13. SURFACE WATER HYDROLOGY AND WATER QUALITY

This chapter describes the hydrology, geomorphology and water quality environmental values of the project area, assesses the potential impacts of the project on these values, and describes the measures Arrow Energy will implement through project design, construction and operations to manage impacts on these hydrology, geomorphology and water quality values.

This chapter is based on the findings of the Surface Water Impact Assessment (Appendix 5) and Stormwater Quality Impact Assessment (Appendix 6) undertaken by Alluvium Consulting Australia Pty Ltd.

Information on flooding and its geomorphological effects on the Calliope River was sourced from the Coastal Processes, Marine Water Quality, Hydrodynamics and Legislation Assessment (Appendix 8) prepared by BMT WBM Pty Ltd. Freshwater quality data of the study area was obtained from the Freshwater Ecology and Water Quality Impact Assessment (Appendix 11) prepared by Aquateco Pty Ltd.

Objectives have been developed based on the relevant legislative and policy context with the aim of protecting the existing surface water environment and identified environmental values. The objectives are provided in Box 13.1.

Box 13.1 Objectives: Surface water hydrology and water quality

- To avoid or reduce potential adverse effects on hydrology, geomorphology and surface water quality during all project phases.
- To identify mitigation strategies to reduce adverse effects on hydrology, geomorphology and surface water quality.

Groundwater resources are discussed in Chapter 14, Groundwater. Marine water quality, including that in the tidally influenced Calliope River and Auckland Creek, is discussed in Chapter 16, Marine Water Quality and Sediment. Coastal processes including storm surge and tidal inundation are discussed in Chapter 15, Coastal Processes.

13.1 Legislative Context and Standards

This section describes the key legislation and policy relevant to surface water within the study area.

13.1.1 Commonwealth and State Legislation

Commonwealth and state legislation designed to protect and manage surface water include:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). The act provides for the protection of matters of national environmental significance, including listed threatened species and ecosystems, listed migratory species and protected areas. The development proposal has been declared a controlled action under the EPBC Act, and the EIS must address potential impacts on matters of national environmental significance identified under the EPBC referrals for the project (EPBC 2009/5007 and EPBC 2009/5008).
- *Water Act 2000* (Qld). The act provides the framework to deliver sustainable water planning, allocation management and supply processes to ensure improved security of water resources.

Permitting and licensing requirements are set out in the act, which also governs the management of certain works in waterways such as destroying vegetation and excavating or placing fill in a watercourse. Permits under the act may be required for works conducted outside a petroleum lease. Written advice from the Queensland Department of Environment and Resource Management (DERM) in February 2011 stated the ephemeral streams located within the project area on Curtis Island are not considered watercourses under the act and therefore do not require authorisations.

- *Environmental Protection Act 1994* (Qld). The act aims to protect Queensland's environment by promoting ecologically sustainable development. The act states that no person may carry out an activity that causes or is likely to cause environmental harm unless that person takes all reasonable and practicable measures to prevent or minimise the harm. The act requires the implementation of pro active measures to prevent environmental degradation.
- *Sustainable Planning Act 2009* (Qld). The act provides a framework for Queensland's approach and planning to achieve sustainable development. Approvals are required under the act where any barriers are to be placed in a waterway.
- *Fisheries Act 1994* (Qld). The act provides for the management, use and protection of fisheries resources and fish habitats in a way that is ecologically sustainable. There are no commercial or recreational freshwater fisheries within the study area. Activities within freshwater areas could impact on adjacent marine fisheries and fish habitat.

13.1.2 Guidelines, Policies and Plans

Guidelines, policies and plans relevant to the assessment of surface water include:

- Environmental Protection (Water) Policy 2008 (Qld) (EPP (Water)). The policy aims to achieve the objectives of the Environmental Protection Act by identifying the environmental values and management goals for Queensland waters. Water quality guidelines and objectives are specified to enhance or protect the environmental values. Monitoring and reporting on the condition of Queensland waters are also addressed under the policy. Environmental values for the Calliope River Basin and Curtis Island have not yet been defined under the act or the policy. DERM intends to identify values for these areas by December 2013. Water quality objectives have been set for Port Curtis.
- ANZECC (2000) Core Environmental Indicators for Reporting on the State of the Environment The core indicators are used to assist with reporting on the state of the environment within Commonwealth, state and territory jurisdictions and include inland indicators for surface water. Indicators are also used to develop environmental monitoring programs to highlight the key measures required to evaluate environmental trends and conditions.
- Water Resource (Calliope River Basin) Plan 2006 (Qld). The plan is subordinate legislation under the Water Act and sets objectives for the sustainable management of water within the basin. Requirements are set out for abstracting water including the process for gaining permission to obtain unallocated water from the Calliope River Basin.
- Healthy Waterways (2006) Water Sensitive Urban Design Technical Guidelines. The guidelines detail the load-based objectives for the discharge of stormwater. Objectives are defined for southeast Queensland for total phosphorous and nitrogen loads as well as total pollution load.
- Queensland Water Quality Guidelines. The guidelines (DERM, 2009b) provide water quality objectives for discharges to surface watercourses, tidal estuaries and marine waters. They

also define the boundaries for lower and upper estuarine waterways. The applicable guidelines for physiochemical indicators are those described for lowland streams of the Central Coast Queensland region, as these streams are considered to be slightly to moderately disturbed.

- ANZECC/ARMCANZ (2000) Guidelines for Water Quality Objectives. The Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) guidelines are to be used where site-specific targets for water quality are not defined elsewhere such as in the EPP (Water). The guidelines are used to determine the freshwater trigger values for toxicant indicators.
- Curtis Coast Regional Coastal Management Plan (EPA, 2003). This plan describes how the coastal zone in the Curtis Coast region is to be managed within the policy framework established by the State Coastal Management Plan - Queensland's Coastal Policy (DERM, 2011a).
- Fish habitat management operational policies. The operational policies outline the Queensland Government's position on the management of declared fish habitat areas. The Queensland government supports the Department of Primary Industries and Fisheries in protecting the environment for a sustainable future by conserving and managing fish habitats. The policy provides guidance for the management of fish habitat areas and helps secure their future by interpreting legislation, defining activities, and guiding the application of legislation for works and activities within declared fish habitat areas. There are currently no declared fish habitat areas within the project area.

13.2 Assessment Method

The assessment method has adopted the significance (sensitivity and magnitude) approach. The study area for the assessment lies within the Calliope River Basin and Curtis Island River Basin as shown in Figure 13.1. The study area includes the catchments within the basins on both the mainland and Curtis Island that contain waterways that may be affected by project activities.

13.2.1 Baseline Assessment

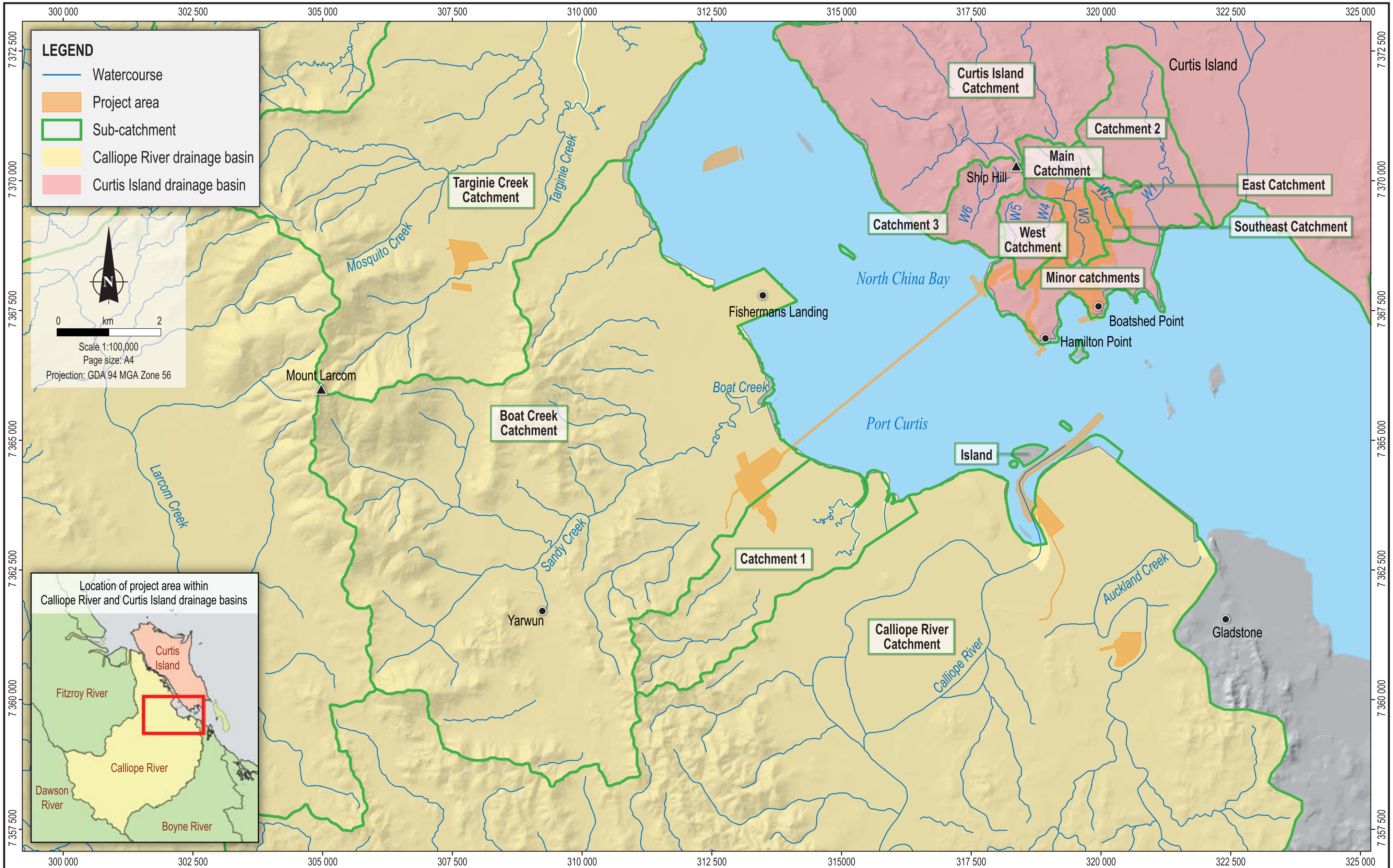
A baseline study was completed to characterise the existing surface water environment and values. The hydrology, geomorphology and water quality features of surface water features were identified through desktop studies, field investigations and with reference to relevant standards and guidelines.

Hydrology

Climatic, flow and flood risk data for the study area was reviewed, including data on current water use and surface water extraction. Catchments and sub catchments were classified using the program CatchSIM. Manual rectification of the data defined sub catchment sizes that would be the most suitable for use in the assessment.

Geosciences Australia 1:100, 000 mapping was used to confirm the names of the established watercourses within the study area. Where streams were unnamed, sub catchments containing these streams were given numbers. Sub catchments on Curtis Island within the project footprint of the LNG plant were identified in finer detail to assist the flood risk assessment process.

The assessment of flooding of the catchments on Curtis Island was mainly conducted as a desk-top exercise using available climate records, terrain data and aerial photography. The assessment was supplemented with information obtained during field visits in June 2010.



Source:
Place names from DME.
Sub-catchments and watercourses from Alluvium.
Drainage basins from DERM.
Project area and digital elevation model from Coffey Environments.

coffey environments

Date: 22.11.2011
MXD: 7033CA_07_GIS177_v1_7
File Name: 7033_07_F13.01_GIS_GL

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Study area catchments and watercourses

Figure No: 13.1

Hydrologic and hydraulic modelling predicted the site conditions under various flooding scenarios. A hydrologic analysis was undertaken to estimate the magnitude and frequency of stream flows that could be expected at the LNG plant site. This was undertaken to aid in the design of the stream diversions necessary during the construction of the LNG plant. A catchment model was created using a runoff routing program called RORB. A digital elevation model and rainfall estimates were included to determine the magnitude of the peak flow rates for various average recurrence intervals (ARI). A combination of 1-D and 2-D modelling was undertaken to assess the flood extents under various ARI events at the site.

Geomorphology

Aerial photography, satellite imagery, and GIS data on topography and geology were used to develop a baseline understanding of the geomorphology of the watercourses in the study area and the surrounding terrain. Site visits to verify this data were carried out in June 2010 and February 2011. The study also examined the proportion of deep rooted vegetation at project sites as this is a contributing factor to geomorphic stability of the watercourses found in the study area.

The River Styles framework was used to assess the geomorphic character and behaviour of the watercourses in the study area. The framework provides a mechanism to describe and explain the distribution of river forms and processes within a given water catchment. Table 13.1 sets out the river styles defined in the framework used to categorise watercourses in the study area.

Table 13.1 River styles of the study area

Valley Setting and River Style	Attributes Relevant to Project Planning
Confined valley setting. Confined occasional floodplain pockets, frequent bedrock controls.	Robust stream form with low sensitivity to disturbance.
Confined valley setting. Headwater, thin alluvial/colluvial deposits in narrow valley floor that is near contiguous with hill slopes, much exposed bedrock/indurated tertiary sediments.	Robust stream form with low sensitivity to disturbance. Usually a first order stream in the upper catchment. Generally steeper gradient and stable with bedrock controls, which are naturally erosion-resistant rock layers that prevent bed deepening by erosion.
Confined valley setting. Partly confined, low sinuosity valley and channel with planform controlled discontinuous floodplain.	Robust stream form with low sensitivity to disturbance. Often feature naturally erosion resistant rock layers that prevent bed deepening by erosion.
Confined valley setting. Partly confined, meandering channel with planform controlled discontinuous floodplain.	May be subject to more rapid rates of erosion on the outside of bends than other partly confined watercourses. Bedrock controls will be present.
Alluvial or partly confined valley setting (no channel when intact). Valley fill, alluvial and colluvial sediments across valley floor with no channel.	These watercourse types store large amounts of sediment and play a critical role in sediment and water flux in the landscape. Can be subject to rapid erosion if disturbed or flow is concentrated (such as occurs with pipes through roads). Careful rehabilitation required if planned to be disturbed.
Alluvial valley setting (continuous channel). Low to moderate sinuosity, fine grained.	Susceptible to erosion if disturbed.
Alluvial valley setting (continuous channel). Low to moderate sinuosity, gravel bed.	Less susceptible to erosion than low to moderate sinuosity fine grained but still requires considered erosion control if disturbed.

Table 13.1 River styles of the study area (cont'd)

Valley Setting and River Style	Attributes Relevant to Project Planning
Laterally unconfined valley setting, continuous channels. Two types have been identified in the project area: Tidal - low moderate sinuosity. Tidal - meandering.	Susceptible to erosion of disturbed.

The categorisation of watercourses also included an assessment of the intactness of riparian vegetation along all the mapped watercourses in the study area. Vegetation was classified as either intact (i.e., largely undisturbed from clearance, agricultural, industrial, or urban activity) or disturbed (i.e., slightly to moderately disturbed, characterised by areas of cleared banks and reaches).

Data from the Queensland Wetland Program (DERM, 2011c) was used to identify the wetland types found within the study area.

The impacts of dredging at the mouth of the Calliope River and its effects on flooding consisted of using 1-D and 2-D TUFLOW hydraulic modelling.

Water Quality

An assessment was performed on the existing water quality conditions in Boat Creek and Targinie Creek. These creeks are the only freshwater watercourses where project activities may pose a threat to water quality. Data from recent sampling activities was obtained from the Port Curtis Integrated Monitoring Program for Boat Creek (DERM, 2011d) and from the Australia Pacific LNG Project EIS for Targinie Creek (WorleyParsons, 2010).

All water bodies on Curtis Island are ephemeral in nature. Water quality monitoring was not possible as the presence of water within these systems is intermittent and only present following rainfall events where overland flow is sufficient to infill areas with defined beds and banks. Water quality of the Calliope River Basin and Curtis Island is discussed in sections 13.3.3 and 13.3.4.

Stormwater Assessment

The stormwater assessment consisted of developing a conceptual level construction, operation and decommissioning stormwater quality treatment arrangement for the LNG plant project. The temporary sediment basins that will be used during construction were designed based on Brisbane City Council's Sediment Basin Design, Construction and Maintenance Guidelines (BCC, 2001). Further details regarding the conceptual stormwater management system have been provided in Section 13.5 and in Appendix 6, Stormwater Quality Impact Assessment.

The water quality objectives for the Port Curtis area as defined in the EPP (Water) were used to develop the operational phase stormwater quality strategy. To meet these water quality objectives, the stormwater quality treatment train was developed in accordance with the Healthy Waterways (2006) Water Sensitive Urban Design Technical Guidelines. The treatment train for the discharge of stormwater from the LNG plant has been designed to reduce the typical pollutant loads that may be present in the stormwater runoff from the site that will subsequently be discharged into any surrounding waterways and drainage networks.

13.2.2 Significance Assessment

The assessment considered direct and indirect impacts on surface water in the study area. The significance of impacts on surface water was assessed using the significance assessment method (as described in Chapter 9, Impact Assessment Method), where the potential impacts are identified as a function of the sensitively of surface water values and the magnitude of the impact.

The sensitivity of an environmental value is determined by its vulnerability to threatening processes or according to its intrinsic value. Five attributes of the value are considered:

- **Conservation value** assigned by governments (including statutory and regulatory authorities) or recognised international organisations (e.g., UNESCO) through legislation, regulations and international conventions.
- **Intactness** was assessed with respect to a values existing condition, particularly its representativeness. This is particularly relevant to the riparian vegetation that plays an important role in fluvial process and morphology of watercourses by stabilising banks and moderating flows.
- **Uniqueness or rarity** was assessed based on the occurrence, abundance, and distribution of a particular watercourse geomorphic type or wetland classification.
- **Resilience to change** was assessed by identifying the ability of a particular watercourse or geomorphic type to cope with change including that posed by threatening processes.
- **Replacement potential** was assessed with regard to the potential for a representative or equivalent example of an environmental value to be found to replace any losses. This is linked to the uniqueness or rarity of the environmental value.

The criteria for determining high, moderate, and low sensitivity for surface water values are set out in Table 13.2.

Table 13.2 Criteria for defining surface water sensitivity

Sensitivity	Description
High	• The environmental value is listed on a recognised or statutory state, national or international register as being of conservation significance. • The environmental value is intact and retains its intrinsic value. • The environmental value is unique to the environment in which it occurs. It is isolated to the affected system/area, which is poorly represented in the region, territory, country or the world. • The environmental value has not been exposed to threatening processes, or there has not been a noticeable impact on the integrity of the environmental value. Project activities would have an adverse effect on the value.
Moderate	• The environmental value is recorded as being important at a regional level, and may have been nominated for listing on recognised or statutory registers. • The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements. • The environmental value is relatively well represented in the systems/areas in which it occurs, but its abundance and distribution are limited by threatening processes. • Threatening processes have reduced the environmental value’s resilience to change. Consequently, changes resulting from project activities may lead to degradation of the prescribed value. • Replacement of unavoidable losses is possible due to abundance and distribution of the environmental value.

Table 13.2 Criteria for defining surface water sensitivity (cont'd)

Sensitivity	Description
Low	• The environmental value is not listed on any recognised or statutory register. It might be recognised locally by relevant suitably qualified experts or organisations, e.g., historical societies. • The environmental value is in a poor to moderate condition as a result of threatening processes, which have degraded its intrinsic value. • The environmental value is not unique or rare, and numerous representative examples exist throughout the system/area. • The environmental value is abundant and widely distributed throughout the host systems/areas. • There is no detectable response to change, or change does not result in further degradation of the environmental value. • The abundance and wide distribution of the environmental value ensures replacement of unavoidable losses is assured.

The magnitude of impact is an assessment of the geographical extent, duration and severity of the impact as follows:

- Geographical extent. The spatial extent of the impact where the extent is defined as site, local, regional or widespread (meaning state-wide or national or international).
- Duration. The timescale of the effect, i.e., if it is short, medium or long term.
- Severity. The scale or degree of change from the existing condition that results from the impact. This change could be positive or negative.

The criteria for determining magnitude of impact are set out in Table 13.3.

Table 13.3 Criteria for magnitude

Magnitude	Description
High	An impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses or the implementation of site-specific environmental management controls are required to address the impact.
Moderate	An impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.
Low	A localised impact that is temporary or short term, and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.

The significance of an impact on the environmental values is determined by the sensitivity of the value itself and the magnitude of the impact it experiences. The significance assessment matrix (Table 13.4) shows how the significance of impacts has been determined.

Table 13.4 Significance of impacts matrix

	Sensitivity of Environmental Value		
Magnitude of Impact	**High**	**Moderate**	**Low**
High	**Major**	**High**	**Moderate**
Moderate	**High**	**Moderate**	**Low**
Low	**Moderate**	**Low**	**Negligible**

The levels of significance of an impact determined using the matrix can be defined as:

- Major significance of impact. Arises when an impact will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.
- High significance of impact. Occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of the environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred in order to preserve the environmental value’s intactness or conservation status.
- Moderate significance of impact. Although reasonably resilient to change, the environmental value would be further degraded due to the scale of the impact or its susceptibility to further change. The abundance of the environmental value ensures that it is adequately represented in the region and that replacement, if required, is achievable.
- Low significance of impact. Occurs where an environmental value is of local importance, and temporary and transient changes will not adversely affect its viability, provided standard environmental management controls are implemented.
- Negligible significance of impact. Where impact on the environmental value will not result in any noticeable change in its intrinsic value; hence, the proposed activities will have negligible effect on its viability. This typically occurs where activities occur in industrial or highly disturbed areas.

13.3 Existing Environment and Environmental Values

The following section describes the hydrology, geomorphology and water quality of the study area and the environmental values against which to assess the impacts of the project.

13.3.1 Climate

Curtis Island and Gladstone have a sub tropical climate with an average annual rainfall of approximately 879 mm. The bulk of rainfall occurs in the summer, with average precipitation ranging from 100 to 190 mm per month. In the winter, these values drop to 20 to 45 mm per month. Mean monthly maximum temperatures range from between 30 and 32°C during the hottest months and decrease to approximately 23°C during the coldest part of the year. Mean monthly minimum temperatures range between 21 and 23°C in the summer and decrease to 11.7°C in the winter. Climate data is important to hydrology and geomorphology as the amount of precipitation an area receives is a contributing factor to the amount of overland flow a given area experiences. The climatic data for the Gladstone area has therefore been included because the area receives significant amounts of rainfall during the summer months, an important influence on the hydrology of the ephemeral streams on Curtis Island.

Climate change impacts on Curtis Island are expected to see rainfall decrease by 3% by 2030 and decrease by 6 to 10% by 2070. If the rainfall trend also applies to the intensity of rainfall, the peak runoff generated from the LNG plant site may decrease as a result of climate change. Global sea level is predicted to rise by 18 to 59 cm by 2100. These rises will not increase saltwater encroachment at the site and are not expected to have an effect on project infrastructure.

Chapter 10, Climate and Climate Change provides a detailed description of the region’s climate and climate change predictions within the study area.

13.3.2 Drainage Basins, Catchments and Sub-catchments

The study area lies within the Calliope River and Curtis Island drainage basins, located within Australia's Northeast Coast Drainage Division. Table 13.5 identifies the catchment areas, catchments, and watercourses within the study area. Not all watercourses are named on the 1:100,000 scale maps for the region and unnamed watercourses were assigned the names as set out in Table 13.5 (and shown on Figure 13.1). No wild rivers are located within the study area.

Table 13.5 Watercourse names

Catchment Area	Catchment	Watercourses
Curtis Island	Catchment 2	With one mapped waterway W1.
	East catchment	No mapped waterway.
	Southeast catchment	One mapped waterway W2.
	Main catchment	With two mapped waterways W4 and W5.
	West catchment	With two mapped waterways W4 and W5.
	Catchment 3	One main waterway with headwater tributaries W6.
Calliope River Basin	Calliope River	Auckland Creek and Calliope River.
	Catchment 1	Poorly defined watercourses with channel modifications in the area of industrial development at Yarwun. Identified as W7.
	Boat Creek	Boat Creek. Tributary W8 has been channelised around the industrial area at Yarwun and flows to Boat Creek. W9 is a headwater tributary of Boat Creek. W10, W11, and W12 are headwater streams that enter floodout zones (without defined channels) before discharging to the coast. W13 consists of two mapped channels, one that enters a floodout zone, and one that discharges to the coast.
Targinie Creek	Targinie Creek	Targinie Creek.

13.3.3 Calliope River Basin

The Calliope River Basin lies within the Fitzroy River Basin, which is the largest basin draining into the Great Barrier Reef lagoon. The 2006 Water Resources (Calliope River Basin) Plan states that the basin has an area of 2,250 km^2, which includes numerous coastal streams within the study area that drain directly to the coast. These include Auckland Creek, Boat Creek and Targinie Creek.

Cattle grazing is the dominant land use within the basin, and this is concentrated on the coastal plains where the majority of the natural vegetation has been thinned or removed. Approximately 85% of the catchment is zoned as rural, 5% as forest and the remainder zoned for the development of infrastructure, village and residential use.

The sub-catchments or waterways within which project components will be located include Auckland Creek, Targinie Creek (Mosquito Creek sub-catchment), Boat Creek sub-catchment, Catchment 1 and the Calliope River. These features are shown on Figure 13.1 in relation to each of the project components.

Calliope River Hydrology

The Calliope River commences in the Calliope Range flowing initially southeast, then easterly towards the township of Calliope. Before reaching the township, the river turns in a north-easterly direction, dropping from the ranges to the coastal plains where it meanders its way to the coast on the northwest edge of Gladstone. The Calliope River is approximately 100 km long with main tributaries of Alma, Larcom, Oaky, Paddock and Double creeks, all of which are outside the study area.

The Calliope River coastal floodplain is between 5 and 16 km wide and has little relief. Most terrain is below 50 m ASL. Maximum elevation within the catchment is approximately 940 m AHD, with several peaks above 700 m AHD. Eroding gullies are a feature of the steep ranges that run parallel to the coast.

Development of the catchment is considered low, with less than 30% allocation of water resources and no storages in the catchment. Surface water consumption from the Calliope River consists of 92% irrigation, 6% urban/industrial and 2% rural uses. Water use information was obtained from the abstraction licences issued for the catchment and has been estimated at between 1,500 and 4,500 ML/yr. Water quality information has shown little change in recent years. The mean annual runoff is 301,000 ML/year, suggesting actual flows are near to natural flows. The hydrology of the Calliope River is therefore relatively unmodified from natural conditions

The river has flooded numerous times since records began in 1938, with the largest flood in 1947 and the most recent in December 2010.

Auckland Creek Catchment Hydrology

The Auckland Creek subcatchment of the Calliope River Basin flows to the coast to the west of Gladstone (Figure 13.1). TWAF 7 is located within a meander of Auckland Creek.

Creeks within the upper Auckland Creek catchment are generally ephemeral, with flows only occurring during larger rainfall events significant enough to generate substantial overland flow. Two weirs located within the Auckland Creek system form Lake Tondoon and Lake Callemondah. The waterways of the lower catchment area are typically saline and tidally influenced, with the weir at the downstream end of Lake Callemondah representing the divide between the freshwater and saltwater sections of Auckland Creek.

Recent hydrologic and hydraulic studies on Auckland Creek by Gladstone City Council modelled four flood events (20-, 50-, 100-, 500-year ARI) and a probable maximum flood scenario. The modelling shows that TWAF 7 will not be affected by the 100-year ARI or probable maximum flooding scenarios.

Targinie Creek and Boat Creek Hydrology

The only recognised fresh watercourses potentially impacted by the project are Boat Creek, which flows north of the mainland tunnel entry shaft and tunnel spoil disposal area on the mudflats near Fishermans Landing, and the upper reaches of Targinie Creek, which is located within the vicinity of TWAF 8. Both tributaries flow directly to the coast and are classified as coastal creeks.

The flood study undertaken by Sargent (2006) of the lower Calliope River included flood mapping for the mainland tunnel entry shaft and tunnel spoil disposal area, which are located within the Boat Creek subcatchment. The results show the location is in a zone of flood inundation for the 10-year ARI event.

The reach of Targinie Creek that may be potentially impacted by project activities is ephemeral in nature with flowing water occurring immediately following rainfall events. Hydrological data is not available for this part of the creek.

Geomorphic Categorisation

Both the Calliope River and Auckland Creek are categorised as tidal – low to moderate sinuosity river style in their lower reaches. Approximately one third of the low to moderate sinuosity river style mapped along the lower reaches of the Calliope River and Auckland Creek is classed as disturbed. Both watercourses have been impacted by vegetation clearance and adjoining land use activities. An example of this river style from Auckland Creek is seen in Plate 13.1.

Wetland Characterisation of Calliope River Basin

A number of coastal wetlands close to the study area have been assigned formal conservation status and include:

- Port Curtis and Narrows wetlands: Listed as Nationally Important Wetlands.
- Great Barrier Reef: Listed as a World Heritage site.

The Nationally Important Port Curtis Wetlands lie within the Calliope River Basin at the tunnel entrance and spoil disposal area, as well as at launch site 1. No project activities are located within The Narrows Wetlands.

Other wetlands that occur in the study area include those in the vicinity of Auckland Creek. These wetlands are classified as estuarine mangroves and related tree communities as well as salt flats and saltmarshes (at the site of TWAF 7). They are highly disturbed due to prior land use and vegetation clearance. The coastal/subcoastal floodplain tree swamps and estuarine salt flats and salt marshes along the mouth of the Calliope River that have been classified as artificial/highly modified wetlands at launch site 1 are also highly disturbed due to vegetation clearance and development.

Wetlands located within the Boat Creek subcatchment include estuarine mangroves and related tree communities as well as salt flats, salt marshes and riverine wetlands. These areas are disturbed to varying degrees by the use of recreational vehicles.

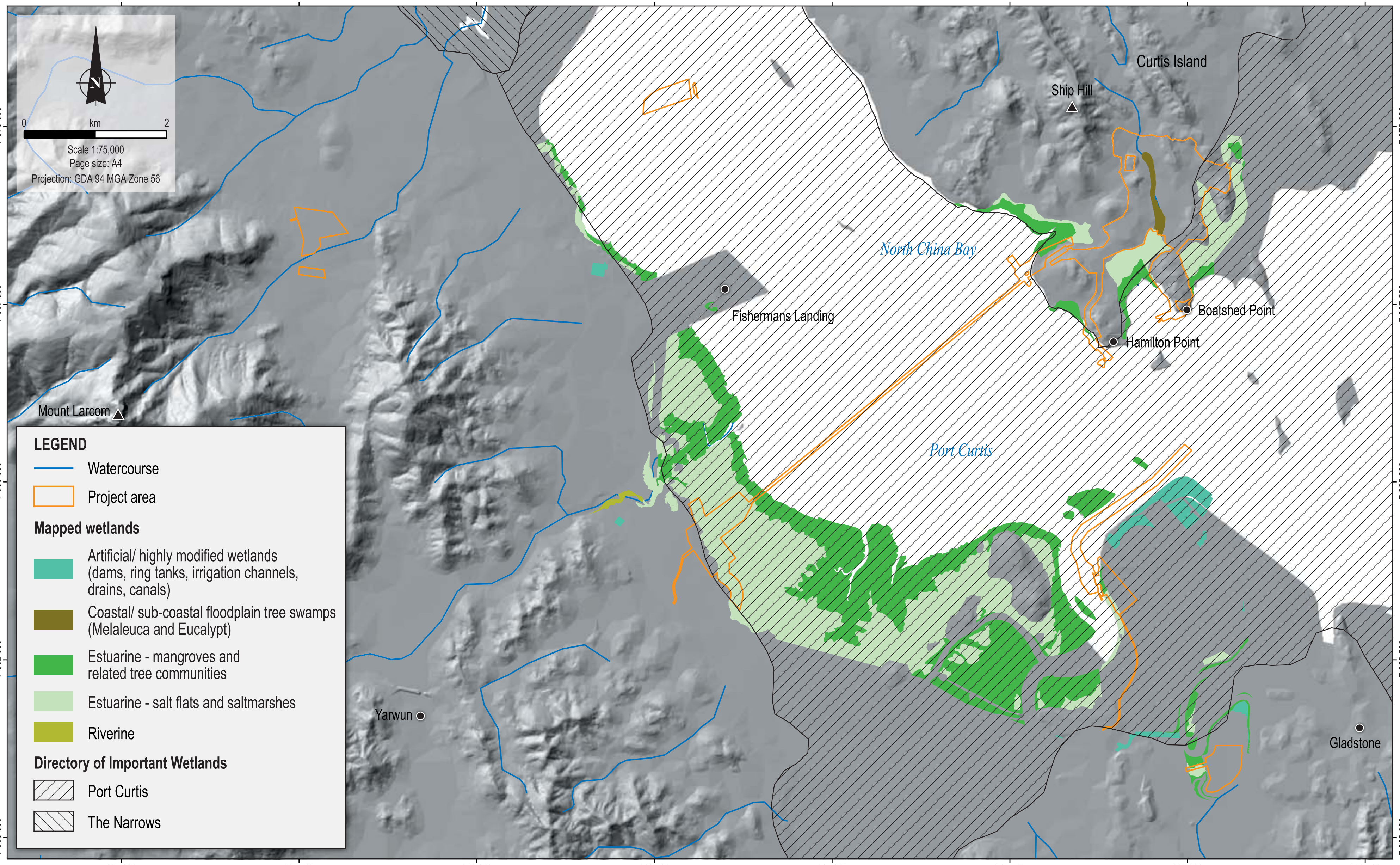
There are no wetlands within the vicinity of the project area along Targinie Creek.

The wetland types that have the potential to be impacted by project activities are shown in Figure 13.2 and detailed in Table 13.6.

Table 13.6 Wetlands in the study area

Wetlands	Hectares (ha)	Comments
Artificial, highly modified wetlands	60.23	None to be disturbed within the project area.
Estuarine – mangroves and related tree communities	653.56	Located at launch site 1 and TWAF 7 on the mainland and in the footprint of the LNG plant and associated infrastructure on Curtis Island.
Estuarine – salt flats and salt marshes	744.03	Located at launch site 1 and TWAF 7 on the mainland and in the footprint of the LNG plant and associated infrastructure on Curtis Island.
Riverine	4.78	A reach of Boat Creek approximately 1 km from the tunnel launch site.
Coastal/subcoastal floodplain tree swamps (Melaleuca and Eucalypt)	112.86	Located in the footprint of the LNG plant on Curtis Island.

Plate 13.1
Auckland Creek on mainland, showing example of tidal - low to moderate sinuosity river style



Source:
Place names from DME. Watercourses from Alluvium.
Wetlands from Qld Qetlands Programme V2 digital mapping.
Directory of Important Wetlands from DSEWPC.
Project area and digital elevation modeal from Coffey Environments.

coffey environments

Date: 17.11.2011
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File Name: 7033_07_F13.02_GIS_GL

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Mapped wetlands

Figure No: **13.2**

Calliope River Basin Water Quality

Two watercourses are located near project activities that may impact on their water quality. Boat Creek flows approximately 500 m to the north of the mainland tunnel entry shaft and tunnel spoil disposal area, and Targinie Creek is located near TWAF 8.

The baseline water quality of Boat Creek was established using data from water and sediment monitoring and metal accumulation in oysters undertaken as part of the Port Curtis Integrated Monitoring Program (DERM, 2011d). Monitoring has been undertaken since 2005 within the lower estuarine reaches of Boat Creek. Results show lower pH, higher conductivity and higher concentrations of bioavailable aluminium, copper, cobalt and manganese in comparison to other Port Curtis estuaries. The monitoring suggests that groundwater intrusion or surface water runoff from the upper reaches of Boat Creek is influencing the water quality within the area.

Targinie Creek, in the vicinity of TWAF 8, is ephemeral in nature with flows only present following rainfall events. No water quality monitoring was therefore possible for this creek near the TWAF 8 site. Water quality monitoring conducted in May 2010 as part of the Australia Pacific LNG Project EIS (WorleyParsons, 2010) has been used to establish the baseline water quality of Targinie Creek for the purposes of this assessment. Sampling was undertaken within the lower estuarine reach, well downstream of the proposed TWAF 8 where flows are more constant.

The results showed concentrations of ammonia (80 to 100 µg/L), total nitrogen (600 to 800 µg/L) and total phosphorous (230 to 3,160 µg/L) exceeding the Queensland Water Quality Guidelines (DERM, 2009b) for the Central Coast region mid estuarine systems. Assessments of the stream conditions within the basin as part of the 2000-2002 National Land and Water Resources Audit (ANRA, 2002) found the condition of the Calliope River Basin was substantially modified based on nutrients and suspended solid loads in the waterways. Metal concentrations were mostly below detection limits, as were levels of benzene, toluene, ethylbenzene, xylenes and polycyclic aromatic hydrocarbons (all less than 2 µg/L). Total petroleum hydrocarbons were also measured showing all but one level below detection limits at all locations.

Water quality of the Calliope River and Auckland Creek is discussed in Chapter 16, Marine Water Quality and Sediment. The area of these watercourses impacted by project activities are classified as tidal estuarine and are heavily influenced by saltwater intrusion from Port Curtis.

13.3.4 Curtis Island Basin

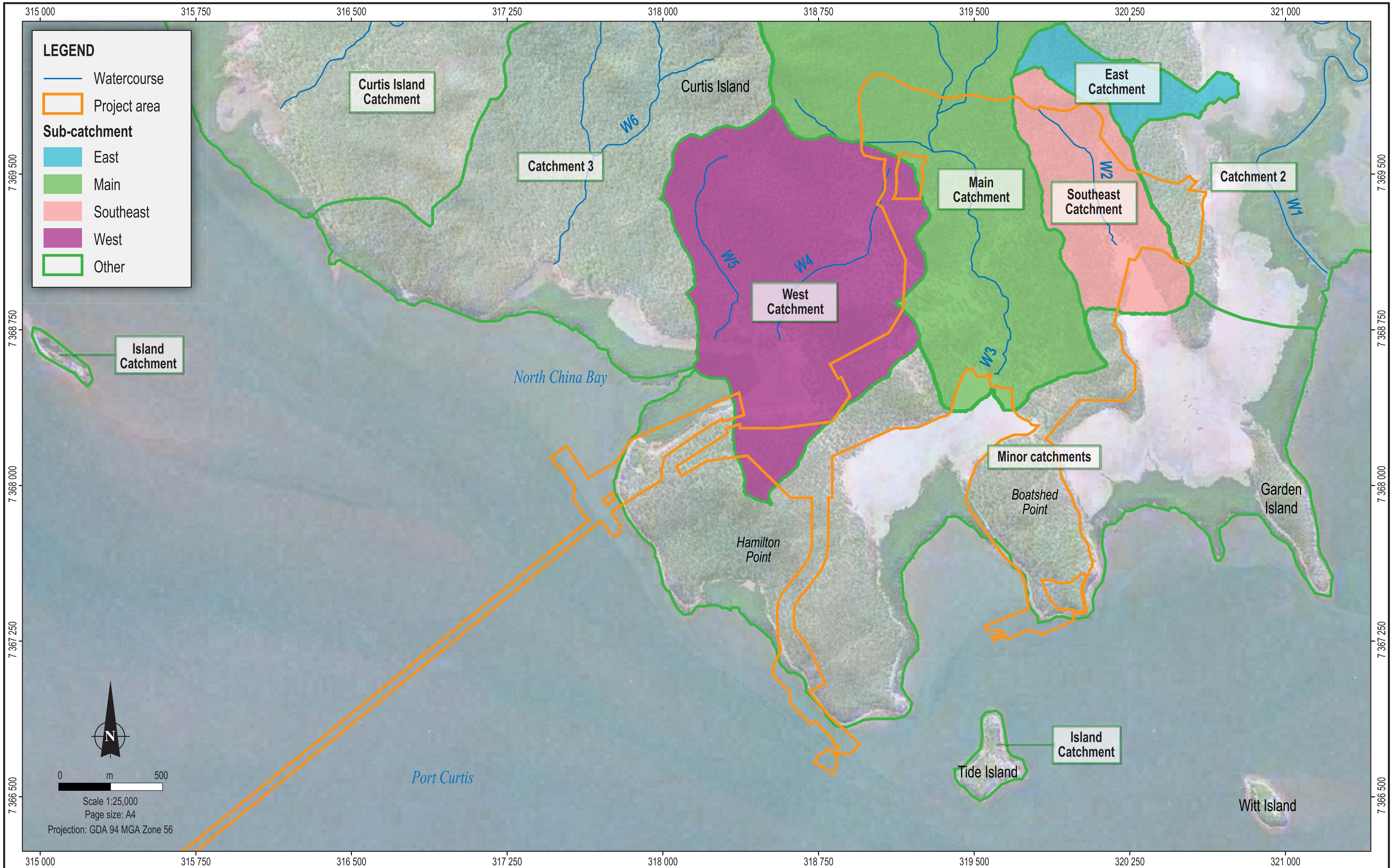
The LNG plant will be constructed within the boundaries of three main and several minor coastal catchments on Curtis Island as shown in Figure 13.3. The catchments include:

- Main catchment.
- West catchment.
- Southeast catchment.
- Minor catchments along the coast.

The sub catchments are mostly steep with multiple gully lines draining to the main watercourse. The catchment has an area of 1.86 km^2.

Hydrology

Ephemeral streams pass through the LNG plant site. The largest is an unnamed watercourse with an 8 m wide bed and 2.5 m banks, indicating the stream conveys large flows. A broad floodplain is also a feature of the site, suggesting that overbank flows occur during peak flows. Hydrological modelling carried out for the Curtis Island catchment suggests a mean annual runoff in the order of 79,000 ML/yr.



Source:
Place names from DME.
Sub-catchments and watercourses from Alluvium.
Project area from Coffey Environments.
Imagery from SPOT (2004-2007).

coffey environments

Date:	22.11.2011
MXD:	7033CA_07_GIS180_v1_2
File Name:	7033_07_F13.03_GIS_GL

Arrow Energy

Arrow LNG Plant

arrow energy go further

Sub-catchments and watercourses at the LNG plant site

Figure No: 13.3

A hydrologic analysis was undertaken to estimate the magnitude and frequency of stream flows within the four sub catchments (see Figure 13.3) that could be expected at the site. This was undertaken to aid in the design of the stream diversions necessary during the construction of the LNG plant. Peak discharge rates for stream flows at the LNG site are shown in Table 13.7. The data shows the flow rates of the ephemeral streams within the project area could be significant.

Table 13.7 Peak discharges for subcatchments surrounding the LNG plant site

	Peak Flow Rate, Q, (m^3/s) for Various Average Recurrence Intervals (ARI)						
Subcatchment Locations	**1-year**	**2-year**	**5-year**	**10-year**	**20-year**	**50-year**	**100-year**
East Outfall	0.9395	1.7082	2.9727	3.7569	4.877	5.9507	7.0147
Southeast Outfall	1.9398	3.3325	5.6243	7.1976	9.3183	11.658	13.8676
West Outfall	4.4952	7.9542	13.4284	16.8996	21.6028	27.2644	32.2567
Main Outfall	6.9891	11.9611	20.0898	25.3312	32.5936	41.6173	49.5091

Water Quality

The ephemeral nature of the watercourses on Curtis Island makes water quality monitoring very difficult. Consequently, specific data was not obtained for watercourses W1 to W6 that occur within the catchments in the project area. No information is available from DERM databases on water quality at the LNG plant site. Historical land use on the island included cattle grazing and the runoff quality is expected to be similar to that for low intensity grazing. The island is no longer used for cattle grazing.

Riparian Vegetation

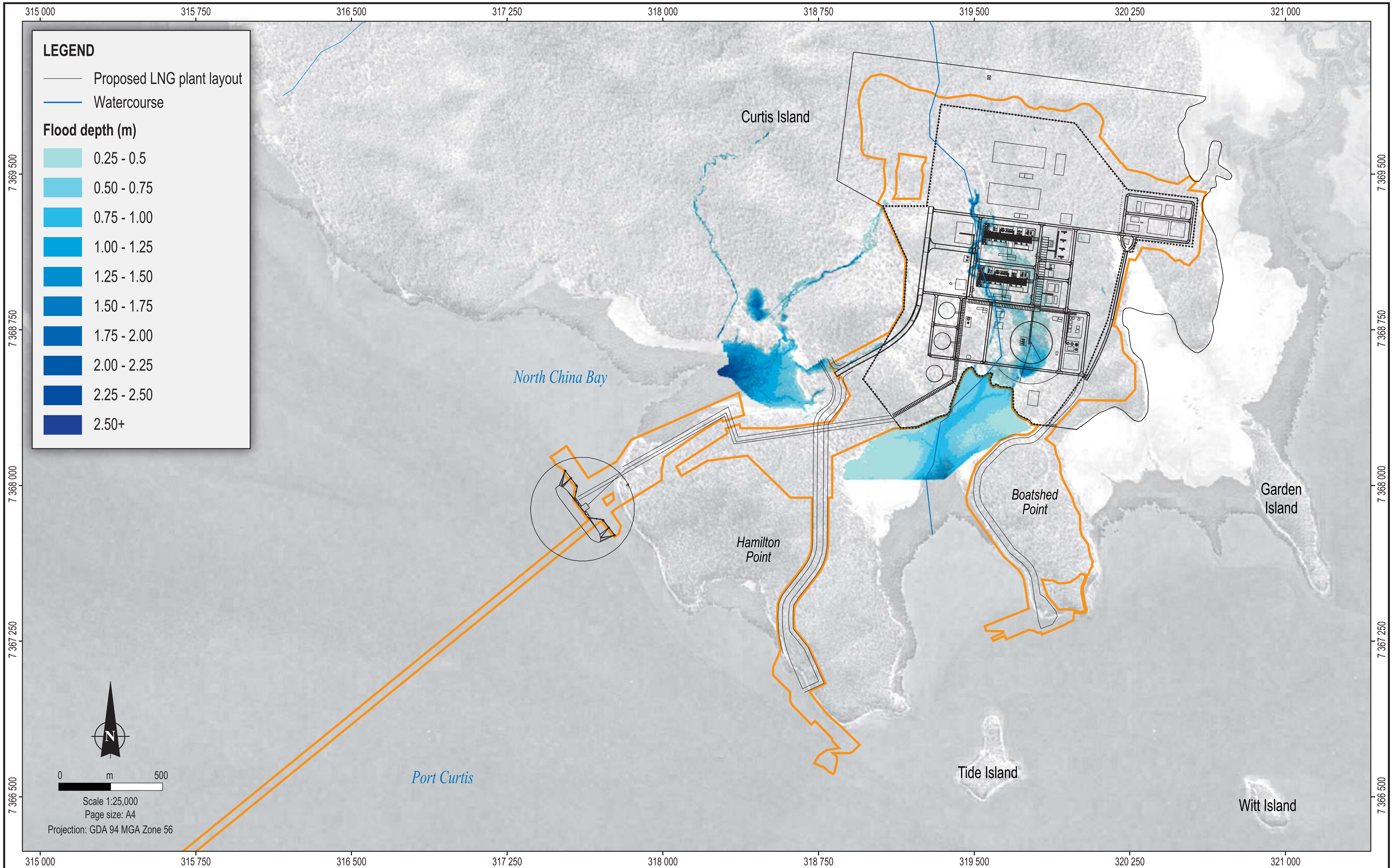
The riparian vegetation of W2, W4, and the upper reach of W3 within the area of disturbance of the LNG plant are currently intact. The lower reach of W3 has been disturbed by prior agricultural use.

Wetlands

Wetlands on Curtis Island are largely undisturbed with the exception of areas that have had some access by vehicles or prior agricultural use. The coastal and subcoastal floodplain tree swamps found within the project area play an important role in the hydrological regime of the coastal and subcoastal area because they absorb and filter water before it enters other wetland systems such as mangrove swamps and estuaries. Figure 13.2 and Table 13.6 identify the wetlands that have the potential to be affected by project activities.

Flood Extents under Existing Conditions

Flood modelling at the LNG plant site within the vicinity of W2, W3 and W4 showed that a significant portion of the central southern end of the site would be inundated by a 100 year event. The flood extent for the 100 year, 1.5 hour event is shown in Figure 13.4. According to the modelling, overland flow depths usually remained below 1 m and were the result of flash flooding, which would rapidly subside. The modelling predicted velocities of 1 m/s, although this was deemed to rarely coincide with areas of high depth. Flood hazard is predicted to be low to moderate at the site.



Source:
Place names from DME.
Flood depth and watercourses from Alluvium.
Proposed LNG plant layout from Arrow Energy.
Project area from Coffey Environments.
Imagery from SPOT (2004-2007).

coffey environments

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File Name: 7033_07_F13.04_GIS_GL

Arrow Energy

Arrow LNG Plant

arrow energy go further

Existing conditions 100 year average recurrence interval flood extents

Figure No: 13.4

Geomorphic Categorisation

A number of river styles will be affected by the construction and operation of the LNG plant on Curtis Island:

- Partly confined low sinuosity. This river style is found in the reaches of waterways W2 and W3 within the area of disturbance of the LNG plant. Both watercourses have been partially disturbed by agricultural activities. Plate 13.2 shows a reach of W2 and provides an example of this river style on Curtis Island.
- Partly confined meandering planform. This river style is found along the upper reach of W3 on Curtis Island, during the transition from hillslope and valley to floodplain. This watercourse is partially disturbed from agricultural activities. Plate 13.3 shows an example of this river style within the area of disturbance of the LNG plant.
- Valley fill. Waterway W3 is an example of this river style and has been partially disturbed by past agricultural activities. It is located within the area of disturbance of the LNG plant. Plate 13.4 shows an example of this river style.

13.3.5 Sensitivity of Environmental Values

The following attributes were used to define the environmental values of the surface water assets found within the study area as specified within the terms of reference for the project:

- Physical integrity, fluvial processes, form and morphology of watercourses and wetlands including riparian vegetation.
- Hydrology of watercourses and wetlands in the catchment – quantity, duration and timing of stream flows.
- Primary and secondary recreational use.
- Physical and hydrologic character contributing to cultural and spiritual values.

The EPP (Water) and the ANZECC (2000) State of the Environment Reporting Taskforce were considered when establishing the environmental values for the project area and assisted in quantifying the impact the project will have on the values. The EPP (Water) identifies the environmental values and management goals for Queensland waters and sets out the water quality guidelines and water quality objectives to enhance or protect environmental values. The ANZECC (2000) guide establishes inland water environmental indicators for surface water assets. The purpose of the indicators is to ascertain the condition of stream and river hydrology within a given area.

The sensitivity of the environmental values was determined for each project site and depends on the condition of the catchments, watercourses and wetlands at each location. The sensitivity of the environmental values is presented in Table 13.8.

The sensitivity of environmental values found at the various project locations is low, with the exception of waterway W3 within the LNG plant site on Curtis Island and dredge site 1 located at the mouth of the Calliope River. Waterway W3 will be diverted as part of the construction of the LNG plant on Curtis Island and was given a sensitivity ranking of moderate. The location of dredge site 1 at the mouth of the Calliope River was given a sensitivity ranking of moderate, as the river was deemed to be resilient to minor changes but susceptible to bed and bank erosion once disturbed.

Plate 13.2

W2 on Curtis Island, showing example of partly-confined with low sinuosity river style

Source: Coffey

Plate 13.3

Upper reach of W3 on Curtis Island, showing an example of partly-confined with meandering planform river style

Source: Coffey

Plate 13.04

W3 on Curtis Island, showing an example of a valley fill reach river style

Source: Coffey

Table 13.8 Sensitivity of environmental values at sites of project activities

Site	Surface Water Asset	Conservation Status	Intactness	Uniqueness or Rarity	Resilience to Change	Replacement Potential	Sensitivity
LNG plant	Local catchments and waterway W3 (valley fill reach).	None.	Largely intact but some disturbance of waterways from former clearance and agriculture.	Not unique or rare. Limited or no recreational use.	Valley fill reach susceptible to erosion if disturbed.	There are many similar waterways in the region.	Moderate
LNG plant	Local catchments; waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point.	Partly within coastal wetlands within Port Curtis Wetlands (Directory of Important Wetlands).	Largely intact but some disturbance of waterways from former clearance and agriculture. Wetlands largely intact with limited disturbance.	Not unique or rare. Limited or no recreational use.	Headwater streams are resilient to change. Resilience decreases as watercourses near marine areas through footprint of LNG plant.	There are many similar waterways and extensive wetlands around Curtis Island and in the region.	Low
TWAF 7	Auckland Creek catchment and Auckland Creek including estuarine wetlands.	None.	In poor condition due to former land use with almost complete clearance.	Primarily watercourse with limited fringing mangroves not unique or rare.	Subject to natural geomorphic change over time through erosion and deposition. Can be stable for many years and subject to rapid change in extreme flow events.	Not applicable as the site is in poor condition.	Low
TWAF 8	Targinie Creek catchment and Targinie Creek.	None.	Moderate to good condition.	Not unique or rare.	Resilient to change to some extent but can be subject to change if highly disturbed.	There are many similar waterways in the area and region.	Low
Feed gas pipeline	Boat Creek catchment and Catchment 1.	Not available.	Area to be disturbed has no mapped waterways. Disturbances will be in the mainland tunnel entry shaft and tunnel spoil disposal area.	Not available.	Not available.	Not available.	Not available.

Table 13.8 Sensitivity of environmental values at sites of project activities (cont'd)

Site	Surface Water Asset	Conservation Status	Intactness	Uniqueness or Rarity	Resilience to Change	Replacement Potential	Sensitivity
Mainland tunnel entrance and tunnel spoil disposal area	Boat Creek catchment, Catchment 1 and estuarine salt flats and salt marshes.	Coastal wetlands within Port Curtis Wetlands (Directory of Important Wetlands).	No mapped watercourses will be disturbed. Disturbance confined to estuarine salt flats and marshes, which are largely intact.	Not unique or rare.	Resilient to change.	Many areas of similar extensive wetlands in the area and region.	Low
Launch site 1	Calliope River catchment and Calliope River including estuarine wetlands.	Coastal wetlands within Port Curtis Wetlands (Directory of Important Wetlands).	Disturbed area of Calliope River estuary bank.	Not unique or rare.	Resilient to change due to location on inside bend of Calliope River.	Many areas of similar extensive estuarine riverbank in area and region.	Low
Dredge site 1	Calliope River catchment and Calliope River.	Coastal wetlands within Port Curtis Wetlands (Directory of Important Wetlands).	Currently intact reach of estuarine bed.	Not unique or rare.	Resilient to minor change but could result in bed and bank erosion if changes are significant.	Many areas of similar extensive estuarine reaches in area and region.	Moderate

13.4 Issues and Potential Impacts

The following section describes the issues and potential impacts on hydrology, geomorphology, and water quality from project construction, operation, and decommissioning activities. Impacts are largely due to:

- Erosion and sedimentation during earthworks at all sites.
- Loss of wetlands and riparian vegetation at the LNG plant site and MOF on Curtis Island, and at the mainland tunnel entry shaft.
- Diversion of an ephemeral stream around the LNG plant on Curtis Island.

13.4.1 Erosion and Sedimentation

Erosion and increases in sediment loads in watercourses will occur during rainfall and runoff events at all project sites as areas are cleared of vegetation and site preparation earthworks are carried out. Runoff from soil stockpiles will also carry sediment into watercourses. Increased erosion and sedimentation will be especially prevalent during heavy rainfall events. Stormwater may become contaminated with hydrocarbon or chemical residues in storage facilities such as bunds. If a storm event is large enough, bunds may overflow, potentially releasing contaminated stormwater. Runoff may carry oil and grease (collected on access tracks and hard standing areas) into watercourses. Spills of chemicals or fuels are also potential sources of contamination if they enter watercourses at project sites. Operating vehicles and machinery near stream banks and within the riparian zone may cause erosion and subsequent deposition of sediment within waterways.

Flooding during high rainfall events could increase erosion and sedimentation rates in areas of exposed earth. This could especially be problematic during construction of TWAF 7 and upgrades to the access road to TWAF 7. TWAF 7 is located within the meander bend of the lower reach of Auckland Creek. The alteration of the existing road crossing of Auckland Creek could change hydraulic conditions and flood flows in the watercourse with resulting offsite impacts. A large flood event or multiple flooding events will change the channel at the road crossing neck cutoff meander loop.

A recent flood study of the Calliope River conducted by Sargent (2006) used historic stream flow records from the Castlehope gauge (located outside the project area) to assess current flood risk downstream of the gauging station for the 10-, 20-, 50-, 100- and 500 year ARI events. Flood mapping for the lower Calliope River was included in this study (see Appendix 5, Surface Water Impact Assessment). The data suggests that launch site 1 is within a zone of flood inundation during varying events from a 10 year ARI to a probable maximum flood.

Flood modelling completed for Curtis Island shows that while a significant portion of the south end of the proposed site could be inundated during a 100 year event, overland flow depths should remain below 1 m and would largely be a result of flash flooding, which would rapidly subside. The flood extent for the 100 year, 1.5 hour event is shown in Figure 13.4.

The magnitude of the impacts of erosion and generation of sediment from project activities ranges from moderate to high with overall significance from **low to moderate.** The magnitude of impacts has been established by averaging the site-based significance ratings.

13.4.2 Loss of Wetlands and Riparian Vegetation

Wetlands are important to surface water hydrology and play a role in regulating drainage and overland flow. Riparian vegetation is important in maintaining the morphology of watercourses by stabilising banks and moderating flows by increasing roughness and subsequently reducing velocities.

Wetland areas will be lost and areas of riparian vegetation will be damaged or removed during construction. Wetlands will either be removed as part of the stream diversion required at the LNG plant site or will be infilled during the construction of the LNG plant, MOF, and tunnel entry shaft.

The estimated loss of wetland areas as a result of project activities is set out in Table 13.9. The loss of wetland areas may change based on the final design of the project. Riparian vegetation along the reaches of W2, W3, and W4 within the LNG plant area of disturbance will be lost during the stream diversion and construction of the LNG plant.

Table 13.9 Estimated loss of wetland areas as a result of project activities

Wetland Classification	Location	Area (ha) to be Removed or Infilled during Construction	Percentage in the Project Area to be Removed
Coastal/subcoastal floodplain tree swamps	LNG plant	11.3	17%
	Launch site 1	1.7	
Estuarine salt flats and salt marshes	LNG plant	1.7	76%
	TWAF 7	1.3	
	Mainland tunnel entry shaft	55.2	
Estuarine mangrove and related tree communities	Boatshed Point MOF	<0.1	8%
	TWAF 7	<0.1	
	LNG plant	5.78	

The most significant loss of wetlands in the project area will occur at the mainland tunnel entry shaft (estuarine salt flats and salt marshes) with a **moderate** significance of impacts during construction of the LNG plant. The wetlands in this area are highly disturbed due to vegetation clearance, development and continuing vehicle access. Infilling of estuarine salt flats and saltmarshes at the LNG plant site will have a **moderate** significance of impacts within the vicinity of waterways W2, W3 and W4 draining to Boatshed Point and Hamilton Point, and a **moderate** significance of impacts within the valley fill reach of waterway W3. There is a significant amount of this type of wetland within the project area. The floodplain tree swamps on Curtis Island will be infilled during the construction of the LNG plant. The wetlands on Curtis Island are largely undisturbed, with the exception of some areas accessed by vehicles or that have had prior agricultural use. The wetlands at Launch site 1 and TWAF 7 have a **low** significance of impacts.

13.4.3 Curtis Island Stream Diversions

Several ephemeral waterways will be infilled during construction of the LNG plant on Curtis Island, with subsequent stream diversions needed to control overland flow from three of the subcatchments within the area.

The cut and fill earthworks will alter the stream flow within these catchments and will involve the diversion of the primary drainage pathway of waterway W3. A total of 2.6 km of minor waterways will be lost due to diversion around the LNG plant site. Surface water flows from upstream of the LNG plant will be intercepted, kept separate from facility runoff, diverted around the facility and discharged downslope into other waterways that will be modified to manage additional flows.

The watercourses that will be diverted are ephemeral and only contain water following heavy rainfall events. As such, the sensitivity of the environmental values of these watercourses is moderate for the upper reach of waterway W3 within the area of disturbance of the LNG plant, and low for waterways W2, W3, and W4 that drain to the estuarine wetlands adjacent to Boatshed Point and Hamilton Point within the area of disturbance of the LNG plant (see Figure 13.3). The magnitude of the impacts of infilling the watercourses W2, W3 and W4 within the LNG plant site and subsequent diversion of the largest stream around the site has a **moderate** significance of impacts. The valley fill reach of W3 that will be infilled and replaced with a stream diversion has a **moderate** significance of impacts.

13.4.4 Calliope River Mouth Dredging

Dredging at the mouth of the Calliope River will potentially cause changes to the tidal hydraulics and regime equilibrium conditions, flood-related sediment transport causing local bed erosion, and geotechnical bank slope stability related to either undermining of bank toe areas or surcharging of the bank itself with works or water table changes. Following dredging, an increase in cross-sectional area of the river is expected, although the exact increase (i.e., the relative amount of widening and deepening) is less certain. Where there is a major bend in the channel upstream, erosion can be expected to be most significant on the outside of the bend. In straighter sections, the erosion may be more evenly distributed across the channel, depending on the amount of erosion experienced by the riverbed and banks.

Modelling of the post-dredging flood levels in the Calliope River showed very little difference in peak flood levels (Appendix 8, Coastal Processes, Marine Water Quality, Hydrodynamics and Legislation Assessment). There was a small reduction in flood levels towards the upstream end of the Calliope River due to the opening up of the Calliope channel. This reduction will have the effect of reducing catchment flooding but will have little effect in terms of combined catchment/storm surge flooding. Peak flood velocities for the post dredging scenario show some small differences (both positive and negative) in the order of 0.1 m/s to 0.2 m/s.

The magnitude of impacts of dredging at the mouth of the Calliope River and its effect on post-dredging flood levels of the Calliope River is low with an overall significance rating of **minor**.

The impact of dredging on storm surge and tidal inundation within the Calliope River is discussed in Chapter 15, Coastal Processes.

Significance of Potential Impacts

Table 13.10 summarises the impacts based on the environmental values found at each project location.

Table 13.10 Significance of impacts on hydrology and geomorphology

Site	Surface Water Asset	Sensitivity	Impacts	Magnitude	Significance
Construction of LNG plant	Local catchments and valley fill reach of waterway W3.	Moderate	• Upstream erosion and downstream deposition.	Moderate	Moderate
Construction of LNG plant	Local catchments and waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point and Hamilton Point.	Low	• The wetlands identified as coastal/sub coastal floodplain tree swamps (11.3 ha) will be removed as part of the LNG plant construction process and the waterway will be replaced with a diversion. • In the footprint of the LNG plant, an area of approximately 2.3 ha of estuarine salt flats and salt marshes will be infilled as part of the construction process. • Possible loss of wetlands identified as estuarine – mangrove and related tree communities: Boatshed Point (0.5 ha) and Hamilton Point (0.6 ha). • Erosion and generation of sediment from rainfall and runoff. • Generation of sediment from tidal movement in areas disturbed within high-tide extents. • Inundation of parts of the construction site from flooding. • Changes to direction and discharge points of surface flow paths. • Disposal of hydrotest water, erosion and generation of sediment if discharged from sediment retention pond.	High	Moderate
Construction of TWAF 7	Auckland Creek catchment and Auckland Creek including estuarine wetlands.	Low	• Riverine flooding during construction, resulting in erosion and generation of sediment in areas below flood level. • Tidal inundation of road crossing construction works results in soil disturbance and generation of sediment. • Changes in the hydraulic conditions of flood flows, resulting in offsite impacts from alterations of the existing road crossing. • A large flood event or events could result in channel change at the road crossing neck cutoff of the meander loop resulting in damage to infrastructure and possible additional erosion. • The altered crossing will remain after the site is decommissioned. If the design of the altered crossing does not retain or increase the hydraulic capacity of the crossing, the post-decommissioned crossing could result in adverse hydraulic conditions compared with preconstruction conditions, leaving ongoing potential for offsite impacts during flooding.	Moderate	Low

Table 13.10 Significance of impacts on hydrology and geomorphology (cont'd)

Site	Surface Water Asset	Sensitivity	Impacts	Magnitude	Significance
Construction of TWAF 8	Targinie Creek catchment and Targinie Creek.	Low	• Erosion and generation of sediment from rainfall and runoff including increased runoff from sealed and disturbed surfaces. • Inundation of parts of the site and infrastructure from flooding. • Localised changes to flood extents.	Moderate	Low
Construction of launch site 1	Calliope River catchment and Calliope River including estuarine wetlands.	Low	• Wetlands identified as coastal/subcoastal floodplain tree swamps (up to 1.7 ha) will be removed or disturbed as part of the construction process. • An area of up to 1.6 ha of estuarine salt flats and salt marshes is planned to be removed or disturbed as part of the construction process. • Erosion and sediment generation.	Moderate	Low
Construction of mainland tunnel entry shaft and tunnel spoil disposal area	Boat Creek catchment and catchment 1 and estuarine salt flats and salt marshes.	Low	• An area of approximately 52.4 ha of wetlands mapped as salt flats and salt marshes will be infilled for the mainland tunnel entry shaft and tunnel spoil disposal area. • Erosion and generation of sediment from rainfall and runoff. • Generation of sediment from tidal movement in areas disturbed within high-tide extents. • Inundation of parts of the construction site from flooding.	High	Moderate
Construction of dredge site 1	Calliope River catchment and Calliope River.	Moderate	• Potential sedimentation if supply exceeds transport. • Potential erosion if transport exceeds supply.	Moderate	Moderate
Operation of LNG plant	Local catchments and waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point.	Low	• Erosion and generation of sediment from rainfall and runoff. • Changed surface flow paths and mixing of surface flows generated from on and off site.	Moderate	Low
Operation of launch site 1	Calliope River catchment and Calliope River including estuarine wetlands.	Low	• Erosion and sediment generation from disturbed areas and boat wash/wave action. • Tidal inundation of infrastructure.	Moderate	Low

Table 13.10 Significance of impacts on hydrology and geomorphology (cont'd)

Site	Surface Water Asset	Sensitivity	Impacts	Magnitude	Significance
Operation of dredge site 1	Calliope River catchment and Calliope River.	Moderate	• Maintenance dredging of the channel could result in upstream headward bed deepening and bank slumping.	Moderate	Moderate
Decommissioning of LNG plant	Local catchments and waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point.	Low	• Post decommissioned waterways erode at greater than preconstruction rates, resulting in sediment discharges downstream. • Erosion and generation of sediment from rainfall and runoff.	Moderate	Low
Decommissioning of launch site 1	Calliope River catchment; and Calliope River including estuarine wetlands.	Low	• Erosion and sediment generation.	Moderate	Low

13.5 Avoidance, Mitigation and Management Measures

This section identifies the avoidance, mitigation and management measures to address the impacts of the project on the surface water hydrology, geomorphology and water quality.

13.5.1 Designing out Impacts

The principles described below will be incorporated into detailed design of the project to minimise the impacts on surface water hydrology and geomorphology.

Prior to construction commencing, a site drainage plan will be developed to define how the civil construction will address site drainage, stormwater management, erosion control and stockpile placement. Risks relating to flood events will also be addressed with appropriate mitigation measures to minimise erosion and surface water quality issues. [C11.16]

Flooding

Measures to protect project infrastructure from flooding include the following:

- Locate sensitive project infrastructure to avoid the 1:100 year ARI event where practical. [C13.01]
- Design stream diversions and adjacent flood corridors to manage a minimum of a 1:100 year ARI event. [C13.02]

Further modelling may be required to inform the design phase including:

- Site specific flood assessment during detailed design of TWAF 8 (if this option is pursued).
- The impact posed by flooding to the road crossing and TWAF 7 (if this option is pursued). Further modelling may also be required if the road access is modified in such a way as to alter the hydraulic capacity of the neck of Auckland Creek.

Stream Diversion

Two options for the stream diversion around the LNG plant are being considered as shown in Figure 13.5. Several catchments will be intercepted and topographic constraints may favour one option over the other. The two options are:

- Option 1: The diversion of flows to the east and west around the LNG plant bench. A western diversion channel will be designed to discharge to the existing ephemeral watercourse that drains to North China Bay. The eastern diversion would discharge to Port Curtis northeast of the LNG plant administration and workshop complex.
- Option 2: The use of diversion channels in combination with the toe drains that extend to the east and west around the LNG plant bench. This option would catch any runoff from the LNG plant bench batters. The western toe drain would then discharge into Port Curtis within the embayment of Boatshed Point, while the eastern toe drain will discharge to Port Curtis northeast of the administration and workshop complex.

A decision on the preferred option will occur during the FEED phase of the project.

The average existing 50 year ARI velocities through the main channel (i.e., watercourse W3 through the site) are 1 m/s to 2.5 m/s. Without the possibility of overland flow, the diversions will need to transport the entire flow in channel. Velocities are expected to increase to approximately 3.6 m/s. Both diversion options will require rock armouring to minimise long term erosion.

The diversion will be designed to keep velocities to a minimum to lessen the effects of erosion. Specifically, the stream diversion(s) design will consider the following principles:

- Design the stream diversion at the LNG plant site to prevent erosion or deposition at greater than natural rates; as a corridor, which may contain a formalised channel and constructed flood plain zone; and to allow for the transport of sediment. [C13.03]
- Consider post decommissioning channel form for the stream diversion design and provide for a self-sustaining waterway, without the need for maintenance beyond the life of the project. [C13.30]

Stormwater Management System

Stormwater will need to be managed across all project sites during construction and operation as this will help control the runoff of sediment and other pollutants. A conceptual design has been developed for the project stormwater systems (see Appendix 6, Stormwater Quality Impact Assessment). Detailed design will be taken forward in the FEED and detail design phases.

Construction

The principles described below will be incorporated into detailed design of the stormwater management system during construction.

- Treat stormwater generated from TWAF 7, TWAF 8, launch site 1, the tunnel shaft entry site and tunnel spoil disposal area in temporary sediment basins located at each site. [C13.08]
- Divert sediment-laden water from disturbed areas at the LNG plant site to temporary sedimentation ponds. [C13.09]
- Manage all surface water generated from the LNG plant by a stormwater treatment system to ensure discharged water complies with regulatory requirements. [C13.10]

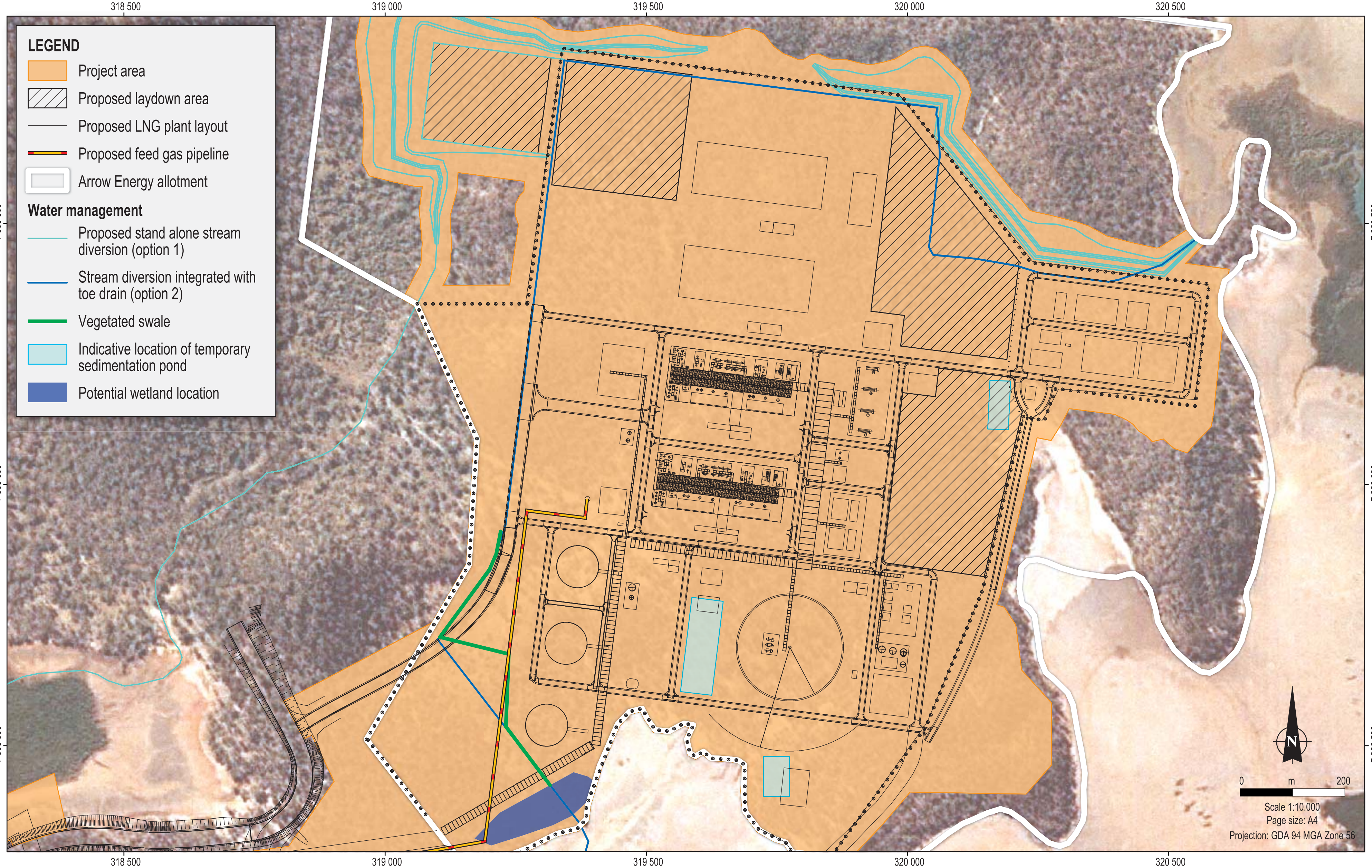
The layout of the proposed stream diversion and stormwater management system is shown in Figure 13.5.

Operation

The water quality objectives for the Port Curtis area (as defined in the EPP (Water)) were used to develop the conceptual stormwater treatment system. To meet the objectives, the stormwater quality treatment train was developed in accordance with the Water Sensitive Urban Design Technical Guidelines (Healthy Waterways, 2006).

The principles described below will be incorporated into detailed design of the stormwater treatment system during operation.

- Only treat surface water generated within the LNG plant site in the stormwater treatment system. Divert runoff generated outside the LNG plant site away from the LNG plant site stormwater system via the proposed stream diversion. [C13.26]
- Collect contaminated stormwater for treatment before discharge. [C13.25]
- Treat all surface water and stormwater generated within the LNG plant site in a stormwater system to ensure discharged water meets regulatory requirements. [C13.24]
- Remove litter and other debris from within the treatment system, especially around the inlet and outlet structures. [C13.28]
- Routinely inspect and maintain the stormwater treatment system. [C13.23]



Source:
Proposed LNG plant layout from Arrow Energy.
Potential wetland location, temporary sediment basins and vegetated swale from Alluvium.
Project area and feed gas pipeline from Coffey Environments.
Imagery from SPOT (2004-2007).

coffey environments

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Arrow Energy

Arrow LNG Plant

arrow energy go further

Proposed stream diversion and stormwater management for the LNG plant

Figure No: 13.5

- Keep areas within and around the stormwater treatment system free of weeds and other undesired overgrowth. [C13.29]

The location of the tunnel shaft entry and TWAF sites will not require operational phase stormwater treatment arrangements as the TWAF will be decommissioned and the tunnel entry site will be rehabilitated following the completion of the construction phase.

Site-specific Considerations

- Design TWAF 8 to minimise disturbance to the 'Of Concern' RE 11.3.4 (*Eucalyptus tereticornis* and *Eucalyptus* spp. tall woodland on alluvial plains) to maintain connectivity of habitat along the Targinie Creek riparian zone. [C13.04]
- Where practical, align the perimeter fence at TWAF 8 to adopt the alignment of the existing fence where it crosses Targinie Creek. [C13.05]
- Design any intra-site access road crossing of Targinie Creek at TWAF 8 to include box culverts (or similar) to enable fauna movement under the road and along the wildlife corridor. [C13.06]
- Keep the footprint of the mainland tunnel entry shaft and tunnel spoil disposal area to a minimum of 500 m clear of Boat Creek. [C13.07]

13.5.2 Erosion and Sedimentation

The following measures will be implemented to manage the effects of erosion and sedimentation during construction and operation of the LNG plant:

- Avoid works near stream banks during periods of heavy rainfall where practical. If works cannot be timed to avoid heavy rainfall, adopt additional measures, such as the use of berms and silt fences. [C11.09]
- Use control measures such as drains, swales, silt fencing and sediment traps around the lower slopes of erodible stockpiles. [C11.12]
- Implement sediment and erosion control measures upslope of watercourses, wetlands and coastal areas or in areas with sodic soils to minimise increases in natural sediment discharge. Measures may include sediment traps, silt fencing, riprap, contour banks, detention dams, sediment ponds and vegetation and diversion berms. [C11.11]
- Design and construct a barrier and sediment control pond to trap sediment leaving the LNG plant site before it enters the Port Curtis marine environment or other surface waters. [C11.22]
- Protect stream channels in soils prone to gully erosion with rock armouring or other appropriate structures and material to reduce the erosion potential. [C11.23]
- Provide secondary containment for any fuel, oil or chemicals in above ground storage facilities in accordance with applicable Australian standards. [C13.11]
- Develop appropriate spill prevention and response plans to cover project activities and the types and quantities of fuel, oil and chemicals held at each site. [C13.12]
- Train all relevant personnel in spill response and recovery procedures. [C13.13]
- Maintain live capacities of storage bunds to maximise capacity in the event of a storm or spill. [C13.14]

- Do not abstract freshwater from watercourses or dispose of effluent directly into freshwater watercourses, except clean stormwater. [C13.15]
- Where waterway crossings are necessary, cross ephemeral streams in preference to permanent streams, where practical. Where pipeline waterway crossings are necessary, approach stream crossings perpendicular to the stream where possible, to reduce bank erosion risk and minimise the footprint within the bed and riparian zone. [C13.16]
- Where works are required in watercourses, they will be confined to reduced width construction right of ways that preserve, to the extent possible, the integrity of the riparian vegetation and any associated wildlife corridors. [C13.22]
- Manage surface runoff to reduce the concentration of surface flow, particularly in erodible soils. Provide drainage channels with suitable design features to minimise erosion where surface runoff is disrupted by roads, tracks, fencing and buildings. Place structures within drainage channels to reduce flow velocity where appropriate. [C11.07]
- Re-profile and reinstate topsoil and re-establish surface drainage lines and vegetation, where practicable, during decommissioning and rehabilitation of the LNG plant site. [C11.29]
- Undertake earthworks and rehabilitation activities to facilitate drainage and reduce the potential for standing water to accumulate. [C13.20]
- Avoid discharging tail water from the tunnel spoil disposal area into Boat Creek. [C13.21]

13.5.3 Loss of Wetlands and Riparian Vegetation

Specific measures to address impacts on wetlands above the highest astronomical tide are included in Chapter 18, Freshwater Ecology. Measures to address impacts on wetlands below the highest astronomical tide are included in Chapter 19, Marine and Estuarine Ecology.

The following measures will be implemented during project activities in order to mitigate against the loss or damage to wetlands and riparian vegetation:

- Where practical, ensure that grasses and other ground cover remain in place to assist with trapping mobilised sediments. [C13.17]
- Avoid the use of herbicides within riparian zones or directly over watercourses. Where this is not possible, use products specifically approved for this purpose. [C13.18]
- Develop site-specific vegetation management plans to reinstate native plant species to areas to be rehabilitated, including riparian margins. Exotic sterile grasses may be used in areas where temporary cover is required to aid in soil stabilisation. [C13.19]

13.5.4 Calliope River Dredging

No specific mitigation is proposed. A dredge management plan will be developed to cover all dredging activities for the project including those required for access to launch site 1 in the Calliope River. The plan will include requirements for monitoring any changes in the hydrology and geomorphology of the Calliope River.

13.6 Residual Impacts

This section assumes the mitigation measures have been applied. Residual impacts occur even after the implementation of mitigation measures.

The aim of the mitigation measures is to provide for self-sustaining hydrologic and geomorphic function during operation of the project and post decommissioning. If mitigation measures are implemented effectively, waterways will operate in a self-sustaining manner without the need for ongoing maintenance. With the exception of the diversion of minor waterways on Curtis Island, all waterways will continue to function in their pre-project condition. The diversion of minor waterways on Curtis Island will also function in a geomorphically and hydrologically self-sustaining manner, but with altered flow paths.

Table 13.11 identifies the residual impacts that will occur once mitigation measures have been applied.

Table 13.11 Residual impacts from project activities

Site	Surface Water Asset	Residual Impacts (post mitigation measures)	Significance
Construction of LNG plant	Local catchments and valley fill reach of waterway W3.	Lower part of waterway W3 (valley fill) reach infilled and replaced with a diversion but stable with no ongoing impacts.	Low
	Local catchments and waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point and Hamilton Point.	Lower reaches of waterways W3 and W2 infilled and replaced with diversion/s but stable with no ongoing impacts. Loss of up to 17.3 ha of wetlands permanent with limited opportunity for replacement.	Moderate
Operation of LNG plant	Local catchments and waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point.	None.	Negligible
Decommissioning of LNG plant	Local catchments and waterways W2, W3 and W4 draining to estuarine wetlands adjacent to Boatshed Point.	Possible minor generation of sediment.	Negligible
Construction of TWAF 7	Auckland Creek catchment and Auckland Creek including estuarine wetlands.	Possible minor generation of sediment.	Negligible
Construction of TWAF 8	Targinie Creek catchment and Targinie Creek.	Possible minor generation of sediment.	Negligible
Construction of launch site 1	Calliope River catchment and Calliope River including estuarine wetlands.	Possible minor generation of sediment. Up to 3.3 ha of wetlands to be removed or disturbed as part of the construction process at Calliope River mouth.	Negligible Low
Operation of launch site 1	Calliope River catchment and Calliope River including estuarine wetlands.	None.	Negligible

Table 13.11 Residual impacts from project activities (cont'd)

Site	Surface Water Asset	Residual Impacts (post mitigation measures)	Significance
Decommissioning of launch site 1	Calliope River catchment and Calliope River including estuarine wetlands.	Possible generation of sediment.	Negligible
Construction of mainland tunnel entry shaft and tunnel spoil disposal area	Boat Creek catchment and catchment 1 and estuarine salt flats and saltmarshes.	Permanent loss of 52.4 ha of wetlands that will not be replaced. Possible minor generation of sediment.	Moderate
Construction, operation and decommissioning of dredge site 1	Calliope River catchment and Calliope River.	No impacts if geomorphically stable. Will require monitoring.	Low

13.7 Inspection and Monitoring

Inspections and montioring will be conducted at regular intervals during construction and operation to confirm that mitigation measures are effective at reducing the magnitude of impact.

13.7.1 Surface Water

The following inspection and monitoring measures are proposed for during construction and operation.

- Check the sediment basins for damage and accumulation of rubbish trash or other debris on a regular basis. Repair any damage as soon as practical. Dispose of sediment in an appropriate disposal area or mix with dry soil on the site, if appropriate.
- Inspect the integrity of fill material (i.e., for slumping) used in construction of drainage systems and repair as necessary.
- Undertake monitoring of the stream diversion to obtain baseline data prior to the commencement of construction and undertake monitoring of the stream diversion during construction and operation to ensure the diversion is performing according to design specifications.
- Inspect sensitive areas, where appropriate, after intense rainfall events and maintain erosion control structures where required.
- Ensure that inspections and monitoring reflects project approval requirements directed by government departments. Develop a detailed site environmental monitoring program and document in construction and operations environmental plans.
- Inspect sediment control measures (drains, sediment and stormwater detention basins) on a quarterly basis.
- Monitor water to be discharged on a quarterly basis during the operational phases.
- Perform operations monitoring of the stream diversion to maintain the channel condition and reduce risk to project infrastructure.

Further details on the inspection and monitoring measures for the stormwater treatment systems are described in Appendix 6, Stormwater Quality Impact Assessment.

13.7.2 Stormwater Quality Monitoring

Specific water quality objectives for the Port Curtis area have been defined in the EPP (Water). The EPP (Water) was created under the Environmental Protection Act to achieve the environmental values and water quality objectives for Queensland waters. Table 13.12 identifies the water quality objectives of monitoring the water quality for receiving waterways within the Port Curtis area as defined in the EPP (Water).

Table 13.12 Proposed LNG plant receiving water objectives

Indicator	Water Quality Objectives
pH	7.0 to 8.5
Dissolved oxygen (% saturation)	80
Turbidity (NTU)	20
Total suspended solids (mg/L) `	30

The initial design of the stormwater management system for the operational phase of the LNG plant aims to meet the water quality parameters set out in Table 13.12. The system has therefore been designed to maintain the water quality in receiving environments in line with the water quality objectives set by the EPP (Water). To achieve this, the treatment train objectives have been adopted from the Water Sensitive Urban Design Technical Guidelines (Healthy Waterways, 2006). The objectives adopted by Healthy Waterways for southeast Queensland are:

- 80% reduction in total suspended solids.
- 60% reduction in total phosphorous load.
- 45% reduction in total nitrogen load, and
- 90% reduction in gross pollutant load.

Full details of the stormwater design system can be found in Appendix 6, Stormwater Quality Impact Assessment.

13.8 Commitments

The measures (commitments) that Arrow Energy will implement to manage impacts on surface water hydrology and water quality are set out in Table 13.13 below.

Table 13.13 Commitments: Surface water

No.	Commitment
C13.01	Locate sensitive project infrastructure to avoid the 1:100 year ARI event, where practical.
C13.02	Design stream diversions and adjacent flood corridors to manage a minimum of a 1:100 year ARI event.
C13.03	Design the stream diversion at the LNG plant site to prevent erosion or deposition at greater than natural rates; as a corridor, which may contain a formalised channel and constructed flood plain zone; and to allow for the transport of sediment.
C13.04	Design TWAF 8 to minimise disturbance to the ‘Of Concern’ RE 11.3.4 (Eucalyptus tereticornis and/or Eucalyptus spp. tall woodland on alluvial plains) to maintain connectivity of habitat along the Targinie Creek riparian zone. Common with Chapter 17, Terrestrial Ecology, and Chapter 18, Freshwater Ecology.
C13.05	Where practical, align the perimeter fence at TWAF 8 to adopt the alignment of the existing fence where it crosses Targinie Creek. Common with Chapter 17, Terrestrial Ecology, and Chapter 18, Freshwater Ecology.

Table 13.13 Commitments: Surface water (cont'd)

No.	Commitment
C13.06	Design any intra-site access road crossing of Targinie Creek at TWAF 8 to include box culverts (or similar) to enable fauna movement under the road and along the wildlife corridor. Common with Chapter 17, Terrestrial Ecology, and Chapter18, Freshwater Ecology.
C13.07	Keep the footprint of the mainland tunnel entry shaft and tunnel spoil disposal area to a minimum of 500 m clear of Boat Creek. Common with Chapter 18, Freshwater Ecology.
C13.08	Treat stormwater generated from TWAF 7, TWAF 8, launch site 1, the tunnel shaft entry site and tunnel spoil disposal area in temporary sediment basins located at each site.
C13.09	Divert sediment-laden water from disturbed areas at the LNG plant site to temporary sedimentation ponds.
C13.10	Manage all surface water generated from the LNG plant site by a stormwater treatment system to ensure discharged water complies with regulatory requirements. Common with Chapter 31, Waste Management.
C11.12	Use control measures such as drains, swales, silt fencing and sediment traps around the lower slopes of erodible stockpiles. Common with Chapter 11, Geology, Landform and Soils.
C11.11	Implement sediment and erosion control measures upslope of watercourses, wetlands and coastal areas or in areas with sodic soils to minimise increases in natural sediment discharge. Measures may include sediment traps, silt fencing, riprap, contour banks, detention dams, sediment ponds and vegetation and diversion berms. Common with Chapter 11, Geology, Landform and Soils.
C11.16	Prior to construction commencing, develop a site drainage plan to define how the civil construction will address site drainage, stormwater management, erosion control and stockpile placement. Risks relating to flood events will also be addressed with appropriate mitigation measures to minimise erosion and surface water quality issues. Common with Chapter 11, Geology, Landform and Soils.
C11.23	Protect stream channels in soils prone to gully erosion with rock armouring or other appropriate structures and material to reduce the erosion potential. Common with Chapter 11, Geology, Landform and Soils.
C11.07	Manage surface runoff to reduce concentration of surface flow, particularly in erodible soils. Provide drainage channels with suitable design features to minimise erosion where surface runoff is disrupted by roads, tracks, fencing and buildings. Place structures within drainage channels to reduce flow velocity where appropriate. Common with Chapter 11, Geology, Landform and Soils.
C11.22	Design and construct a barrier and sediment control pond to trap sediment leaving the LNG plant site before it enters the Port Curtis marine environment or other surface waters. Common with Chapter 11, Geology, Landform and Soils.
C11.09	Avoid works near stream banks during periods of heavy rainfall where practical. If works cannot be timed to avoid heavy rainfall, adopt additional measures, such as the use of berms and silt fences. Common with Chapter 11, Geology, Landform and Soils, and Chapter 18, Freshwater Ecology.
C13.11	Provide secondary containment for any fuel, oil or chemicals in above ground storage facilities in accordance with applicable Australian standards.
C13.12	Develop appropriate spill prevention and response plans to cover project activities and the types and quantities of fuel, oil and chemicals held at each site. Common with Chapter 14, Groundwater, and Chapter 31, Waste Management.
C13.13	Train all relevant personnel in spill response and recovery procedures. Common with Chapter 31, Waste Management.
C13.14	Maintain live capacities of storage bunds to maximise capacity in the event of a storm or spill.
C13.15	Do not abstract freshwater from watercourses, or dispose of effluent directly into freshwater watercourses, except clean stormwater. Common with Chapter 18, Freshwater Ecology.
C13.16	Where waterway crossings are necessary, cross ephemeral streams in preference to permanent streams, where practical. Where pipeline waterway crossings are necessary, approach stream crossings perpendicular to the stream where possible, to reduce bank erosion risk and minimise the footprint within the bed and riparian zone. Common with Chapter 18, Freshwater Ecology.

Table 13.13 Commitments: Surface water (cont'd)

No.	Commitment
C13.17	Where practical, ensure that grasses and other ground cover remain in place to assist with trapping mobilised sediments.
C13.18	Avoid the use of herbicides within riparian zones or directly over watercourses. Where this is not possible, use products specifically approved for this purpose.
C13.19	Develop site-specific vegetation management plans to reinstate native plant species to areas to be rehabilitated, including riparian margins. Exotic sterile grasses may be used in areas where temporary cover is required to aid in soil stabilisation.
C13.20	Undertake earthworks and rehabilitation activities to facilitate drainage and reduce the potential for standing water to accumulate. Common with Chapter 18, Freshwater Ecology.
C13.21	Avoid discharging tail water from the tunnel spoil disposal area into Boat Creek. Common with Chapter 18, Freshwater Ecology.
C13.22	Where works are required in watercourses, they will be confined to reduced width construction right of ways that preserve, to the extent possible, the integrity of the riparian vegetation and any associated wildlife corridors. Common with Chapter 18, Freshwater Ecology.
C13.23	Routinely inspect and maintain the stormwater treatment system.
C13.24	Treat all surface water and stormwater generated within the LNG plant site in a stormwater system to ensure discharged water meets regulatory requirements.
C13.25	Collect contaminated stormwater for treatment before discharge.
C13.26	Only treat surface water generated within the LNG plant site in the stormwater treatment system. Divert runoff generated outside the LNG plant site away from the LNG plant site stormwater system via the proposed stream diversion.
C13.27	Place structures within drainage channels to reduce flow velocity where appropriate.
C13.28	Remove litter and other debris from within the treatment system, especially around the inlet and outlet structures.
C13.29	Keep areas within and around the stormwater treatment system free of weeds and other undesired overgrowth.
C13.30	Consider post-decommissioning channel form for the stream diversion design and provide for a self-sustaining waterway, without the need for maintenance beyond the life of the project.
C11.29	Re-profile and reinstate topsoil, vegetation and re-establish a stable surface, where practical, during decommissioning and rehabilitation of the LNG plant site. Common with Chapter 11, Geology, Landform and Soils.