Australia Pacific LNG Project

Volume 5: Attachments

Attachment 25: Water Resource Technical Report – Pipeline

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Executive summary

Australia Pacific LNG Pty Limited (Australia Pacific LNG) proposes to develop a world-scale project sustaining a long-term industry that utilises Australia Pacific LNG's substantial coal seam gas resources in Queensland. The coal seam gas reserves occur in the Surat and Bowen Basins with the main development planned for the Walloons gas fields area.

A 450km underground high pressure gas pipeline will connect the Walloons gas fields with the LNG plant on Curtis Island in Gladstone. The 1050mm (42 inch) diameter pipeline will be co-located with other high pressure gas pipelines, where practicable, particularly within the Callide and Gladstone State Development Area Common-user Infrastructure Corridors being developed by the Queensland Government.

This report outlines the assessment of potential impacts on groundwater and surface water associated with the construction of the proposed gas pipeline. It presents preliminary hydrologic and hydraulic modelling that was undertaken in order to determine potential scour risks at proposed gas pipeline crossings of creeks and rivers along the adopted pipeline route.

Groundwater

A review of groundwater resources along the proposed gas pipeline route has been undertaken. Potential impacts on groundwater levels, flows and quality, and on groundwater dependent ecosystems have been identified. Monitoring, management and mitigation measures have also been proposed to minimise the potential impacts.

A search of the Department of Environment and Resource Management (DERM) groundwater bore database within the pipeline corridor (ie. 5km either side of the proposed pipeline route) was conducted. It revealed that the water level is generally greater than 5m below ground surface (mbgs) and mostly in the range of 10mbgs to 20mbgs. Exceptions to this are generally in the vicinity of major creeks and rivers, particularly the Kroombit and Callide Creeks, where water levels may be less than 10mbgs. Water levels in those areas have been declining since the late 1970s and are typically in excess of 10mbgs. Even after significant recharge events such as in 2002, the water level did not rise above 5mbgs. The Calliope River continues to flow throughout most years, indicating that it is groundwater fed (baseflow).

Groundwater quality along the pipeline route is predominantly in the range of 1000μS/cm to 2500μS/cm and appears to be best in the vicinity of Bell Creek at the Dawson Highway crossing. It is anticipated to be poorest (highest salinity) as the pipeline corridor approaches 'The Narrows' due to the influence of seawater.

Springs and areas of seepage are abundant in the marginal regions of the Great Artesian Basin (GAB), particularly in the southern, south-western and northern areas. Most springs are concentrated in groups and are distributed over relatively small areas (GABCC 1998). 'Groundwater dependent ecosystems' (GDEs) are common in spring areas and are classified as ecosystems which have their species composition and their natural ecological processes determined by groundwater (ANZECC 2000). The only spring complexes within the 5km radius of the pipeline route are located in the vicinity of where the pipeline crosses Cockatoo Creek.

The potential impacts on shallow groundwater associated with the construction and operation of the gas pipeline include:

- Impacts on surface water bodies, groundwater dependent ecosystems or groundwater users as a result of trench dewatering or inflows.

- Alteration of local groundwater flow patterns.
- Changes to rainfall recharge along the trench.
- Contamination of shallow groundwater resources.

For the first three of these potential impacts to occur, it is necessary for the trench and/or pipeline to intersect the watertable. It is anticipated that the watertable will generally be deeper than the base of the pipeline trench, however in the vicinity of creeks (particularly Calliope River), 'The Narrows' and on Curtis Island, the watertable may be intersected. The limited duration of the pipeline installation means that impacts associated with dewatering would be localised and temporary.

Based on the current location of the pipeline corridor, the likelihood of impacts occurring to GDEs would be minimal, although further investigation would be required to ensure the pipeline does not intersect any springs.

Groundwater extraction from bores for the purpose of construction, dust suppression or hydrostatic testing may result in localised drawdown effects. Groundwater is not the preferred source of water for these activities and the volume of water used for hydrostatic testing will be minimised through recycling of the test water. Given the short duration of the pipeline construction, these effects are likely to be reasonably localised and temporary only.

The Environmental Values (EVs) which may be affected by these potential impacts include the use of shallow groundwater resources for stock watering and agriculture, or as a complementary source of water for domestic use. It is not anticipated that the gas pipeline will cause any significant impact on groundwater resources, so the EVs should not be affected

Management and mitigation strategies have been devised relating to the potential impacts on groundwater resources during the construction and operation periods. These strategies include monitoring of groundwater levels and quality, appropriate design for waterway crossings and implementation of appropriate techniques and site management during construction.

Surface Water

The assessment of the potential impact of the pipeline on surface water resources has focussed on flooding and erosion, scour and sediment transport. The assessment of potential impacts on water quality has been addressed in the aquatic ecology, water quality and geomorphology technical report (Volume 5, Attachment 21).

100 years Average Recurrence Interval (ARI) design event flood characteristics were estimated for a number of locations. These included peak flood flows, levels, depths and velocities at the proposed gas pipeline crossings of creeks and rivers along the adopted pipeline route from the gas fields near Miles to the proposed LNG plant to be constructed on Curtis Island.

The assessments were undertaken at 27 locations where the adopted pipeline route crosses watercourses having a stream order classification of 3 or greater. These represent the larger creeks and the Calliope River.

The pipeline crossings are generally located on ungauged creek catchments, or are not located near stream gauging stations. Therefore peak flows for the 100 years ARI design flood events were estimated initially using the Rational Method with design rainfall data. A base runoff coefficient of 0.5 was adopted for the assessments relating to rural catchments. This assumes a medium infiltration capacity for soils along the route and light to medium bush and grass cover. This is in accordance with the Queensland Urban Drainage Manual (QUDM).

Flood frequency analyses were then undertaken for DERM gauging stations located near to the adopted pipeline route in order to derive regional flood frequency relationships. This was done to asssess the estimated 100 years ARI peak flows against historical flow data.

The estimated peak flows determined using the Rational Method were found to be approximately 60% of the expected peak flows based on the flood frequency analyses regional relationships. Therefore, due to the uncertainties associated with peak flows estimation using the Rational Method, it was considered that the regional flood frequency peak flow estimates were more appropriate for adoption as design flood flows.

The construction of the pipeline creek crossings will be undertaken during the 'dry' season (between April and November) where practicable. Techniques will be used that result in minimal damage to the creek banks and riparian vegetation. The backfill placed over the pipeline will be compacted in order to minimise the potential for scour along the trench line and resultant erosion of the creek banks.

It is considered that the proposed pipeline will have a negligible impact on flood behaviour, with minor flow diversions or ponding possible in minor events during the creek crossing construction period. The construction of each crossing is expected to be completed within the shortest time practicable, with small to moderate crossings generally completed within one day

The estimation of potential scour risk at proposed pipeline crossings was undertaken using procedures for stream scour and sediment transport analysis. Creek channels are susceptible to scour and erosion when the average particle size D_{50} of the bed material is smaller than the critical grain size D_c. Armouring of the creek bed can occur when the D_{95} grain size of the bed material is larger than the armour grain size, thereby limiting the depth of scour.

The critical grain sizes for scour and armouring were found to be generally much larger than the average grain sizes obtained from the particle grading information for most of the crossing sites. Therefore, it is concluded that most creek crossing sites are prone to scouring of the creek beds during flood events. The Dogwood Creek crossing site is the only site investigated that was found to have a low risk of scour of the creek channel during flood events.

Detailed scour assessments will be required to be undertaken during detailed design phases of the project in order to determine the appropriate depth of cover or scour protection measures to be adopted at each crossing

It is proposed that water required for construction activities will be obtained from sources other than surface waterways or groundwater. Therefore, it is anticipated that the gas pipeline project will have a negligible or zero impact on the supply of water from surface waterways or groundwater to existing consumers either locally or regionally.

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Appendix A Abbreviations and Glossary of Terms

1. Introduction

Australia Pacific LNG Pty Limited (Australia Pacific LNG) proposes to develop a world-scale project sustaining a long-term industry that utilises Australia Pacific LNG's substantial coal seam gas resources in Queensland. The coal seam gas reserves occur in the Surat and Bowen Basins with the main development planned for the Walloons gas fields' area.

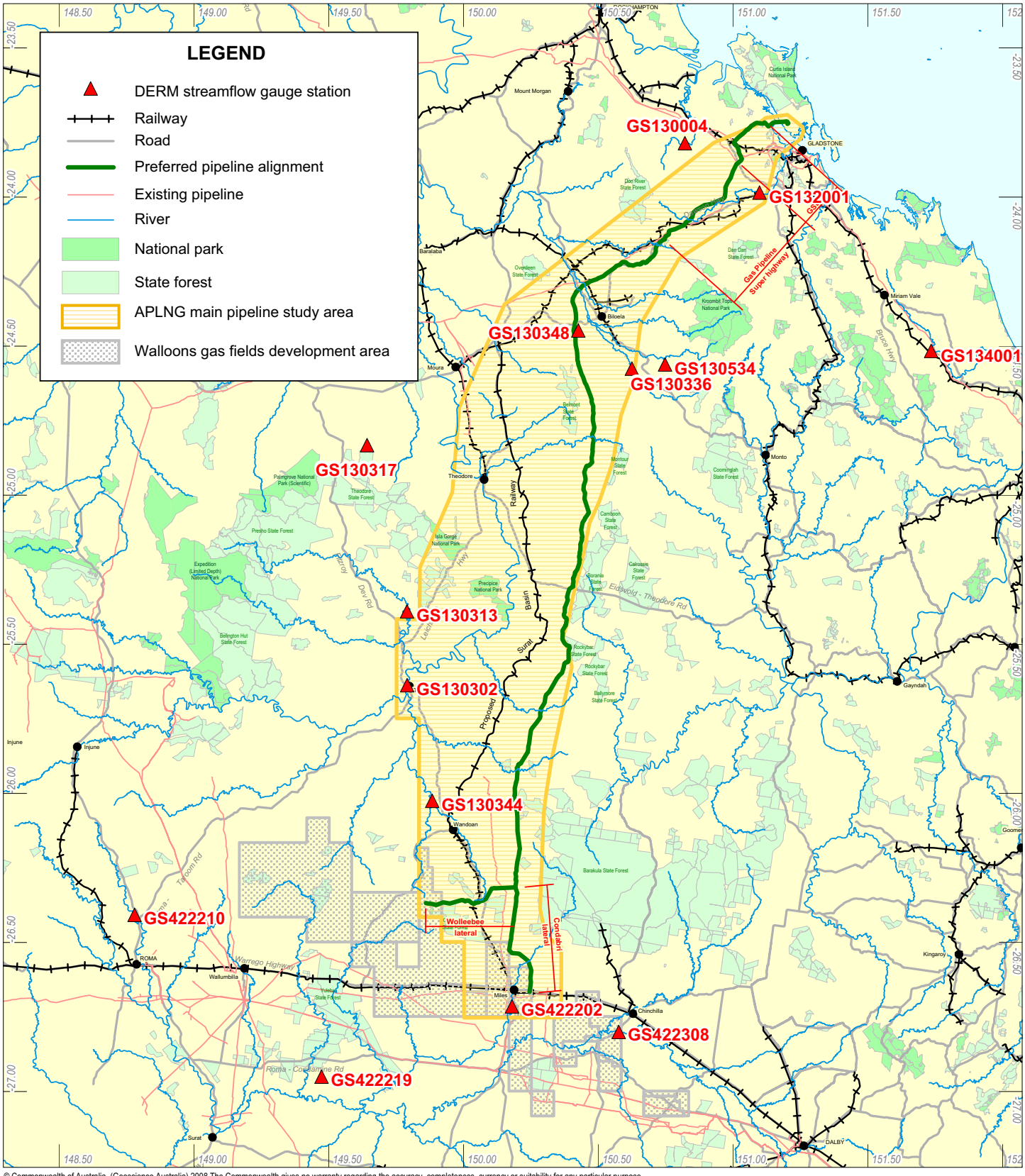
A 450km underground high pressured gas pipeline will connect the Walloons gas fields with the LNG plant on Curtis Island in Gladstone. Where practicable, the 1050mm (42 inch) diameter pipeline will be co-located with other high pressure gas pipelines. This includes the Callide and Gladstone State Development Area Common-user Infrastructure Corridors currently being developed by the Queensland Government.

This report outlines the assessment of potential impacts on groundwater associated with the construction of the proposed gas pipeline. It presents the preliminary hydrologic and hydraulic modelling that was undertaken in order to provide 100 years Average Recurrence Interval (ARI) estimates. These estimates include design flood flows, levels and velocities, as well as potential scour risks at proposed main gas pipeline crossings of creeks and rivers along the adopted route from the gasfield near Miles to the proposed LNG plant to be constructed on Curtis Island.

The proposed route of the gas pipeline is shown on Figure 1.1 and comprises three branches:

- The Woleebee lateral extending approximately 35km from the Combabula-Ramyard, Woleebee and Carinya tenements south-west of Wandoan to the main pipeline.
- The Condabri lateral extending approximately 44km from the Condabri tenement south of Miles to the main pipeline.
- The main pipeline extending 360km from the junction of the Woleebee and Condabri laterals to the proposed LNG plant site on Curtis Island.

The main pipeline will include the crossing of 'The Narrows' to Curtis Island. This crossing will be completed using horizontal directional drilling.



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Figure 1.1 : Proposed pipeline route

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2. Legislative framework

When assessing what potential impacts the construction and operation of the pipeline might have on groundwater and surface waters in the study area, the following legislation was considered:

- The Water Act 2000 and Water Resource Plans prepared under the Act
- The Environmental Protection Act 1994 and Amendments, Regulations and Policies, particularly the Environmental Protection (Water) Policy 1997 (the Water EPP)
- The Fisheries Act 1994

An overview of the relevant Queensland legislation referred to above and its purpose is provided in Chapter 2. Statutory plans, state planning policies, and legislative regulations that are directly relevant to activities undertaken for the Australia Pacific LNG Project that impact upon water resources are discussed below.

2.1 Water Act 2000

This Act seeks to advance the sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water. The Act also seeks to protect the biological diversity and health of ecosystems associated with waterways and groundwater resources. In order to achieve the latter, the Act requires that permits be obtained for the removal of riverine vegetation and for the excavation or placing of fill in a watercourse.

2.1.1 Water Resource Plans

Water Resource Plans (WRPs) are administered under the Water Act. They have been prepared for the Fitzroy, Boyne and Condamine-Balonne river basins, all of which are intersected by the proposed gas pipeline route. The Plans provide a framework for the sustainable management of water and the taking of water. The Plans also establish water allocations and regulate the taking of overland flow. The Plans apply to:

- Water in a watercourse or lake.
- Water in springs not connected to artesian water, or sub-artesian water connected to artesian water.
- Overland flow water other than water in springs connected to artesian water, or sub-artesian water connected to artesian water.

The Plans do not apply to groundwater, although the Minister has announced his intention to prepare a draft amendment to address groundwater in the Central Condamine Alluvium area.

2.2 Environmental Protection Act 1994

The purpose of this Act is to protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

The EP Act also shields landholders from the financial burden of others who cause environmental harm. This provides assurance to landholders located adjacent to the study area that they will not be

exposed to any financial hardship as a result of environmental degradation or restoration that may be caused by Project activities.

These aims are achieved through the implementation of an integrated management program administered by the Department of Environment and Resource Management (DERM), formerly the Environmental Protection Agency (EPA). The program incorporates policies and guidelines that have been refined over the last 15 years. This approach ensures that proposed future developments are ecologically sustainable.

2.2.1 Environmental Protection (Water) Policy 1997

The purpose of this policy is to achieve the objective of the Environmental Protection Act 1994 in relation to Queensland waters. This policy develops a framework for identifying environmental values, developing water quality objectives, managing the intent for waters and developing management plans.

2.3 The Fisheries Act 1994

The main purpose of this Act is to provide for the use, conservation and enhancement of the community's fisheries resources and fish habitats in a way that seeks to apply and balance the principles of ecologically sustainable development and promote ecologically sustainable development. The Act requires that a permit be obtained for the removal of marine plants and also approval of waterway barriers.

3. Methodology

The assessment of potential impacts of the proposed gas pipeline on groundwater comprised the following:

- A review of existing groundwater resources along the pipeline route. Because the construction of the pipeline is of relatively short duration, changes to the depth to the watertable resulting from dewatering are expected to be minimal, therefore a search radius of 5km either side of the pipeline was considered sufficient.
- Identification of potential groundwater dependent ecosystems along the pipeline route.
- Identification of potential impacts on groundwater levels, flows and quality, and on groundwater dependent ecosystems.
- Identification of monitoring, management and mitigation actions necessary to address the identified impacts.

The assessment of potential impacts on surface waterways was undertaken at locations where the adopted pipeline route crossed watercourses having a stream order classification of 3 or greater. The stream order classification is explained in Section 5.1. The methodology adopted for the assessments comprised the following activities:

- Review of the proposed route to identify crossings having stream order 3 or greater.
- Estimation of 100 years ARI peak flows at crossing sites.
- Estimation of peak flood levels and velocities at crossing sites.
- Estimation of potential scour depths at crossing sites.
- Identification of mitigation strategies relating to impacts.

The work undertaken for each activity is outlined below.

The assessment of potential impacts on surface water quality and aquatic ecology was included in the aquatic ecology, water quality and geomorphology impact assessment presented in Volume 5, Attachment 21. The relevant findings of that assessment have been included in summary form in this report.

Site inspections were undertaken at 16 proposed crossing locations as part of the soils, geology and topography investigations (Volume 5, Attachment 7) and the existing water quality was sampled and analysed at five of the waterways to be crossed listed below and from the Dawson River. Although the pipeline route does not cross the Dawson River, the water quality was tested in order to assess regional water quality.

4. Groundwater

4.1 Existing conditions

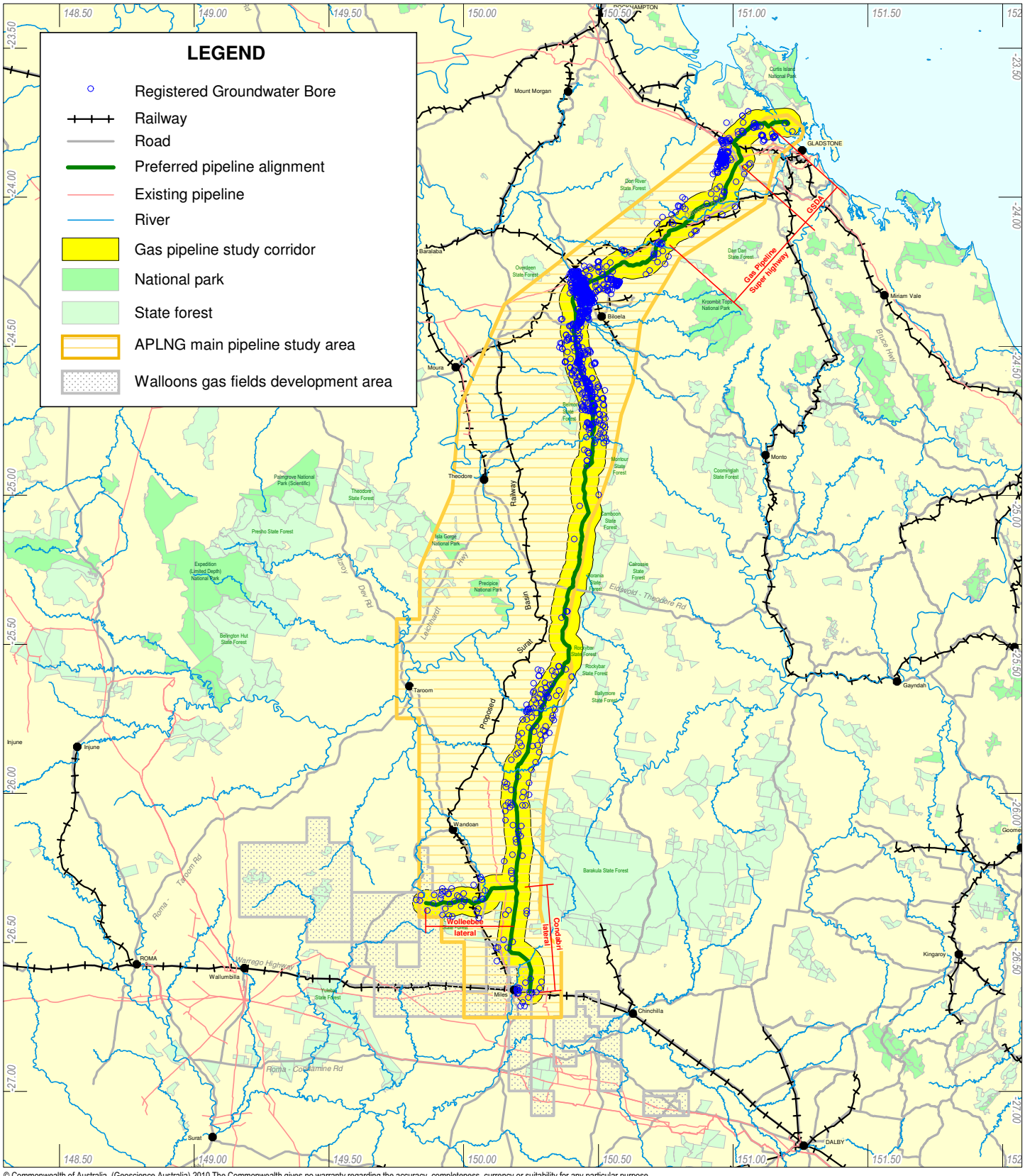
The southern section of the pipeline route, extending for the first 145km (approximately), is within the Surat Basin. More importantly, it is within the recharge zone of the Surat Basin units and hence the intake beds for recharge to the Great Artesian Basin (GAB). When the pipeline crosses the Great Dividing Range and exits the Surat Basin, it generally transects igneous rocks (for example, Camboon Volcanics, Glandore Granodiorite, Galloway Plains Tonalite). In these areas the groundwater flow is likely to be fracture-dominated, and therefore groundwater effects would be localised or otherwise limited to regional fracture sets. In the creek and river valleys, groundwater is utilised from high yielding alluvial deposits, for example the Callide Creek, Calliope River and Kroombit Creek Alluvia. A detailed description of the geology of the pipeline route is presented in the baseline soils, geology and topography technical report (Volume 3, Chapter 5).

A search of the DERM groundwater bore database (GWBD) within the pipeline corridor 5km either side of the proposed pipeline route identified 1148 registered groundwater bores as shown on Figure 4.1. Although the uses of these extraction bores have not been identified, it is likely that the majority are extraction bores used for stock and domestic purposes.

The bore data revealed that the water level is generally greater than 5m below ground surface (mbgs) and mostly in the range of 10mbgs to 20mbgs. Exceptions to this are generally in the vicinity of major creeks and rivers, particularly the Kroombit and Callide Creeks, where water levels may be less than 10mbgs. Water level hydrographs for selected bores in the vicinity of these creeks near the crossing are presented in Figure 4.2. These would indicate that water levels have been declining since the late 1970s and are generally in excess of 10mbgs. Even with significant recharge events, such as in 2002, the water level did not rise above 5mbgs. The available groundwater bore data for creek crossings is summarised in Table 4.1. As suggested in Volume 5 Attachment 21, Calliope Creek is continues to flow throughout most years, indicating that it is groundwater fed.

Groundwater quality along the pipeline route is predominantly in the range of 1000µS/cm to 2500µS/cm and appears to be best in the vicinity of Bell Creek at the Dawson Highway crossing. It is anticipated to be poorest as the pipeline corridor approaches 'The Narrows' due to the influence of seawater. Detailed chemistry results (major cations and anions) were only available for bores in the vicinity of Kroombit and Callide Creeks. The major ion data indicates that the groundwater is a sodium-chloride water-type, but also contains high relative concentrations of calcium and magnesium. It is generally neutral to alkaline (pH 6.9-9.7). Surface water sampling was not undertaken at this location,

Surface water sampling undertaken for this EIS (Volume 5 Attachment 21) indicated that Cockatoo Creek contained higher salinity water (1500µS/cm) suggesting that this creek was fed by waters from deeper aquifers. The sampling also suggested groundwater contribution to the surface water at Calliope River. C & R Consulting (2005) reported that the Calliope River has naturally elevated surface water conductivity levels. This is considered to be due to shallow aquifers overlying aquifers with moderate to high salinities, which may infiltrate the shallower alluvial systems, particularly if overexploited (C & R 2005).



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Figure 4.1 : Registered groundwater bores within pipeline corridor (DERM groundwater bore database)

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It should be noted that no groundwater bore data was available in the search radius in the vicinity of:

- Calliope River at the Dawson Highway crossing
- Cockatoo Creek
- Bungaban Creek
- Dogwood Creek
- Juandah Creek

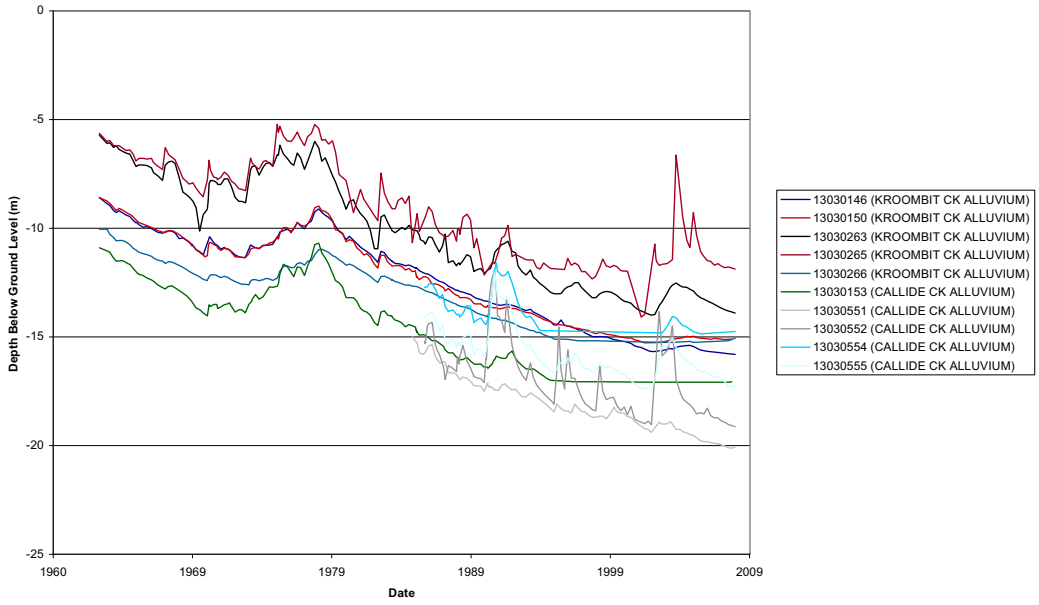


Figure 4.2 Selected water level hydrographs from the vicinity of the Kroombit Creek and Callide Creek pipeline crossings

Table 4.1 Summary of hydrogeological information at major creek crossings along the pipeline

Crossing location	No of bores	Water level (mbgs)			Electrical conductivity (µS/cm)			Yield (L/s)	
		Min	Max	Median	Min	Max	Median	Min	Max
Bell Creek @ Dawson Highway	9	15.45	6.00	9.60	650	1,260	815	0.38	2.00
Kroombit & Callide Creeks @ Burnett Highway	170	18.50	0.71	11.30	500	7,300	1925	0.01	46.60
Pump Creek	8	20.90	12.00	20.70	1,200	5,600	4,250	0.03	1.70
Cockatoo Creek	6	33.00	33.00	33.00	1,500	1,500	1,500	3.78	3.78

Springs and areas of seepage are abundant in the marginal regions of the Great Artesian Basin, particularly in the southern, south-western and northern areas. Most springs are concentrated in groups and are distributed over relatively small areas (GABCC 1998). 'Groundwater dependent ecosystems' (GDEs) are common in spring areas and are classified as ecosystems which have their

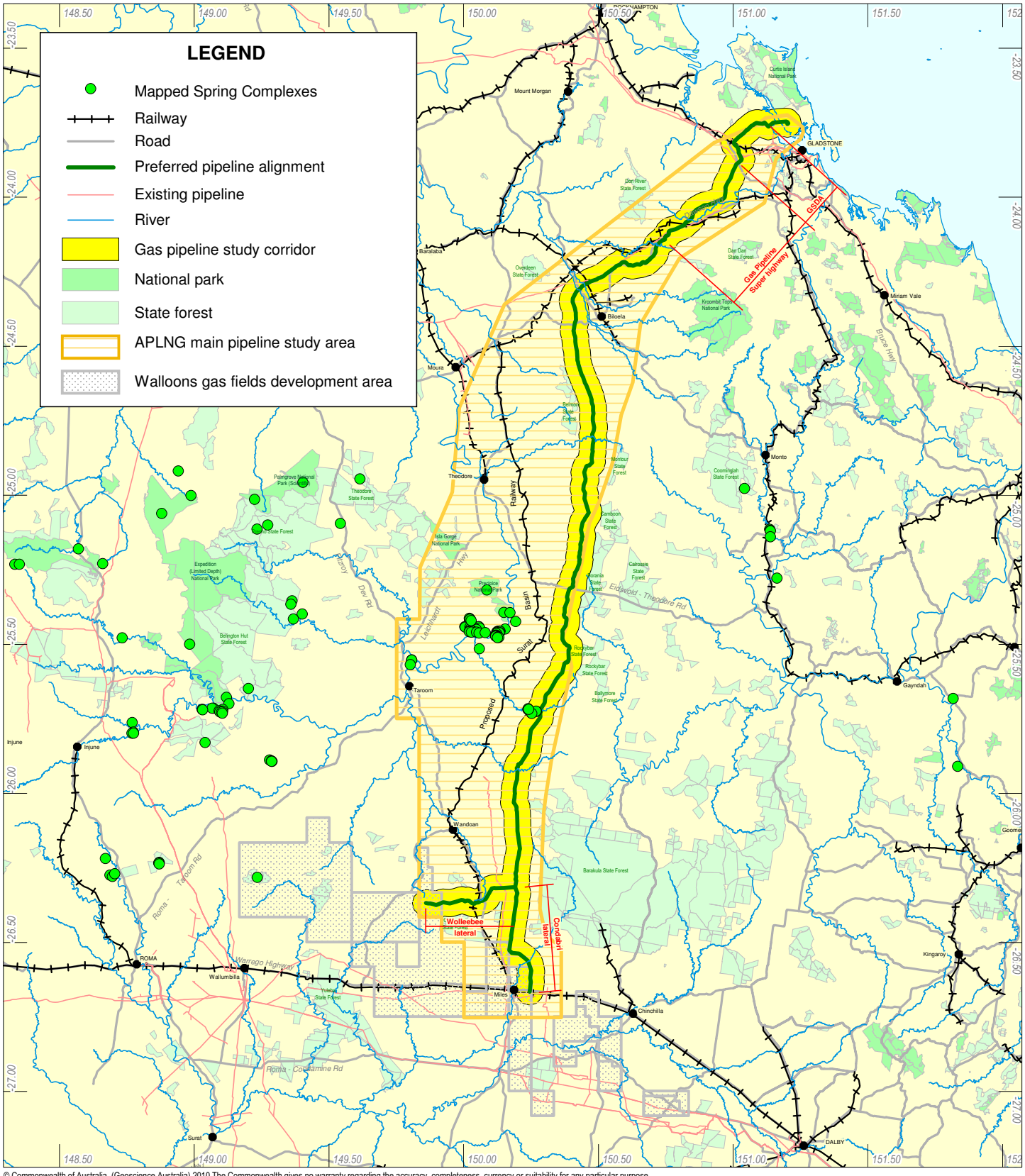
species composition and their natural ecological processes determined by groundwater (ANZECC 2000).

The locations of known springs in proximity to the study area (as sourced from the DERM wetlands mapping database) are shown on Figure 4.3. A detailed discussion of GDEs specifically pertaining to the Australia Pacific LNG pipeline route is provided in Volume 5 Attachment 21.

From Figure 4.3 it can be seen that the only spring complexes within the 5km radius of the pipeline route are located in the vicinity of where the pipeline crosses Cockatoo Creek.

In areas not dominated by spring activity, the greatest potential for groundwater dependency is likely to be within shallow alluvial sequences associated with drainage lines. In these areas, the water table may be shallow and higher than the maximum rooting depth of established vegetation. The level of groundwater dependency in these areas is therefore likely to be low (opportunistic at best) with species potentially utilising groundwater in the saturated zone only during drought conditions where surface water flux is uncommon. Given the local climatic conditions and drainage characteristics of these areas, surface water runoff and infiltrated rainfall are likely to represent the primary source of water flux required to satisfy plant requirements.

Established vegetation on non-alluvial sequences may also potentially utilise groundwater opportunistically during dry periods. However, the potential level of dependency is likely to be less than that required for vegetation in the vicinity of drainage lines, as shallow groundwater in non-alluvial sequences is likely to represent interface drainage, which only persists after high intensity rainfall events.



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Volume 3 Chapter 23
Figure 4.3 Spring complexes in proximity to the study area (DERM wetland mapping database)

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4.2 Potential impacts

The potential impacts on shallow groundwater associated with the construction and operation of the gas pipeline include:

- Dewatering/inflows impacting on surface water bodies, groundwater dependent ecosystems or groundwater users
- Alteration of local groundwater flow patterns
- Changes to rainfall recharge along the trench
- Groundwater dependent ecosystems
- Drawdown effects to landholder bores due to taking water for construction and testing activities
- Contamination of shallow groundwater resources
- Environmental values impacts.

For the first three of these potential impacts to occur, it is necessary for the trench and/or pipeline to intersect the watertable. As outlined in the previous section, it is anticipated that that the watertable will generally be deeper than the base of the pipeline trench, however in the vicinity of creeks (particularly Calliope River), 'The Narrows' and on Curtis Island, the watertable may be intersected.

The construction of the pipeline is outlined in Volume 3, Chapter 3 of this EIS.

Recreational values are either unlikely to be impacted upon or impacts will be insignificant due to the limited extent, magnitude and duration of disturbances to the shallow groundwater system.

The potential impacts are discussed further below.

4.2.1 Impacts associated with inflows/dewatering

As stated above, it is anticipated that the pipeline trench is unlikely to intersect the watertable. However, should the trench intersect the watertable, groundwater will flow into the trench at a rate dependent on:

- Depth of the trench below the watertable
- Length of the trench below the watertable
- Hydraulic and storage properties of the material
- Elapsed time since the watertable was intersected.

Similar to a cone of depression that typically develops around a pumping borehole, the water level around the trench will be depressed promoting inflow of groundwater. The distance at which this depression may extend from the trench will be predominantly related to the duration of dewatering. If the trench is allowed to fill with water, there will effectively be no major effects on local water levels.

A limited duration, generally less than one day, will be required to install the pipeline in a section of the trench. Therefore it is anticipated that this depression of the watertable would be limited to the immediate vicinity of the trench and would be of a temporary nature only – that is, the water level would recover once dewatering ceased. The use of horizontal directional drilling (HDD) to install pipeline beneath a river or creek, even if it is below the watertable, should not require dewatering to be carried out.

4.2.2 Changes to groundwater flow

Disturbance of the ground and the pipeline itself may affect the hydraulic properties of the subsurface strata and therefore may affect local groundwater flow.

The backfilling of pipe trenches may increase the hydraulic conductivity of the trench relative to the surrounding ground. This would be particularly evident if the backfill is not compacted or a bedding layer is used, which would create a conduit for preferential flow. This may be of particular concern if the trench is on a slope as the increased hydraulic conductivity and gradient may result in increased groundwater velocities. This in turn would lead to a greater risk of subsurface erosion should the watertable be intersected.

Conversely, reduced permeability due to over-compaction of the backfill material may result in potentially elevated water levels.

Should the pipeline intersect the watertable at a creek crossing, there should be no net effect on water levels. This is because the pipe will be deeper under the creek than the watertable, which will be at or slightly above the water level in the creek. Therefore, the trench will not act as a conduit for lateral flow away from the creek itself.

In the hard rock sections crossing the Great Dividing Range, the pipeline trench may be blasted. This may result in increased fracturing in the blast area and potentially alter groundwater flow on a local scale. This is of particular concern if the blast location is in the vicinity of springs and associated groundwater dependent ecosystems (GDEs), as it has the potential to inadvertently relocate the spring.

It is not proposed to source water for the construction of the pipeline from groundwater sources. Therefore, changes in groundwater flow behaviour due to abstraction of groundwater for the pipeline are not predicted.

4.2.3 Groundwater dependent ecosystems (GDEs)

For flows to artesian springs and hence their associated GDEs to be impacted, the spring would need to be in the immediate vicinity of the pipe trench, and the trench would have to intersect the watertable and be dewatered. Any potential impacts would also be of a temporary nature only and would cease when dewatering ceased. Short term reductions in spring flows to GDEs are unlikely to impact on the integrity of the ecosystem as such reductions in flow may occur through natural climatic variability

Given that the gas delivery pipeline route has not yet been confirmed, there is potential for disturbance to artesian spring communities via direct excavation or increased sediment and turbidity. The EPBC listed Salt pipewort and Artesian milfoil are known to be associated with artesian springs within Cockatoo Creek. Based on the current location of the pipeline corridor, the likelihood of impacts occurring would be minimal, although further investigation would be required to ensure the pipeline does not cross any GAB springs.

4.2.4 Impacts associated with groundwater extraction

Groundwater extraction from bores for the purpose of construction, dust suppression or hydrostatic testing may result in localised drawdown effects. Groundwater is not the preferred source of water for these activities and the volume of water used for hydrostatic testing will be minimised through recycling of the test water.

If these requirements were to be supplied using groundwater, there would be drawdown effects in the vicinity of the extraction bore. The magnitude and extent of these effects would be related to the rate

of extraction and the hydraulic nature of the aquifer. If the aquifer is confined and of low hydraulic conductivity, the effects may be noticeable several kilometres from the pumping centre. However, if the hydraulic conductivity is high and the aquifer unconfined, the noticeable effects may be limited to a few hundred metres.

Without specific information related to extraction rates, durations, and target aquifer geometry and hydraulic nature, it is not possible to assess potential impacts particularly to neighbouring landholder bores, however given the short duration of the pipeline construction, these effects are likely to be temporary only.

4.2.5 Groundwater contamination

The quality of shallow groundwater has the potential to be impacted through:

- Spillages and leaks during construction
- Drilling fluid losses during HDD
- Uncontrolled discharge of hydrostatic test water
- Exposure of acid sulphate soils (ASS)

Potential sources of contamination relating to construction are predominantly related to diesel and hydrocarbon-based lubricants associated with the machinery. A secondary potential source of contamination is human effluent associated with camps. Camps, refuelling and maintenance facilities will be located and laid out (ie, within dedicated bunded areas) so as to minimise the potential for spills.

Drilling fluids containing bentonite (a natural clay) and other additives are used in the HDD process. These fluids are designed to minimise fluid loss into the formation. Therefore, potential impacts to groundwater surrounding the pipeline are likely to be of localised extent only and are unlikely to change the chemistry of the groundwater.

Hydrostatic test water can include chemical additives such as corrosion inhibitors and biocides. Uncontrolled releases and spills of this water have the potential to degrade the local groundwater quality. Appropriate procedures will be employed during the filling and emptying of the section of the pipeline being tested to minimise the potential for spills.

There is the potential to intercept acid sulphate soils (ASS), particularly at the mudflats on the landward approach to 'The Narrows'. Exposure of these soils during trenching has the potential to generate sulphuric acid which may acidify the local groundwater and mobilise other chemical constituents. This has been discussed further in the baseline soils, geology and topography technical report. (Volume 5, Chapter 10).

4.2.6 Environmental values

Environmental Values (EVs) are the qualities of waterways that need to be protected from the effects of pollution, waste discharges and deposits to ensure healthy aquatic ecosystems and waterways that are safe and suitable for community use (DERM, 2008). These range from the maintenance and protection of healthy aquatic ecosystems, health and safety, commercial and cultural heritage values.

EVs of groundwater resources that may be exposed to potential impacts include the use of shallow groundwater resources for stock watering and agriculture, or as a complementary source of water for domestic use. It is not anticipated that the gas pipeline will cause any significant impact on groundwater resources, so these EVs should not be affected.

4.3 Risk evaluation

The risk assessment of potential hydrogeological impacts associated with construction and operation phases of the proposed gas pipeline, including the proposed control measures, is summarised in Table 4.2.

Table 4.2 Risk assessment of potential hydrogeological impacts - proposed gas pipeline

Potential risk	Possible cause(s)	Possible consequences	Proposed controls	Residual risk ranking
Drawdown effects associated with dewatering during pipeline construction	Pipeline trench intersects shallow groundwater	Potential to impact the flow regime associated with shallow groundwater systems.	(1) The pipeline alignment has been selected to minimise potential for crossing of watercourses, limiting the risk of the intersection of groundwater.	Low
Risks of groundwater contamination during pipeline construction and operation	Poor practices in waste management and fuel transfer Pipeline failure	Potential localised groundwater contamination.	(1) Appropriate fuel and waste storage and transfer methods and protocols to be employed. (2) Supervisory Control and Data Acquisition (SCADA) monitoring of pipeline pressures to provide rapid notification of pressure reductions (that is, potential leaks) (3) Clean up spills immediately and remediate if necessary	Low
Potential disturbance of Groundwater Dependent Ecosystems during pipeline installation	Pipeline alignment intersects Groundwater Dependent Ecosystems, disturbing habitat conditions and ecosystem structure.	Potential to degrade Groundwater Dependent Ecosystems.	(1) Further investigation to determine the location of artesian springs in the vicinity of Cockatoo Creek with final pipeline alignment avoiding sensitive environmental areas as best as possible	Low

Potential risk	Possible cause(s)	Possible consequences	Proposed controls	Residual risk ranking
			(2) Pipeline construction via directional drilling if actively discharging springs cannot be avoided.	
Drawdown effects associated with water abstraction for construction or testing	Groundwater extracted	Potential reduction in yield to landholder bores, spring flows and baseflow	(1) Locate extraction bores at suitable stand-off distance from potential receptors (2) Construct and operate water bore in accordance with license conditions	Low
Potential degradation of local groundwater quality during pipeline construction	Acid sulphate soils exposed during trenching	Potential to degrade local groundwater quality	(1) Minimise to disturbance to potentially acid generating soils (2) Neutralise spoil	Low

4.4 Monitoring, management and mitigation of impacts

Where groundwater is intercepted during trenching, inflow volumes, rates and water quality will be monitored and recorded. The water will be allowed to re-infiltrate into the ground at a location within a short distance of the trench. Erosion potential associated with the disposed water will be controlled using appropriate flow control mechanisms and filter materials.

If the watertable is intersected in proximity to existing monitoring bores, daily water level records will be maintained for these bores for the duration of pipe laying activities in the local area.

If groundwater is extracted for construction purposes, this will be undertaken in accordance with the Water Act 2000 and a groundwater extraction license will be obtained. Conditions associated with the license will be adhered to. For due diligence purposes, a survey of landholder bores surrounding the proposed extraction point will be undertaken. If the landholder bores are unduly influenced, their water supply will be supplemented for the duration of the activities. Volume 5 Chapter 22 identifies how this may be achieved (‘make good’).

Backfilling of the trench will be undertaken following pipe laying to minimise any potential changes to the permeability of the backfill. Trench breakers will be installed in sloping areas to minimise the potential for the trench to act as a preferential pathway for groundwater movement. The breakers will be designed to ensure that the water does not discharge at the surface.

Drilling fluids used during HDD will be managed on-site using tanks and sumps to avoid concentrated discharge to a surface watercourse or surface water body.

It is anticipated that hydrostatic test water will be reused, thereby minimising the volumes required. The disposal method for this water will depend upon the nature of any additives included. Specific management plans will be implemented which take into account its chemical nature, that of the receiving waters and other environmental considerations.

Should potentially acid sulphate generating soils be encountered, these will be managed in accordance with ASS guidelines to ensure that the potential for acid generation is minimised. This will include minimising the disturbance of the soils and neutralization of the spoil as required.

Vehicle maintenance and fuel storage areas should be impervious and will be bunded in accordance with the relevant Australian standards to minimise the potential for contaminated run-off to infiltrate to the watertable. Any leaks or spills will be cleaned up in accordance with appropriate emergency response plans. Refuelling in the field will not take place near or adjacent to watercourses.

The gas pipeline will have a Pipeline Integrity Management System developed as well as Pipeline Safety and Operating systems. Additionally, a SCADA (Supervisory Control and Data Acquisition) system will monitor its status and operating parameters. This will be supported by regular inspection and maintenance activities, including pigging and intelligent pigging of the internal surface and pipeline thickness to detect possible corrosion sites and other imperfections such as dents.

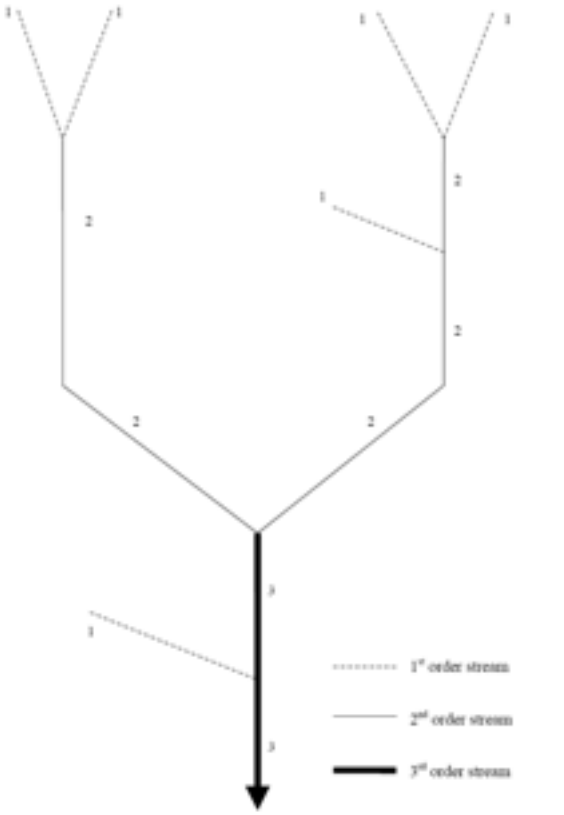
5. Surface waters

5.1 Overview

The stream orders at crossing sites were determined with reference to 1:250,000 digital topographic mapping. Stream order is defined as follows and illustrated in Figure 5.1:

1. A first-order stream does not have tributary branches.
2. Two first-order streams flow together to form a second-order stream.
3. Two second-order streams combine to make a third-order stream.
4. Each time a bifurcation node is encountered, the order is increased by one if both upstream branches have the same order, otherwise the larger order is used.
5. The maximum stream order is 12.

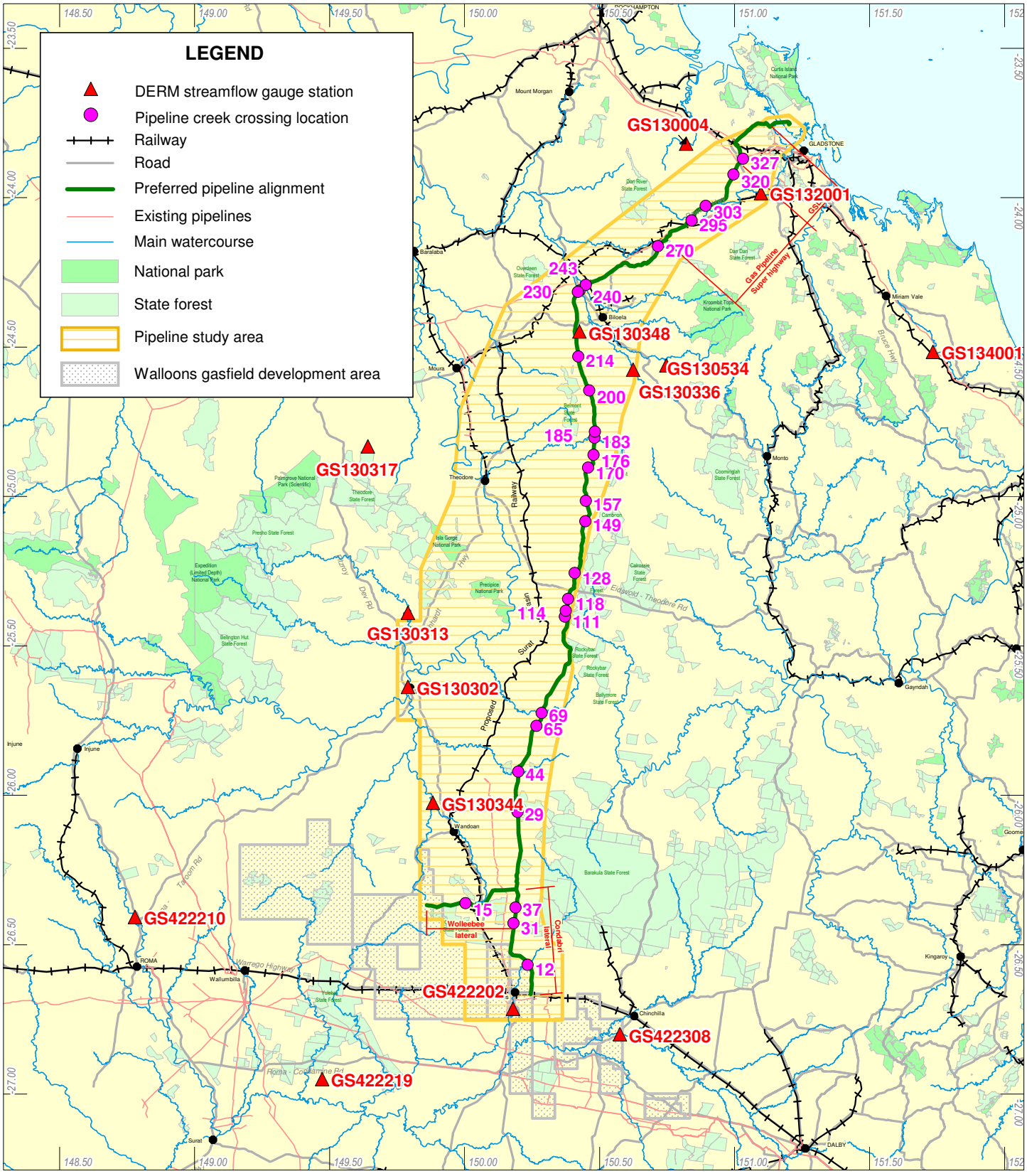
First through third order streams are also called headwater streams and constitute any waterways in the upper reaches of the watershed. Streams that are classified as fourth through sixth order are medium streams while anything larger (up to 12th order) is considered a river (Strahler 1964).



After Strahler, A.N. (1964) 'Quantitative geomorphology of drainage basins and channel networks', in Chow,V.T. (ed.), *Handbook of Applied Hydrology*, New York, McGraw-Hill, section 4-11.

Figure 5.1 Definition sketch of stream order

The 27 crossing sites having a stream order of 3 or greater are shown on Figure 5.2.



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0 25 50km

Scale 1: 2,000,000 (at A4)

Latitude - Longitude
Geocentric Datum of Australia 1994

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Rev	Date	Revision Description	ORIG	CHK	ENG	APPD
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Figure 5.2 : Pipeline Creek Crossing Locations

Project No: 301001-00448	Figure: 00448-00-EN-DAL-0272	Rev: 0

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Catchment areas were delineated and stream lengths and slopes determined in order to estimate times of concentration for Rational Method peak flow estimation. The catchment areas at the crossing sites vary between 28km^2 and 2,351km^2.

Flood frequency analyses were undertaken using the streamflow records at DERM gauges and the results used to define regional flood frequency estimates for the 100 years ARI flows at each site.

Cross-sections at each crossing site were extracted from the 25m grid topographic surface elevation digital data provided by DERM. The cross-section data was used to develop stage-discharge rating curves at each site based on an average Manning's roughness coefficient of 0.05 and channel slopes based on the digital elevation data.

Peak flood levels and flow velocities at each crossing site were obtained for the estimated 100 years ARI peak flows

Limited soil particle grading information was obtained at a number of crossing sites in order to enable potential scour risk to be estimated using scour estimation formulae.

5.2 Design flood flow estimates

5.2.1 Hydrologic modelling

As the pipeline crossings are generally located on ungauged creek catchments, or are not located near stream gauging stations, peak design flows were estimated initially using hydrologic modelling techniques.

Design rainfall intensity-frequency-duration data were calculated in accordance with Australian Rainfall and Runoff (AR&R 2001) for five reference locations along the pipeline route. The design rainfall data at the reference locations for the 100 years ARI events are summarised in Table 5.1.

Table 5.1 100 years ARI design rainfall data

Storm Duration (hrs)	Miles (mm/hr)	Wandoan (mm/hr)	Cracow (mm/hr)	Biloela (mm/hr)	Gladstone (mm/hr)
3.0	34.7	36.0	38.6	39.3	54.8
4.5	25.6	26.3	28.3	28.8	43.4
6.0	20.6	21.1	22.7	23.0	36.8
9.0	15.2	15.5	16.6	16.9	29.2
12.0	12.3	12.5	13.3	13.6	24.7
18.0	9.4	9.6	10.4	10.8	20.5
24.0	7.8	7.9	8.6	9.2	18.0

The design rainfall data exhibits a gradually increasing trend from south to north for the inland catchments located on the western side of the Great Dividing Range. The design rainfall data for Gladstone and coastal catchments on the eastern side of the range are significantly higher than for the inland catchments.

The times of concentration adopted for the Rational Method estimations were calculated using the Bransby-Williams Formula in accordance with the recommendations in the Queensland Urban Drainage Manual (QUDM 2007).

A runoff coefficient of 0.5 was adopted for the rural catchments, based on medium infiltration capacity for soils along the route and light to medium bush and grass cover, in accordance with QUDM.

5.2.2 Flood frequency analyses

Flood frequency analyses were then undertaken for DERM gauging stations located near to the adopted pipeline route in order to assess the estimated 100 years ARI peak flows against historical flow data. The 1% Annual Exceedance Probability (AEP) (equivalent to 100 years ARI) flows determined by flood frequency analyses are summarised in Table 5.2.

Table 5.2 Flood frequency results

River Basin	Station	Name	Catchment Area (km2)	1%AEP Flow (m3/s)
Condamine	GS422202	Dogwood Ck	3,010	880
	GS422210	Bungil Ck	710	810
	GS422219	Yuleba Ck	490	355
	GS422308	Chinchilla Weir	19,190	2,635
	GS422201	St George	75,370	2,833
	GS422321	Spring Ck	35	89
	GS422334	Kings Ck	516	631
Dawson	GS130302	Taroom	15,846	2,881
	GS130313	Palm Tree Ck	2,660	180
	GS130317	Woodleigh	28,503	1,835
	GS130319	Bell Ck	300	971
	GS130334	South Kariboe Ck	284	675
	GS130336	Grevillea Ck	233	427
	GS130344	Juandah Ck	1,678	1,080
	GS130348	Prospect Ck	369	607
Coastal	GS130004	Raglan Ck	389	1,599
	GS132001	Calliope R	1,288	4,070
	GS134001	Baffle Ck	1,402	2,895

The flood frequency analyses yielded the following regional peak flow relationships for the river basins:

Condamine $Q_{1\%} = 25.85\ CA^{0.442}$

Dawson $Q_{1\%} = 122.81\ CA^{0.293}$

Coastal $Q_{1\%} = 45.25\ CA^{0.6}$

where $Q_{1\%}$ = 1%AEP peak flow (m^3/s)

CA = catchment area (km^2)

The regional relationships derived from the flood frequency analyses and the hydrologic modelling exhibit significant variability between inland and coastal basins, particularly in the exponent. The regional flood frequency results are presented on Figure 5.3.

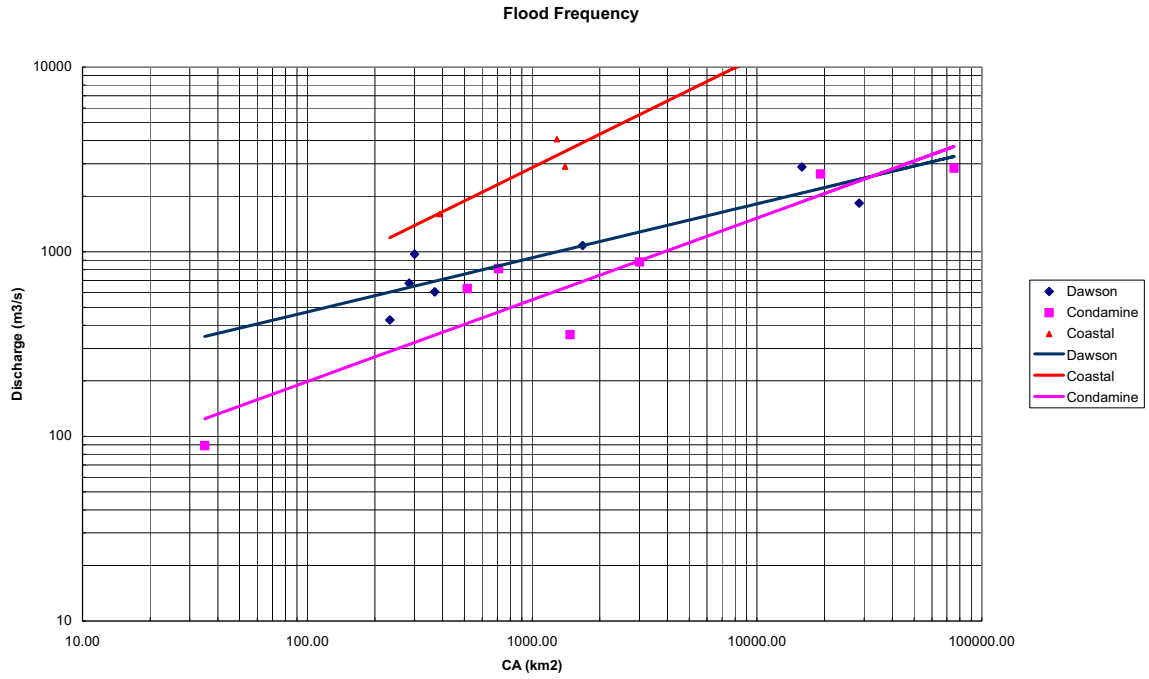


Figure 5.3 1% AEP peak flow regional relationships

5.2.3 Adopted design flows

The Rational Method is generally applied to catchment areas less than 250km^2 and thus is appropriate for almost all of the crossing locations. However, the peak flows estimated using the Rational Method were found to be approximately 60% of the expected peak flows based on the flood frequency analyses regional relationships.

The assumed run-off coefficient is considered to be appropriate for the catchments, so the apparent under-estimation of peak flows may be due to over-estimation of times of concentration resulting in lower rainfall intensities.

Therefore, due to the uncertainties associated with peak flows estimation using the Rational Method, it was considered that the regional flood frequency flow estimates were more appropriate for adoption as design flood flows for all crossing sites.

The flood levels and the maximum depth and velocity of floodwaters at the crossing sites were determined using cross-section conveyance and slope data derived from the available digital elevation data. The estimated 100 years ARI peak flows, flood levels, depths and velocities at the identified crossing sites are presented in Table 5.3.

Table 5.3 100 years ARI flood data at crossings

Pipeline Branch	Stream	Crossing (KPkm)	Q100 (m3/s)	Level (mAHD)	Depth (m)	Velocity (m/s)
Condabri	Dogwood Creek	12	773.9	302.97	4.21	0.77
	L Tree Creek	31	222.7	335.75	2.23	1.31
	Bottle Tree Creek	37	150.8	337.15	1.34	0.89
Main	Roche Creek	29	509.6	291.3	2.12	1.65
	Bungaban Creek	44	667.7	263.95	2.73	1.53
	Kennedy Creek	65	388.4	252.1	1.46	1.59
	Cockatoo Creek	69	607.4	235.6	3.12	2.66
	Ross Creek	111	418.1	332	2.47	1.94
	Ross Creek	114	390.9	342.3	1.82	1.72
	Ross Creek	118	326.7	363.9	1.95	2.02
	Cracow Creek	128	389.7	353.1	1.80	2.00
	Delusion Creek	149	512.1	334.6	2.34	2.09
	Oxtrack Creek	157	447.9	347.8	2.51	1.42
	South Creek	170	347.4	341.68	1.84	2.03
	Keen Creek	176	414.4	323.5	1.86	2.07
	Pump Creek	183	482.1	297.65	3.05	2.68
	Twenty Mile Creek	185	414.3	302	1.77	1.76
	Prospect Creek tributary	200	349.5	260.96	0.97	1.35
	Prairie Creek	214	413.1	219	3.02	2.12
	Kroombit Creek effluent	239				
	Kroombit Creek	240	1190.4	151.12	2.73	0.98
	Callide Creek	243	870.3	150.1	1.98	2.05
	Bell Creek	278	400.2	314.25	2.95	2.84
	Calliope River	295	1073.4	62.35	2.94	1.46
	Harper Creek	303	537.1	51.16	1.97	1.85
	Larcom Creek (crossing #1)	320	1334.5	29.2	4.83	1.47

Pipeline Branch	Stream	Crossing (KPkm)	Q100 (m3/s)	Level (mAHD)	Depth (m)	Velocity (m/s)
	Larcom Creek (crossing #2)	327	674.4	47.5	2.33	1.47
Woleebee	Juandah Creek	15	374.4	336.2	1.49	1.97

5.3 Water quality

The assessment of existing surface water quality was undertaken for the aquatic ecology, water quality and geomorphology impact assessment (Volume 5, Attachment 21). The assessment of existing surface water quality is summarised below.

Two dry season water quality surveys and one dry season aquatic ecology and geomorphology survey were undertaken at sites throughout the Dawson, Don and Calliope catchments. Information collected during the dry season surveys was used to supplement reported literature in order to describe the existing aquatic environment and assess the potential impacts associated with the gas transmission pipeline component of the Project. Water samples were collected from the Dawson River (although the pipeline route does not cross the Dawson River) and at five of the waterways to be crossed listed below:

- Cockatoo Creek
- Bungaban Creek (two sites)
- Juandah Creek
- Kroombit Creek
- Calliope River

Although the pipeline route does not cross the Dawson River, the water quality was tested in order to assess regional water quality.

Most waterways along the main gas delivery pipeline route in the Dawson and Don catchments were intermittent and a number of sites were dry during sampling. Where water was present, sampling was generally confined to small (non-flowing) pools. A notable exception was Cockatoo Creek, which is a spring fed stream. The Calliope catchment has a sustained base flow due to its connection to shallow underlying aquifers

Water quality in the Fitzroy catchment is characterised by low to moderate conductivity levels, high turbidity and suspended solids and high nutrients. Monitoring by DERM has also found elevated metals at various sites within the Fitzroy Basin. The catchment has been heavily impacted by stock, loss of riparian vegetation and diffuse pollution and numerous weirs and dams have modified flow regimes and contributed to reduced water quality.

Water quality in the Calliope River catchment is highly seasonal, although, it is generally characterised by moderate to high conductivity levels, low to moderate turbidity and low to moderate levels of nutrients.

5.4 Project water usage

Each section of the pipeline will be hydrostatically pressure-tested (hydro-testing) in accordance with Australian Standard AS2885.5 *Pipeline – Gas and liquid petroleum Part 5 – Field testing* to establish

the leak tightness of the section, and to confirm the pipeline's capability to operate at the maximum allowable operating pressure (MAOP). It is expected that a maximum of 100ML of non-potable water will be required for hydro-testing.

In addition to the hydrostatic testing described, several pre-tests will be performed during construction of road borings, Horizontal Directional Drilled and other specialised sections. The volumes of these sections are limited and test water will be sourced locally.

The water required for testing will be obtained from the sources listed below, in order of preference:

- Treated water from existing Australia Pacific LNG coal seam gas field reverse osmosis (RO) plants
- Re-used water from other test sections, continuously pumped down the pipeline for the next section to be tested
- Commercial suppliers
- Water from local watercourses/rivers
- Untreated coal seam gas associated water.

In all situations, permits will be obtained from the relevant regulatory authority, where required.

The water requirements for construction of the gas pipeline are described in Volume 3, Chapter 3 – Project description.

Given the preference to obtain water from other sources than surface waterways, it is anticipated that the gas pipeline project will have a negligible or zero impact on the supply of water to existing consumers either locally or regionally. The necessary permits required by the relevant water resource plan (WRP) will be obtained in the event that water is required to be sourced from a surface watercourse.

5.5 Estimation of scour

The depth of scour in alluvial channels is dependent on the depth and velocity of flows and the particle size distribution of the bed material. Limited bed material particle size grading information was collected at 16 of the crossing sites, as listed in Table 5.4

The estimation of potential scour risk at proposed pipeline crossings was undertaken using procedures for stream degradation analysis outlined in Stream Stability at Highway Structures (FHWA 2001).

The critical sediment particle size that can be moved by the hydraulic forces was calculated using the Shields formula:

$$D_c = \tau_0 / (K_s (\gamma_s - \gamma))$$

where: D_c = diameter of sediment particle (m)

τ_0 = boundary shear stress (Pa)

K_s = Shields parameter

γ_s = specific weight of sediment (N/m^3)

γ = specific weight of water (N/m^3)

For sand material the shear stress is computed using the following formula:

$$\tau_0 = \gamma n^2 V^2 / (K_u R^{0.333})$$

where: n = Manning's roughness coefficient

V = average channel velocity (m/s)

R = hydraulic radius (m)

K_u = coefficient = 1.0

For coarser grained material the shear stress is computed using the formula:

$$\tau_0 = \rho V^2 / [5.75 \log(12.27R/k_s)]$$

where: ρ = density of water (kg/m^3)

k_s = grain roughness (m) = 3.5 D_{84} for gravel and coarser material

Creek channels are susceptible to scour and erosion when the average particle size D_{50} of the bed material is smaller than the critical grain size D_c. Armouring occurs when the hydraulic forces are sufficient to remove the smaller particles but not sufficient to move the larger particles. The smaller particles are removed from the bed leaving the coarser material to form an armour layer, thus limiting the depth of scouring. Armouring can occur when at least 5% of the bed material is larger than the critical grain size, ie D_{95} is greater than D_c. The thickness of the armour layer is typically two to three times the critical grain size.

The bed material at the crossing sites is generally comprised of fine to medium sands. The exceptions to this were at Prairie Creek, where the bed was comprised of medium to coarse gravels, and Roche and Bungaban Creeks, where the bed material was predominantly silty. Grain size distribution curves for the sampled sites are plotted on Figure 5.4.

The particle grading summary and critical sediment sizes at the crossing sites are listed in Figure 5.4.

The critical grain sizes for scour and armouring are generally much larger than the D_{50} sizes obtained from the particle grading information for most of the crossing sites. Therefore, it is concluded that most creek crossing sites are prone to scouring of the creek beds during flood events.

Detailed scour assessments will be required to be undertaken in order to determine the appropriate depth of cover or scour protection measures to be adopted at each crossing.

The Dogwood Creek crossing site is the only site investigated that was found to have a low risk of scour of the creek channel during flood events. The critical grain size for scour is slightly greater than the average grain size but the D_{95} grain size is greater than the critical armour grain size, suggesting that armouring may limit the depth of scour.

More detailed discussion of the soil and waterway assessments are contained in the soils, geology and topography report (Volume 5, Attachment 7).

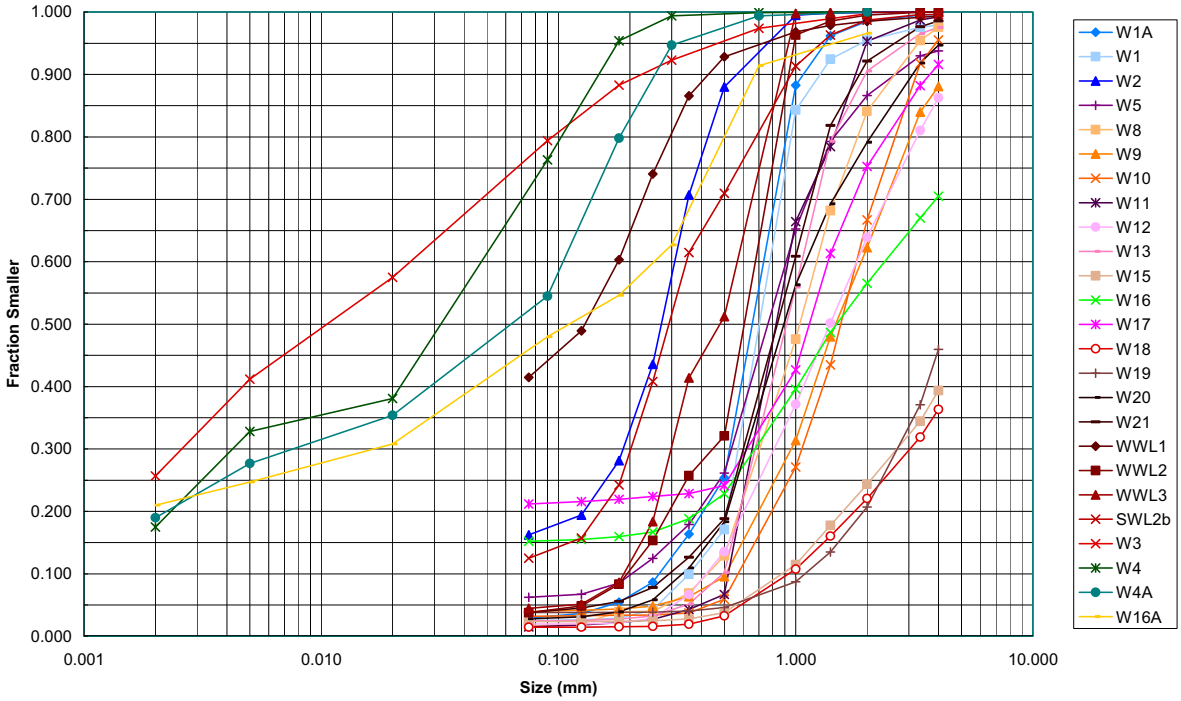


Figure 5.4 Bed material gradings

Table 5.4 Particle gradings and critical grain sizes

Pipeline Branch	Stream	Crossing (KPkm)	Sample No	Soil Grading			Scour Dc (mm)	Armour Dc' (mm)
				D50 (mm)	D84 (mm)	D95 (mm)		
Condabri	Dogwood Creek	12	W1A	0.70	0.98	1.45	0.95	1.39
	L Tree Creek	31	W1	0.75	1.00	1.90	6.35	4.58
	Bottle Tree Creek	37	W2	0.28	0.45	0.75	2.59	1.99
Main	Roche Creek	29	W3	0.01	0.15	0.45	13.11	5.03
	Bungaban Creek	44	W4	0.03	0.13	0.18	9.10	3.97
	Kennedy Creek	65					14.09	8.34
	Cockatoo Creek	69	W5	0.80	1.80	5.00	45.11	20.04
	Ross Creek	111					19.72	10.45
	Ross Creek	114					15.95	9.07
	Ross Creek	118					24.76	12.16
	Cracow Creek	128	W8	1.05	1.95	3.30	25.09	13.07
	Delusion Creek	149	W10	1.58	2.90	3.90	25.20	14.80
	Oxtrack Creek	157	W11	0.87	1.60	2.00	7.65	5.84
	South Creek	170	W12	1.40	3.70	6.00	26.08	15.82

Pipeline Branch	Stream	Crossing (KPkm)	Sample No	Soil Grading			Scour Dc (mm)	Armour Dc' (mm)
				D50 (mm)	D84 (mm)	D95 (mm)		
	Keen Creek	176					27.54	13.05
	Pump Creek	183	W13	0.93	1.60	3.00	46.38	19.82
	Twenty Mile Creek	185					17.16	9.52
	Prospect Creek tributary	200					10.63	6.90
	Prairie Creek	214	W15	6.00	8.00	10.00	23.05	18.54
	Kroombit Creek effluent	239	W16	1.50	10.00	20.00	2.38	14.80
	Kroombit Creek	240						
	Callide Creek	243	W17	1.15	2.90	5.00	25.72	22.11
	Bell Creek	278	W21	0.85	1.50	2.70	56.13	5.57
	Calliope River	295					7.67	10.21
	Harper Creek	303					19.06	4.77
	Larcom Creek	320					6.05	6.12
	Larcom Creek	327					8.83	11.07
Woleebee	Juandah Creek	15	WWL2	0.65	0.90	1.00	26.46	4.32

5.6 Potential impacts

The potential impacts on surface waterways associated with the construction and operation of the gas pipeline are essentially related to flood behaviour. These may result in changes in flood levels, depths and velocities of floodwaters and temporary or long-term changes in flow paths and erosion of the banks and scour/sedimentation of the channels of the waterways.

The potential impacts on the riverine environment essentially relate to removal of vegetation and changes in bank formation for access to the waterway during the construction period.

The potential impact on surface water quality is considered to relate to scour, erosion and sedimentation resulting from excavation and vegetation removal during the construction period.

5.6.1 Impacts on flooding

It may be necessary to divert the flow at some crossing locations during the construction period in order to protect pipe laying equipment and exposed works, particularly if any crossings need to constructed during the 'wet' season or if heavy rainfall is forecast. The temporary diversions will be repaired following completion of the creek crossing construction.

The creek channels at most crossing locations are relatively confined and associated with much wider floodplains that convey a significant proportion of the flow during flood events. Therefore, no changes in flood behaviour in moderate and major flood events are expected during the construction period.

During trenching, excavated material is stored along the right of way (RoW). In the event of a flood during the construction period, the trench may fill with water and the excavated material washed downstream of the pipeline RoW. The stockpiled material is not expected to increase sediment loading significantly during a flood event.

The majority of watercourse crossings are expected to be constructed using standard open cut (trenching) construction. This technique is most suited to dry or low flow conditions which are expected during most of the construction period. If water is present, flow diversion techniques will be employed where necessary, subject to relevant approvals. It is considered that the proposed pipeline will have a negligible impact on flood behaviour, with minor flow diversions or ponding possible in minor events during the creek crossing construction period.

5.6.2 Impacts on water quality, riverine environment and ecology

The potential impacts on water quality, riverine environment and ecology are addressed primarily in the aquatic ecology, water quality and geomorphology impact assessment (Volume 5, Attachment 21) and discussed briefly in the terrestrial ecology report (Volume 5, Attachment 18).

The former found that waterways within the project area could potentially be impacted during the construction phase through the construction of roads and pipelines and associated infrastructure. The main impact mechanism likely to affect the aquatic environment during this phase is sediment mobilisation through the clearing of vegetation adjacent to waterways and bank or bed excavation. However, other impacts may also present a significant risk to aquatic biota, such as accidental chemical spillages, effluent generated from construction camps, direct removal of aquatic flora and fauna from excavation and a range of geomorphic impacts. Temporary standing waterbodies and pools created during the construction phase may also provide suitable mosquito and biting midge breeding habitat.

The potential operational impacts include sediment mobilisation and erosion from exposed areas (road and pipeline crossings) and accidental spillages and altered low flow hydrology / hydraulics associated with road crossings.

The main source of impact on flora as a result of the Project will result from clearing of the RoW during pipeline construction. Clearing of the RoW involves the removal of trees, shrubs, stumps and other obstacles to provide access for pipeline construction. Whilst the flora assessment and analysis have adopted a standard 50m clearing width for calculating impacts, it is expected that vegetation clearance shall be minimised as far as practicable, particularly at sensitive areas such as endangered regional ecosystems (REs) or watercourses.

It is likely to be necessary to obtain permits under the Water Act to remove riverine vegetation at creek crossings or under the Fisheries Act to remove marine plants where the pipeline crosses tidal wetlands in the vicinity of ‘The Narrows’

5.7 Mitigation and management

The potential impacts on surface waterways will be minimised by adopting the following measures during the construction and operation phases, as appropriate.

The pipeline creek crossings will be constructed during the ‘dry’ season where practicable to minimise flood impact risks, construction delays and damage to plant and machinery. Construction will involve excavating a trench across the dry creek beds and covering the pipeline with the excavated bed

material. The creek beds will be reinstated to be consistent with the surrounding banks. The pipeline is predicted to cause no impacts on post-construction flood behaviour.

The construction of the pipeline creek crossings will be undertaken in a manner that results in minimal damage to the creek banks and riparian vegetation. The backfill placed over the pipeline will be compacted in order to minimise the potential for scour along the trench line and resultant erosion of the creek banks. Construction of the pipeline is discussed in Volume 3, Chapter 3 - Project description.

Detailed scour assessments will be undertaken in order to determine the appropriate depth of cover or scour protection measures to be adopted at each crossing. The detail design of the creek crossings will incorporate works and measures to minimise the following:

- The risk of damage to the creek banks during construction.
- Change in the sediment transport regime at the crossing.
- The risk of creek bank collapse or erosion during flood events.
- The risk of damage to the pipeline during flood events

The potential impact on surface water quality was considered to relate to scour, erosion and sedimentation resulting from excavation and vegetation removal during the construction period. The management and mitigation of potential impacts on water quality in surface waterways are included in the aquatic ecology, water quality and geomorphology impact assessment (Volume 5, Attachment 21).

5.8 Risk evaluation

For the purposes of this EIS, the risk assessment has focussed on potential risks to third parties, property and the environment. The risk assessment has been undertaken using a 6x6 matrix for likelihood and consequence, with five levels of risk from ‘low’ through ‘medium’, ‘high’, ‘severe’ up to ‘extreme’. The risk assessment process is discussed in detail in Volume 1, Chapter 4 Risk assessment.

The surface water risks to third parties, property and the environment for the proposed gas pipeline relate primarily to potential changes in streamflow and waterway geomorphology and riparian vegetation.

The risk assessment is summarised in Table 5.5. The risk assessment of potential impacts on water quality in surface waterways is included in the aquatic ecology, water quality and geomorphology impact assessment (Volume 5, Attachment 21).

Table 5.5 Risk assessment

Potential risk	Possible causes(s)	Possible consequences	Proposed controls	Residual risk ranking
Flood afflux due to pipeline construction activities.	Obstruction to flowpaths due to construction machinery, temporary stockpiles and diversion works.	Changes in flood flow distributions, possible increased flow onto adjoining properties and damage to buildings, personal injury.	Creek crossings to be constructed in ‘dry’ season where practicable. Pipe laying	Low

Potential risk	Possible causes(s)	Possible consequences	Proposed controls	Residual risk ranking
			machinery to be relocated to high ground when heavy rainfall imminent.	
Sediment and erosion during construction of pipeline.	Clearing for access and trench excavation	Siltation of natural drainage lines	Minimal removal of riparian vegetation and changes in bank formation.	Medium
Sediment and erosion post-construction (Scour)	Overland flow along trenchlines not adequately reinstated. Induced erosion or scour as a result of pipeline protection measures.	Siltation of natural drainage lines	Appropriate design of crossings and provision of adequate cover to pipeline.	Low
Rupture of pipeline	Seismic activity, corrosion or fatigue of pipe	Contamination to waterways, crater formation resulting in collapse of banks, damage to nearby infrastructure. Public safety issues.	Pipeline design in accordance with relevant Standards and Codes SCADA monitoring of pipeline pressures to provide rapid notification of pressure reductions	Low

6. Conclusions

Construction of the pipeline and associated activities has the potential to affect shallow groundwater systems. Potential impacts may only be realised if the pipeline or the trench intersects the watertable, which may only occur at creek crossings. Potential impacts to groundwater dependent ecosystems associated with discharge springs on Cockatoo Creek can be mitigated by selection of the final pipeline route to avoid these springs. Reduction in landholder bore yields due to groundwater extraction for construction and testing, if required, are expected to be short-term.

Environmental values of groundwater resources that may be affected by these potential impacts include the use of shallow groundwater resources for stock watering and agriculture, or as a complementary source of water for domestic use. It is not anticipated that the gas pipeline will cause any significant impact on groundwater resources, so the EVs should not be affected

The potential impacts on the riverine environment essentially relate to removal of vegetation and changes in bank formation for access to the waterway during the construction period. These impacts are addressed in Volume 4, Chapter 8 - Terrestrial ecology of this EIS.

Peak flows for the 100 years ARI design flood events for the creek crossing sites have been estimated using regional flood frequency analysis and Rational Method calculations. The regional frequency analysis flows were generally slightly greater than the Rational Method estimates and were adopted for the investigation.

Peak flood levels, depths and velocities were estimated using stage-discharge ratings for each crossing site based on coarse cross-section data and floodplain slopes. The depths of floodwaters in the 100 years ARI design events were generally less than 4 metres and the velocities were generally less than 3m/s.

In general, it is considered that the proposed pipeline will have a negligible impact on flood behaviour, with minor flow diversions or ponding possible in minor events during the creek crossing construction period.

The estimation of potential scour risk at proposed pipeline crossings was undertaken using procedures for stream scour and sediment transport analysis. The critical grain sizes for scour and armouring are generally much larger than the average grain sizes obtained from the particle grading information for most of the crossing sites. Therefore, it is concluded that most creek crossing sites are prone to scouring of the creek beds during flood events.

Detailed scour assessments will be required to be undertaken in order to determine the appropriate depth of cover or scour protection measures to be adopted at each crossing

The potential impact on surface water quality was considered to relate to scour, erosion and sedimentation resulting from excavation and vegetation removal during the construction period.

It is anticipated that the gas pipeline project will have a negligible or zero impact on the supply of water from surface waterways or groundwater to existing consumers either locally or regionally.

7. References

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality. National Water Quality Management Strategy - ANZECC and ARMCANZ. 2000

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Appendix A Abbreviations and Glossary of Terms

Abbreviations

AEP	Annual Exceedance Probability
ASS	Acid Sulphate Soils
ARI	Average Recurrence Interval
EV	Environmental Value
DERM	Department of Environment and Resource Management
EPBC	Environment Protection and Biodiversity Conservation
GAB	Great Artesian Basin
GDE	Groundwater dependent ecosystem
GWBD	Groundwater bore database
L/s	Litres per second
MAOP	Maximum Allowable Operating Pressure
mbgs	Metres below ground surface
QUDM	Queensland Urban Drainage Manual
RoW	Right of Way
SCADA	Supervisory Control and Data Aquisition
WRP	Water Resource Plan
µS/cm	MicroSiemens per centimetre

Glossary of Terms

D_{50}	Average sediment grain size
D_{84}	Sediment grain size greater than 84% by weight of sediment
D_{95}	Sediment grain size greater than 95% by weight of sediment