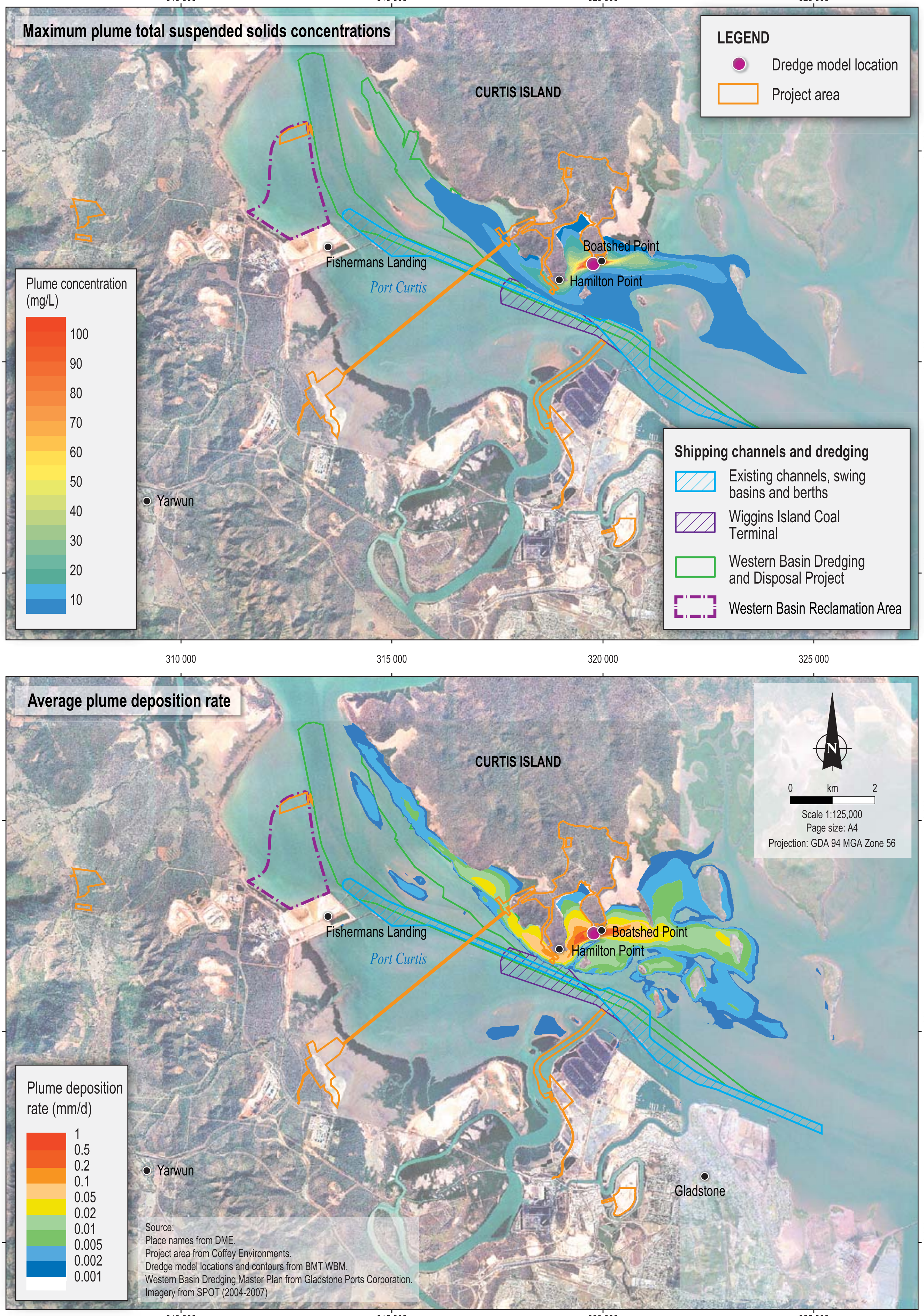
Dredge model site 2 – modelled dredge plume maximum TSS concentrations and average deposition rate

Figure No: 16.3



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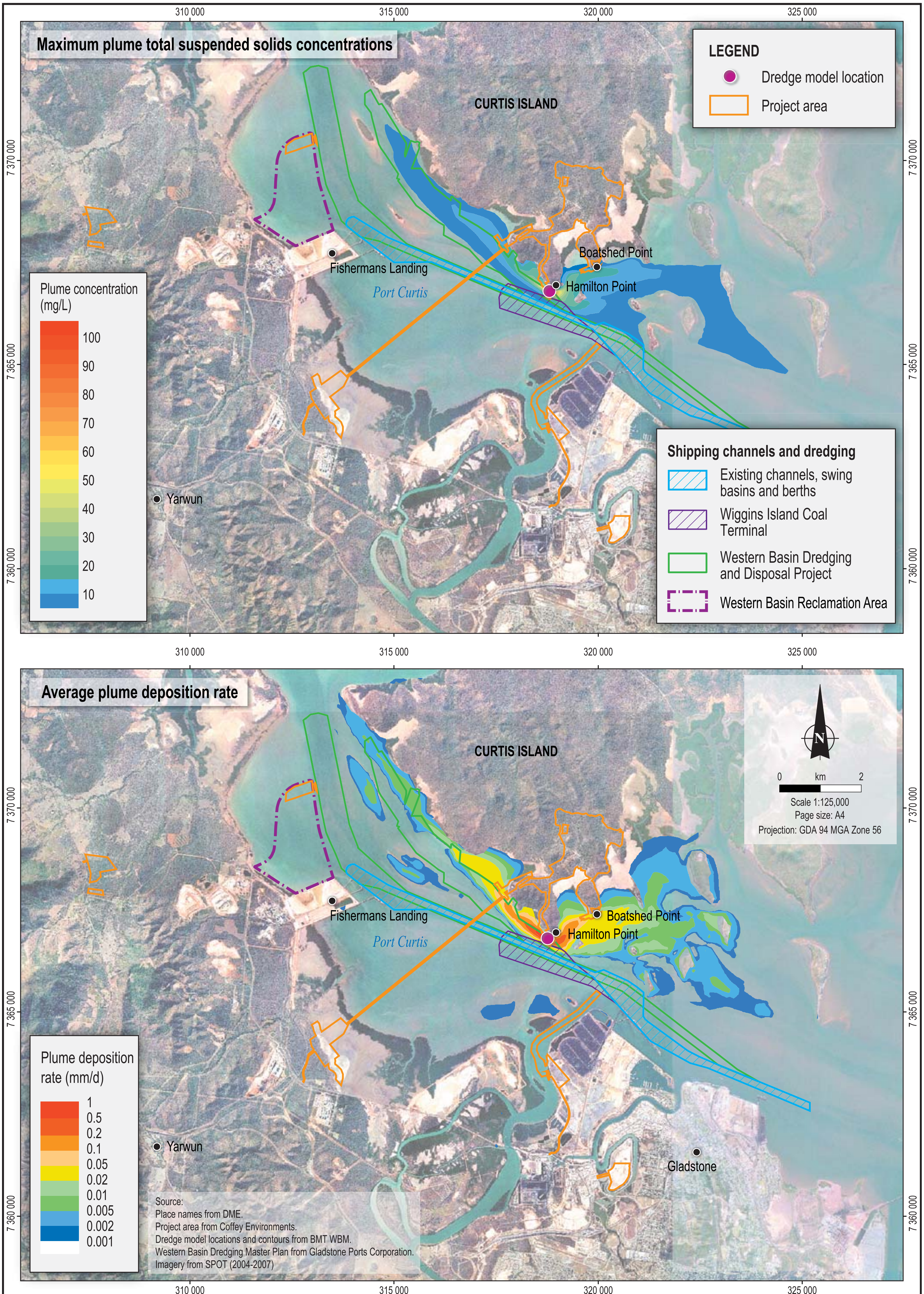

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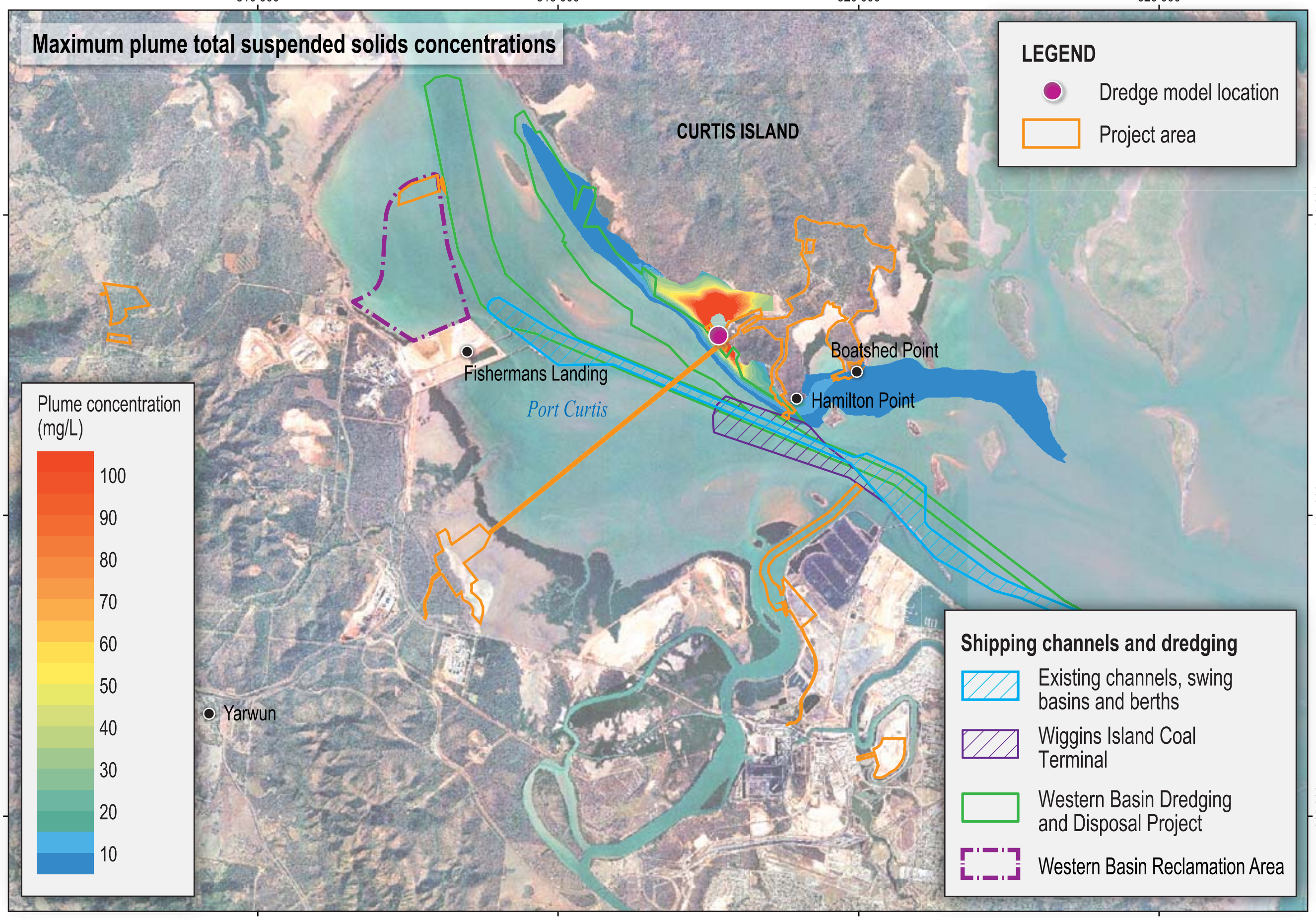

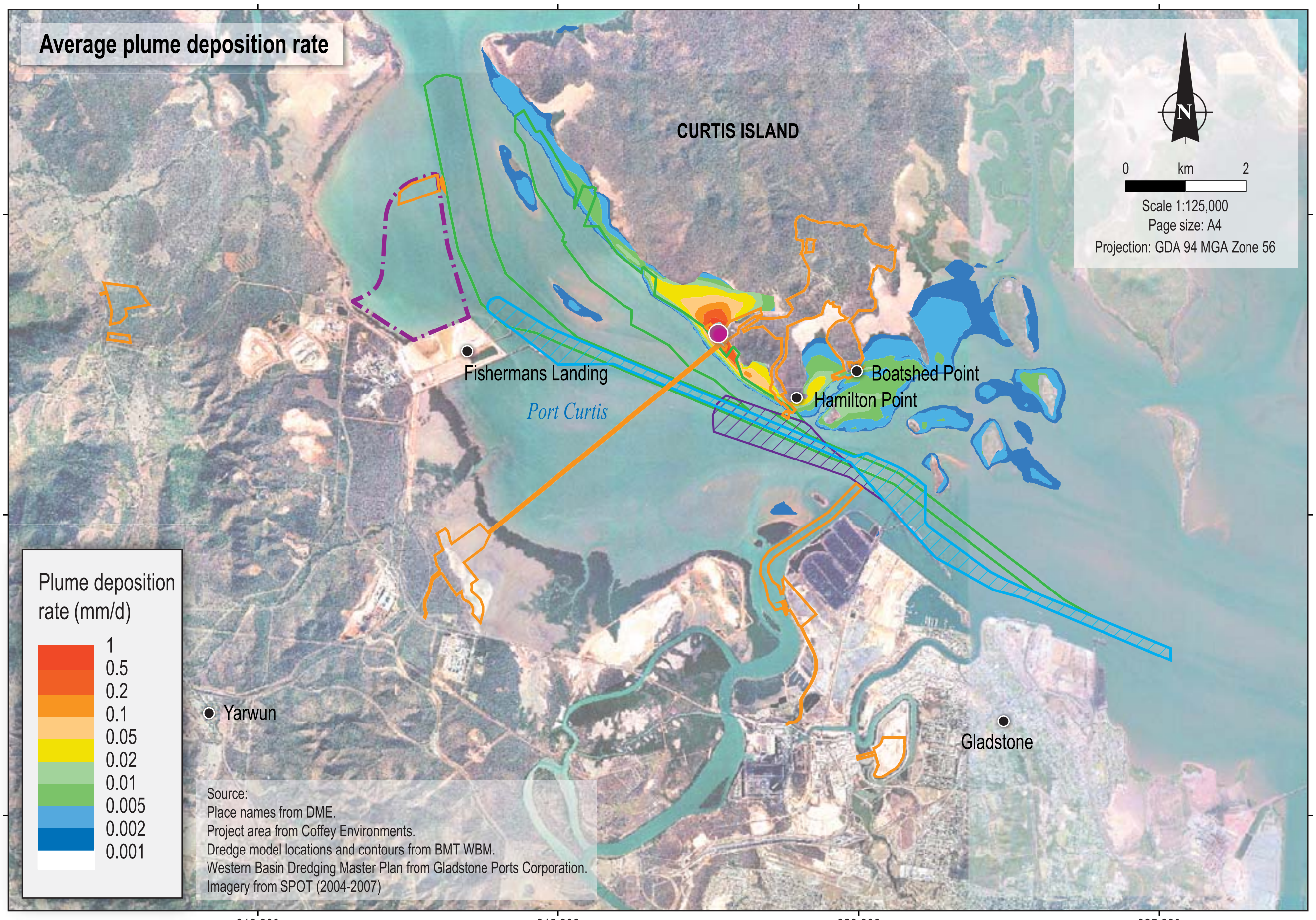

coffey environments

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File Name: 7033_07_F16.06_GIS_GL

Arrow Energy

Arrow LNG Plant

arrow energy go further

Dredge model site 5 – modelled dredge plume maximum TSS concentrations and average deposition rate

Figure No: 16.6

Results are provided in Table 16.13 and show that the magnitude of impacts at all sites have been assessed as low, largely due to the short duration of dredging activities i.e., less than six months. The resulting significance of impacts from suspended sediment plumes is **minor**.

Table 16.13 Magnitude of dredge plume discharge impacts

Severity of Impact (Percentage Increase over Existing Conditions)		***70%***	***50%***	***30%***	***10%***	
Model Location	**Maximum Duration (Effective Dredging Days)**	**Geographic Extent (m) i.e., Distance from Source**				**Magnitude of Impact**
1 – Launch site 1	28	563	1,728	2,019	5,152	Low
2 – Launch site 1	28	438	610	1,217	2,350	Low
3 – Boatshed Point MOF and personnel jetty	14	425	616	1,305	3,182	Low
4 – Hamilton Point South MOF and personnel jetty	14	72	123	263	1,097	Low
5 – LNG jetty	21	680	697	938	1,584	Low

Modelling shows that the rate of plume deposition to the seafloor is greatest at the dredge location (i.e., 1 mm/d) and gradually reduces with distance. Water currents driven by the tidal cycle influence the location at which plumes settle to the seafloor. The relatively high deposition rates in close proximity to dredging locations are due to the coarse sand and gravel component of the plume material rapidly settling to the seafloor. Much of this material will be re-dredged and taken onboard the dredging vessel as areas are dredged to required water depths.

Based on the period of dredging at each site, the maximum thickness of the material settling on the seafloor at each modelling site is shown in Table 16.14. The actual thickness at the end of dredging will be much less as this material will be re-dredged and is likely to be undetectable, resulting in a **negligible** magnitude and significance of impact.

Table 16.14 Maximum depositional thickness of dredge plume

Model Location	**Maximum Predicted Depositional Thickness (cm)**
1 – Launch site 1	7.5
2 – Launch site 1	7.5
3 – Boatshed Point MOF and personnel jetty	4.0
4 – Hamilton Point South MOF and personnel jetty	4.0
5 – LNG jetty	2.1

Accidental Discharge of Hazardous Substances

Accidental spills of hazardous substances such as diesel fuel, oils, solvents, paints and hydraulic fluids could impact marine water quality and sediment. Such impacts will adversely affect environmental values; however, it is difficult to quantify the effect spillages will have as the volume and location of spills is not known.

A spill could cause a change in water quality and/or sediment greater than 30% of existing conditions over an area exceeding 100 m for a period between 6 and 12 months. The magnitude of such an impact is medium and the significance **minor**, which, for the purpose of this assessment, represents a worst case, pre mitigation impact. A larger spill would constitute a major incident, and risks associated with such a spill are discussed in Chapter 29, Hazard and Risk.

Discharge of Water from the Mainland Tunnel Launch Site

Dewatering of tunnel spoil (which may include acid sulfate soils) during construction of the feed gas pipeline Port Curtis tunnel crossing will require excess water to be discharged to Port Curtis at the tunnel launch site. This water will be tested and treated in an onsite water treatment plant to meet water quality criteria as required, prior to discharge to Port Curtis. The magnitude and resulting significance of impacts is predicted to be **negligible**.

Discharge of Hydrostatic Test Water

The volume of water required during hydrostatic testing of the feed gas pipeline and LNG tanks is expected to be approximately 100,000 m^3 to 250,000 m^3. Seawater is the preferred test medium. If biocides or oxygen scavengers are added to the hydrostatic test water, the water will be tested and treated to meet water quality criteria as necessary, prior to discharge to Port Curtis. The discharge from hydrostatic testing will not impact marine water quality or sediment and the magnitude and resulting significance of impacts is predicted to be **negligible**.

Discharge of Treated Sewage from the Construction Camp

Sewage generated during construction will be treated to comply with water quality criteria in a package treatment plant and discharged to Port Curtis. The package treatment plant will be sized for the maximum number of workers expected on Curtis Island at any one time (i.e., daily commuters and construction camp residents). As all effluent discharged to Port Curtis will be treated prior to release, the magnitude and resulting significance of impacts is predicted to be **negligible**.

16.4.2 Operations

The impacts on marine water quality and sediment during operations include:

- Discharge of brine from the desalination plant (which provides potable and process water for the project) into Port Curtis off Boatshed Point at the southern end of Curtis Island will increase salinity at and around the point of discharge until the discharge stream has been diluted to ambient salinity concentrations. This discharge may also include process water and, under circumstances exceeding design (e.g., extreme rainfall events), treated effluent from the LNG plant sewage treatment plant.
- Some maintenance dredging may be required during operations to maintain a channel from mainland launch site 1 to the main Port Curtis shipping channels. No other project-related dredging will occur during operations. Maintenance of the main shipping channels and swing basins in Port Curtis will be managed by Gladstone Ports Corporation and impacts from these dredging activities have been assessed in the WBDD Project EIS (GHD, 2009a).
- Vessel movements during operations may result in the spillage of small amounts of hazardous substances into Port Curtis, causing local contamination of receiving waters. Impacts will be similar to those for construction and are not discussed further.

Effluent Discharge to Port Curtis at Boatshed Point

Hydrodynamic modelling for three discharge scenarios was conducted to predict the behaviour and fate of effluent discharged offshore of Boatshed Point. The modelling for the effluent discharge assumed that the discharge outfall would be designed to include a three-port diffuser at the end of the pipeline located close to the water surface (or the ports angled towards the surface) to maximise dilution of the negatively buoyant discharge stream.

Wastewater from the effluent treatment plant will only be discharged under extreme circumstances where the design capacity of the treatment plant is exceeded. When this occurs, wastewater that is discharged to Port Curtis will be the component of the plant that has been treated and will comply with Guidelines for Sewerage Systems – Use of Reclaimed Water (ARMCANZ/ANZECC/NHMRC,2000) (see Scenario 3 in Table 16.2 for characteristics of treated wastewater). Therefore, no impacts are expected to occur from the discharge of this waste stream. Instead, this waste stream and the cooling tower blowdown, demineralisation plant and clean stormwater runoff waste streams will dilute the brine effluent stream prior to discharge.

Modelling scenario 1 (brine discharge only) will cause the greatest impacts on water quality as this scenario results in the highest concentrations of salinity.

Modelling shows that the discharge of effluent for all three scenarios will result in localised impacts. Water quality criteria will be achieved within 10 m from the point of discharge under all hydrodynamic and tidal conditions. Similarly, salinity levels will return to a natural range of salinity offshore of Boatshed Point within 10 m from the discharge location.

Establishing a mixing zone around the point of discharge will allow effluent to mix with ambient seawater. Inside the mixing zone, effluent concentrations are allowed by regulations to be higher than water quality criteria, provided compliance is achieved at the mixing zone boundary. Assuming a mixing zone boundary is set at least 10 m distance from the point of discharge, the magnitude of impacts on water quality and sediment outside of this zone will be negligible, resulting in a significance of impact of **negligible**.

Modelling outputs will be reviewed if project design elements change, including the composition and volume of the discharge streams.

Maintenance Dredging

Maintenance dredging during operations will be limited to the channel between launch site 1 and the main Port Curtis shipping channel. Monitoring will be necessary to determine the volume of material to be dredged and the frequency of dredging required to maintain this channel but it is expected to be significantly less than construction dredging at this location. While the impacts from maintenance dredging are expected to be less than that which will occur during construction, the same magnitude of impact from dredging during construction has been applied to maintenance dredging, i.e., the magnitude of impact has been assessed as low, due to the uncertainty regarding the extent and duration of these impacts. The resulting significance of impact is **minor**.

16.4.3 Summary of Impacts

Table 16.15 summarises the predicted magnitude of impacts and shows that the significance of all impacts is either minor or negligible.

Table 16.15 Significance of impacts on water quality and sediment

Impact	Sensitivity	Magnitude	Significance of Impact
Construction			
Dredging – suspended sediment plumes	Low	Low	Minor
Dredging – plume deposition	Low	Negligible	Negligible
Accidental discharge of hazardous substances	Low	Medium	Minor
Mainland launch site excess water discharge	Low	Negligible	Negligible
Hydrostatic test water discharge	Low	Negligible	Negligible
Effluent discharge to Port Curtis	Low	Negligible	Negligible
Operations			
Effluent discharge to Port Curtis	Low	Negligible	Negligible
Maintenance dredging	Low	Low	Minor
Accidental discharge of hazardous substances	Low	Medium	Minor

16.5 Avoidance, Mitigation and Management Measures

This section describes management measures to address the potential impacts on marine water quality and sediment.

16.5.1 Planning and Design

Arrow Energy is currently undertaking a geotechnical investigation to characterise sediment material in areas to be dredged. The results of the investigation will further inform the development of the dredge management plan and the review of potential disposal locations.

Specific measures to be implemented during the planning and design are described below.

- Design of the discharge outfall from the LNG Plant will include a three-port diffuser at the end of the pipeline located close to the water surface (or the ports angled towards the surface) to maximise dilution of the negatively buoyant discharge stream. [C16.01]
- Obtain sediment samples from geotechnical drill cores to further characterise marine sediments disturbed during construction. Use the results to inform the development of the dredge management plan. [C16.02]
- Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g. current WBDD Project data) and will include: [C15.02]
  - Requirements for monitoring of water quality. [C15.03]
  - Actions to be taken to minimise the impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan. [C15.04]

16.5.2 Construction and Operation

The avoidance, mitigation and management measures to be implemented during construction and operation include:

- Prior to discharge to Port Curtis, test and treat excess water at the mainland tunnel launch site in an onsite water treatment plant to meet water quality criteria. [C16.03]

- Test and treat all discharges to Port Curtis to meet water quality criteria, as required, prior to discharge. [C16.04]
- Develop spill response plans to cover marine activities, including all vessel operations. [C16.05]
- Refuel vessels in designated areas where spill response kits are located. [C16.06]
- Train all relevant personnel in spill response and recovery procedures. [C13.12]
- Limit activities on vessels that may cause spillages to the deck to areas where deck water can be routed to and passed through oil/water separators (to meet water quality criteria) before discharge overboard. [C16.07]
- Store solvents and other oil-based or flammable materials in accordance with applicable Queensland regulations. [C16.08]
- Maintain a minimum practical inventory of hazardous materials on board vessels. [C16.09]
- Store on board wastes produced by vessels that cannot be discharged under the MARPOL Convention and then transfer to an approved onshore facility for treatment, reuse, recycling or disposal. [C16.10]
- Where practical, schedule the timing of maintenance dredging to coincide with the most favourable climatic conditions for minimising impacts on water quality and sediment (i.e., during neap tides when water currents are weakest or periods of calm winds and waves). [C16.11]
- Source hydrostatic test water from Port Curtis, the town water supply or from fresh water generated in the reverse osmosis plant. Test and treat water to meet water quality criteria as necessary prior to discharge to Port Curtis. [C16.12]

16.5.3 Decommissioning

The following measure will be implemented during decommissioning:

- Develop a detailed decommissioning plan for the site to include procedures and methods for managing effluent during decommissioning. [C16.13].

16.6 Residual Impacts

With implementation of all avoidance, mitigation and management measures, residual impacts will largely be the same as those described in Section 16.4, Issues and Potential Impacts.

16.6.1 Construction

The development and implementation of a dredge management plan and associated measures to address dredging impacts will most likely reduce the magnitude and significance of impacts on marine water quality and sediment. However, it is not possible to accurately estimate the magnitude of changes to impacts, and the significance of pre mitigation impacts is unchanged, i.e., the significance of impacts is **minor** for suspended sediment plumes and **negligible** for plume deposition.

The significance of residual impacts associated with discharge of excess water from dewatering activities at the mainland tunnel launch site and discharge of hydrostatic test water will not change, i.e., the significance of impacts is **negligible**.

The significance of impacts associated with the accidental discharge of hazardous materials will reduce to **negligible** following implementation of mitigation measures.

16.6.2 Operations

The impact assessment for the effluent outfall assumed that a diffuser will be incorporated into the discharge pipeline and that wastewater from the effluent treatment plant will be treated to standards defined in the Guidelines for Sewerage Systems – Use of Reclaimed Water (ARMCANZ/ANZECC/NHMRC, 2000) prior to discharge. Therefore, residual impacts will not change.

Implementation of the dredge management plan and associated measures will reduce pre mitigation impacts. However, it is not possible to accurately estimate the magnitude of changes to impacts, and the significance of pre mitigation impacts will not change, i.e., **minor** for suspended sediment plumes and **negligible** for plume deposition.

The significance of residual impacts associated with the accidental discharge of hazardous materials is **negligible** assuming implementation of mitigation measures.

16.7 Inspection and Monitoring

The dredge management plan will detail inspection and monitoring activities including those to determine compliance with water quality criteria. The plan will also specify water quality and marine ecology monitoring requirements including those to assess the impact of dredging in the Calliope River. Sediment and water quality sample results will provide information to inform the development of the dredge management plan.

Periodic marine water quality monitoring will be carried out to establish water quality both inside and outside the mixing zone in Port Curtis, and for compliance with the water quality criteria at the mixing zone boundary.

Arrow Energy will participate in the ongoing Port Curtis Integrated Monitoring Program water quality monitoring studies.

16.8 Commitments

The measures (commitments) that Arrow Energy will implement to manage impacts on marine water quality and sediment are set out in Table 16.16.

Table 16.16 Commitments: Marine water quality and sediment

No.	Commitment
C16.01	Design of the discharge outfall from the LNG Plant will include a three-port diffuser at the end of the pipeline located close to the water surface (or the ports angled towards the surface) to maximise dilution of the negatively buoyant discharge stream.
C16.02	Obtain sediment samples from geotechnical drill cores to further characterise marine sediments disturbed during construction. Use the results to inform the development of the dredge management plan.
C15.02	Develop a dredge management plan that considers the appropriate water and sediment monitoring data (e.g. current WBDD Project data) and will include:
C15.03	• Requirements for monitoring of water quality. Common with Chapter 16, Marine Water Quality and Sediment.

Table 16.16 Commitments: Marine water quality and sediment (cont'd)

No.	Commitment
C15.04	• Actions to be taken to minimise the impacts of dredging on sensitive areas should water quality monitoring data show performance criteria are exceeded. Finalise specific actions in the dredge management plan. Common with Chapter 15 Coastal Processes, and Chapter 19, Marine and Estuarine Ecology.
C16.03	Prior to discharge to Port Curtis, test and treat excess water at the mainland tunnel launch site in an onsite water treatment plant to meet water quality criteria.
C16.04	Test and treat all discharges to Port Curtis to meet water quality criteria, as required, prior to discharge.
C16.05	Develop spill response plans to cover marine activities, including all vessel operations.
C16.06	Refuel vessels in designated areas where spill response kits are located.
C13.12	Train all relevant personnel in spill response and recovery procedures. Common with Chapter 13, Surface Water Hydrology, and Water Quality and 31, Waste Management.
C16.07	Limit activities on vessels that may cause spillages to the deck to areas where deck water can be routed to and passed through oil/water separators (to meet water quality criteria) before discharge overboard.
C16.08	Store solvents and other oil-based or flammable materials in accordance with applicable Queensland regulations.
C16.09	Maintain a minimum practical inventory of hazardous materials on board vessels.
C16.10	Store on board wastes produced by vessels that cannot be discharged under the MARPOL Convention and then transfer to an approved onshore facility for treatment, reuse, recycling or disposal.
C16.11	Where practical, schedule the timing of maintenance dredging to coincide with the most favourable climatic conditions for minimising impacts to water quality and sediment (i.e., during neap tides when water currents are weakest or periods of calm winds and waves).
C16.12	Source hydrostatic test water from Port Curtis, the town water supply or from fresh water generated in the reverse osmosis plant. Test and treat water to meet water quality criteria as necessary prior to discharge to Port Curtis.
C16.13	Develop a detailed decommissioning plan for the site to include procedures and methods for managing effluent during decommissioning.