8.6 Groundwater

8.6.1 Introduction

A groundwater assessment study was conducted for the LNG facility and associated infrastructure of the GLNG Project (refer Appendix P1). The following section provides a summary of the study findings, including a description of the existing environmental values, assessment of potential groundwater impacts and recommended mitigation measures.

8.6.2 Methodology

The groundwater assessment was based on a desk top review of available geological and hydrogeological information and additional data compiled during field programs conducted in June 2008. The review and evaluation of data allowed for the compilation of the baseline groundwater descriptions and assessment of possible impacts.

A review of applicable legislation and regulatory guidelines was conducted as well as regulatory consultation to ensure that the hydrogeological studies and outcomes achieved compliance.

An evaluation of the underlying geology, aerial photography, topography, and the proposed LNG facility layout was conducted in order to select target areas for drilling and constructing monitoring boreholes on Curtis Island. A suitable track mounted drilling rig was contracted to conduct rotary-air-percussion and auger drilling. Based on the underlying geology three boreholes were drilled into the alluvial and estuarine deposits and five boreholes were constructed within the weathered and fractured mudstone and greywacke units of the Wandilla Formation as shown in Figure 8.6.1.

Variable head tests, comprising slug and falling head tests, were conducted to obtain site-specific hydraulic conductivity values for the underlying aquifers. The resultant data was assessed using standard analytical methods.

The boreholes were equipped with pressure transducers in order to monitor tidal and storm water recharge influences on the groundwater levels.

Groundwater samples were collected from the boreholes and analysed to determine the ambient hydrochemistry.

The proposed LNG facility, processes and infrastructure, have been evaluated and the potential impacts on the shallow groundwater were identified. The significance of these impacts, based on their consequence and likelihood, was compiled using a risk assessment method. The risk assessment of impacts allowed for the determination of optimum mitigation, management, and monitoring strategies.

Groundwater management options were identified, evaluated, and assessed in order to determine the most environmentally sound and cost effective approaches.

8.6.3 Regulatory Framework

An outline of the groundwater regulatory framework is provided in Section 6.6.1.3.

8.6.4 Existing Environmental Values

8.6.4.1 Geology

The main geological unit underlying the proposed LNG facility site is the Wandilla Formation, which comprises sediments and metamorphic units, related to the complex structural geology recognised within the study area. Granite dykes have been mapped adjacent to the LNG facility site. Faulting occurs within the south-western portion of Curtis Island. These zones of secondary alteration are associated with the complex structural geology of the study area.

N
W E
S

0 250m 500m

Scale 1:20 000 (A4)
Datum : GDA94

LNG Facility Site Boundary
LNG Facility Study Area
URS Monitoring Bore

Source: This map may contain data which is sourced and Copyright. Refer to Section 18.2 of the EIS for Ownership and Copyright.

Client	Project	Title
LNG / URS	GLADSTONE LNG PROJECT ENVIRONMENTAL IMPACT STATEMENT	**MONITORING BORES ON LNG FACILITY SITE**
	Drawn: RG / Approved: JB / Date: 26-02-2009	Figure: **8.6.1** / Rev:B
	Job No: **4262 6220** / File No: 42626220-g-992b.wor	A4

Manganese deposits have been mapped within the Wandilla Formation on islands adjacent to Curtis Island. Turquoise deposits were recorded on older geological maps of Curtis Island; however, these have been removed from the most recent maps. Groundwater results indicate elevated concentrations of dissolved metals (manganese) and metalloids (arsenic) within shallow and deeper aquifers. Based on the complex structural geology of the area it is considered that tectonics, resulting in intrusive bodies and metamorphism, have caused alteration and the natural elevated concentrations (compared to similar geological units) of metals within the Wandilla Formation units.

Quaternary aged alluvial and colluvial unconformably overlie the Wandilla Formation units. Thicker alluvium has been deposited along the drainages lines draining the island. Quaternary aged mud, sand and gravel estuarine deposits flank the shores in the area of the potential bridge abutments and many places across the LNG facility study area.

8.6.4.2 Aquifers

Eight groundwater monitoring bores were constructed to obtain site-specific data. The drilling results allowed for the identification of two types of aquifers; alluvial type aquifers adjacent to drainage lines, and weathered (intergranular) and fractured rock type aquifers.

Falling head tests were conducted and results identified the alluvium aquifers to have relatively low hydraulic conductivity (3.05×10^{-3} to 6.43×10^{-2} m/day). The alluvium deposits are confined to the drainage lines and are not regionally extensive. These factors indicate that groundwater extraction at high rates would not be sustainable in the long term. The hydraulic conductivity of the weathered and fractured rock aquifer is higher, 0.01 to 1.165 m/day. The aquifer permeability is controlled by the spacing, aperture size, and interconnectivity of the discontinuities. As the bedrock aquifer is variably fractured and the extent of any high hydraulic conductivity fracture zones is not expected to be regionally extensive, groundwater extraction at high rates would not be sustainable in the long term. Depth to groundwater varies from approximately 1 to 4 m below ground level in the alluvium, and 2 to 22 m below ground level in the bedrock aquifer.

8.6.4.3 Hydrochemistry

Groundwater sampling indicated that the groundwater is brackish in the deeper weathered and fractured rock aquifers and brine in the shallow alluvium aquifers, indicating low permeable confining layers between the shallow and deep groundwater resources, which limits mixing. The majority of the groundwater has an acidic to neutral pH and is reducing.

The groundwater, from both shallow (< 8 m) and deep (> 20 m) boreholes across the site, is recognised to contain elevated concentrations of dissolved solids (sodium 184 to 6,030 mg/l, chloride 550 to 12,880 mg/l, sulfate 8 to 2,110 mg/l) and dissolved metals (manganese 11.5 to 59.9 mg/l, arsenic 0.018 to 0.094 mg/l, nickel 0.013 to 0.534 mg/l) compared to the Australian Drinking Water Guidelines (NHMRC, 2004) and the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) for freshwater and marine ecosystems. The elevated concentrations, when compared to groundwater quality associated with similar geological units, are recognised to occur naturally due to alteration caused by tectonics, which have led to the complex structural geology in the area. The groundwater is unsuitable for domestic use and is not suitable for discharge into the fresh or marine water environments. The groundwater can, however, be used for livestock watering.

Due to the elevated concentrations of arsenic, groundwater intercepted on site will require specific storage, handling, and disposal to ensure health and safety compliance.

8.6.4.4 Current Groundwater Usage

There is only one registered borehole within the proposed LNG facility study area. The borehole is located within the centre of the proposed site and is currently utilised for stock watering. The borehole intersects fractured rock aquifers within the Wandilla Formation mudstone, resulting in moderate yields of brackish groundwater.

8.6.4.5 Environmental Values

The environmental values of the water have been assessed according to the values identified in the EPP Water. The environmental values to be enhanced or protected are:

- Biological integrity of a pristine or modified aquatic ecosystem;
- Suitability for primary, secondary, and visual recreational use;
- Suitability for minimal treatment before supply as drinking water;
- Suitability for use in agriculture;
- Suitability for use in aquacultural use;
- Suitability for producing aquatic food for human consumption;
- Suitability for industrial use; and
- Cultural and spiritual values of the water.

The review of available data allowed for a preliminary assessment of the shallow groundwater resources associated with the lithologies present within the LNG facility study area. The available information allowed for limited evaluation to the groundwater resource environment values.

Cultural and Spiritual Values

The groundwater resource, as recognised has had little or no current or past groundwater usage, restricted future development potential, and poor ambient groundwater quality. Based on the work undertaken, groundwater resources of the LNG facility hold no specific cultural or spiritual values. For further discussion of cultural heritage, see Section 8.13.

Biological Integrity of a Pristine or Modified Aquatic Ecosystem

The biological integrity of the aquifers identified within the LNG facility area have elevated dissolved solids and metal concentrations exceeding the ANZECC guidelines Trigger Levels for Freshwater and Marine Ecosystems. The naturally occurring discharge of shallow groundwater into the water resources occurs at concentrations above the ANZECC guidelines.

Suitability for Recreational Use

This category of environmental values is not considered relevant in relation to groundwater.

Suitability for Minimal Treatment before Supply as Drinking Water

All groundwater samples collected in and adjacent to the proposed LNG facility site are unsuitable for drinking purposes and thus would require treatment to achieve recognised drinking water quality guidelines. This groundwater would require complex and expensive treatment, such as reverse osmosis, to achieve drinking water quality to satisfy the Queensland Water Quality Guidelines 2006 or the Australian Drinking Water Guidelines 2004.

Issues of salinity and the ease of obtaining a rainwater tank supply are factors which preclude the usage and potential for usage of the groundwater as a drinking water source.

Suitability for Use in Agriculture, Aquaculture, Aquatic Food for Human Consumption

The water quality data indicates that the salinity is above the range recommended for irrigation of crops. Thus the groundwater appears to have limited potential use in terms of irrigation, depending on crop type, soil type and irrigation regime.

The onsite aquifers contain limited groundwater (low sustainable bore yields), which reduces suitability for use in aquaculture or the production of aquatic food for human consumption as these activities would typically require reliable assured water supplies.

Suitability for Industrial Use

The groundwater quality is generally suitable for a large number of industrial processes including; cooling water, process water, utility water, and wash water. As industrial processes require particular water quality, specific hydrochemical data will be required to evaluate suitability for use.

Limited opportunities for industrial use are currently available on Curtis Island. Industrial users tend to require large volumes of water which would be unsustainable for the groundwater resources identified within the LNG facility study area.

8.6.5 Potential Impacts and Mitigation Measures

8.6.5.1 Construction Phase Impacts

Dewatering of Excavations

Groundwater level measurements indicate that the groundwater table within the alluvial and estuarine formations is generally less than 5 metres below ground level (mbgl). It is envisaged that any deep excavations will require dewatering, which will be difficult due to the very low permeability of the shallow saturated clay-rich material. During dewatering the groundwater cannot be discharged directly to the fresh or marine water receiving environment due its hydrochemistry characteristics (e.g. elevated metals) without characterisation.

Due to the elevated concentration of naturally occurring arsenic it is recommended that deep excavations below groundwater table be avoided if possible and the use of piling be considered. Where excavations are present, groundwater will require characterisation to determine suitability for discharge. Where unsuitable management measures will be adopted after assessment of the water quality and volume of water removed from the excavation.

Compression of Aquifers

Compression of the ground surface associated with the construction of roads, potential bridge abutments and buildings is not expected to reduce recharge to the groundwater resources beneath the site. The pre-construction permeability of the weathered residual soils and the upper alluvial aquifers is already low (consequently reducing the potential for pollution of the groundwater from construction activities). Therefore, any minor reductions in recharge infiltration due to compaction should be negligible.

Hydrocarbon Spills

The potential release of construction vehicle fuels and workshop oils and lubricants, as well as other stored chemicals, could potentially impact on the underlying and down gradient aquifers. Workshop areas, vehicle and equipment wash-down areas, and equipment and machinery repair areas all have the potential to spill fuels, lubricants, solvents, or other hazardous products.

The low permeability of the soils and bedrock would reduce the impacts of the spills, however, as the spills can potentially migrate offsite and enter the marine environment all accidental spills should be assessed on a case-by-case basis and remediated, which may include excavation and disposal of any contaminated soil in accordance with the requirements of the Environmental Protection Agency (EPA).

Secondary containment areas for construction vehicle fuels and lubricants should be provided with spill cleanup kits in accordance with relevant Australian standards. All transfers of fuels and oils should be controlled and managed to prevent spillage outside bunded areas. Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is regularly maintained.

Appropriate design of fuel and chemical storage areas, which includes spill containment bunding and sealing the surface area, will reduce the risk of groundwater contamination resulting from spills. The development of a rapid response plan and training can ensure the impacts of spills, leaks, or accidents are reduced.

Potential for leaks and spills from operating equipment can be reduced by ensuring that all equipment is well maintained. Record keeping regarding oil and fuel purchased, utilised, and recycled is recommended to identify losses from the system.

Waste Water and Sanitation

Waste water from accommodation camps has the potential to contaminate aquifers locally. The management systems utilised on site will contain, treat and then dispose of waste water. This will reduce the potential impacts associated with these limited volumes of water. During construction waste waters will be contained and treated on site, it will then be transported off site and disposed of at a licensed waste water facility. More information on waste management is in Section 5.

8.6.5.2 Operational Phase Impacts

Loss of Recharge

The facility will cover a significant area of the ground surface with hardstand, reducing the recharge areas for the alluvium and weathered and fractured rock aquifers. However the pre-construction permeability of the alluvium aquifers is low thus any reductions in recharge infiltration should be negligible compared to the total extent of the alluvium and weathered and fractured rock aquifer recharge areas on Curtis Island.

Suppression of the groundwater level by reduced infiltration is expected to be minimal as the groundwater levels measured are < 5 mbgl in the alluvium aquifers. The groundwater level will be maintained by infiltration in surrounding areas, the connection of the alluvium to the drainage lines, and the estuarine deposits to the ocean.

The access road will have minimal impact in relation to the reduction of recharge through the area covered by the road, as groundwater will be compensated by increased recharge through drains.

Compression of Aquifers

The weight of the facility could potentially cause additional compaction of the underlying material. This could alter the permeability of these units and cause (temporary) inundation in areas adjacent to the compacted areas. The low permeability and storage of the alluvium deposits will reduce the extent of these impacts to immediately adjacent to the facilities. The already low groundwater potential of these units will be reduced further but as these aquifers have little groundwater potential and poor groundwater quality the impacts are recognised as small-scale alterations.

Chemical and Fuel Storage

The potential release to ground of hydrocarbons, as well as other stored chemicals, may impact on the underlying soils and down-gradient aquifers. Workshop areas, vehicle and equipment wash down areas and equipment and machinery repair areas all have the potential to spill fuels, lubricants, solvents, or other potentially hazardous products. Refrigerants and compressor lubricating oils are also envisaged to be stored on site.

Secondary containment areas for fuels and lubricants will be provided with spill cleanup kits in accordance with relevant Australian Standards. All transfers of fuels and oils will be controlled and managed to prevent spillage outside bunded areas. Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is regularly maintained.

Appropriate design of fuel and chemical storage areas, which includes spill containment bunding and sealing the surface area, will reduce the risk of groundwater contamination resulting from spills. The development of a rapid response plan and training will ensure the impacts of spills, leaks, or accidents are reduced.

Potential for leaks and spills from operating equipment will be reduced by ensuring that all equipment is well maintained. Record keeping regarding oil and fuel purchased, utilised, and recycled will also be undertaken to identify losses from the system.

Waste Management

Poor waste management practices and substandard waste storage facilities could act as surface contaminant sources to the shallow groundwater resources. Rainfall infiltration and poor quality runoff can seep into the underlying groundwater and alter the hydrochemistry.

In order to manage potential impacts from waste stockpiles, the waste will be stored on hard pan or concrete bases and a “clean / dirty “ water separation system, comprising berms and trenches, will be installed and maintained. The disturbed areas will be contoured to facilitate runoff and prevent ponding. All dirty runoff is to be captured in synthetic membrane lined or compacted clay lined ponds. More information on waste management is in Section 5.

Waste Water and Sanitation

Waste water from accommodation camps has the potential to contaminate aquifers locally. The management systems to be utilised on site to contain, treat and then dispose of waste water, will reduce the potential impacts associated with these limited volumes of water. During operation waste waters will be contained and treated on site. Once treated the waste water will be used for irrigation around the facility site. More information on waste management is in Section 5 and 8.5.

8.6.5.3 Cumulative Impacts

Including the GLNG project there are a number of industrial facilities that are proposed for Curtis Island (as described in section 1.7). There is limited information available as to the planned development of these proposed projects or the scale and timing of their development. However, a qualitative assessment can be made of the possible cumulative impacts.

Only proposed facilities located on Curtis Island will contribute to any cumulative impacts on the groundwater resources on the LNG facility site. Due to the limited data available for the projects, it is envisaged that the impacts associated with the construction and operation of facilities on the shallow groundwater resources would be similar to those identified for the GLNG facility, these include reduced recharge, altered aquifers below the facility footprint (permanent alteration to aquifers due to compaction), and potential contaminant sources.

Poor quality and limited aquifers can be impacted over a larger area on the island as a result of the cumulative impacts of developments in the area, potentially resulting in the loss of usable groundwater resources for life of projects. Additional risk of spills, leaks, and leachate generation will occur, which can result in the alteration of groundwater quality over a larger area.

Detailed groundwater characterisation and impact assessment is required for each potential development to manage cumulative impacts. It is likely, however, that these facilities will include some or all of the proposed mitigation measures outlined within, thereby minimising cumulative impact on the receiving environment.

Table 8.6.1 provides a summary of the potential groundwater impacts and mitigation measures for the LNG facility.

Table 8.6.1 Potential Groundwater Impacts and Mitigation Measures

Aspect	Potential Impact	Mitigation Measures	Objective
Construction			
Local groundwater resources, fresh and marine water resources.	Dewatering of excavations may result in the storing of poor quality groundwater on site, alter groundwater flow patterns, and cause potential acid sulphate soil (ASS) issues.	• Utilise pilings where possible. • Store, treat, or utilise captured water for stock watering. • Assess ASS potential prior to dewatering.	Ensure no impact on down gradient water resources and reduce potential for groundwater quality deterioration.
	Reduction in recharge area and compression of aquifers.	• Minimise the footprint of disturbed areas. • Monitor groundwater levels during construction. • Manage any seeps so as not to discharge off site.	Reduce the amount of recharge reduction and prevent poor quality groundwater entering down gradient water resources.
	Oil and fuels spills can alter hydrochemistry, which may be difficult and expensive to remediate.	• All fuel and oil storage facilities to be bunded. • All industrial waste storage tanks to be bunded. • Bunds to be inspected regularly for evidence of leakage. • Spills to be reported and immediately contained. • Contaminated soil to be removed and remediated. • Contaminated water (e.g. stormwater in bund) to be treated. • Monitoring and maintenance programs to be undertaken as required. • Spill cleanup kits (AS1940 and AS3780) to be located in convenient locations (i.e. all vehicles on the easement.). • Refuelling to occur in bunded areas away from watercourses (> 50 m). • Following further site IAS, develop and implement a water quality monitoring program, including telemetry and event based grab water samples, to further refine mitigation measures.	Minimise potential of contaminating soils and shallow groundwater.

Aspect	Potential Impact	Mitigation Measures	Objective
		• Spill cleanup kits in accordance with Australian Standards (AS1940 and AS3780) to be located in convenient locations, ie work vehicles. • All vehicles, plant and equipment to be checked regularly for integrity of fuel tanks. • Refuelling to occur in bunded areas.	
Operation			
Local groundwater resources, fresh and marine water resources	Alteration of topography and reduction of recharge.	• Minimise the footprint of disturbed areas, • Monitor groundwater levels during operation, and • Manage any seeps so as not to discharge off site.	Reduce loss in recharge to limit losses to shallow groundwater.
	Additional ground loading due to LNG facility may alter aquifers and result in seepage zones adjacent to the infrastructure.	• Minimise the footprint of disturbed areas. • Manage possible seeps so as not to discharge off site. • Conduct geotechnical studies during design to determine extent of compaction. • Replace existing bore if aquifer dewaters.	Ensure poor quality seepage does not impact on offsite water resources, ensure impacted or loss of water is replaced.
	Spills or contaminant leaks may alter groundwater quality and migrate off site.	• Refer to the construction section above	Reduce potential of contaminating soils and shallow groundwater.
	Waste resulting from LNG operations can act as contaminant sources to shallow groundwater.	• Refer to “Spills or contaminant leaks” above • Install clean and dirty water separation systems. • Prevent ponding. • Manage waste waters in water management system.	Reduce potential of contaminating soils and shallow groundwater. Reduce potential to impact on human health and environment.
Decommissioning and Rehabilitation			
Local groundwater resources	Loss of groundwater supply after LNG infrastructure is removed.	• Rehabilitate or construct a new bore to return pre-construction groundwater use.	Ensure make good water to replace current groundwater use on site.

8.6.6 Summary of Findings

The groundwater resources in and adjacent to the proposed LNG facility site have been assessed as unsuitable for drinking purposes, with limited potential use in terms of irrigation and stock watering and as an unsustainable groundwater resource for industrial uses.

The potential impacts to groundwater during construction and operation include dewatering of excavations, hydrocarbon spills and waste management. All impacts will be minimised with the use of mitigation measures including storage and treatment of water from dewatering, secondary containment of chemicals and fuel storage facilities, and treatment and disposal of waste waters.