March 2009

# COAL SEAM GAS FIELD COMPONENT FOR ENVIRONMENTAL IMPACT STATEMENT

# QGC Surface Water Studies, Surat Basin, Queensland

**Submitted to:**
Queensland Gas Company
Procurement Department
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REPORT

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# Executive Summary

QGC is proposing to expand its Coal Seam Gas (CSG) field in the Chinchilla area of southern Queensland. The extended CSG field is divided into three development areas: the North West Development Area; the Central Development Area; and the South East Development Area.

No fatal flaws, with respect to the surface water environment, were found; provided that the recommended investigations, management actions and mitigation measures are implemented. This report was based on available information and data collected during a site visit.

The two main risks posed by the proposed activities to the surface water environment are:

- management of the associated water once it has been brought to the surface
- surface water flow and water quality affected by the development and placement of infrastructure.

These risks will require management throughout the life of the Project.

The primary legislative requirements that will guide the management and development of surface water components for the Project are the Queensland Coal Seam Gas Water Management Policy 2008, the *Water Act 2000,* the *Environmental Protection Act 1994,* the *Environmental Protection (Water) Policy 1997* and the *Water Resource (Condamine and Balonne) Plan 2004.*

## The existing environment and values

The CSG gas field is situated beneath three surface water catchments. The Project is located largely within the Condamine and Balonne River catchment. The Condamine and Balonne Rivers catchment, and the Moonie River catchment, are upper catchments of the Murray Darling Basin. Part of the development area is also located within the Fitzroy catchment that contains a number of smaller streams including Horse Creek, Wandoan Creek and Woleebee Creek.

Tenements ATP 676P, PL 179, PL 201, PL 211 and ATP 647P lie within the Condamine River catchment. Tenements PLA 261 and PLA 262 are located in the Moonie River catchment. The North West Development Area tenements, ATP 651P and ATP574P occur in the upper sub-catchments of the main Fitzroy River.

Diverse landforms, from steep mountainous terrain near the Great Dividing Range to extensive floodplains of the Condamine River occur. The region is essentially flat with low relief hills scattered throughout the floodplains of the Moonie River. The majority of the floodplains and lowland areas have been cleared of native vegetation.

The climate of the Project area is sub tropical with dry winters. Precipitation is irregular but intense, and flooding regularly occurs. Predictions indicate that climate change may cause a 30% increase in precipitation intensity in peak tropical cyclone precipitation and increase existing average runoff by 10%.

There are no significant wetlands within the present tenements although 2000 wetlands, ranging from 1 to 350 hectares in area, have been recorded within the Condamine catchment. Two nationally significant wetlands within the vicinity of the Project area are: Lake Broadwater, located within Lake Broadwater Conservation Park southwest of Dalby and directly east of tenement ATP648; and The Gums Lagoon near Tara. There are seven other nationally listed wetlands in the Condamine catchment, downstream of the site; one of which, the Narran Lakes is also an internationally listed Ramsar site. Within the reserve areas, migratory birds under Japan-Australia Migratory Bird Agreement (JAMBA) and China-Australia Migratory Bird Agreement (CAMBA) have been recorded.

The surface waters flowing through the Project area have been detrimentally affected by anthropogenic activities such as land clearing, grazing, cropping and irrigation. Hydrochemical analysis of river samples taken during the site reported elevated total suspended solids, total nitrogen and total phosphorus; compared to ANZECC water quality guidelines. The site assessment, a review of available information and the results of groundwater monitoring of the Condamine River Alluvium have indicated that baseflow to the rivers has also been affected by these anthropogenic activities.

The surface water catchment runoff characteristics in the project area are composed of riparian areas, undulating overland flow plains and near flat overland flow plains. Riparian areas are located directly adjacent to the streams and are characterized by flooding. Undulating overland flow plains are areas of long gently sloping plains with poorly defined drainage networks. Near flat overland flow plains adjoin the riparian areas and are prone to flooding from the backwater effect of the riparian area, along very poorly defined drainage lines. The flow type in this area is generally overland sheet flow of shallow depth and low velocity.

All streams in the Project area have been classified as 'type C' according to Rosgen stream classification system. These streams are typically well defined, meandering channels, with a low gradient and riffle/pool bed morphology. They are characterized by alluvial soils and broad, well defined floodplains. Three subclasses of type C streams, C4, C5 and C6, defined by the bed material, were identified in the Project area.

The stream reach environmental condition was analysed at 31 sites and the results showed: 28% had poor reach environ conditions; 50% had moderate reach environ conditions; 16% had good reach environ conditions; and 3% had very good reach environ conditions.

The overall condition of the stream sites surveyed was moderate. The major factors impacting the stream sites were: erosion; sedimentation; lack of riparian vegetation diversity; corridor width; poor aquatic vegetation and habitats.

The bank stability was assessed, on average, to be moderate across the sites. The sites surveyed had, on average, moderate bed and bar stability.

The Condamine River catchment and upper Fitzroy sub catchments were typified by poor channel diversity and habitat types. In the Moonie River catchment, the Moonie River and Finch Creek were both rated as having moderate channel diversity and habitat types. Pools, riffles and runs were the dominant channel habitat types.

Riparian vegetation was generally rated as moderate at all sites surveyed. The dominant vegetation types included eucalypt open woodlands, eucalypt woodlands and cypress pine forest. Prickly pear weeds were also present.

Aquatic vegetation was rated as poor at most sites with only emergent vegetation and grasses observed within creek beds. At sites where water was present, the turbidity of the water was generally too high to see any aquatic vegetation.

Aquatic habitat is predominantly poor due to little or no water and numerous obstructions such as fallen trees within the creek bed. It is estimated that these factors restrict aquatic organism movement at 70% of the sites visited. However, most of these restrictions could be overtopped with flow at one-third of the bank height.

Good scenic value and moderate conservation value occurs at most sites. However, Horse Creek in the Fitzroy catchment was rated very poor for conservation value and scenic value.

## Potential impacts on environmental values

Clearing land of vegetation to enable infrastructure development such as construction of roads, ponds and other facilities; increases the area of impervious surfaces throughout a catchment. This, in turn, increases the chances of erosion and hence stream sedimentation rates, runoff, stream flow volumes and velocity, and flood levels.

The loss of riparian vegetation increases the chance of bank collapse that together with channel siltation, can reduce biodiversity values.

Erosion and sediment transport are primary mechanisms for transferring nutrients into streams and increasing nutrient concentrations in stream waters. Increased nutrient concentrations can result in eutrophication that reduces water oxygen levels which affects on aquatic organisms and vegetation.

There is an increased risk of hydrocarbon loss from vehicles to water courses due to increased volumes of traffic associated with the Project. Hydrocarbons can impact adult fish, eggs and larvae.

Accidental release of CSG water stored in evaporation ponds from overtopping, wall failure and seepage could increase levels of salinity in the watercourses within the Project area. This would affect potential water users including irrigators, farmers, domestic water supply, town water supplies and infrastructure users, fishermen, and other recreational water users.

Dewatering of the Walloon coal seam measures to allow the release of coal seam gas has the potential to lower the water table in other aquifers. The Condomine River Alluvium, a potential source of base flow to the Condamine River, could potentially be impacted. A reduction in base flow can affect environmental values such as aquatic and riparian biodiversity. Ground water modelling by Golder Associates indicates that the dewatering of the coal measures will have minimal impact on the Condamine Alluvium water levels, and therefore on the base flow of the Condamine. It is important to note that water levels in the Alluvium have been declining for decades. The decline is considered to be due to abstraction from the Alluvium mainly for irrigation purposes.

CSG gas field water abstraction will deplete an existing underground water resource during the life of the operation. Abstraction of associated water reduces the potential for other uses of the water. Historically, associated water brought to surface has been evaporated, which is not a sustainable use of a potential water resource.

## Mitigation measures

To minimise the erosion and sedimentation impacts from land clearing, a Sediment and Erosion Control Plan should be developed for the Project area. Techniques for erosion and sediment control could include, the following, as applicable:

- overland flow interception drains to move runoff away from disturbed areas
- sediment fences and bunding of disturbed areas
- installation of stream flow retardation structures in drains to limit flow velocities
- slope and drain stabilisation using mulching, rip-rap or similar devices
- installation of sediment dams
- early revegetation using defined maximum landform stability criteria
- the application of defined buffer zones and clearing limits
- regular clean out of sediment traps, ponds and drains until erosion stability has been achieved
- visual monitoring to identify active erosion rills and gullies and implementation of remediation measures

Increased flow from land clearing activities and from creating impervious surfaces can be reduced by the installation of drains to intercept overland flow, upslope of the areas. Drains can be designed to move the water around infrastructure. Drains, down slope from the infrastructure can also be installed. Where the water is loaded with sediment, the drains can direct water to siltation dams and sediment traps.

All water interception and storage facilities should be designed to hold a minimum of a 1:100 year storm event, plus an average three month wet season volume, to reduce the chance of overtopping. New designs should consider increased rainfall and runoff from climate change factors. CSG evaporation ponds should have an overflow capacity for a 1:10,000 return event.

To avoid impacts from the Project on natural water courses, infrastructure should as far as possible be located above flood levels. This approach will also reduce the impact of any flood on the CSG operation. Consideration should be given to reducing or placing roads, ponds, pipelines, and other infrastructure below the flood level.

Any management of the associated water will be required to consider designing for a 30% increase in rainfall intensity during peak tropical cyclone precipitation events and a 10% increase in runoff. These factors are to be incorporated by QGC in their design parameters and sizing selection for all infrastructure, including storm water structures and evaporation ponds. Consideration should be given to the development of a more sophisticated surface water model, which can incorporate all these factors.

A water monitoring program should be implemented to monitor potential impacts of the Project in the various river catchments and potential impacts from evaporation ponds and other infrastructure. For natural rivers and streams the flow and quality of water upstream and downstream of the development areas should be monitored. This approach should apply to infrastructure, but in some instances, downstream monitoring alone may be sufficient. Evidence of increasing pollutant discharge to the watercourses requires immediate investigation to determine if it is due to the Project development. If it is the case, water quality improvement devices should be installed at the locations of concentrated flow discharging off the Project area.

The Queensland Government's CSG policy for associated water management aims to phase out the use of evaporation ponds to encourage re-injection of associated water into aquifers and beneficial use of the water. Investigation into the beneficial uses of associated water is good environmental practice and aligned with sustainable development principles. Ideally, using associated water within the tenement and with no treatment would be the best option. However, the water volumes and quality are such that this approach will not be possible for all the water. Partial or full treatment of the associated water may be required for a particular use. The most suitable water treatment technology should be identified and where necessary, brine handling and disposal methods investigated. Associated water management options include discharge to surface water courses, agriculture including irrigation, stock watering and domestic supply, industrial applications, aquaculture, municipal and town water supplies and re-injection into aquifers.

All aspects of water management are best quantified with the use of a water balance model. It is recommended that a life of operation water balance is developed.

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# GLOSSARY

| Term | Meaning |
|---|---|
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| ArcMap | Graphical Information Systems (GIS) software |
| ASS | Average surface store capacity |
| AWBM | Australian Water Balance |
| AWBM | A catchment water balance model that can relate runoff to rainfall for both gauged and ungauged catchments (Catchment Modelling Toolkit website). |
| BG-QGC | Queensland Gas Company and BG International Limited Alliance |
| BOM | Bureau of Meteorology |
| CAMBA | China-Australia Migratory Bird Agreement |
| CCMA | Condamine Catchment Management Association |
| CDI | Capacitive Desalination or Deionization |
| CSG | Coal Seam Gas |
| CSG water | Groundwater that comes to the surface in the process of coal seam gas extraction |
| CSIRO | Australian Commonwealth Scientific and Industrial Research Organisation |
| DO | Dissolved oxygen |
| DOC | Dissolved organic carbon |
| EA | Environmental Authority |
| EC | Electrical conductivity |
| EIS | Environmental impact statement |
| EMP | Environmental Management Plan |
| EPA | Environmental Protection Agency |
| EPP | Environmental Protection (Water) Policy |
| GAB | Great Artesian Basin |
| GMAs | Groundwater Management Areas |
| GMUs | Groundwater Management Units |
| HYDSTRA | A software package utilised by the water resources, hydropower and wastewater industries for managing large amounts of data in a single archive providing the capacity for storage, management and analysis of time series data |
| IFD | Intensity Frequency Duration |
| IROL | Interim Resource Operations Licence |
| JAMBA | Japan-Australia Migratory Bird Agreement |
| LNG | Liquefied Natural Gas |
| LRAM | Land Resource Assessment and Management Pty. Ltd. |
| m AHD | Australian Height Datum |
| ML/d | megalitres per day |
| Mtpa | Million tonnes per annum |
| NOx | Nitrate + nitrite |
| NRW | Department of Natural Resources and Water |
| NWI | National Water Initiative |
| QA/QC | Quality control and quality assurance |
| QGC | Queensland Gas Company |
| Quaternary Alluvium Unit | The gradient between the Walloon Unit and Condamine River Alluvium |

| Term | Meaning |
|---|---|
| RO | Reverse osmosis |
| SAR | Sodium absorption ratio |
| SDPWO Act | State Development Public Works Organisation Act 1971 |
| SRTM | Shuttle Radar Topography Mission |
| SS | Suspended Solids |
| TDS | Total dissolved solids |
| TOC | Total organic carbon |
| TOR | Terms of Reference |
| TSS | Total suspended solids |
| WCM | Walloon Coal Measures |
| WMA | Water Management Area |
| WMP | Water Monitoring Plan |
| WQOs | Water quality objectives |
| WRP | Water Resource Plan |

# 1.0 INTRODUCTION

Queensland Gas Company (QGC) proposes to develop a Liquefied Natural Gas (LNG) export facility at Gladstone in Central Queensland (the Project). Phase 1 of the Project consists of the construction of a facility to produce three to four million tonnes per annum (Mtpa) of LNG, with the potential for future expansion to 12 Mtpa. The Project consists of the following key components:

- development of Coal Seam Gas (CSG) fields
- construction of pipelines for gas transmission
- development of an LNG liquefaction and export facility.

The Project was declared a significant project in July 2008, under the *State Development Public Works Organisation Act 1971 Qld* (SDPWO Act) (section 26). An Environmental Impact Statement (EIS) is required, as part of the significant project declaration. This study has been prepared to support the preparation of the EIS.

To assist in the development of the EIS, Golder Associates Pty Ltd (Golder) was commissioned by QGC to examine the effects of the CSG Field component of the Project on groundwater and surface water resources. This report considers the surface water component of the Project (Figure 1). It recognises that surface water is part of the larger hydrological cycle and it interlinks strongly with groundwater. The effect of the CSG Field groundwater component of the Project is covered in a separate Golder report.

The purpose of an EIS in Queensland is to:

- provide stakeholders with sufficient information to understand the type, nature, and extent of the proposed project
- identify, examine and assess direct, indirect and cumulative impacts on the natural, built and social environment
- determine how adverse impacts can be avoided or mitigated so that any residual effects are acceptable
- ensure the project is based on sound environmental protection and management criteria.

An EIS should provide this information in a form suitable for use by:

- affected persons
- interested persons
- relevant Queensland State Government agencies
- the Australian Government Minister for the Environment, Heritage and the Arts.

## 1.1 Project Background

Coal Seam Gas is a natural gas, composed primarily of methane gas. It is used in the home for cooking and warming buildings. It is also used as a fuel for buses, cars and power plants. The gas is absorbed in underground coal beds. The procedure for recovering this gas involves drilling a series of wells into targeted coal beds. Groundwater (CSG water or associated water) is pumped out to lower the reservoir pressure in the coal measures, in order to release the methane gas from the coal.

Groundwater extraction for CSG is closely linked to gas pressure and gas extraction. The groundwater and gas extraction process consists of placing a pump in a well, typically above the coal seam. Depending on the geology and reservoir conditions, a tail pipe may be placed below the pump to enable the intake depth of the pump to be lowered.

Groundwater pumping continues until the gas flows freely (decreasing the water pressure in the coal seam(s) liberates the gas). Often, no pumping is required at this stage as the velocity of the gas entrains and lifts the groundwater and the pump may be removed. When the gas rate falls, and the groundwater can no longer be extracted by the gas lifting effect, a pump is set back into the well.

CSG has been under exploration in the Surat Basin, Queensland, since the early 2000's, and its development has progressed at an accelerated rate since 2005. The Walloon Coal Measures (WCM) are the main gas bearing units within the Surat Basin. Pumping of CSG water from the Walloon Coal Measures has successfully lowered the reservoir pressure, producing good quantities of methane gas.

## 1.2 Project Description

The proposed LNG export facility at Gladstone will allow QGC to commercialise their Surat Basin CSG resources and export the processed gas, in the form of LNG, to overseas markets. The project will consist of two phases:

- Phase 1 – construction of a 380 km gas transmission pipeline from the QGC CSG fields to the LNG facility in Gladstone
- Phase 2 – expansion of the LNG facility.

To supply the LNG facility, QGC will need to significantly increase output from its CSG fields. This will involve a major expansion of well development, in-field compression stations, processing plants, associated water management, land access and ancillary infrastructure. The CSG field component of the Project will comprise developing:

- a total of 6000 production wells
- associated surface equipment; gas and water gathering systems; and gas processing and compression infrastructure
- ways to manage, store and beneficially use CSG water.

CSG Field components to be developed will include:

- production well sites, gas and associated water gathering infrastructure
- field compression and processing facilities
- support infrastructure
- access tracks
- CSG water management infrastructure could include one or more of the following:
  - evaporation ponds
  - water treatment plants and/or re-injection wellfield/s
  - associated water reticulation systems.

Wells will be located approximately 750m apart to optimise production. The well sites will require a firm and level area of approximately 100m by 100m size (approximately 1 hectare) for the drilling rig and associated plant. Site selection will be based primarily based on the geological analysis completed as part of the exploration works.

A network of pipelines will link the gas wells to the main gas pipeline infrastructure corridor. This pipeline network has a planned minimum design life of 40 years. The pipelines will be monitored remotely through a central control room, as well as by field inspection. Raw water will be used for hydrotesting the pipeline during construction.

## 1.3 Regional surface water catchments

In Queensland, surface water is administered and managed on a catchment basis. The Project is contained within three catchments:

- The Condamine and Balonne River catchment (The Condamine River is the name given to an upstream portion of the Balonne River)
- The Moonie River catchment
- The Fitzroy River catchment.

The project is primarily located within the Condamine and Balonne catchment. Surface water in this catchment is administered through the *Water Resource (Condamine and Balonne) Plan 2004* (CB WRP) and the *Condamine and Balonne Resource Operations Plan 2008* (CB ROP). The CB ROP sets out the regulations and requirements that guide day to day management of water to achieve the objectives and outcomes of the *Water Resource (Condamine and Balonne) Plan 2004.* There are also small sections of the Project area draining into the Moonie and Fitzroy catchments. The Condamine and Balonne catchment, together with the Moonie catchment are upstream tributaries of the Murray Darling Basin.

## 1.4 Local hydrological context

The Project area lies approximately 200 km west of Brisbane (Figure 1). The major towns near the proposed area of operation include Chinchilla, Miles, Moonie, Kogan, Wallumbilla and Dalby. The major rivers running through the area include the Condamine and Balonne, Moonie, and the Weir Rivers. The area is serviced by major roads; railways; and many gas pipelines, including one that transfers gas from Roma to Brisbane.

The Project area is located within the Surat Basin of the Great Artesian Basin (GAB). It is approximately 280 000 sq km in area and is located in the southeast corner of the Great Artesian Basin.The GAB underlies the majority of inland Queensland and inland northern New South Wales. The Surat Basin contains significant geological resources including coal, coal seam gas, oil, natural gas, water and bentonite.

Native woodland covers large areas of the Surat Basin Most of this native woodland is contained within protected State Forests and National Parks, including the Carnarvon National Park located in the northern part of the basin..

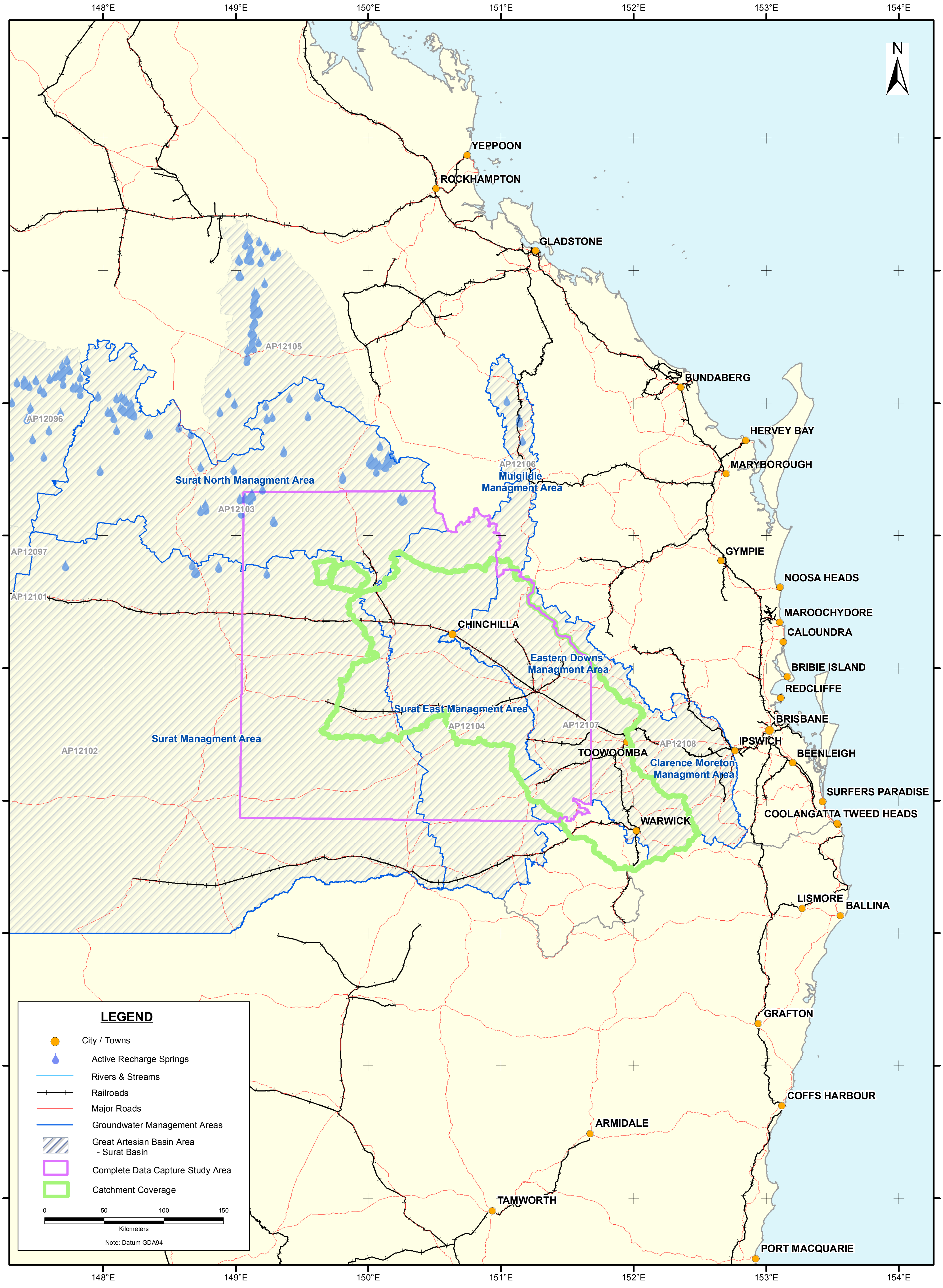
There are nationally significant wetlands located on the lower Balonne River system in New South Wales and on the Narran River. The Ramsar-listed Narran Lake Nature Reserve (which includes Back and Clear Lakes) is part of a large terminal wetland system.

The headwaters of the Condamine River catchment originate on the western flanks of the Great Dividing Range, as far south as Killarney and Warwick. The Condamine River flows north towards Dalby and Chinchilla. From Chinchilla, the river flows west to the town of Condamine, where it joins the Balonne River, north of Surat. From Surat, the Balonne River flows south through St. George and Dirrambandi into New South Wales. The Condamine/Balonne river system is highly regulated with off-take for irrigation occurring throughout the catchment area in Queensland.

Land use in the Condamine and Balonne system is dominated by cattle and sheep grazing, and grain and cotton production. The eastern part of the basin supports significant agricultural production due to the presence of fertile cracking clay soils and adequate rainfall. Grazing and dry land cropping dominate in the western part of the basin, where the climate becomes drier. Agriculture in the western portion of the basin is supported by irrigation. Over 112,000 hectares of irrigated crops were grown in 2000 and 63% of the irrigated crop was cotton (CSIRO 2008). Surface water is the main source of irrigation water. Approximately 55% of surface water in the WMA is diverted to agricultural purposes (CSIRO 2008).

Less than 5% of Queensland's total population lives in the basin (OESR, 2008). The region is managed by three local government areas:

- Toowoomba Regional Council
- Dalby Regional Council
- Roma Regional Council.



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| CHECKED | DS* | DATE | 03-03-09 |
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Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.

## 1.5 EIS Terms of Reference

The Terms of Reference (TOR) for the EIS identifies three main components of the Project:

- the CSG field
- the gas transmission pipeline and
- the LNG liquefaction and export facility.

The TOR identifies three phases of the Project:

- construction
- operation
- decommissioning and rehabilitation.

For each component and phase, the TOR requires that the EIS contains an explanation or description of the following things:

- the need for the Project
- costs and benefits of the Project
- alternatives to the Project
- the methodologies used to prepare the EIS
- how pubic consultation will be managed and conducted, the management and method of public consultation
- the relevant policies and legislation that the Project must comply with
- the Project's consistency with existing land uses or long-term policy framework/s for the Project area
- a description of the local and regional context including:
  - natural, built and social environment
  - State and National environmentally sensitive assets
  - natural resources to be used by the project
  - built and social infrastructure required by the project
  - modifications to be made to the natural, built and social environment
- proposed waste management systems
- identification and characterisation of direct, indirect and cumulative impacts on the local and regional natural, built and social environment
- proposed methods for avoiding, ameliorating, and managing impacts on the:
  - local and regional natural, built and social environment
  - local and regional State and National environmentally sensitive assets
  - resources used by the project.

In terms of the CSG field, the TOR requires that the EIS contain information about:

- local and regional water resources, particularly the GAB and the Condamine River and its tributaries
- local and regional aquatic and terrestrial ecosystems
- the use of local and regional ground and surface water resources, particularly the GAB and the Condamine River and its tributaries
- demand for raw and treated water for the various processes and the proposed and optional sources of water (e.g. bores, surface storage such as dams and weirs, and municipal water supply pipelines) for construction and operational aspects of the Project
- estimated rates of supply from each source (average and maximum rates)
- identification and characterisation of daily, seasonal and/or peak operational requirements
- total annual consumption
- potable water demand and supply requirements for each phase, including existing town water supply to meet such requirements
- storage and distribution of water on and off the CSG fields
- the capability of the water network to provide for the necessary demand
- any additional water supply infrastructure
- current and projected raw and treated water consumption and storage
- contingency plans for planned and non-planned supply failures
- projected dates for increased raw and treated water supplies
- the water balance
- impacts of the project on ground and surface water resources
- project hydrological and climatic risks
- storage and treatment of saline water
- decommissioning of saline water and other waste storage facilities.

## 1.6 Scope of Work

Golder was commissioned to provide information to support preparation of the groundwater and surface water components of the Project's EIS.

For the purposes of this report Golder was commissioned to conduct eight tasks:

- describe the environmental values associated with surface water environments in the upstream Project area
- describe the quality, current yields and capacities, and other physical features of the surface water resources in the CSG Field

- conduct a legislative review with respect to surface water
- review the climatic and hydrologic history of the CSG Field
- assess the likelihood of flooding within the CSG Field and suggest mitigation measures where relevant
- identify constraints to well development and operation, access track construction, water and gas gathering pipeline installation and other infrastructure
- identify and assess likely impacts of the Project on:
  - surface water resources and associated ecosystems
  - any State or Nationally significant environmental assets
- review and identify measures for management and mitigation of surface water risks and impacts, including an assessment of reinjection.

This report only covers the surface water component of the original scope of work provided.

## 1.7 Groundwater and surface water studies

Two separate reports have been produced on hydrological aspects for the EIS. This report covers the surface water component. The groundwater studies are documented in a separate Golder report. It is recognised that within the hydrological cycle, groundwater and surface water are inextricably linked and therefore, reference to the groundwater study is provided.

The groundwater study covers:

- the majority of the Surat Basin, which lies in the south eastern part of the GAB
- small sections of the Clarence and Moreton Basins.

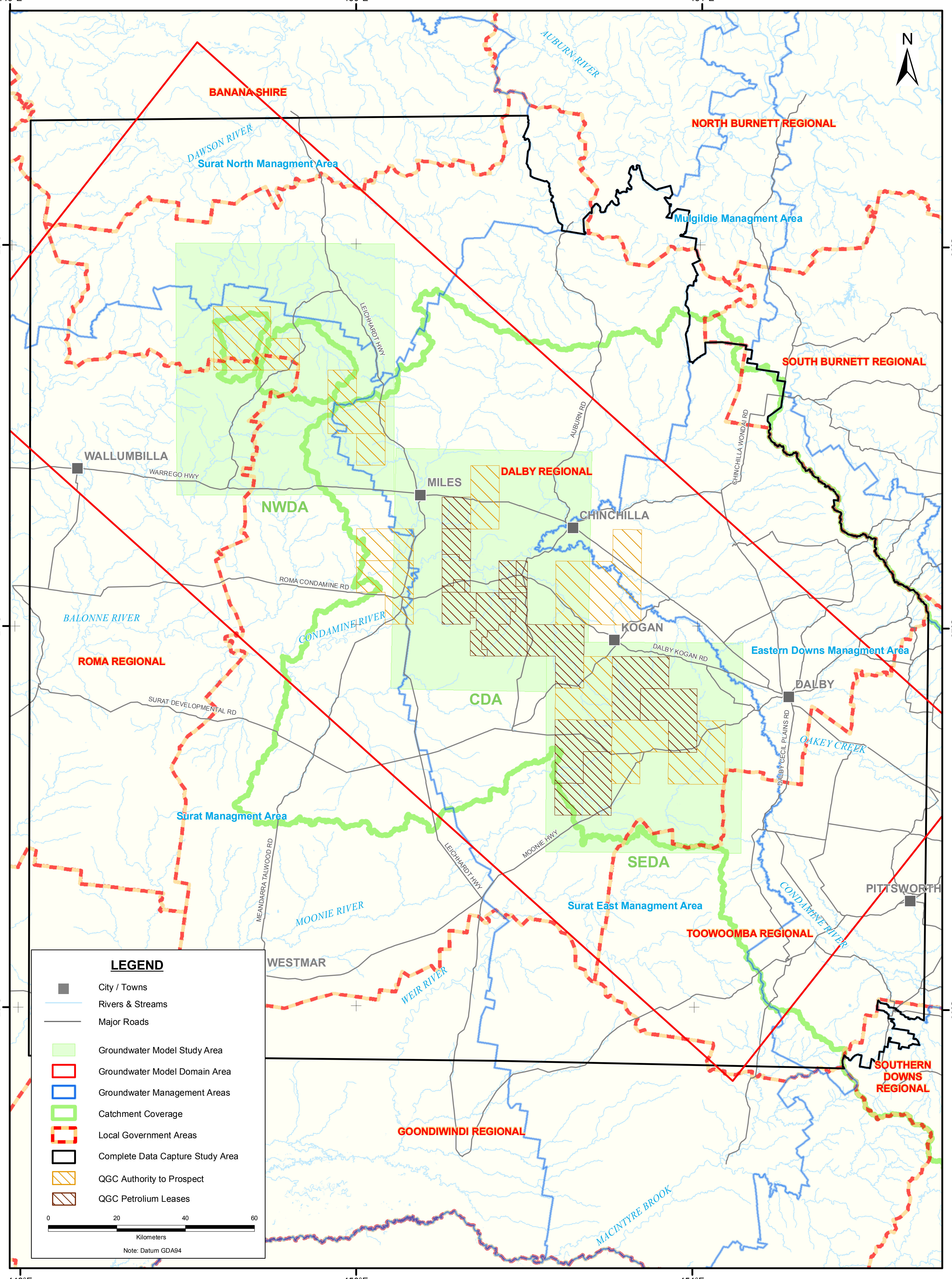
The groundwater investigation area is contained within the Surat, Surat North, Surat East, and Eastern Downs Groundwater Management Areas defined in Schedule 2 of the *Water Resources (Great Artesian Basin) Plan 2006*. The investigation area extends beyond the predicted area for likely water impacts that are associated with the operation of the CSG field.

QGC's Surat Basin petroleum leases are listed in Table 1 below. The lease boundaries, the groundwater investigation area, and the surface water catchments are indicated in Figure 2.

**Table 1: Petroleum tenements included in the study area**

| Block Names | ATP/PL Number |
|---|---|
| Marcus, Peebs and Pinlands | ATP574 |
| Arvin, Connor and Grace | ATP 632 |
| Andrew | ATP 647 |
| Barney, Broadwater, Celeste, Clunie, Cougals, Glendower, Harry, Jordan, and Michelle | ATP 648 |
| Cam, Kathleen, Mamdal, Ross and Woleebee Creek | ATP 651 |
| Avon Downs, Jade, Madeline, McNulty, Owen, and Wyalla | ATP 676 |
| Argyle | PL179 |
| Codie, Kenya, Lauren | PL180 |
| Berwyndale South | PL201 |
| Berwyndale | PL211 |
| | PL212 |
| Kate | PL228 |
| | PL229 |
| Bellevue | PL247 |
| Jammat, Kenya East, Margaret | PL257 |
| David, Poppy and Sean | PL259 |
| Myrtle, Ridgewood and Will | PL261 |
| Alberdeen and Teviot | PL262 |
| Matlida-John | PL263 |
| Isabella, Jen and Ruby | PL269 |

[1] ATP for Authority to Prospect, PL for Petroleum Lease

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2. Authority To Prospect & Petroleum Leases data supplied by Queensland Gas Company (QGC), dated 15-10-2008 and 23-10-2008.

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Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.

## 1.8 Previous and Related Studies

A number of studies have been undertaken for major watercourses in the vicinity of the Project area that relate to water quality and water availability within the region. The *'State of the River'* reports have been developed for the Lower Condamine River, Moonie River and their major tributaries. The Cooperative Research Centre for Freshwater Ecology has developed a *'State of the Catchment'* Report for the Condamine River System. These reports describe the ecological and physical conditions of the river systems and the values of and threats to the systems.

The CSIRO has developed two reports relevant to watercourses within the project area – *Water Availability in the Condamine-Balonne* (2008) and *Water Availability in the Moonie* (2008). These reports provide the results of an assessment on water availability on a catchment and aquifer basis and take into account climate change and other risks.

The Land Resource Assessment and Management Pty Ltd (LRAM, 2002) report identifies the flood plain elements of the Condamine River, the flow types and potential hazards and formulates objectives and strategies for the management of land use activities within the flood plain.

A list of the previous surface water studies is provided in Table 2 below.

**Table 2: List of water studies**

| Reference | Content |
| --- | --- |
| Johnson D.P. (1999) State of the Rivers Border Rivers and Moonie River Catchments, An Ecological and Physical Assessment of the Condition of Streams in the Border Rivers and Moonie River Catchments. The State of Queensland, Department of Natural Resources, Australia | A summary of the ecological and physical properties of the Border Rivers and Moonie River catchments. |
| Manen N.V. (2001)State of the Rivers Maranoa, Balonne and Lower Condamine Rivers and Tributaries, An Ecological and Physical Assessment of the Condition of Streams in the Maranoa, Balonne and Lower Condamine River Catchments. The State of Queensland, Department of Natural Resources, Australia. | A summary of the ecological and physical properties of the Maranoa, Balonne and Lower Condamine River and tributaries. |
| Wilson G.C. & J.C.Adams (2004) State of the Catchment Report for the Condamine River System – Water. CRC for Freshwater Ecology. | Values of and threats to the Condamine River catchment and major tributaries. |
| LRAM (2002) Draft Condamine Flow Co-ordination NRM Report Technical Working Paper A. Submitted to the Department of Local Government and Planning. | Description of flood plain elements, flow types, potential hazards and a formulation of objectives and strategies for the management of land use activities in each of the flood plain elements. |
| CSIRO (2008) Water Availability in the Condamine-Balonne – A Report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia. | Assessment of current water use within the Condamine catchment and an estimate of water availability on an individual catchment and aquifer basis, taking into account climate change and other risks. |
| CSIRO (2008)Water Availability in the Moonie. A Report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project. CSIRO, Australia. | Assessment of current water use within the Moonie catchment and an estimate of water availability on an individual catchment and aquifer basis, taking into account climate change and other risks. |

## 1.9 Limitations of this Report

This report has been prepared by Golder in accordance with the Scope of Works. It is based on data provided by QGC and NRW. No responsibility is taken by Golder for data interpreted by QGC and NRW.

This surface water impact study has been developed for the sole interest and use of QGC. This report and associated deliverables may not be adequate for a contractor, or even some other consulting civil engineer. This report should not be used by other persons for any purpose or by the client for a different purpose. No individual other than the client should apply a report, even apparently for its intended purpose, without first conferring with the consultant. No person should apply a report for any purpose other than that originally contemplated without first conferring with the consultant.

Surface conditions are changed by natural processes and human activities. This report is based on conditions which existed at the time of preparation. Decisions should not be based on this report if its adequacy may have been affected by time. Speak with the consultant to learn if additional tests or modelling are advisable.

Costly problems can occur when design professionals develop their plans based on misinterpretations of a report such as this. To help avoid these problems, Golder should be retained to work with appropriate design professionals to:

- explain relevant findings
- review the adequacy of their plans and specifications relative to contamination issues.

The information provided within this report was obtained from:

- relevant literature
- from modelling undertaken using available data provided predominately by QGC and NRW
- brief field studies.

Where site specific data was not available, regional parameters were used, and assumptions were made based on experience and knowledge of the project context. When site specific data is collected, this may change the some or all of the results and findings of this report.

# 2.0 QUEENSLAND LEGISLATIVE AND POLICY FRAMEWORK

The legislation relevant to groundwater and surface water in Queensland, including plans and policies that were assessed, are summarised below. To some extent, the legislation recognises the continuity of surface and groundwater in the hydrological cycle. Therefore, it is important to understand plans and policies for both surface water and groundwater.

The report includes the following acts, plans and policies:

- *Petroleum and Gas (Production and Safety) Act 2004*
- Queensland Coal Seam Gas Water Management Policy 2008
- *Water Act 2000*
- *Environmental Protection Act 1994*
- *Environmental Protection (Water) Policy 1997*
- *Water Resource (Great Artesian Basin) Plan 2006* and Great Artesian Basin Resource Operations Plan 2007
- *Water Resource (Condamine and Balonne) Plan 2004* and Condamine and Balonne Resource Operations Plan 2008
- *Water Resource (Moonie) Plan 2003* and Moonie Resource Operations Plan 2006
- *Water Resource (Fitzroy Basin) Plan 1999*
- *Water Supply (Safety and Reliability) Act 2008*
- *Water Fluoridation Act 2008*
- *National Water Initiative*

The main elements of the legislation and policies for using water by the petroleum industry in Queensland are discussed in the following sections.

## 2.1 Petroleum and Gas (Production and Safety) Act 2004

The *Petroleum and Gas (Production and Safety) Act 2004* (P&G) considers the underground water taken or interfered with from a petroleum well. This water is called ‘associated water’ (section 185). The Act requires the production of a water impact report, defines uses of associated water, monitoring requirements and ‘trigger’ values.

### 2.1.1 Associated water use

A petroleum tenure holder can use associated water for domestic or stock purposes on the land in the area of the tenure or land that joins land in the area of the tenure and is owned by the same person (section 186). If the tenure holder wants to use associated water for another purpose, the holder must obtain a water licence under the *Water Act 2000*. The water extraction rights for or during petroleum purposes as defined in the P&G Act include:

- taking water when drilling a bore, however, the bore construction must comply to the regulation and be completed as a water supply bore

- no limit to the volume of water that may be taken (section 185 (3))
- the associated water can be used for the authorised mining activity or for domestic and stock purposes on the land covered by the tenure and adjoining land or by any land owned by the land owner (section 186).

### 2.1.2 Monitoring associated water

Section 187 of the P&G Act, further identifies the requirements for water monitoring for associated water. Water monitoring is required for assessing compliance with the tenure. The following requirements are set out under this act:

- gathering information about, or auditing an existing Water Act bore (termed a water monitoring activity). (An existing Water Act bore for a petroleum tenure is a water bore as defined under the Water Act if taking of or interference with water from the bore is authorised under the Water Act; it required a development approval under the *Integrated Planning Act 1997*; and the bore was in existence prior to the start of approved testing for petroleum production or the start of commercial production.)
- gathering information for an underground water impact report, pre-closure report, monitoring report or review report
- monitoring the effect of the exercise of the underground water rights for the tenure
- constructing or plugging and abandoning a water observation bore
- carrying out restoration measures in relation to an existing Water Act bore for which the make good obligation applies.

A petroleum tenure holder may also apply for a water monitoring authority (section 190), which may include land outside the tenure area to allow the holder to comply with the tenure requirements. This allows the authority holder to carry out any water monitoring activity, but not water transmission, treatment or sales activities, in the area of the authority (section 194). For example, permitted activities include gathering information about, or auditing an existing Water Act bore.

### 2.1.3 Water impact report

The holder of the tenure must provide a water impact report of its activities (sections 252 to 257).

### 2.1.4 Trigger values

The legislation does not specify maximum drawdown of groundwater levels or water extraction limits. Instead, the P&G Act requires the fixing of a "trigger threshold" for aquifers in the area affected by the exercise of underground water rights for a petroleum tenure in order to prepare an underground impact report for the tenure. Section 253 states that "*The petroleum tenure holder may ask the chief executive what the trigger threshold is for the aquifers".* The trigger value is defined as "*the water level drop in the aquifers that the chief executive considers would be a level that causes a significant reduction in the maximum pumping rate or flow rate of the existing Water Act bores in the area affected by the exercise of the underground water rights."* (section 254(1)). Hydraulic conductivity, geometry and water levels of the aquifers are defined as the criteria to be considered in the definition of the trigger value.

No time value over which the pumping is performed to create the associated impact is mentioned in the P&G Act. However, the length of time used to estimate the drawdown is critical to the establishment of a trigger value. The length of time for evaluation of triggers should also consider:

- the regime of the pumping (intermittent, continuous)
- the total length of time over which the pumping will take place.

When the trigger value fails to incorporate the notion of time, its value becomes meaningless as it will not characterise the range of impacts of groundwater extraction on the aquifers.

## 2.2 Queensland Coal Seam Gas Water Management Policy 2008

The Queensland Government has recently developed a water management policy framework for the CSG industry to address the potential environmental risks associated with the anticipated expansion of CSG activity in the major Queensland basins. This expansion will result in a significant imbalance between the volume of produced CSG water and demand by potential users. The purpose of the new policy is to achieve environmentally sustainable outcomes and encourage greater beneficial use of CSG produced water. The key implications of the proposed groundwater policy are as follows:

- Use of evaporation ponds to manage produced water is to be phased out over the next three years, along with remediation of existing evaporation ponds to render the land suitable for alternative future uses.
- Beneficial reuse of produced water is promoted as the preferred management option, which may require treatment to achieve appropriate water quality standards for various end uses.
- CSG producers are responsible for treating and disposal of produced water. Unless CSG producers have arrangements for injection and reuse of untreated CSG water, produced water must be treated to a standard defined by the EPA before disposal or supply to other water users.
- Aggregation of surplus produced water will be considered as a last option where no feasible alternative management option exists. Details regarding aggregation and disposal of surplus water are still under development, but will likely require a significant financial commitment to be borne by the participating members of the CSG industry.
- The policy also outlines that a CSG Water Monitoring Plan (WMP) is to be incorporated in the Environmental Management Plan (EMP) required for Level 1 Environmental Authority (EA) applications.

A flowchart of the new management framework is presented in Figure 3 below.

The release date of the final discussion paper on this policy was indicated to be in late 2008. To date, it has not been released.

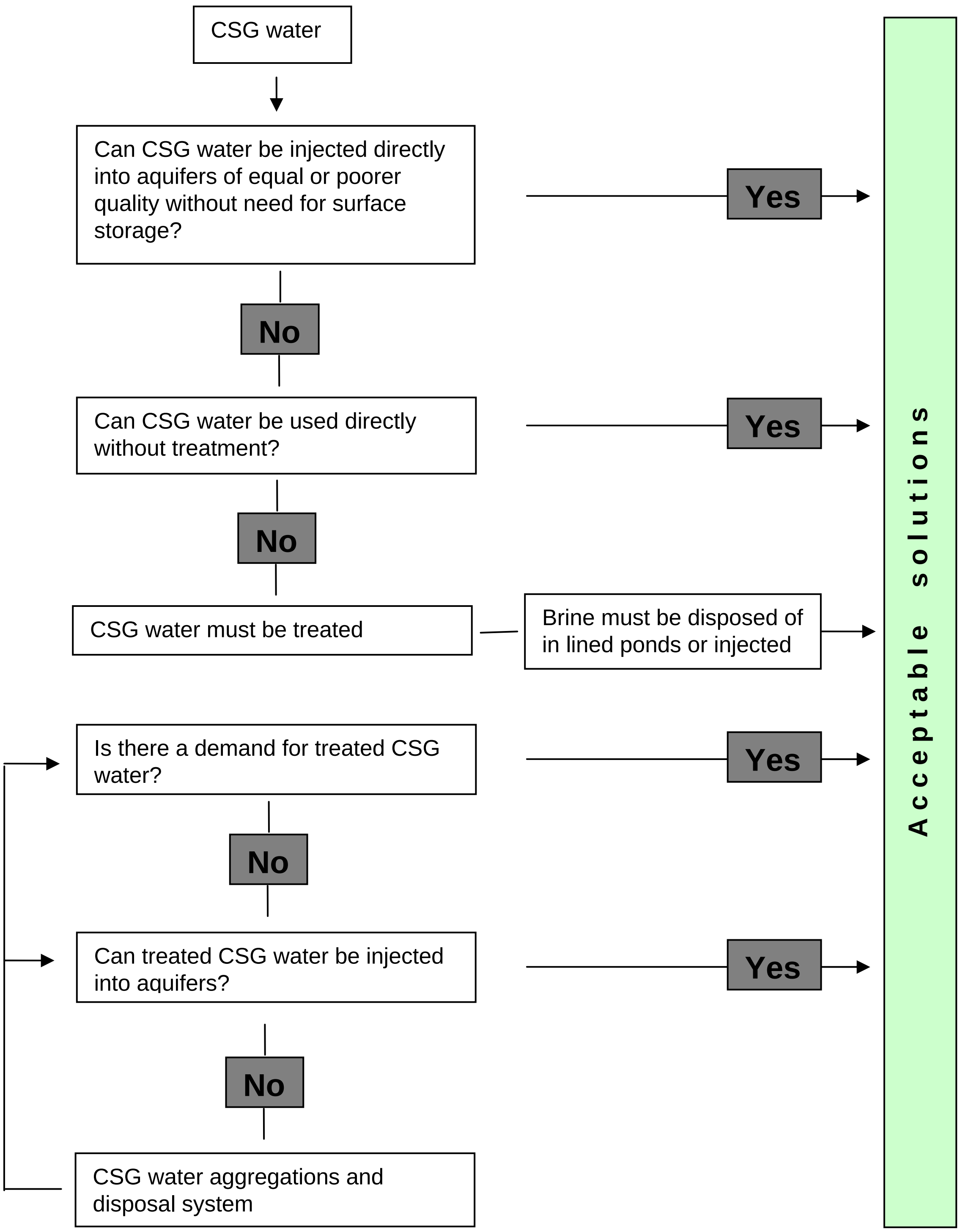



*Figure 3: Queensland CSG Management Framework*

## 2.3 Water Act 2000

The *Water Act 2000* vests the use and control of all water in Queensland in the state. The act was developed to provide for the sustainable management of water and other resources and the establishment and operation of water authorities, and for other purposes. The *Water Act 2000* states that a water licence is required to take water or interfere with the flow of water and provide it to any use other than domestic and stock watering (section 206, 206A). The decisions made in regards to taking or interfering with the flow of water are to be in accordance with the relevant WRP. The legislation states that a petroleum tenure holder may apply for a water licence only if the water is associated water under the *Petroleum and Gas (Production and Safety) Act 2004* or the water is not being used, or proposed to be used, for an activity that, under the Act, is an authorised activity for the tenure. If a water licence is granted to a petroleum tenure holder, there may be a requirement under section 214 (e) to carry out and report on a stated monitoring program.

It sets out the requirements for who may apply for a transmission water licence. Various entities, such as QGC may apply for a water licence (a transmission water licence) for taking water from a water source.

Abstraction of the groundwater may result in reduction in baseflow to the watercourses within the Project area; therefore, QGC may be required to obtain a water licence.

## 2.4 Environmental Protection Act 1994

Sections of the *Environmental Protection Act 1994* (EP Act) relevant to the project are:

- Sections 14 to 17 of the (EP Act) define environmental harm, environmental nuisance, material environmental harm and serious environmental harm. Environmental harm is any adverse effect, or potential adverse effect on an environmental value.
- Section 18 which classifies petroleum activities as environmentally relevant activities.
- Sections 77 and 78 outline what constitutes a petroleum activity. It includes:
  - activities required under a condition of an environmental authority
  - rehabilitating or remediating environmental harm caused, for example, by conveying petroleum resources.
- Section 98 may impose conditions on a petroleum activity. Under the act the, Environmental Protection Agency (EPA) may:
  - ask the petroleum activities to prepare environmental reports and prepare and carry out environmental programs
  - report on monitoring programs
  - limit the petroleum activities holder to change, replace or operate any plant if the action can substantially increase the risk of environmental harm
  - order the activity to cease or be on hold.

  Conditions may be imposed and continue to apply after the environmental authority has ceased.

## 2.5 Environmental Protection (Water) Policy 1997

The purpose of the *Environmental Protection (Water) Policy 1997* is to provide a framework for:

- identifying environmental values for Queensland waters
- deciding and stating water quality guidelines and objectives to enhance or protect the environmental values
- making consistent and equitable decisions about Queensland waters that promote efficient use of resources and best practice environmental management
- involving the community through consultation and education and promoting community responsibility.

The *Environmental Protection (Water) Policy* identifies environmental values for watercourses though no specific guidelines refer to the watercourses within the Project area. Where no specific guidelines relate, the *Environmental Protection (Water) Policy* states that the following documents are to be used to identify the environmental values of the watercourse:

a) site specific documents

b) the AWQ guidelines

c) documents published by a recognised entity.

The main sections of the *Environmental Protection (Water) Policy* relevant to the Project relate to waste water recycling, waste water releases on land, waste water releases to surface water and stormwater management. In each case the administrating authority must consider the existing quality of waters that may be affected, the cumulative effect of the release in question, the water quality objectives for waters affected and the maintenance of acceptable health risks.

Section 7 sets out the environmental values for waters. The waters for this project are not listed in Schedule 1 which sets out environmental values for those waters. Section 8 and 9 set out the indicators for environmental values.

The direct release of water to surface water and to groundwater is regulated under sections 15 and 16. There is a management four step hierarchy that sets out how waste water release will be allowed. It establishes the requirements for waste water treatment; waste water recycling options; and disposal to groundwater. Where there will be a release of waste water or contaminants to water; section 16 provides the management intent for high ecological value waters; slightly to moderately disturbed waters; and highly disturbed waters.

## 2.6 Water Resource (Great Artesian Basin) Plan 2006

The plan is concerned with allocating and managing groundwater for current users; storing water in aquifers for future generations; and protecting the flow of water to springs and baseflow to watercourses that support significant cultural and environmental values. Water licenses for associated water under the *Petroleum and Gas (Production and Safety) Act 2004* are excluded from the allocation and management of water in the plan area where the goal is not to increase the average volume of water taken (section 10).

Schedule 2 sets out the management areas for the plan area.

## 2.7 Great Artesian Basin Resource Operations Plan 2007

The Great Artesian Basin Resource Operation Plan identifies groundwater management areas and management units within each management area. A ‘unit’ corresponds to a formation or a group of formations. (These units should not be confused with the Groundwater Management Units defined by the Australian Natural Resource Atlas, which define the areal boundaries for reasons such as protection of town water supplies and to enable legislative control of groundwater in response to various development pressures.) For each unit a specified upper annual take (or allocation) of water, that can be sustainably extracted, has been allocated under the plan. From time to time, NRW may see fit to announce a reduced allocation, typically as a percentage of the full allocation although other rules may also be imposed.

## 2.8 Water Resource (Condamine and Balonne) Plan 2004

*The Water Resource (Condamine and Balonne) Plan 2004* defines the availability of water in the Condamine and Balonne catchments and regulates the taking of water from all surface water bodies (rivers, lakes, runoffs).

The plan identifies surface water monitoring requirements relative to the quantity and quality of the water, and its associated natural ecosystems.

The purpose of the Water Resource Plan (WRP) for the Condamine and Balonne is to:

- define the availability of water in the plan area
- provide a framework for sustainably managing water and the taking of water
- identify priorities and mechanisms for dealing with future water requirements
- provide a framework for establishing water allocations
- provide a framework for reversing, where practicable, degradation that has occurred in natural ecosystems, including, for example, stressed rivers
- regulate the taking of overland flow water.

The WRP defines the regulatory requirements and the amount of surface water for use in the relevant plan area. The main sections of the WRP that may pertain to the Project relate to the taking of overland flow water by capturing direct rainfall in evaporation ponds or construction of evaporation ponds or other infrastructure within an overland flow path.

## 2.9 Condamine and Balonne Resource Operations Plan 2008

This plan provides the method to implement the day to day management requirements contained in the *Water Resource (Condamine and Balonne) Plan 2004*. This plan applies to surface watercourses; lakes; springs connected to artesian water or subartesian water which is connected to artesian water; and overland flow. It deals with water supply schemes, water management areas and resource operations plan zones. It also deals with the water licences allocated under the *Water Act*.

## 2.10 Water Resource (Moonie) Plan 2003

The *Water Resource (Moonie) Plan 2003 defines* the availability of water in the Moonie catchment and regulates the taking of water from all surface water bodies (eg. rivers, lakes, runoffs).

The plan identifies surface water monitoring requirements relative to the quantity and quality of the water, and its associated natural ecosystems.

The purpose of the Water Resource Plan (WRP) is the same as the *Water Resource (Condamine and Balonne) Plan 2004* outlined above.

The WRP defines the regulatory requirements and the amount of surface water for use in the relevant plan area. The main sections of the WRP that may pertain to the Project relate to the taking of overland flow water by capturing direct rainfall in evaporation ponds or construction of evaporation ponds or other infrastructure within an overland flow path.

## 2.11 Moonie Resource Operations Plan 2006

This plan implements the day to day management of *Water Resource (Moonie) Plan 2003*. This plan applies to watercourses, lakes, springs and overland flow. It deals with water supply schemes; water management areas; and resource operations plan zones. It also deals with the water licenses allocated under the *Water Act*.

## 2.12 Water Resource (Fitzroy Basin) Plan 1999

The purposes of the plan is to: provide a framework for sustainably managing water and the taking of water; providing a framework for establishing water allocations; and to regulate the taking of overland flow water. This plan would apply to the small catchments in the north of the project area that flow into the Dawson River. It outlines environmental flow objectives and water allocation security objectives. There are also monitoring and reporting requirements.

## 2.13 Water Supply (Safety and Reliability) Act 2008

This act provides a regulatory framework for providing recycled water and drinking water quality, primarily for health. It governs who must apply for registration as a service provider.

It defines recycled water as waste water and it defines manufactured water as water, including desalinated or recycled water or any substance resulting from the production of desalinated or recycled water.

The act also outlines who must apply for registration as a service provider and what the requirements are for a service provider.

## 2.14 Water Fluoridation Act 2008

This act sets out the requirements for adding fluoride to relevant public potable water supplies. (Potable- means water that is intended to be, or is likely to be, used for human consumption.) There are also exemptions to fluoridation outlined.

## 2.15 National Water Initiative (NWI)

The NWI represents a shared commitment by the Commonwealth and State Governments to:

- prepare water plans with provision for the environment
- deal with over-allocated or stressed water systems
- introduce registers of water rights and standards for water accounting
- expand the trade in water
- improve pricing for water storage and delivery
- meet and manage urban water demands.

The Project will have an excess of water due to groundwater abstraction. It is therefore possible that the Project may be able to supply water to an over allocated or stressed water region.

## 2.16 Existing and Anticipated Environmental Authorities

Environmental Authorities (EA) set the conditions that the company must comply with. EAs are required under the *Environment Protection Act 1994* and the *Petroleum and Gas (Production and Safety) Act 2004*.

Petroleum activities are classified as either level 1 or level 2 environmentally relevant activities (ERAs). ERAs require a corresponding EA (petroleum activities) under the *Environment Protection Act 1994*.

- Level 2 activities are petroleum activities that have a low risk of environmental harm and they must comply with the standard environmental conditions.
- Level 1 activities are prescribed in the schedule of the *Environment Protection Regulation 1998*. Level 1 ERAs require site specific environment management plans as part of the EA.

A number of the EAs have been issued to QGC. The Project EA for the current QGC operations is number 150161.

The Queensland Government Policy for Level 1 Environmental Authority (EA) applications requires a CSG Water Monitoring Plan (WMP) to be incorporated in the Environmental Management Plan.

# 3.0 METHODOLOGY

This section describes the methodologies used to:

- obtain, prepare and interpret available data for the purpose of the surface water investigation
- conduct the field investigations.

## 3.1 Data Collation and Review

The TOR states that the EIS should:

- provide a description of the existing surface drainage patterns and flows in major streams and wetlands
- address the likelihood of flooding in the project area
- describe the existing surface water quality in surface waters and wetlands likely to be affected by the project.

The following sections identify the data sources used to provide the information requested in the TOR.

### 3.1.1 Streamflow Data

Streamflow data for four sites within the Project area were obtained from NRW. These sites are as follows:

- 422333A – Condamine River near Dalby (1969 – 2008)
- 422336A – Condamine River at Brigalow (1972 – 1981)
- 422308C – Condamine River at Chinchilla Weir (1955 – 2008)
- 422325A – Condamine River at Cotswold (1966 – 2008)

HYDSTRA was used to create Intensity Frequency Duration (IFD) curves for each of the sites. IFD curves provide a probability of the rainfall for any event exceeding the intensity (and corresponding rainfall depth).

That is, for a given rainfall event, the probability of exceeding the 1 in 2 year intensity is 50%. If this intensity is 10mm/hour, and the event of interest is 2 hours long, then the rainfall depth would be 20mm with a 50% of occurrence. It is important to understand that this is a probability.

HYDSTRA is a software package utilised by the water resources, hydropower and waste water industries for managing large amounts of data in a single archive. It provides the capacity for storage, management and analysis of time series data. HYDIST is a function within HYDSTRA used for the statistical analysis of extreme rainfall/runoff events and was used to generate the IFD curves.

HYDIST has the capacity to utilise conventional hydrological analysis statistical tools such as Gumbel, Generalised Extreme Value, Normal, Lognormal, Pearson and Generalised Pareto distributions for the prediction of the frequency of extreme rainfall/flood events. Statistical analysis is used for the calculation of the average recurrence interval (ARI) or return period of extreme events. The LPIII (Log-Pearson type III) distribution has been adopted for use as a general flood frequency distribution in Australia (McMahon & Srikanthan, 1981) and as the standard distribution in the USA (Patra, 2002). The LPIII distribution has been selected within HYDIST for this analysis. The frequency analysis plot produced is a line fitted to a series of annual peaks of the data record. Upper and lower 90% confidence limits are also given.

### 3.1.2 Water quality data

Water quality data was obtained from NRW and from field investigations. The water quality data from NRW was obtained for four sites within the Project area and are as follows:

- 422333A – Condamine River near Dalby (sporadically from 1963 – 2006)
- 422336A – Condamine River at Brigalow (sporadically from 1973 – 1999)
- 422308C – Condamine River at Chinchilla Weir (sporadically from 1962 – 2008)
- 422325A – Condamine River at Cotswold (sporadically 1971 – 2002)

Quality codes were provided with the data and were generally good.

Water quality samples were collected at five sampling sites as detailed in Section 3.4 below. The samples were analysed for the analytes shown in Table 3. The sodium absorption ration (SAR) was also calculated for each sample.

Samples were also taken for quality control and quality assurance (QA/QC). The purpose of QC sampling is to identify, quantify, and document bias and variability in data that result from the collection, processing, shipping, and handling of samples.

**Table 3: Surface Water Quality Parameters**

| Group | Surface Water Quality Parameters |
|---|---|
| **Major Anions (dissolved)** | Chloride, Sulfate |
| **Major Cations (dissolved and total)** | Magnesium, Calcium, Sodium, Potassium |
| **Nutrients** | Ammonia, Total Kjeldahl Nitrogen, Total Phosphorus, Total Nitrogen, $NO_x$ (nitrate + nitrite), Dissolved organic carbon (DOC), Total organic carbon (TOC) |
| **Physicochemical** | Dissolved oxygen (DO), pH, Turbidity, Conductivity/salinity, Temperature, Total suspended solids (TSS), Total alkalinity, Bicarbonate alkalinity, Hydroxide alkalinity, Carbonate alkalinity, Total acidity |

## 3.2 Spatial Analysis and Catchment Definition

Catchment boundaries were derived from the Shuttle Radar Topography Mission (SRTM) Raster. The SRTM Raster is the most accurate high-resolution digital topography database for the region. It has a resolution of approximately 90 metres. Hydrological analysis of the data was then conducted using ArcMap to identify and delineate the catchment boundaries in the region. This was done in three main steps.

- The direction of flow from every cell in the raster was determined.
- The flow accumulation for each cell in the raster was calculated.
- Finally, the location of streams and discharge points was estimated using the ArcMap watershed function.

## 3.3 Hydrological Analyses

Hydrological analysis was undertaken from available data to assess the impact of floods and baseflows in the Project area.

### 3.3.1 Flood Impact Assessment

Data for the flood impact assessment was obtained from the Bureau of Meteorology (BOM), NRW, and Land Resource Assessment and Management Pty. Ltd. (LRAM). The history of flooding in the Condamine River, Moonie River, Dogwood Creek, Charley's Creek and adjacent tributaries was obtained from the BOM website. Stream flow data was obtained from NRW and converted to IFD curves using Hydstra as detailed in section 3.1.1 above.

The Condamine floodplain elements and flow paths were obtained from LRAM. LRAM developed the *Condamine Flow Co-ordination NRM Report* for the Department of Local Government and Planning (2002).The report details the landscape elements, flow characteristics and implications for land use within the Condamine catchment.

Data from the BOM website was also used to develop the flood inundation map for the Condamine River.

### 3.3.2 Baseflow Assessment

Minimal data was available to undertake a baseflow assessment for the watercourses within the Project area. In lieu of recorded data, relevant literature, anecdotal evidence identified during the field visit and regional parameters for the project area were used to assess the contribution of baseflow to streamflow in the Project area.

## 3.4 Field Assessment

A field visit was undertaken by Golder staff from the 17th to the 21st November 2008. The purpose of the field visit was to collect water quality samples and to undertake a geomorphologic assessment of the watercourses within the Project area. Photos of each site visited are included in APPENDIX A.

Fifteen sites were identified as potential water quality sampling sites, although the majority of those sites were dry or only had isolated pools of water. Therefore only five sites could be sampled. The locations of these sites are shown in Figure 4.

Water quality samples were collected in accordance with the EPA's *Water Quality Sampling Manual* (1999) and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). Analysis was carried out by a National Association of Testing Authorities (NATA) accredited commercial environmental contract analysis laboratory.

The geomorphologic assessment was conducted for 39 sites throughout the Project area. These sites are shown in Figure 4. The stream type analysis undertaken, followed the Rosgen (1996) method. This involves assessing the stream in regards to channel slope, channel shape, channel patterns and landform and soil features.

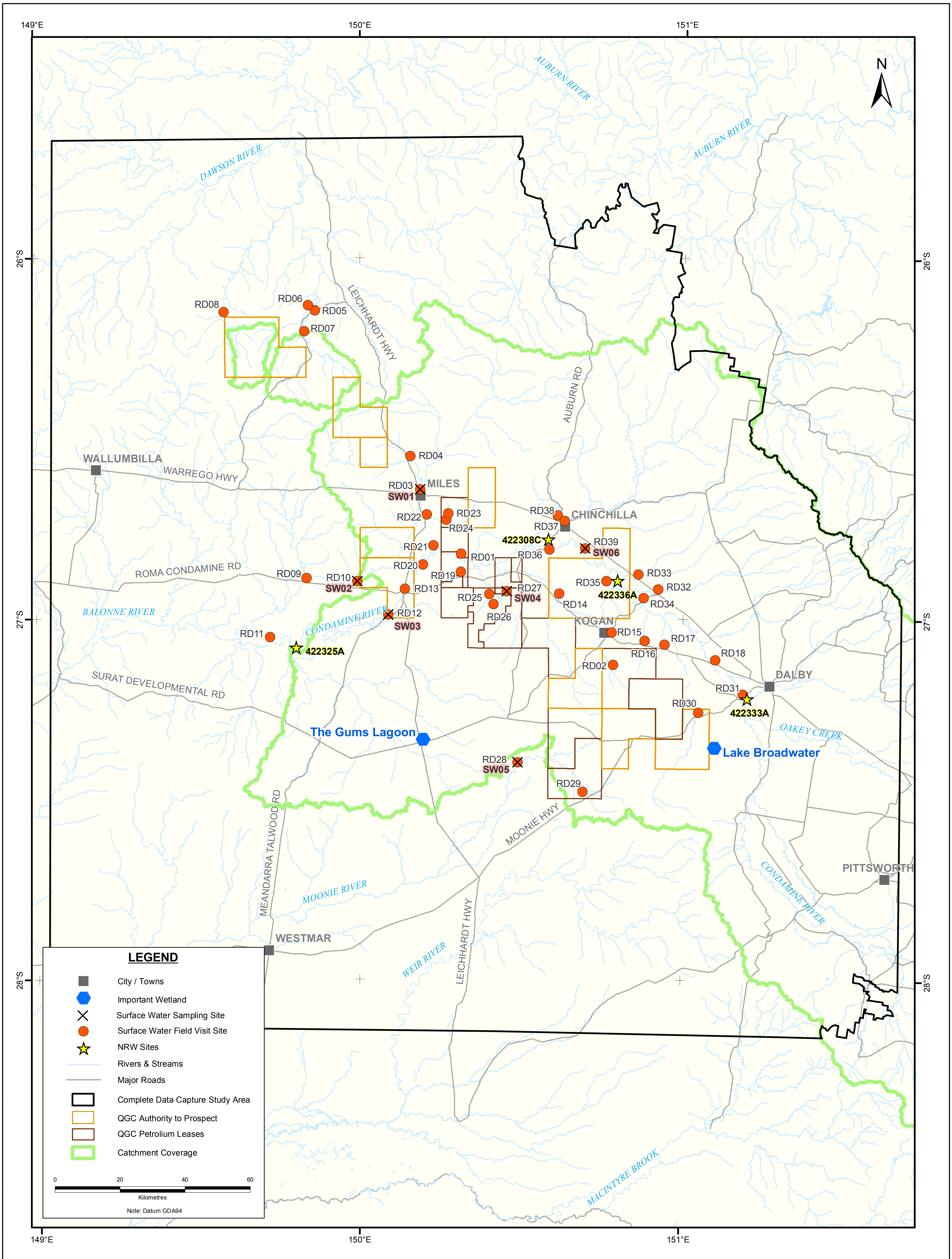
The Pfankuch method (Pfankuch, 1975) was used to evaluate channel stability and involves assessing a variety of geomorphological and vegetative characteristics such as bank slope, debris jam potential, vegetative bank protection, channel capacity, bank rock content, existence of cuttings and existence of scour to determine bank, bed and overall channel stability, the potential for mass failure and the erodibility of bed and bank materials. The characteristics assessed and their ratings are shown in APPENDIX B.

Each site was given a *poor*, *fair*, *good* or *excellent* rating for each of the Pfankuch characteristics and an overall site score was calculated to produce an assessment of channel stability at the sites.

The sites were also assessed (APPENDIX B) as per the State of the Rivers reports (Johnson, 1999; Manen, 2001) and given a rating of *very poor*, *poo*r, *moderat*e, *good* and *very good* for the following characteristics:

- Reach Environs – those lands immediately beside the riparian zone for the reach including the floodplain and valley flat.
- Channel Habitat Diversity – the proportions and dimensions of the various types of channel habitats within the reach i.e. pools, rapids, riffles, cascades, etc.
- Bank Stability – banks are rated by the percentage of stable stream bank of each side of the reach and the dominant processes at each site i.e. erosion, slumping or aggradation.
- Bed and Bar Stability – stream beds are rated by the proportion of stream bed where bars are forming and overall bed stability.
- Riparian Vegetation – the percentage cover by structural vegetation types such as trees, shrubs, herbs and the percentage cover over the riparian zone is assessed.
- Aquatic Vegetation – the percentage cover by structural vegetation types such as emergent aquatics, submerged aquatics and floating aquatics.
- Aquatic Habitat – the percentage stream bed covered by in-stream debris, rock outcrops, vegetation and the overhanging stream cover provided along the bank by vegetation, bank and man-made infrastructure.
- Scenic, Recreation and Conservation Value – determined by generating a spectrum of recreational types such as camping, walking, picnic area etc. and assessing the conservation merit of sites in relation to the sites value as a habitat for aquatic plant and animal species, riparian plant and animal species, and as a wildlife corridor.

The majority of the geomorphological assessment is subjective and the ratings provided to streams is dependent on the person undertaking the survey.






Notes:
1. Base map data copyright Mapinfo Australia Pty Ltd
2. Authority To Prospect & Petroleum Leases data and the borehole Locations supplied by Queensland Gas Company (QGC), dated 15-10-2008 and 23-10-2008.
3. Important Wetlands extracted Feb 2009 from Australian Wetlands Database Dept Env, Heritage and The Arts.

*This product is based on or contains data provided by the State of Queensland (Department of Natural Resources and Water) [2008]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws.*

Golder Associates

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| CLIENT Queensland Gas Company | | PROJECT QGC - LNG EIS Surface Water Studies | | | |
| DRAWN DK/BQ | DATE 03-03-09 | TITLE WATER SAMPLING SITES | | | |
| CHECKED DS* | DATE 03-03-09 | | | | |
| SCALE 1:1,050,000 | | PROJECT No 087633050_014 | FIGURE No 4 | REV No 1 | A3 |

File Location: R:\Env\2008\087633050\GIS\Projects\ArcGIS\087633050_014_R_F0004_Rev1_WaterCourseAndSamplingSites_A3.mxd
Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.

# 4.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

The existing environment, as it relates to surface water, is described in this section to fulfil the terms of reference for the EIS.

## 4.1 Topography and Drainage

The topography across the study area is generally flat, ranging between 200 and 400 m and sloping gently towards the south west. A steep ridge, aligned northwest to southeast and rising up to 1100m, defines the northeast boundary of the area.

The Project area is contained within three catchments:

- Condamine and Balonne
- Moonie
- Fitzroy.

The Condamine and Balonne catchment, together with the Moonie catchment, form part of the Murray Darling Basin.

The Condamine River is the major river in the region, which flows north northwest through the study area, within the Condamine and Balonne catchment. An elevated area (400m) in the landscape forms the watershed between the Moonie and the Balonne Rivers in the southwest of the study area. In the north of the study area, three small catchments flow north into the Dawson River which is part of the Fitzroy River catchment.

## 4.2 Climate

The climate for the study area is sub tropical with a dry winter season. Table 4 presents the mean monthly rainfall and evaporation data for the Roma Airport, Miles Post Office and Dalby Airport weather stations. The yearly climate pattern is illustrated in Figure 5. The histogram represents the mean rainfall and the curve represents the mean temperature.

The dry season takes place during winter, from April to September. December and January are the hottest months, where the temperature can exceed 40ºC. The average annual rainfall is 610mm. Rainfall is received throughout the year; however more rainfall is expected in the summer months from November to February. Evaporation ranges from 9.3mm per day in summer (January) to 2.9mm per day in winter.

**Table 4: Climate Characteristics**

| | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rainfall in mm** | | | | | | | | | | | | | |
| Average | 82.6 | 82.3 | 47.0 | 30.8 | 38.2 | 34.9 | 29.3 | 24.8 | 26.4 | 59.2 | 69.8 | 87.0 | 610.2 |
| **Evaporation in mm/day** | | | | | | | | | | | | | |
| Average | 9.3 | 7.8 | 7.0 | 5.6 | 3.7 | 2.8 | 2.9 | 4.1 | 6.1 | 7.5 | 8.4 | 9.2 | 6.2 |
| **Temperature in °C** | | | | | | | | | | | | | |
| Maximum | 33.3 | 32.1 | 30.9 | 27.7 | 23.5 | 20.1 | 19.7 | 21.8 | 25.7 | 28.9 | 30.8 | 32.5 | 27.3 |
| Minimum | 19.8 | 19.4 | 16.8 | 12.5 | 8.1 | 5.3 | 3.8 | 4.9 | 8.9 | 13.3 | 16.3 | 18.4 | 12.3 |
| Average | 26.5 | 25.7 | 23.9 | 20.1 | 15.8 | 12.7 | 11.7 | 13.4 | 17.3 | 21.1 | 23.6 | 25.5 | 19.8 |

Source: Climate statistics for the Roma Airport, Miles Post Office and Dalby Airport weather stations, data from the Bureau of Meteorology website (www.bom.gov.au)

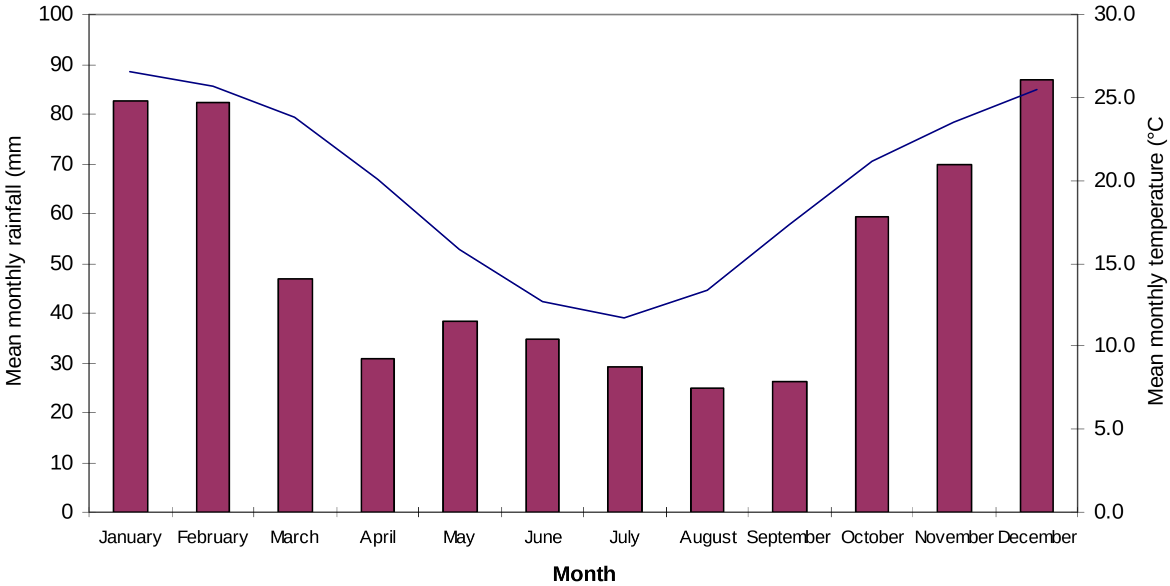



*Figure 5: Mean Climate Statistics for Roma Airport, Miles Post Office and Dalby Airport Weather Stations*

## 4.3 Catchment Hydrology

### 4.3.1 Watercourses in Project area

#### *4.3.1.1 Condamine River*

The major watercourse within the Project area is the Condamine River, which traverses tenements ATP 676P, PL 179, PL 201, PL 211 and ATP 647P, as shown in

Figure 6. The Condamine River flows in a north-westerly direction from Dalby to Chinchilla where it takes a south-westerly turn and becomes the Balonne River at the Dogwood Creek junction, south-west of Miles

(downstream of the Project area). The Condamine River forms part of the Queensland section of the Murray-Darling basin and it is located within the southern part of the Brigalow Belt Bioregion (CSIRO, 2008).

The Condamine catchment has a diversity of landforms ranging from the steep mountainous terrain along the Great Dividing Range to the extensive floodplains of the Condamine River. Sandstone hills and slopes are the dominant geomorphic unit in the catchment. Alluvium extends east of Warwick to west of Chinchilla; and undulating clay downs occur mainly downstream of Dalby (Condamine Alliance, 2004).

The vegetation communities of the Condamine catchment are diverse. It is vegetated by tall Eucalypt open forests in the north, woodlands, open woodlands, and grasslands in the south. The predominant species are poplar box, silver-leaved ironbark and narrow-leaved ironbark along with smooth-barked apple, mountain coolibah, black box, gum-topped box and spotted gum. Brigalow-belah open forest and woodland, mulga open forest and woodland, and white cypress pine open forest and woodland are also found throughout the Project area (Condamine Alliance, 2004). Along with native species, there are numerous weeds such as Prickly pear (*Opuntia spp*.) and lippia (*Phyla canescens*) commonly found in the Project area.

The predominant land use in the Condamine catchment is agriculture. Beef cattle and sheep grazing, utilising native and improved pastures, are the main livestock industries. Wheat and sorghum are the main crops grown. Other crops grown include chickpeas, mung beans, forage oats, lab lab, millet and sunflower (Manen, 2001).

Grazing and cropping practices have resulted in the majority of the floodplain and lowland areas being cleared of native vegetation. Weeds throughout the area have also had an impact on the diversity, distribution and abundance of native species although areas of native and remnant vegetation may be found in national parks and state forest areas (Manen, 2001).

There has been a decline in native fauna species in the region. This has been caused by changes to the environment such as clearing of vegetation, habitat degradation and the introduction of feral species. Approximately 63 species of mammals, 284 bird species and 13 fish species have been recorded within the Condamine catchment (Manen, 2001). Many reptile species are also found in the area; some of which are considered vulnerable or rare. Of the 25 native frog species, one is listed as rare though no species are considered endangered or vulnerable (Manen, 2001).

Soil erosion is the most significant form of land degradation in the area. Extensive clearing, cultivation, over-grazing and burning has resulted in increased run-off and soil-structure decline. Kangaroos, wallabies and wild pigs have also contributed to grazing pressure; soil erosion; and an increase in the concentration of nutrients discharging into streams. Water quality is also being affected by the use of agricultural chemicals in the area. Fish habitats have been impacted on by impoundments and weirs, where the movement of fish upstream has been restricted.

The Condamine catchment, regardless of the current degradation of land and water quality, is still a major contributor to the Queensland economy. It is also an important ecosystem for endangered, vulnerable and rare fauna and flora species.

#### 4.3.1.2 Moonie River

The upper Moonie River and tributaries traverse tenements PLA 261 and PLA 262. The Moonie River flows in a south-westerly direction from its headwaters near Dalby and forms part of the Queensland section of the Murray-Darling Basin and the Southern Brigalow belt bioregion (Figure 6).

The region is essentially flat with low relief hills scattered throughout the floodplains of the Moonie River. Local heavy rainfall can result in major flooding downstream and cause many thousands of hectares of low-lying land, properties and highways to be inundated (QMDC & SWNRM, 2004).

The dominant land uses in the Moonie region are dryland pasture used for grazing, followed by irrigated crops for cereals, cotton, pasture and hay (Condamine Alliance, 2004).

The Moonie catchment is one of the most heavily cleared areas within Queensland. Only 24% of remnant vegetation remains (NPWS, 2003). The Southern Brigalow Belt is a bioregion dominated by stony red earth soils in the upper catchment with the main vegetation type being grassy woodlands of Poplar Box (*Eucalyptus populnea*), Wilga (*Geijera parviflora*), White Cypress Pine (*Callitris glaucophylla*), Budda (*Eremophila mitchellii*), Ironwood (*Backhousia myrtifolia*), and Belah (*Casuarina cristata*) with mixed grasses.

There are no nationally or internationally significant wetlands in the Moonie catchment; however the waterholes in the river are important aquatic habitats. The ecological value of the Moonie River instream environments are not well described, although it has been reported that the area contains high biodiversity and unique systems (MDBMC, 2001).

Soil erosion is the most widespread form of land degradation in the Moonie catchment, along with stream bank erosion, sedimentation, dryland salinity, soil acidity and surface water logging (Johnson, 1999). Excessive growth of algae is a major problem throughout streams in the north-western part of the catchment. Algal growth has resulted from nutrient enrichment from agricultural runoff; erosion of soils naturally high in phosphorus; urban stormwater runoff; sewage effluent; and low turbidity waters.

#### 4.3.1.3 Horse Creek, Wandoan Creek and Woleebee Creek

There are no major river systems traversing the northern tenements of ATP 651P and ATP574P. A number of tributaries traverse the Project area and these are Horse Creek, Wandoan Creek and Woleebee Creek. These creeks flow into to the Fitzroy River catchment.

Woleebee Creek connects to Juandah Creek, a major tributary that flows into the Dawson River approximately 60 km downstream of the Project area. Wandoan Creek starts within the Project area and then it flows through the town of Wandoan. From Wandoan, water flows into Woleebee Creek, and then into Juandah Creek. The catchment of Horse Creek begins on the northern side of the Great Dividing Range within the Project area and flows north, where it flows into Juandah Creek, approximately 40 km downstream of the Project area.

Wandoan lies within fertile brigalow country. The major land uses in the area are dryland pasture grazing and irrigated wheat cropping. The Mount Organ State Forest is situated in the upper reaches of the Wandoan Creek catchment.

#### 4.3.1.4 Wetlands

There are approximately 2000 recorded wetlands within the Condamine catchment ranging from 1 to 350 hectares in area (Wilson & Adams, 2004). The nationally and internationally recognised (Ramsar) wetlands within the Condamine catchment are detailed in Table 5 below. Two nationally significant wetlands within the vicinity of the Project area are Lake Broadwater and The Gums Lagoon (CSIRO, 2008) (Figure 6 and APPENDIX C).

**Table 5: Ramsar wetlands and wetlands of national significance**

| Site Code | Name | Area[(1)] (ha) | Ramsar sites |
|---|---|---|---|
| NSW011 | Narran Lakes | 30,000 | Yes* |
| NSW098 | Great Artesian Basin Springs | Highly variable | None |
| NSW170 | Culgoa River Floodplain | 22,986 | None |
| QLD015 | Lake Broadwater | 215 | None |
| QLD020 | The Gums Lagoon | 343 | None |
| QLD084 | Balonne River Floodplain | 24,000 | None |
| QLD166** | Wyandra-Cunnamulla Claypans Aggregation** | 30,000 | None |
| QLD173*** | “Myola”-“Mulga Downs” Salt Lake and Claypans | 6,873 | None |
| QLD193 | Dalrymple and Blackfellow Creeks | 392 | None |

[(1)] Wetland areas are extracted from the Australian Wetlands Database and are assumed to be correct as provided from State and Territory agencies.* Narran Lake Nature Reserve Ramsar Site, 5531 ha.

** Spread over 1.5M ha.

*** QLD166 and QLD173 span the boundary between the Condamine-Balonne and Warrego regions.

Source: A Directory of Important Wetlands in Australia (Environment Australia, 2000).

Within the Upper Moonie, Horse Creek, Wandoan Creek or Woleebee Creek catchments; there are no significant wetlands in the vicinity of the Project area.

The wetlands within the Condamine catchment include both palustrine and lucustrine systems. The Environment Protection Agency (EPA) defines palustrine systems as “wetlands and deepwater habitats situated in topographic depressions, dammed river channel or artificial waterbodies. This includes areas where emergent perennial vegetation has less than 30% areal coverage and the total waterbody area exceeds 8ha” (EPA, 2008. Lacustrine systems are described as “wetlands dominated by persistent emergent vegetation or where water in the deepest part of the basin is less than 2m in depth, active wave formed shores or bedrock features are lacking” (EPA 2008).

Wetlands are important components of an ecosystem as they filter sediments; nutrients and pesticides; and provide habitat for waterbirds, native fish and other aquatic fauna (Condamine Alliance, 2004). They may also contain terrestrial and aquatic plants, thereby offering aesthetic value and short-term grazing opportunities to landholders, without compromising longer-term ecological condition.

The variable character of river flows in the Condamine catchment; due to summer-dominant, though erratic, rainfall; often leads to drying of floodplain wetlands. During these times, the Condamine wetlands are a refuge for aquatic biodiversity. In periods of flow events they supply colonising individuals or organic matter to nearby streams or other wetlands. The Condamine wetlands are also likely to function as intermittent water bodies across the landscape for larger migrating fauna such as turtles and waterbirds (Wilson & Adams, 2004).

#### 4.3.1.5 Lake Broadwater

Lake Broadwater, within Lake Broadwater Conservation Park southwest of Dalby and directly east of EPP648 (Figure 6 and APPENDIX C), is listed in the *Directory of Important Wetlands in Australia* (Environment Australia, 2001) and meets four of the six criteria for inclusion in this national directory as shown in Table 6 below (Environment Australia, 2001). The lake is characterised as a palustrine system with lacustrine wetlands on the outskirts of the lake. The catchment for Lake Broadwater is the elevated land southwest of the site that includes Wilkie Creek and Broadwater Gully, and from the Condamine River when in flood.

Tenement EPP648 lies within the Lake Broadwater catchment.

**Table 6: Criteria used to categorise the national significance of two Condamine catchment wetlands - Lake Broadwater and the Gums Lagoon**

| Criterion | | Wetland |
|---|---|---|
| 1 | It is a good example of a wetland type occurring within a biogeographic region in Australia. | Lake Broadwater & The Gums Lagoon |
| 2 | It is a wetland which plays an important ecological and hydrological role in the natural functioning of a major wetland system/complex. | Lake Broadwater |
| 3 | It is a wetland which is important for the habitat of animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail. | Lake Broadwater & The Gums Lagoon |
| 4 | The wetland supports 1% or more of the national populations of any native plant or animal taxa. | |
| 5 | The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level. | Lake Broadwater |
| 6 | The wetland is of outstanding historical or cultural significance. | |

Source: Environment Australia (2001)

Water supply, particularly from Wilkie Creek, to Lake Broadwater is principally from runoff, flood outs and stream flow from the catchment. Evidence suggests that there is minimal groundwater infiltration to Lake Broadwater, with it drying out completely at times, as in 1981-1983 and 1986-1987 (Department of Environment, Heritage and The Arts Australian Wetlands Database). The lake is shallow (maximum depth of 4m) and is subject to erratic rainfall. It often floods, and then dries out completely. During the field assessment in November 2008, Lake Broadwater was observed to contain water. A rainfall event occurred the day before the lake was visited (Photo 1 below).

The water quality within the lake is generally good.

Four wetland vegetation communities are recognised in the lake:

- open water communities dominated by a range of species including shiny nardoo, swamp lily, native water hyacinth, wavy mashwort, ribbon weed and water primrose
- lake edge communities dominated by river red gum with an understorey of grasses and sedges
- marsh communities
- riparian communities of similar structure to the lake edge communities (Australian Wetlands Database).

A variety of fauna is associated with the lake including frogs, reptiles, mammals and a range of waterbirds. During a visit to Lake Broadwater conducted in November 2008, kangaroos and waterbirds were observed.

Lake Broadwater is a significant indigenous site. It is also a popular location for camping, fishing and powerboat water sports (Wilson & Adams, 2004).

*Photo 1: Lake Broadwater Conservation Park and Resources Reserve (November 2008)*

#### 4.3.1.6 The Gums Lagoon

The Gums Lagoon, near Tara (Figure 6 and APPENDIX C), is also listed in the *Directory of Important Wetlands in Australia* ((Environment Australia, 2001) and meets two of the six criteria for inclusion in this national directory as shown in Table 6 (above).

No tenements lie within The Gums Lagoon catchment area.

The Gums Lagoon is a palustrine system. It is described as a relatively undisturbed wooded swamp in a small reserve of similarly undisturbed woodlands and open forest, (Department of Environment, Heritage and The Arts Australian Wetlands Database). It is located in a region where most remnant vegetation has been cleared. The lagoon supports low open river red gum forest with perennial tussock grasses; and ephemeral semi aquatic plants, during periods of inundation. The Gums Lagoon represents a relatively undisturbed wetland in a region largely cleared for agricultural purposes and therefore a threatened plant community within the brigalow bioregion.

The lagoon is a relatively shallow depression in an otherwise flat plain with silty clay to clay loam soils. The lagoon fills on a frequency of once every seven to ten years, and it may stay full for more than one year depending on subsequent seasonal filling. It is a shallow freshwater feature, less than 0.5m deep, and water quality is generally good (Department of Environment, Heritage and The Arts Australian Wetlands Database). The information provided by the database suggests that The Gums Lagoon is fed by direct precipitation and rainfall events. Photo 2 (below) shows The Gums Lagoon during the field visit in November 2008.

*Photo 2: The Gums Lagoon (November 2008)*

Although Lake Broadwater and The Gums Lagoon have been affected by clearing in the vicinity of the wetlands; infrastructure development and grazing are still the main threats to both wetland ecosystems. A major impact on the wetlands may result from changes in the frequency of flooding, areal extent and duration, altering the natural water flow regime. Disruption to the natural cycle of flooding and drying will reduce the emergence of riparian seedlings and the productivity and species diversity of aquatic fauna as will occur if flows into wetlands are reduced or cease altogether (Wilson & Adams, 2004).

Within the Gums Lagoon Reserve, 79 species of birds, some of which come under Japan-Australia Migratory Bird Agreement (JAMBA) and China-Australia Migratory Bird Agreement (CAMBA), have been recorded (Australian Wetlands Database).

### 4.3.2 Climate change effects on surface water

The CSIRO (2008) has estimated the effects of different climate change on surface water in the region. In the median climate change scenario by the year 2030, it is projected that:

- average annual runoff will be reduced by 9%
- average surface water availability in the Condamine-Balonne will be reduced by 8%
- total end-of-system flow will fall by 12%.

In the high climate change scenario by 2030, it is projected that:

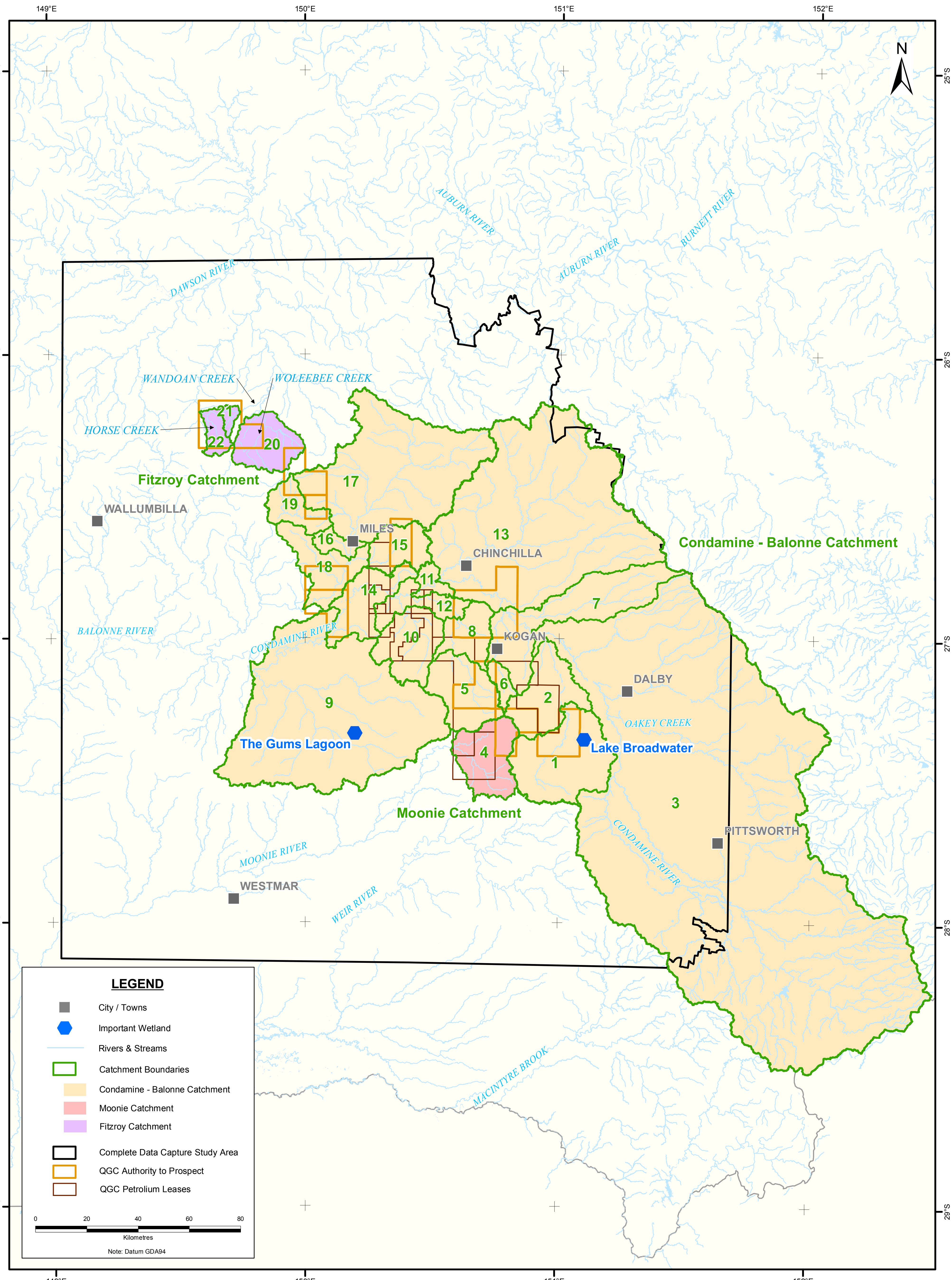
- average surface water availability will decrease by 26%
- diversions will decrease by 16%
- end-of-system flows will decrease by 35%
- the relative level of use under the current water sharing arrangements will increase by 60%.

#### *4.3.2.1 Design parameters for climate change projections*

QGC standards require consideration for climate change to be built into design parameters and when sizing infrastructure, including storm water structures and evaporation ponds. QGC is designing for a 30% increase in rainfall intensity during peak tropical cyclone precipitation events and a 10% increase in mean annual runoff. Infrastructure and ponds will be located above the maximum expected flood levels. Roads and access tracks will occasionally be inundated.

## 4.4 Catchment Boundaries

Figure 6 shows the catchment boundaries of the streams and river systems in the Project area. Table 7 (below) shows the area and land use of each catchment. The ‘Catchment ID’ in the table provides a code for each catchment labelled on Figure 6.




Notes:
1. Base map data copyright Mapinfo Australia Pty Ltd
2. Authority To Prospect & Petroleum Leases data and the borehole Locations supplied by Queensland Gas Company (QGC), dated 15-10-2008 and 23-10-2008.
3. Important Wetlands extracted Feb 2009 from Australian Wetlands Database Dept Env, Heritage and The Arts.

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|---|---|---|---|
| CLIENT | Queensland Gas Company | PROJECT | QGC - LNG EIS Surface Water Studies |
| DRAWN | DK/BQ | DATE | 03-03-09 |
| CHECKED | DS* | DATE | 03-03-09 |
| TITLE | CATCHMENT BOUNDARIES | | |
| SCALE | 1:1,400,000 | PROJECT No | 087633050_014 |
| FIGURE No | 6 | REV No | 1 |
| A3 | | | |

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Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.

**Table 7: Catchment area and land use**

| Catchment ID | Catchment | Major tributaries | Tenements traversed | Land Use | Area km$^2$ |
|---|---|---|---|---|---|
| 1 | Wilkie Ck US | Gilbert Gully, Lake Broadwater | ATP 648P | Dryland, native vegetation, pasture, regrowth | 984 |
| 2 | Wilkie Ck | Gilbert Gully, Lake Broadwater, Back Ck, Clayhole Ck | ATP 648P, PLA 259 | Dryland, native vegetation, pasture, irrigated, regrowth | 1,580 |
| 3 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck | ATP 648P, PLA 259 | Dryland, native vegetation, pasture, irrigated, regrowth | 15,142 |
| 4 | Finch Ck | US end of Moonie R, Piebald Ck, Durabilla Ck, Dunmore Ck | PLA 261, PLA 262, ATP 648P | Dryland, native vegetation, pasture, irrigated | 537 |
| 5 | Wambo Ck US | Stockyard Ck, Twenty Six Mile Ck, Horse Ck | ATP 648P, PLA 259, PLA 257, PLA 261 | Native vegetation, pasture, regrowth | 566 |
| 6 | Kogon Ck US | Bloodwood Ck | PLA 259, ATP 648P, PLA 257 | Dryland, native vegetation, pasture, regrowth | 101 |
| 7 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck, Kogon Ck, Braemar Ck, Bloodwood Ck | ATP 648P, PLA 259, ATP 676P | Dryland, native vegetation, pasture, irrigated, regrowth | 16,250 |
| 8 | Wambo Ck Middle | Stockyard Ck, Twenty Six Mile Ck, Horse Ck, Braemar Ck | ATP 648P, PLA 259, PLA 257, PLA 261, ATP 676P | Native vegetation, pasture, regrowth, horticulture | 892 |
| 9 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck, Kogon Ck, Braemar Ck, Bloodwood Ck, Wiemabilla Ck, Cobareena Ck, Wambo Ck | ATP 648P, PLA 261, PLA 259, PLA 257, ATP 676P, PL 228, PLA 180, PL 179, PL 229, PLA 263, PLA 212, PL 201, PLA 211, PLA 247, ATP 647P, ATP 676P | Native vegetation, pasture, regrowth, horticulture, irrigation | 26,319 |
| 10 | Wieambilla Ck | Cobareena Ck, Jack Ck, Nine Mile Ck | PL 179, PL 229, PLA 180, PLA 228, PLA 226 | Pasture, native vegetation, regrowth | 526 |

| Catchment ID | Catchment | Major tributaries | Tenements traversed | Land Use | Area |
|---|---|---|---|---|---|
| | | | | | km$^2$ |
| 11 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck, Kogon Ck, Braemar Ck, Bloodwood Ck | ATP 648P, PLA 259, ATP 676P, PL 179, PL 229 | Native vegetation, pasture, regrowth, horticulture, irrigation | 20,552 |
| 12 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck, Kogon Ck, Braemar Ck, Bloodwood Ck, Wiemabilla Ck, Cobareena Ck, Wambo Ck, Charley's Ck | ATP 648P, PLA 261, PLA 259, PLA 257, ATP 676P, PL 228, PLA 180, PL 179, PL 229, PLA 263, PLA 212, PL 201, PLA 211, | Native vegetation, pasture, regrowth, horticulture, irrigation | 22,255 |
| 13 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck, Kogon Ck, Charley's Creek, Rocky Ck | ATP 648P, PLA 259, ATP 676P | Dryland, native vegetation, pasture, irrigated, regrowth | 20,439 |
| 14 | Condamine River | Jimbour Ck, Oakey Ck, Myall Ck, Wilkie Ck, Clayhole Ck, Back Ck, Kogon Ck, Braemar Ck, Bloodwood Ck, Wiemabilla Ck, Cobareena Ck, Wambo Ck, Jingi Jingi Ck, Rocky Ck | ATP 648P, PLA 261, PLA 259, PLA 257, ATP 676P, PL 228, PLA 180, PL 179, PL 229, PLA 263, PLA 212, PL 201, PLA 211, PLA 247, ATP 647P, ATP 676P | Native vegetation, pasture, regrowth, horticulture, irrigation | 22,734 |
| 15 | Coolumboola Ck | Cameby Ck | PLA 247, ATP 676P, PLA 211 | Pasture, native vegetation, regrowth, dryland | 333 |
| 16 | Dogwood Ck Middle | Paddy Ck, Wallan Ck, Camisla Ck, Eleven Mile Ck, Bottle Tree Ck | ATP 574P, ATP 632P, ATP 676P | Native vegetation, pasture, dryland | 2,674 |
| 17 | Dogwood Ck US | Wallan Ck, Camisla Ck, Eleven Mile Ck, Bottle Tree Ck, Tin Hut Ck | ATP 574P, ATP 632P, ATP 676P | Native vegetation, pasture, dryland | 2,277 |
| 18 | Dogwood Ck DS | Paddy Ck, Wallan Ck, Camisla Ck, Eleven Mile Ck, Bottle Tree Ck, Drillham Ck, Columboola Ck | ATP 574P, ATP 632P, ATP 676P, PLA 211, ATP 647P | Native vegetation, pasture, dryland | 3,482 |

| Catchment ID | Catchment | Major tributaries | Tenements traversed | Land Use | Area |
|---|---|---|---|---|---|
| | | | | | km$^2$ |
| 19 | Wallan Ck | Two Mile Ck, Camisla Ck, Kangaroo Ck | ATP 574P, ATP 632P | Native vegetation, pasture, dryland | 279 |
| 21 | Wandoan Ck US | Nail Can Ck, Hardknock Ck (flow into the Dawson- part of the Fitzroy catchment) | ATP 651P | Dryland, native vegetation, pasture | 50 |
| 20 | Woleebee Ck | Ogle Ck, Sheep Station Ck, Conloi Ck, Bluey Ck(flow into the Dawson- part of the Fitzroy catchment) | ATP 651P | Dryland, native vegetation, pasture | 420 |
| 22 | Horse Ck US | Nine Mile Ck, Lucky Gully (flow into the Dawson- part of the Fitzroy catchment) | ATP 651P | Dryland, native vegetation, pasture | 131 |

## 4.5 Surface Water and Drainage Patterns

The sections below outline the types of surface water runoff characteristics for each catchment within the Project area. Results from the field assessment for each watercourse component are provided.

### 4.5.1 Condamine Catchment

The topography is dominated by the Great Dividing Range in the north-east which resulted from volcanic activity millions of years ago. Most creeks flow away from the Great Dividing Range through undulating basaltic landscapes and valley systems that widen as they approach the Condamine River. Flow across the floodplain to the river system is generally shallow sheet flow.

Rainfall events in the Condamine catchment tend to be irregular and intense, resulting in rapid rises and falls in stream flood height.

The Project area contains three categories of catchment runoff characteristics and these are shown in Figure 7. These categories were identified in the *Condamine Flow Co-ordination NRM Report* (LRAM, 2002) and are described below:

1) The Riparian Area

   This area is located directly adjacent to the stream and is characterised by flooding which occurs when runoff cannot be contained within the stream of flow channel. Generally flow velocity is high in these areas and rapid rises and falls in stream flood height are evident. Floods occurring in these areas are generally caused by localised rainfall events.

2) The Undulating Overland Flow Plains

   These are areas of long gently sloping plains with poorly defined drainage networks. Flow type may be slow to moderately fast moving sheet flow of shallow depth or both channel and sheet flow at moderately fast flows of moderate depths.

3) The Near Flat Overland Flow Plains

   These areas adjoin the riparian areas and are prone to flooding from the backwater effect of the riparian area along very poorly defined drainage lines. Overland flow from steeper sloping overland flow plains may also contribute to the flow in these areas. The flow type in this area is generally overland sheet flow of shallow depth and low velocity.

Photo 3 illustrates shallow sheet flow after a rainfall event observed near Dalby in November 2008. Photo 4 illustrates rapid flooding within a creek after the rainfall event (~1m deep at crossing) in November 2008. Flooding occurred after approximately 50mm of rainfall received the previous evening. Figure 8 shows the flow paths traversing the Project area.

### 4.5.2 Upper Moonie Catchment

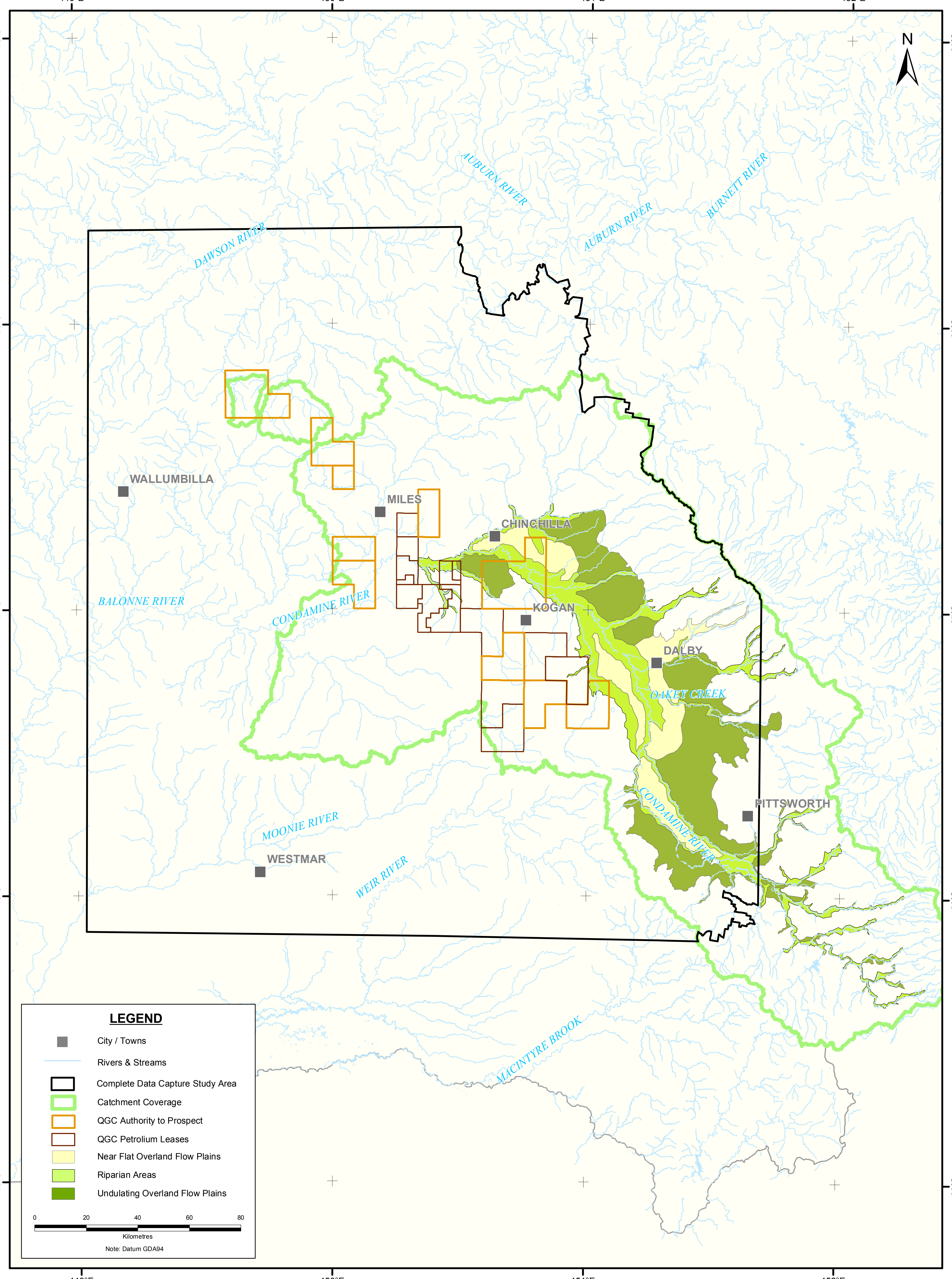
The Upper Moonie catchment has similar catchment runoff characteristics to the Condamine catchment. However, the region within the Project area is relatively flat and there are minimal undulating overland flow plains.

### 4.5.3 Horse Creek, Wandoan Creek and Woleebee Creek

Horse Creek, Wandoan Creek and Woleebee Creek catchments also have similar catchment runoff characteristics to the Condamine catchment. As the upper reaches of these catchments are at higher elevations, due to their proximity to the Great Dividing Range; there are more undulating overland flow plains and less near flat overland flow plains.

*Photo 3: Shallow sheet flow observed after a rainfall event in November 2008.*

*Photo 4: Rapid flooding within creek after rainfall event*

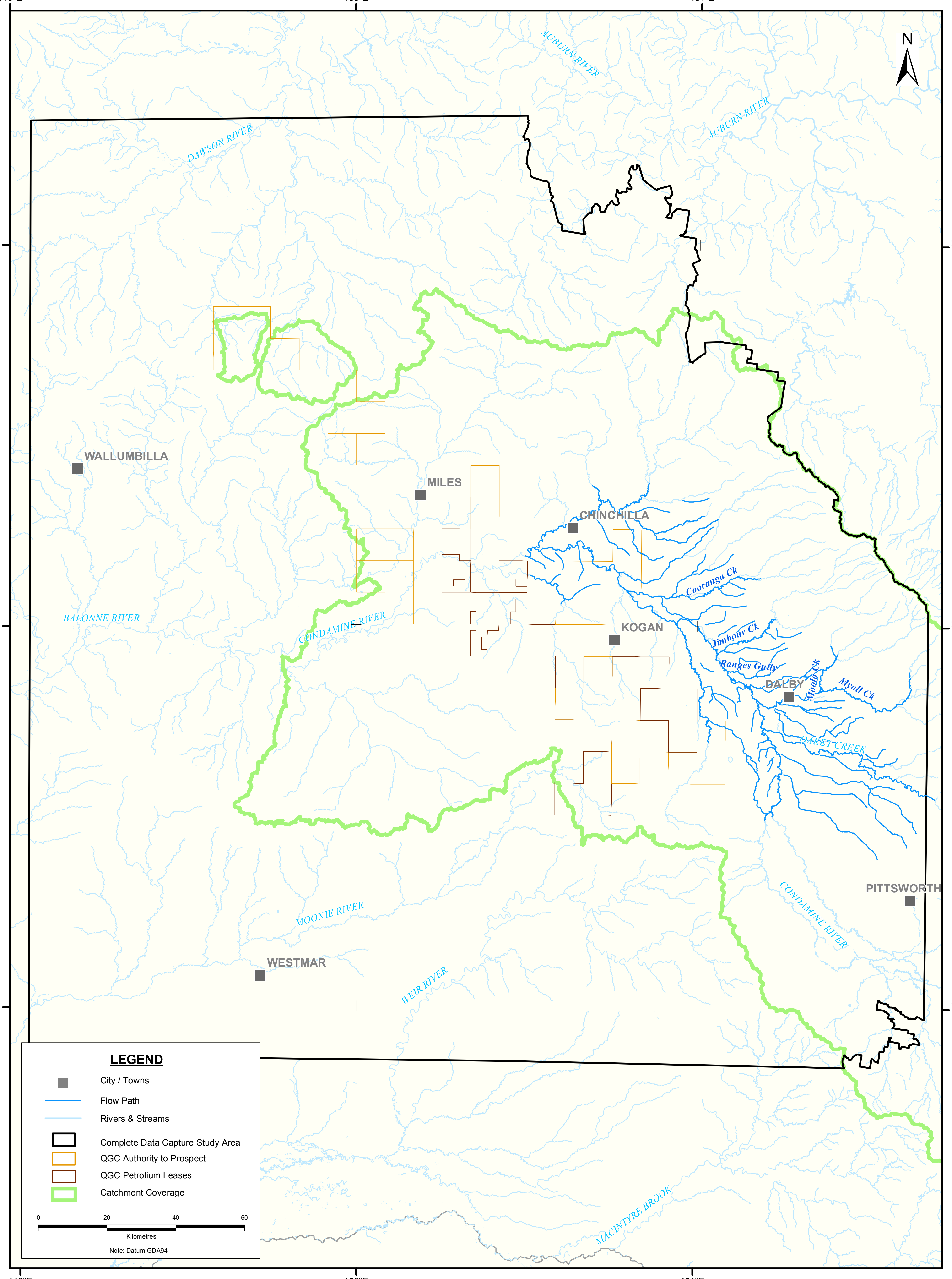



Notes:
1. Base map data copyright Mapinfo Australia Pty Ltd
2. Authority To Prospect & Petroleum Leases data and the borehole Locations supplied by Queensland Gas Company (QGC), dated 15-10-2008 and 23-10-2008.

Golder Associates

| | | | |
|---|---|---|---|
| CLIENT | Queensland Gas Company | PROJECT | QGC - LNG EIS Surface Water Studies |
| DRAWN DK/BQ | DATE 03-03-09 | TITLE | CATCHMENT RUNOFF CHARACTERISTICS |
| CHECKED DS* | DATE 03-03-09 | | |
| SCALE 1:1,400,000 | | PROJECT No 087633050_014 | FIGURE No 7 / REV No 1 / A3 |

File Location: R:\Env\2008\087633050\GIS\Projects\ArcGIS\087633050_014_R_F0007_Rev1_CatchmentRunoff_A3.mxd
Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.






Notes:
1. Base map data copyright Mapinfo Australia Pty Ltd
2. Authority To Prospect & Petroleum Leases data and the borehole Locations supplied by Queensland Gas Company (QGC), dated 15-10-2008 and 23-10-2008.

Golder Associates

| | | | | | |
|---|---|---|---|---|---|
| CLIENT Queensland Gas Company | | PROJECT QGC - LNG EIS Surface Water Studies | | | |
| DRAWN DK/BQ | DATE 03-03-09 | TITLE Flow Paths | | | |
| CHECKED DS* | DATE 03-03-09 | | | | |
| SCALE 1:1,050,000 | | PROJECT No 087633050_014 | FIGURE No 8 | REV No 1 | A3 |

File Location: R:\Env\2008\087633050\GIS\Projects\ArcGIS\087633050_014_R_F0008_Rev1_FlowPaths_A3.mxd
Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.

### 4.5.4 Watercourse Characteristics

The streams within the Project area have been classified as 'type C' streams using the Rosgen stream classification system (Rosgen 1942) as detailed in section 3.4. Type C streams are typically well defined meandering channels with a low gradient and riffle/pool bed morphology. Type C streams are characterised by alluvial soils and broad, well defined floodplains. Within the Project area, C4, C5 and C6 stream types were found.

- C4 stream types have predominately gravel channel material, with lesser amounts of cobble, sand and silt/clay.
- C5 stream types have predominately sand bed and banks, with occasional gravel and silt/clay.
- C6 stream types have silt-clay bed and bank material.

APPENDIX B shows the stream type classification for each of the field visit sites along with the bank stability rating identified using the Pfankuch (1975) procedure detailed in Section 3.4.

Streams within the Project area have been classified in terms of their:

- reach environs
- bank stability
- bed and bar stability
- channel diversity and habitat types
- riparian vegetation
- aquatic vegetation,
- aquatic habitat
- scenic, recreation and conservation value.

Streams have been rated as very poor, poor, moderate, good and very good for the above characteristics as shown in APPENDIX B and detailed in the sections below.

### 4.5.5 Reach Environs

#### *4.5.5.1 Condamine catchment*

Within the Condamine catchment, streams on average had moderate reach environ conditions. Of the 31 sites surveyed:

- 28% had poor reach environ conditions
- 50% had moderate reach environ conditions
- 16% had good reach environ conditions
- 3% had very good reach environ conditions.

The dominant land use in the reach environs is grazing, occurring mostly on thinned native vegetation and on cleared native vegetation. Other land use within the reach environs includes broadacre non-irrigated row crops, irrigated crops, native vegetation and urban residential areas (Manen, 2001).

During the field visit, the following impacts to streams were recorded: grazing; clearing of land for agricultural purposes; and road infrastructure, including bridges and culverts.

At the time of the survey the water levels of the streams varied:

- 13% were dry
- 29% contained isolated pools of water
- 29% were below the water mark
- 6% were at the water mark
- 23% were above the water mark.

Those sites identified as being above the water mark were surveyed after a rainfall event had occurred.

#### *4.5.5.2 Moonie catchment*

The two sites surveyed within the Upper Moonie catchment differed considerably in reach environ conditions. Moonie River was rated as having poor reach environ conditions at the site surveyed, while Finch Creek was rated as having very good reach environ conditions at the site surveyed.

The land use in the reach environ for the Moonie River site was: cleared native vegetation that was grazed; and cleared land for crops. The riparian corridor width on either side of the Moonie River was less than 40 m. Observations by the landholder suggest that the land on the left overbank area had recently been cleared and caused an increase in sediment runoff to the river (pers. comm. Property owner, 20 November 2008).

The Finch Creek survey site is located within Kumbarilla State Forest. Unsurprisingly, the Finch Creek reach environ received a very good rating.

At both sites the water level was at the water mark.

#### *4.5.5.3 Horse Creek, Wandoan Creek and Woleebee Creek*

The reach environs within the northern tenements at Horse Creek, Wandoan Creek and Woleebee Creek ranged from poor to very good, with two of the sites receiving a moderate rating.

The dominant land use within those reach environs is: natural vegetation, State Forest and grazing. Horse Creek, Wandoan Creek and Woleebee Creek catchments lie within Mount Organ State Forest.

### 4.5.6 Bank stability

Streams within the Condamine catchment and the northern tenements had, on average, moderate bank stability. The Moonie River had good bank stability while Finch Creek had moderate bank stability.

A number of stream morphology processes were recorded in the streams. Erosion was the most commonly recorded process. Slumping was recorded along the length of the lower bank, at bends and at seepage points. Aggrading was recorded mainly at bends, obstacles and seepage points. Moderate to extensive scouring and bank failure was recorded at 10 of the 37 sites surveyed.

At the streams surveyed, high velocity flow, stock access and the clearing of vegetation were having an impact on bank stability.

### 4.5.7 Bed and bar stability

Bars were recorded at the majority of the sites surveyed and occurred as points on alternate and irregular sides of the stream, at obstructions, as mid-channel islands or dunes and as island or dunes with encroaching vegetation (see Photo 5 below). Bed material was predominately moderately compacted.

The sites surveyed had, on average, moderate bed and bar stability:

- 13% had poor bed and bar stability
- 58% had moderate bed and bar stability
- 26% had good bed and bar stability
- 3% had very good bed and bar stability.

*Photo 5: Mid-channel islands within Condamine River*

No bed-stabilising structures were found at any of the sites surveyed though natural vegetation growth appeared to be a stabilising control at a number of the sites.

### 4.5.8 Channel diversity and habitat types

The Condamine catchment and Horse Creek, Wandoan Creek and Woleebee Creek catchments were generally rated as having poor channel diversity and habitat types. Moonie River and Finch Creek were both rated as having moderate channel diversity and habitat types.

Pools, riffles and runs were the dominant channel habitat types.

### 4.5.9 Riparian vegetation

Riparian vegetation was generally rated as moderate at the sites surveyed. Eucalypt open woodlands, eucalypt woodlands and cypress pine forest were the dominant vegetation types noted. Prickly pear weeds were also noted.

Structural diversity was generally good with most sites having grasses, rushes, small trees, medium trees and tall trees. Riparian corridor width ranged from 10m – 300m with the average width being around 30m.

### 4.5.10 Aquatic vegetation

Aquatic vegetation was rated as poor at most sites. At sites where water was present, the turbidity of the water was generally too high to see any aquatic vegetation. The aquatic vegetation observed was generally emergent vegetation namely rushes and sedges. Grasses were also present within the creek bed at most sites.

### 4.5.11 Aquatic habitat

Aquatic habitat was rated as poor at most sites surveyed. Aquatic organism passage was restricted at approximately 70% of the sites, due to little or no water, and numerous obstructions from fallen trees within the creek bed. Most of these, however, could be overtopped with flow at one-third of the bank height.

### 4.5.12 Scenic, recreation and conservation values

The scenic, recreation and conservation value was rated as moderate for most of the sites surveyed. Some sites were used for recreational purposes with walking paths, barbecues and picnic areas. An ‘undeveloped rural’ setting was the dominant recreational opportunity type for those sites not currently used for recreational activities.

Most sites had good scenic value while the conservation value was moderate for most sites. Horse Creek rated very poor for conservation value and scenic value.

### 4.5.13 Overall condition of the sites surveyed

The overall condition of the sites surveyed was moderate. The major factors impacting the stream sites were:

- erosion
- sedimentation
- lack of riparian vegetation diversity
- corridor width
- poor aquatic vegetation and habitats.

## 4.6 Identification of Existing Surface Water Uses

The predominant water uses in the Project area are irrigation for crops and town water supply. Irrigation farming represents the major category of water use in the catchment which is estimated at around 80% of all water used (Taylor & Meecham, 2003). Irrigation farmers divert overland flow so it can be pumped from a sump or high capacity pumping into a dam or ring tank.

Chinchilla weir is the main public water storage within the Project area. Chinchilla weir has the dual purpose of providing an assured supply of irrigation water along the alluvial flats of the Condamine River and augmenting the water supply to the town of Chinchilla.

Other weirs include Loudon weir near Dalby and Dogwood Creek weir near Miles.

### 4.6.1 Volume of water usage

According to the Department of Local Government and Planning, in August 2001 there were 484 reported irrigation storage structures on the Condamine floodplains. Table 8 shows the number and capacity of the main irrigation storages on the Condamine floodplains at Dalby and Chinchilla, which have a combined storage capacity of 8,440 ML.

**Table 8: Irrigation Storages on the Condamine Floodplains**

| Local Government Area | Overland Flow | | Water Harvesting | | Total | |
|---|---|---|---|---|---|---|
| | No. | Capacity (ML) | No. | Capacity (ML) | No. | Capacity (ML) |
| Dalby | 1 | 240 | | | 1 | 240 |
| Chinchilla | 10 | 4,000 | 8 | 4,200 | 18 | 8,200 |

Source: Taylor & Meecham (2003)

The Draft Water Allocation Management Plan (draft WAMP) for the Condamine-Balonne assumed the mean annual diversions of overland flow for on-farm storage capacity within the Condamine and Brigalow-Jimbour Floodplains (Loudon to Chinchilla) as being 19,000 ML/yr with 35,000 ML approximate equivalent offstream storage capacity (2000).

Table 9 below shows the water allocation for the Chinchilla Weir as identified in the Interim Resource Operations Licence (IROL) for Chinchilla Weir Water Supply Scheme (Natural Resources and Mines, 2006 (currently NRW)),.

**Table 9: Interim water allocation for Chinchilla weir**

| Section | Customer | Megalitres of Interim Water Allocation | | Purpose | Priority |
|---|---|---|---|---|---|
| | | Customer | SunWater | | |
| Condamine River – Chinchilla Weir Storage | Chinchilla Shire Council | 1,160 | | Urban | High |
| | Amenities at Chinchilla Weir | | 5 | Urban | High |
| | River/Storage Irrigators | 2,021 | | Agriculture | Medium |
| Condamine River – downstream of Chinchilla Weir | River Irrigators | 861 | | Agriculture | Medium |
| **Total** | | **4,042** | **5** | | |

Source: Natural Resources and Mines, 2006.

### 4.6.2 Extraction locations

Water storages for irrigation are located throughout the entire Project area. Chinchilla weir is located approximately 8km from Chinchilla.

### 4.6.3 Allocations and entitlements

Table 10 shows data extracted from the CSIRO report *Water Availability in the Condamine-Balonne* (2008) and provides a summary of surface water sharing arrangements within the Condamine-Balonne region in Queensland. The above table details the entire Condamine-Balonne Region in Queensland, not just the Condamine-Balonne Region within the Project area.

**Table 10: Summary of surface water sharing arrangements within the Condamine-Balonne region, Queensland**

| Water Products | Priority of Access | Allocated Entitlement (ML) | | |
|---|---|---|---|---|
| | | Regulated Water Supply Schemes(1) | Unregulated Water Management Area (2) | Nebine Water Resource Plan |
| Total licensed (long-term) extraction limit | | 123,394 | 444,578 | 2,039 |
| Annual volumetric extraction limit | | 123,394 | Not specified | 3,209 |
| Supplemented access | High priority | 7,552 | 21,522(8) | 0 |
| | Risk(7) | 8,245 | | |
| | Medium priority | 107,597 | | |
| Domestic and stock | | | 0(3) | 0(3) |
| Unallocated | | | 0 | 1,000 |
| Unsupplemented access | Low priority | | 1,597,574 | 2,039 |
| Water harvesting of overland flow(4) | | | 868,375 | |
| Substitution of groundwater(5) | | | Not specified | |
| Environmental provisions | | | (6) | (6) |

(1)Includes Upper Condamine Water Sharing Scheme, Chinchilla Weir Water Supply Scheme, Maranoa River Water Supply Scheme and the St George Water Supply Scheme.
(2)Includes Upper Condamine Water Management Area, Condamine-Balonne Water management Area, Tributaries Water Management Area and Lower Balonne Water Management Area.
(30)Domestic and Stock allocations have been converted to nominal allocations.
(4)Lower Balonne Water Management Area. This limit is included in the unsupplemented access storage limit.
(5)Upper Condamine Water Management Area. This volume is not specified as it is tied to groundwater use which is not part of the Condamine and Balonne draft Resource Operations Plan, but it is constrained by existing infrastructure.
(7)Risk Class A and B as defined in the Condamine and Balonne Resource Operations Plan.
(8)The volume of Cooby Dam and Warra Weir is included as an allocation has not yet been assigned to demands from these storages.
Source: CSIRO, 2008.

## 4.7 Surface Water Quality

### 4.7.1 Environmental values for water quality

The main management plans detailing desired environmental values for the Condamine catchment are the Condamine Alliance *Natural Resource Management Plan* (2004), the Condamine Catchment Management Association (CCMA) *Condamine Catchment Strategic Plan* (2001) and the *Runoff and Flow Coordination Framework for the Condamine Floodplains* (2003). Water quality objectives are detailed in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000).

#### 4.7.1.1 Natural Resource Management Plan

The *Natural Resource Management Plan* (Condamine Alliance, 2004) provides an integrated framework for the future sustainable management of natural resources in the Condamine catchment. The plan has five main themes of natural resource management: salinity; water (quality, access, use and management); vegetation, biodiversity and nature conservation; land use and management; and community.

The aspirational targets of the *Natural Resource Management Plan* detailed within the Water Theme are:

- WA1 – Improved water management planning and use processes established by 2054;
- WA2 – Community knowledge increased to influence the improvement of water quality by 2054; and
- WA3 – Water supporting a range of environmental, economic and social desires by 2054.

#### 4.7.1.2 Condamine Catchment Strategic Plan

The strategic plan identifies 13 key issues within the Condamine catchment that require attention and highlight floodplain management as a key issue. The strategic plan identifies the following objectives:

- Floodplain Management

  Objective 1: Integrated and coordinated planning and management between the local community, state government agencies and local government.

  Objective 2: A comprehensive inventory of ecological, physical and cultural characteristics of floodplain areas.

  Objective 3: Adoption of better management practice to reduce adverse impacts on the floodplain and in stream biota.

- Riverine Management

  Objective 1: To maintain and enhance the ecological values (physical and biological) and the condition of in-stream and riparian zones within the catchment.

- Water Quality

  Objective 1: To protect water quality for agricultural, urban, industrial and environmental uses, including protection of ecosystems.

  Objective 2: Develop and implement a permanent water quality monitoring program to reliably assess and report on water quality condition and trend.

#### 4.7.1.3 Runoff and Flow Coordination Framework for the Condamine Floodplains

The framework (Qld Dept of local government and planning, 2003) consists of seven principles and seven strategic goals that set the foundation for coordinated and focused actions to improve management, planning and development on the Condamine floodplains. The principles are summarised as follows:

- Principle 1: Floodplain planning should be coordinated in a whole-of-catchment context and include all stakeholders.
- Principle 2: Natural flow paths should be maintained, except where alterations are socially, technically and environmentally sound.

- Principle 3: Development on the floodplains and upland catchment areas should be coordinated and be in accordance with best management practices.
- Principle 4: Local and cumulative impacts on inundation times, flood heights and velocity caused by existing or proposed development should be restrained to acceptable levels as determined by agreed floodplain management and/or development criteria.
- Principle 5: Natural resource impacts, including erosion, should be minimised to an acceptable level as determined by agreed floodplain management and/or development criteria.
- Principle 6: The action or inaction of an individual or group should not impact adversely on other stakeholders, including those downstream of the floodplains.
- Principle 7: Water allocation processes should be guided by the best available technical information applied to establish transparent criteria for determining access to and use of overland flows by individual floodplain holdings.

#### 4.7.1.4 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Table 11 shows the water quality guidelines for aquatic ecosystems and primary industries as per the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC guidelines).

**Table 11: ANZECC water quality guidelines**

| Analyte | unit | Aquatic freshwater ecosystems | Primary industries |
|---|---|---|---|
| pH Value | pH Unit | 6.5 - 8.0 | 5 - 9.0 |
| Sodium Absorption Ratio | - | 12 -15 | 46 - 102 affects wheat, cotton and barely |
| Electrical Conductivity @ 25°C | µS/cm | 125 - 2200 | 4500 = moderate |
| Total dissolved solids | mg/L | | <3000 |
| Suspended Solids (SS) | mg/L | | <40 |
| Turbidity | NTU | 6 - 50 | |
| Total Alkalinity as CaCO3 | mg/L | 0 - 59 = soft<br>60 - 119 = moderate<br>120 - 179 = hard<br>180 - 240 = very hard<br>400 = extremely hard | <60 = increased corrosion potential<br>20 - 100 = recommended<br>>350 = increased fouling potential |
| Sulfate as $SO_4{}^{2-}$ | mg/L | | <1000 |
| Chloride | mg/L | | 350 = moderate |
| Calcium | mg/L | | <1000 |
| Magnesium | mg/L | | <2000 |
| Sodium | mg/L | | 460 = moderate |
| Nitrite + Nitrate as N | mg/L | | <30 |
| Total Nitrogen as N | mg/L | 0.5 | 5 (long-term) |
| Total Nitrogen as NOx | mg/L | 0.04 | |
| Total Phosphorus as P | mg/L | 0.05 | 0.05 (long-term) |
| Total Phosphorus - Filtered | mg/L | 0.02 | |
| Dissolved Oxygen | | 85 – 110 % | >5 mg/L |

### 4.7.2 Existing Surface Water Quality

During the field visit, six sites were sampled for water quality testing. These sites are labelled as SW01 to SW06 and shown on Figure 4 . The water quality results are summarised in Table 12 (below). The results shown in bold in below exceed the ANZECC guidelines. The full suite of water quality results are provided in APPENDIX D.

**Table 12: Water quality sampling site results**

| Analyte | Units | ANZECC Guidelines | | Water Sampling Sites | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic Ecosystems | Primary Industries | QGC_SW01 | QGC_SW02 | QGC_SW03 | QGC_SW04 | QGC_SW05 | QGC_SW06 |
| pH Value | pH Unit | 6.5 - 8.0 | 5 - 9.0 | 7.02 | 7.08 | 7.32 | 7.88 | 6.60 | 7.26 |
| Sodium Absorption Ratio | - | 12 -15 | 46 - 102 affects wheat, cotton and barely | 1.50 | 2.92 | 1.00 | **23.4** | 1.26 | 1.58 |
| Electrical Conductivity @ 25°C | µS/cm | 125 - 2200 | 4500 = moderate | 89 | 115 | 254 | 483 | 82 | 146 |
| Suspended Solids (SS) | mg/L | | <40 | **90** | **450** | 33 | **200** | **3270** | **1550** |
| Hydroxide Alkalinity as $CaCO_3$ | mg/L | | | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | mg/L | | | <1 | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as $CaCO_3$ | mg/L | | | 24 | 41 | 104 | 172 | 35 | 51 |
| Total Alkalinity as $CaCO_3$ | mg/L | 0 - 59 = soft<br>60 - 119 = moderate<br>120 - 179 = hard<br>180 - 240 = very hard<br>400 = extremely hard | <60 = increased corrosion potential<br>20 - 100 = recommended<br>>350 = increased fouling potential | 24 | 41 | 104 | 172 | 35 | 51 |

| Analyte | Units | ANZECC Guidelines | | Water Sampling Sites | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic Ecosystems | Primary Industries | QGC_SW01 | QGC_SW02 | QGC_SW03 | QGC_SW04 | QGC_SW05 | QGC_SW06 |
| Sulfate as $SO_4^{2-}$ | mg/L | | <1000 | 4 | 4 | 2 | 3 | <1 | 3 |
| Chloride | mg/L | | 350 = moderate | 10 | 11 | 20 | 58 | 10 | 10 |
| Calcium | mg/L | | <1000 | 3 | 2 | 18 | 1 | 6 | 6 |
| Magnesium | mg/L | | <2000 | 2 | 1 | 9 | <1 | 2 | **3** |
| Sodium | mg/L | | 460 = moderate | 13 | 21 | 21 | 114 | 14 | 19 |
| Potassium | mg/L | | | 4 | 2 | 8 | 3 | 4 | 5 |
| Nitrite + Nitrate as N | mg/L | | <30 | 0.07 | 0.13 | <0.01 | 0.15 | <0.01 | 2.54 |
| Total Kjeldahl Nitrogen as N | mg/L | | | 0.5 | 1.2 | 0.8 | 4.5 | 3.9 | 1.3 |
| Total Kjeldahl Nitrogen - Filtered | mg/L | | | 0.4 | 0.7 | 0.8 | 1.1 | 0.7 | 1.2 |
| Total Nitrogen as N | mg/L | 0.5 | 5 (long-term) | **0.6** | **1.3** | **0.8** | **0.9** | **0.6** | **3.8** |
| Total Nitrogen as NOx | mg/L | 0.04 | | **1.5** | **0.8** | **3.5** | **2.5** | **0.7** | **3.8** |
| Total Phosphorus as P | mg/L | | | 0.40 | 0.28 | 0.13 | 0.90 | 1.36 | 0.85 |
| Total Phosphorus - Filtered | mg/L | 0.05 | 0.05 (long-term) | **0.16** | **0.14** | **0.07** | **0.29** | **0.24** | **0.64** |

| Analyte | Units | ANZECC Guidelines | | Water Sampling Sites | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Aquatic Ecosystems | Primary Industries | QGC_SW01 | QGC_SW02 | QGC_SW03 | QGC_SW04 | QGC_SW05 | QGC_SW06 |
| Total Anions | meq/L | 0.02 | | 0.85 | 1.22 | 2.69 | 5.13 | 0.99 | 1.36 |
| Total Cations | meq/L | | | 0.95 | 1.16 | 2.72 | 5.10 | 1.18 | 1.47 |
| Ionic Balance | % | | | | | | 0.27 | | |
| Dissolved Organic Carbon | mg/L | | | 11 | 8 | 8 | <1 | 23 | 8 |

The results show that all of the sites, except site SW03, exceed the ANZECC guidelines for suspended solids. All sites exceed the ANZECC guidelines for total nitrogen and total phosphorus. Site SW04 recorded high alkalinity while sites SW01 and SW02 recorded low alkalinity indicating corrosion potential.

The tables in APPENDIX D show the average monthly water quality results for NRW sites along the Condamine River.

Water samples were not collected at the same locations as the NRW sites and water quality data was not available from NRW for November 2008 therefore results from the NRW sites were not able to be accurately compared to results from the field sampling. However, water quality results from the field sampling were in the same range as average results for water quality along the Condamine River obtained from NRW.

### 4.7.3 Existing discharges of waste water

Waste water from Toowoomba's Wetalla Sewage Treatment Plant discharges to Gowrie Creek, a tributary of the Condamine River, upstream of the Project area (Wilson & Adams, 2004). It lies outside the Project area.

The Darling Downs Vision 2000 project (ECOS, 2003) is a proposal to pipe waste water from Brisbane to the Darling Downs for irrigation of cropland. The treated waste water would replace the use of surface water and groundwater for irrigation (Wilson & Adams, 2004).

The Berwyndale South sewerage treatment plant has an EA (EA150272) for the release of water. There are no known discharges from this plant.

## 4.8 Flood Characteristics

### 4.8.1 History of flooding

Though rainfall in the catchment is variable, flooding occurs regularly throughout the Project area. Table 13 (below) shows the history of flooding in the major watercourses in the vicinity of the Project area as recorded by the Bureau of Meteorology (BOM).

**Table 13: History of flooding in watercourses traversing the Project area (BOM)**

| Year | Month | Town | Watercourse |
|---|---|---|---|
| 1862 | July | Dalby | Condamine River |
| 1863 | Feb | Dalby | Condamine River |
| 1863 | Feb | Condamine | Condamine River |
| 1864 | Mar | | Lower Condamine River |
| 1864 | Mar | Dalby | Condamine River |
| 1866 | Dec | Kogon | Condamine River |
| 1870 | Aug | Condamine | Condamine River |
| 1871 | Feb | Dalby | Condamine River |
| 1871 | Dec | Condamine | Condamine River |
| 1873 | Dec | Condamine | Condamine River |
| 1874 | Apr | Condamine | Condamine River |
| 1879 | Aug | Dalby | Condamine River |
| 1908 | | Miles | Dogwood Creek |
| 1908 | | Chinchilla | Condamine River |
| 1909 | Feb | Chinchilla | All watercourses in the vicinity of |
| 1917 | Nov | Chinchilla | All watercourses in the vicinity of |
| 1919 | Mar | | Condamine River |
| 1921 | Dec | Chinchilla | Condamine River |
| 1921 | Dec | Dalby | Condamine River |
| 1924 | Jan | | Condamine River |
| 1927 | Feb | Miles | Condamine River |
| 1928 | Feb | | Condamine River |
| 1934 | Dec | | Condamine River |
| 1942 | Feb | Chinchilla | Condamine River |
| 1942 | Feb | Warra | Condamine River |
| 1946 | Jan | Condamine | Condamine River |
| 1950 | Feb | | Condamine River |
| 1950 | Feb | Miles | Dogwood Creek |
| 1950 | Aug | Condamine | Condamine River |
| 1951 | Mar | Condamine | Condamine River |
| 1954 | July | | Condamine River |
| 1954 | July | Miles | Dogwood Creek |
| 1954 | Aug | Condamine | Condamine River |
| 1956 | Jan | Condamine | Condamine River |
| 1956 | June | | Condamine River |
| 1956 | June | | Moonie River |
| 1961 | Mar | Condamine | Condamine River |
| 1961 | Nov | Chinchilla | Charley's Creek |
| 1961 | Nov | Miles | Dogwood Creek |
| 1962 | Mar | | Condamine River |
| 1962 | Mar | | Moonie River |
| 1969 | Nov | | Moonie River |
| 1970 | Dec | | Condamine River |
| 1970 | Dec | | Moonie River |

| Year | Month | Town | Watercourse |
|---|---|---|---|
| 1971 | Jan | | Condamine River |
| 1975 | Dec | | Condamine River |
| 1975 | Dec | | Condamine River |
| 1981 | Feb | Dalby | Condamine River |
| 1981 | Feb | Miles | Wallan Creek |
| 1981 | Feb | Chinchilla | Charley's Creek |
| 1983 | May | | Condamine River |
| 1983 | May | Chinchilla | Charley's Creek |
| 1983 | May | | Moonie River |
| 1984 | July | Chinchilla | Condamine River |
| 1984 | July | Flinton | Moonie River |
| 1996 | Jan | Condamine | Condamine River |
| 1998 | Aug | Condamine | Condamine River |
| 1998 | Aug | Chinchilla | Charley's Creek |
| 1998 | Aug | Miles | Dogwood Creek |
| 1999 | Mar | Condamine | Condamine River |
| 2000 | Jan | Brigalow | Condamine River |
| 2001 | Feb | Chinchilla | Condamine River |

### 4.8.2 Runoff volumes and frequency

Stream flow data was available for the Condamine River, but not for tributaries within the Project area. Runoff volumes and frequency were assessed at four sites in the Condamine River. These sites are shown in Figure 4 as the NRW sites. IFD tables were developed using HYDSTRA as detailed in section 3.1.1. It should be noted that the IFD tables developed by HYDSTRA are only an indication of the peak flow and may not be exact.

Table 14 (below) shows that the peak flow during a 24 hour duration, 1 in 100 year ARI flood event at Condamine River, upstream of Dalby, is 2,239 $m^3/s$. Figure 9 and Figure 10 show the average daily, maximum daily and total annual flow for the Condamine River, upstream of Dalby.

The results are based on historically recorded rainfall data and do not incorporate potential impacts of climate change. Evidence suggests that climate change may result in a 10% increase in rainfall during a tropical cyclone, potentially increasing runoff volumes and flooding impacts (Queensland Government, 2004).

**Table 14: Condamine River IFD Table (upstream of Dalby)**

| Annual Exceedance Probability | Return Period (1/Y) | Peak Flow ($m^3/s$) | | |
|---|---|---|---|---|
| | | Mean | Upper 90% Confidence Limit | Lower 90% Confidence Limit |
| 0.990 | 1 | 1 | 4 | 0 |
| 0.500 | 2 | 211 | 20 | 2 |
| 0.200 | 5 | 670 | 41 | 6 |
| 0.100 | 10 | 1,061 | 89 | 21 |
| 0.040 | 25 | 1,571 | 325 | 137 |
| 0.020 | 50 | 1,925 | 418 | 185 |
| 0.010 | 100 | 2,239 | 1014 | 443 |
| 0.005 | 200 | 2509 | 1697 | 664 |
| 0.002 | 500 | 2,801 | 2684 | 919 |
| 0.001 | 1,000 | 2,977 | 3421 | 1083 |

The maximum flow recorded between 1969 and 2005 at NRW site 422333A on the Condamine River, upstream of Dalby, was 1,630 $m^3/s$ in February 1976. The average daily flow over the recorded period ranged from 3 $m^3/s$ to 25 $m^3/s$ though the flow varied greatly each year.

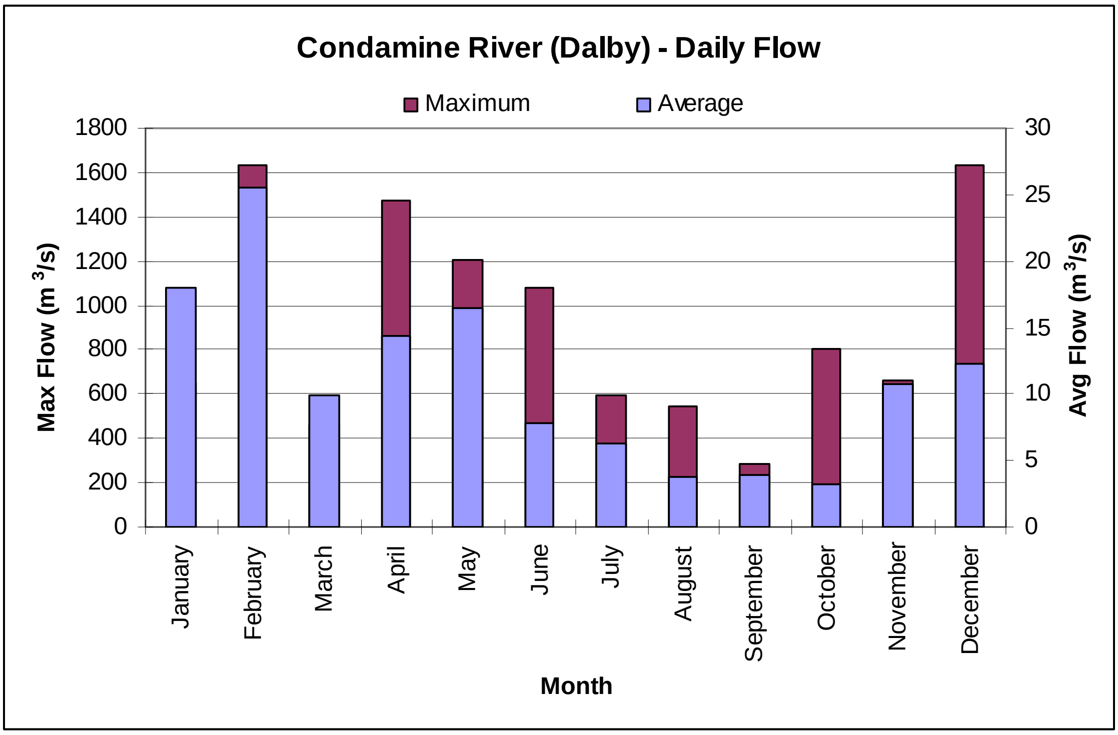



*Figure 9: Average and maximum daily flow in the Condamine River (upstream of Dalby)*

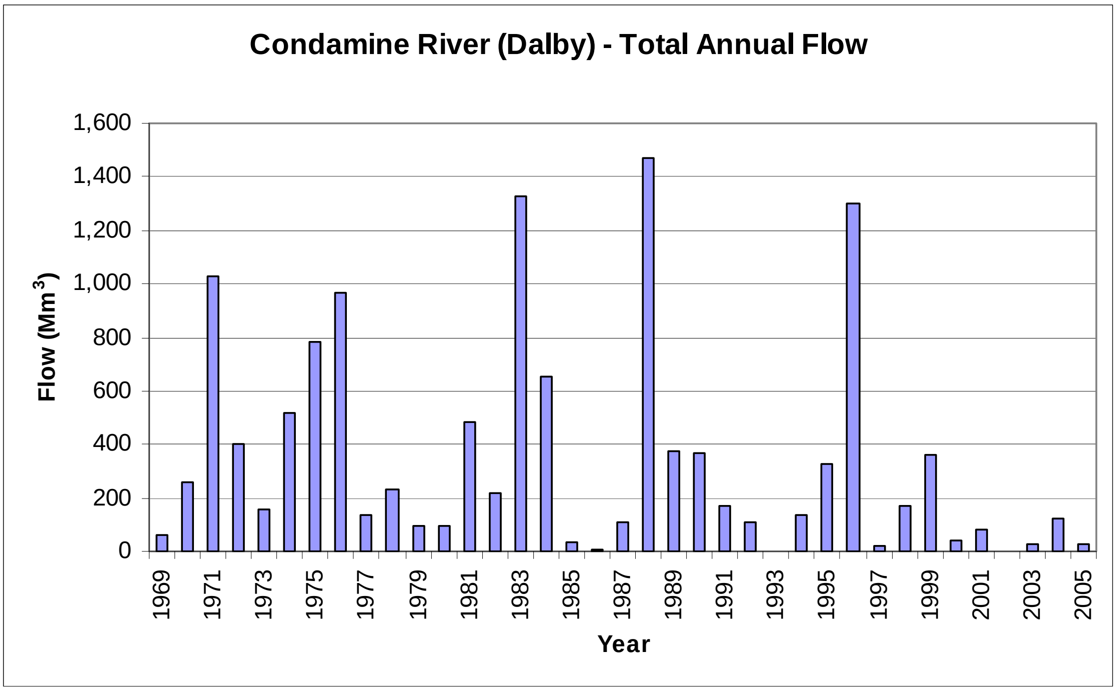



*Figure 10: Total annual flow in Condamine River, upstream of Dalby*

The maximum flow recorded between 1973 and 2007 at NRW site 422366A in Condamine River at Brigalow, was 2,056 $m^3$/s in February 1976. The average daily flow ranges between 3.5 $m^3$/s and 31 $m^3$/s though the flow varies each year. Table 15 below shows the IFD table for Condamine River at Brigalow and Figure 11 and Figure 12 show the average and maximum daily flow and the total annual flow.

**Table 15: Condamine River IFD Table (Brigalow)**

| Annual Exceedance Probability | Return Period (1/Y) | Peak Flow ($m^3$/s) |
|---|---|---|
| 0.990 | 1 | 2 |
| 0.500 | 2 | 247 |
| 0.200 | 5 | 766 |
| 0.100 | 10 | 1,233 |
| 0.040 | 25 | 1,892 |
| 0.020 | 50 | 2,391 |
| 0.010 | 100 | 2,871 |
| 0.005 | 200 | 3,320 |
| 0.002 | 500 | 3,852 |
| 0.001 | 1,000 | 4,206 |

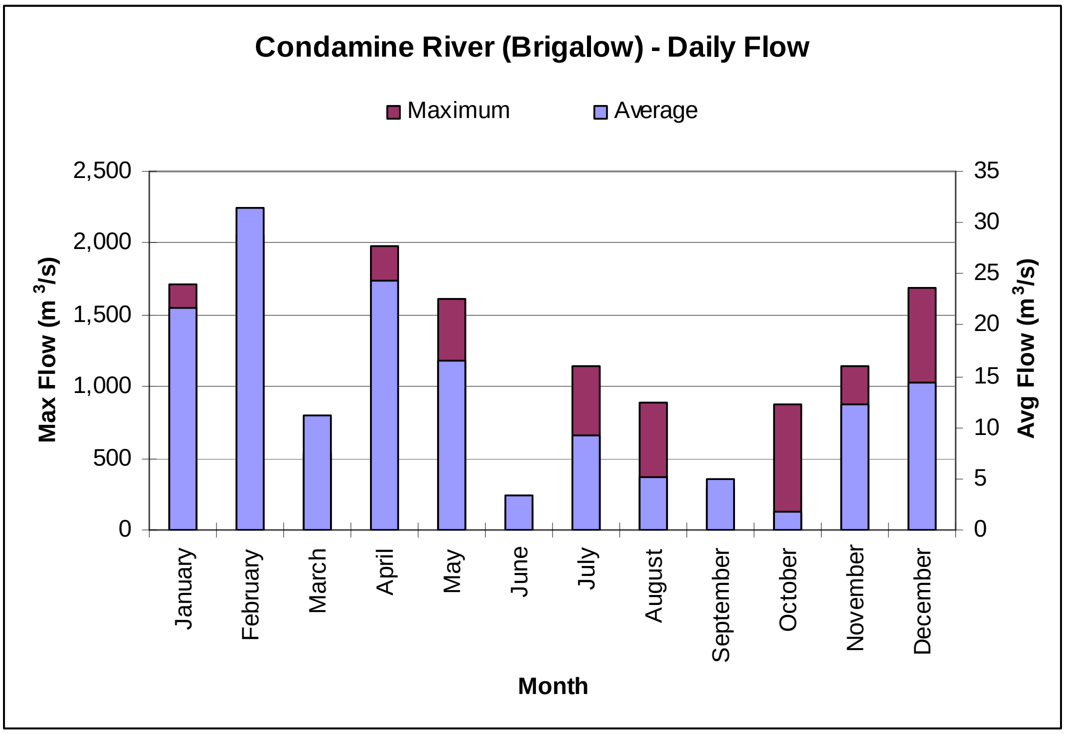



*Figure 11: Average and maximum daily flow in Condamine River at Brigalow*

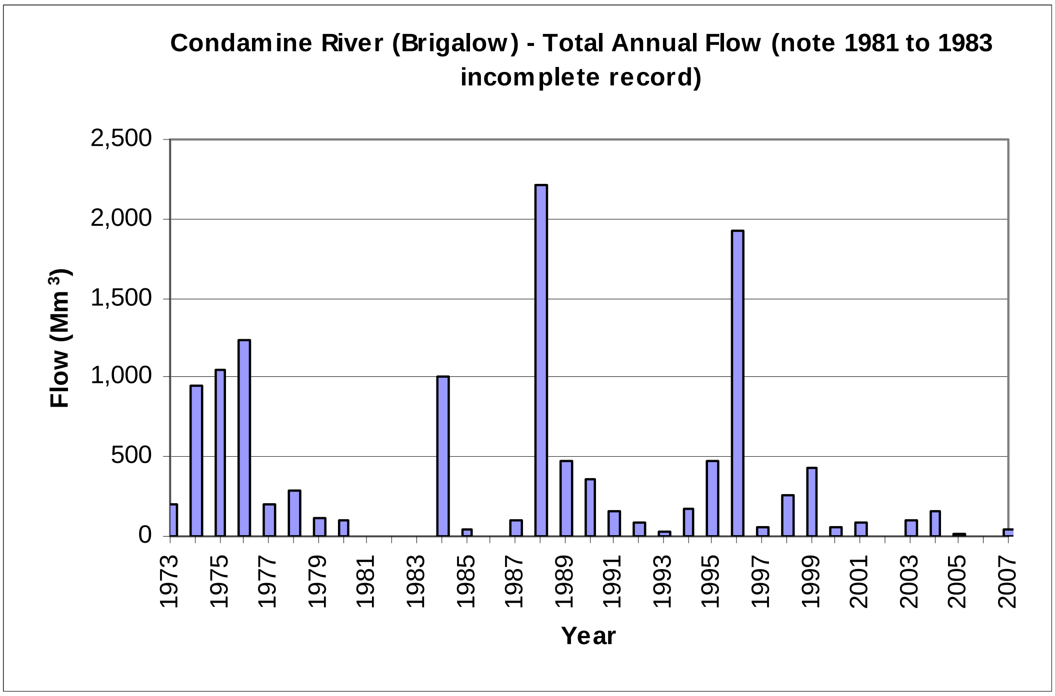



*Figure 12: Total annual flow in Condamine River at Brigalow*

The maximum flow recorded between 1956 and 2001 at NRW site 422308C in Condamine River at Chinchilla, was 2,855 $m^3/s$ in April 1986. The average daily flow ranges between 2.2 $m^3/s$ and 50 $m^3/s$ though the flow varies each year. Table 16 below shows the IFD table for Condamine River at Chinchilla. Figures Figure 13 and Figure 14 below show the average and maximum daily flow and the total annual flow.

**Table 16: Condamine River IFD Table (Chinchilla)**

| Annual Exceedance Probability | Return Period (1/Y) | Peak Flow ($m^3/s$) |
|---|---|---|
| 0.990 | 1 | 2 |
| 0.500 | 2 | 276 |
| 0.200 | 5 | 828 |
| 0.100 | 10 | 1,325 |
| 0.040 | 25 | 2,036 |
| 0.020 | 50 | 2,584 |
| 0.010 | 100 | 3,120 |
| 0.005 | 200 | 3,629 |
| 0.002 | 500 | 4,248 |
| 0.001 | 1,000 | 4,668 |

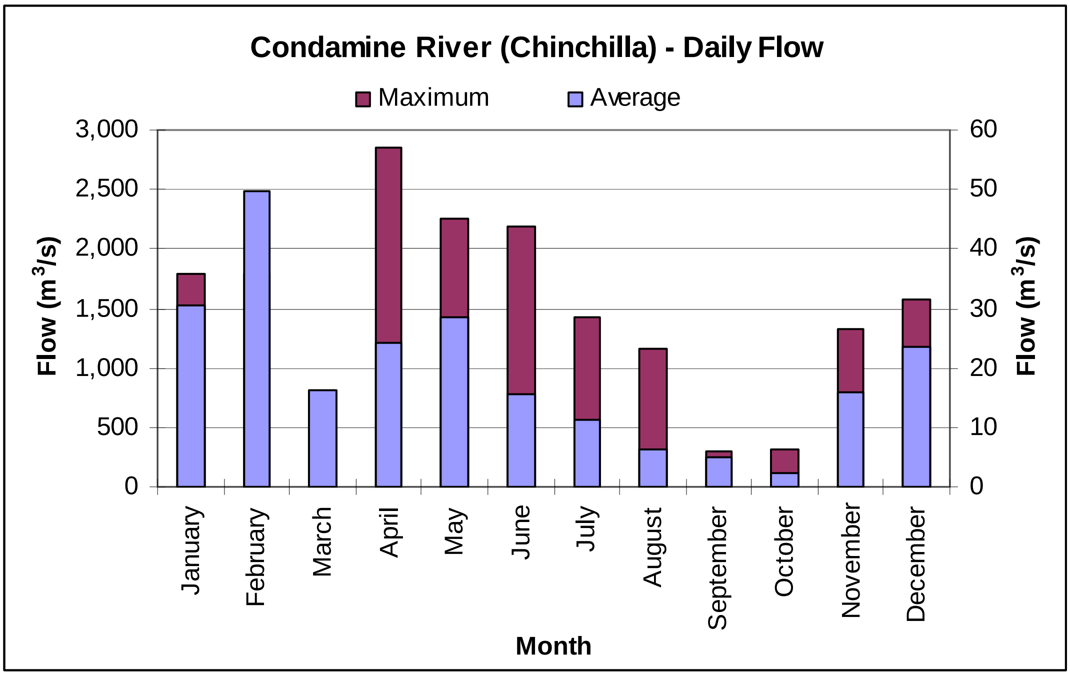



*Figure 13: Average and maximum daily flow in Condamine River at Brigalow*

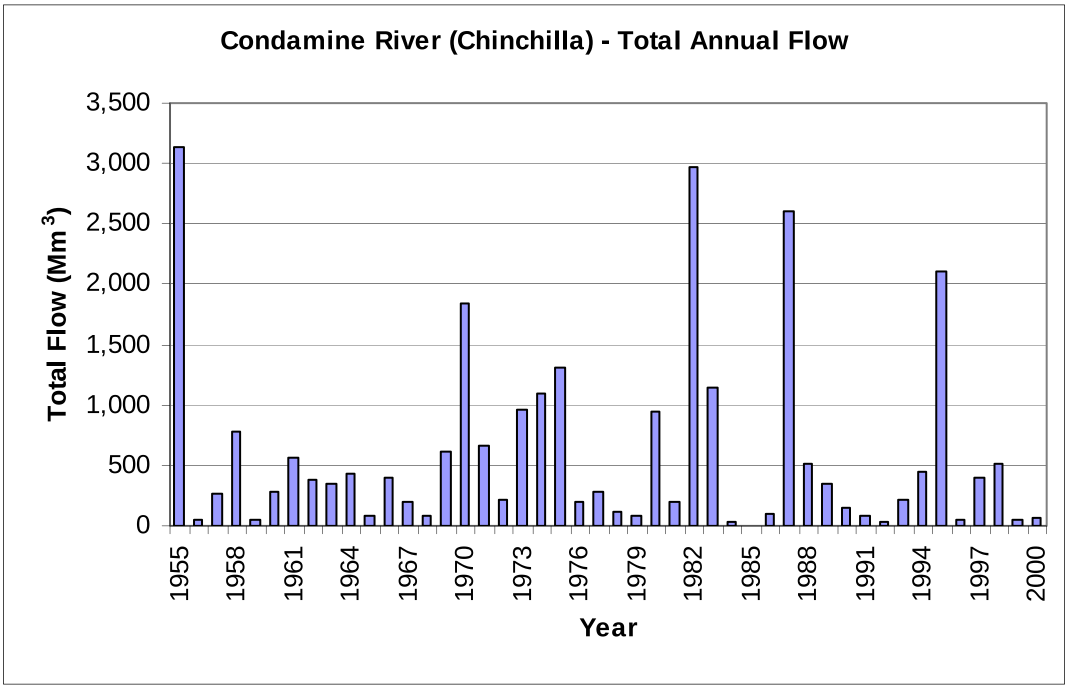



*Figure 14: Total annual flow in Condamine River at Brigalow*

The maximum flow recorded between 1956 and 2001 at NRW site 422308C in Condamine River at Cotswold, was 2,326 $m^3/s$ in May 1983. The average daily flow ranges between 2 $m^3/s$ and 43 $m^3/s$ though the flow varies each year. Table 17 below shows the IFD table for Condamine River at Chinchilla. Figures Figure 15 and Figure 16 show the average and maximum daily flow and the total annual flow.

**Table 17: Condamine River IFD table (Cotswold)**

| Annual Exceedance Probability | Return Period (1/Y) | Peak Flow ($m^3/s$) |
|---|---|---|
| 0.990 | 1 | 7 |
| 0.500 | 2 | 287 |
| 0.200 | 5 | 810 |
| 0.100 | 10 | 1,325 |
| 0.040 | 25 | 2,159 |
| 0.020 | 50 | 2,898 |
| 0.010 | 100 | 3,716 |
| 0.005 | 200 | 4,599 |
| 0.002 | 500 | 5,838 |
| 0.001 | 1,000 | 6,807 |

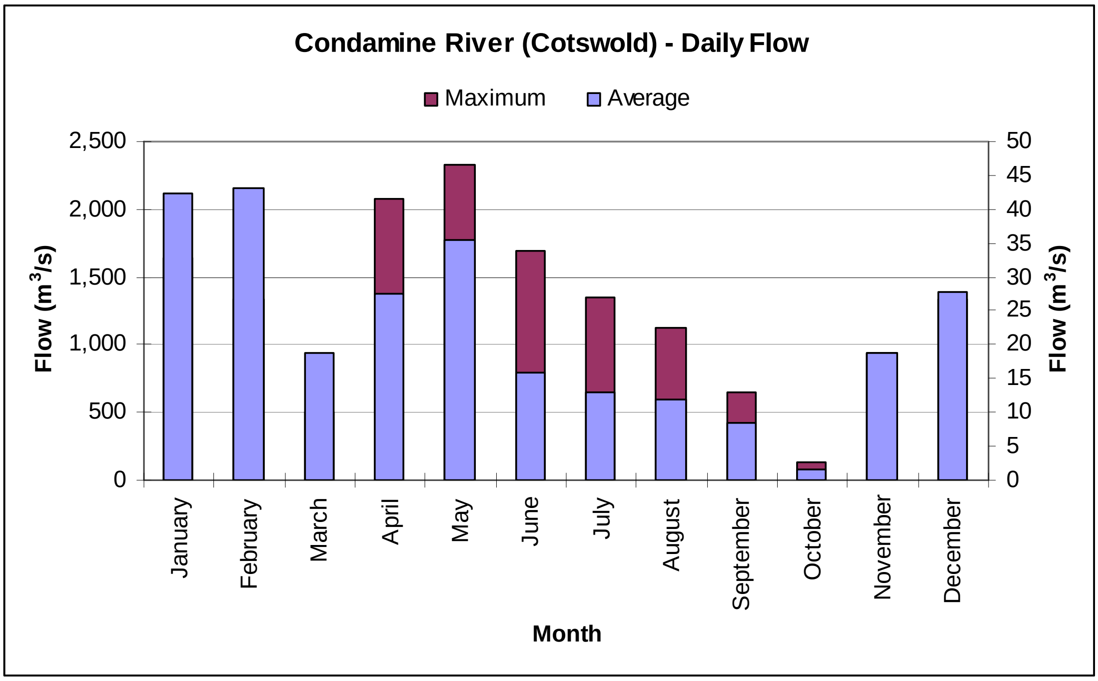



*Figure 15: Average and maximum daily flow in Condamine River at Cotswold*

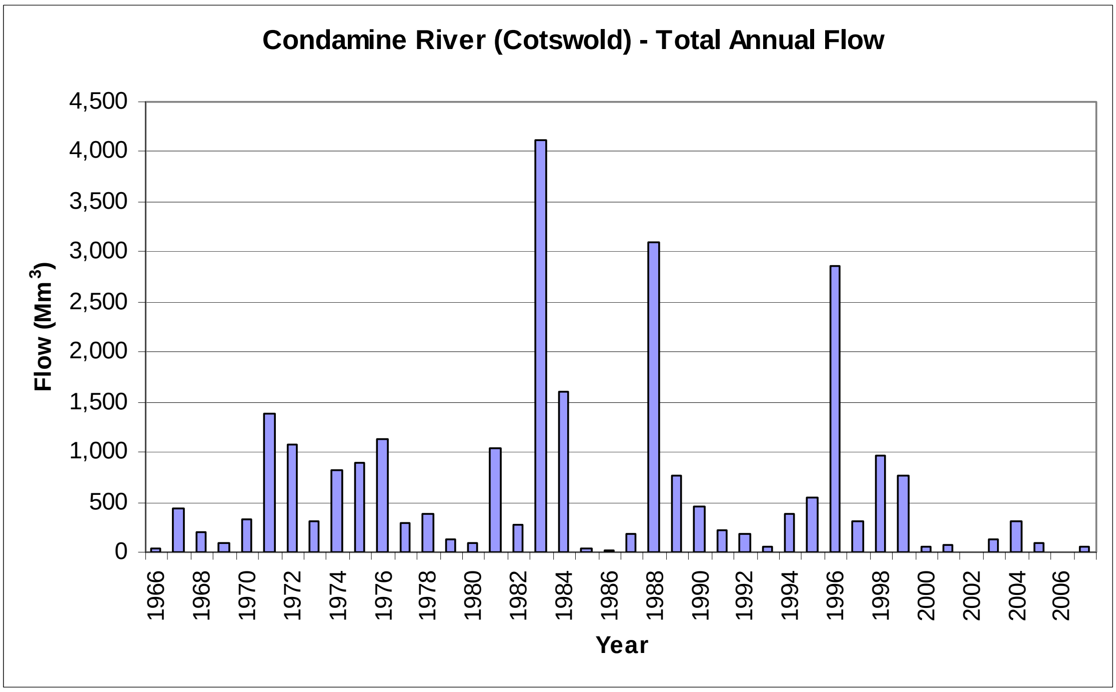



*Figure 16: Total annual flow in Condamine River at Cotswold*

### 4.8.3 Flood Extent and Levels

Flood levels from NRW were available for the Condamine River and Moonie River, and they were available for the smaller tributaries within the Project area.

According to the Bureau of Meteorology, average catchment rainfalls in excess of 25mm, with isolated 50mm falls in 24 hours, may result in stream rises and minor flooding in the Condamine River potentially causing localised traffic interruption. Average catchment rainfalls in excess of 50mm, with isolated 75 to 100mm falls in 24 hours, may result in significant stream rises with the possibility of moderate to heavy flooding within the catchment (BOM website).

Within the Moonie River catchment, rain in excess of 50mm in isolated areas and 25mm over more extensive areas, will cause minor flooding. Rain in excess of 50mm in isolated areas will cause moderate flooding and rain in excess of 50mm over a wide area will cause major flooding.

Table 18 and Table 20 show the depth of flooding at various locations along the Condamine River and the Moonie River and Table 19 and Table 21 shows the severity of flooding. Figure 17 shows the May 1996 flooding event inundation and the gauging station locations. The flooding extent has been estimated from the flow height gauge records and 2m contour data obtained from NRW and may not be accurate.

During the May 1996 flood event, the peak flow recorded in the Condamine River at Chinchilla weir was 2023.87 $m^3$/s and the maximum rainfall in a 24 hour period was 110mm.

**Table 18: Condamine River Flood Levels**

| River height station | Feb 1942 | Jan/Feb 1956 | Feb 1976 | May 1983 | May 1996 | Feb 2001 | Jan 2004 |
|---|---|---|---|---|---|---|---|
| | m | m | m | m | m | m | m |
| Loudoun Bridge | - | 10.67 | 10.89 | 10.28 | 10.32 | - | 8.40 |
| Ranges Bridge | - | 10.52 | 11.05 | 9.75 | 9.70 | 5.85 | 7.20 |
| Warra-Kogan Road Bridge | - | 14.00 | - | 13.71 | 13.53 | 5.5 | 8.25 |
| Brigalow Bridge TM | - | - | 13.99 | - | 13.40 | 6.11 | 8.88 |
| Chinchilla Weir | - | 13.87 | 13.90 | 13.51 | 13.32 | 3.44 | 7.41 |
| Condamine Town | 14.25 | 14.14 | 12.74 | 14.05 | 13.40 | 3.60 | 5.20 |
| Cotswold TM | - | - | 14.22 | 16.13 | 14.95 | 6.01 | 8.74 |

Source: BOM website

**Table 19: Severity of Condamine River flooding**

| River Height Station | First Report Height | Crossing Height | Minor Flood Level | Crops & Grazing | Moderate Flood Level | Towns and Houses | Major Flood Level |
|---|---|---|---|---|---|---|---|
| | m | m | m | m | m | m | m |
| Loudoun Bridge | 3.00 | 9.10 (A) | 5.00 | 5.00 | 7.00 | - | 9.00 |
| Ranges Bridge | 3.00 | 7.50 (B) | 6.00 | 8.00 | 6.50 (d/s) | - | 7.00 (d/s) |
| Warra-Kogan Road Bridge | 3.00 | 9.10 (B) | 7.00 | - | 8.00 | - | 9.00 |
| Brigalow Bridge TM | - | - | 7.50 | - | 9.00 | - | 10.05 |
| Chinchilla Weir | 6.00 | 10.00 (R) | 6.00 | 8.00 | 8.00 | - | 10.00 |
| Condamine Town | 3.00 | 10.10 (B) | 5.00 | 7.00 | 7.00 | 10.70 | 8.00 |
| Cotswold TM | - | 4.29 (W) | 7.00 | - | 10.00 | - | 11.00 |

B) = Bridge (A) = Approaches (C) = Causeway (R) = Road (W) = Weir (d/s) = Down Stream Source: BOM website

**Table 20: Moonie River flood levels**

| River height station | Feb 1942 | Jan/Feb 1956 | Feb 1976 | May 1983 | May 1996 | Feb 2001 | Jan 2004 |
|---|---|---|---|---|---|---|---|
| | m | m | m | m | m | m | m |
| The Deep Crossing | 3.70 | 4.45 | 3.70 | 2.99 | 3.70 | 1.85 | - |
| Tartha | 5.70 | 6.35 | 6.08 | 3.80 | 6.10 | 3.30 | - |
| Southwood | 5.60 | 6.35 | 6.03 | 3.85 | 6.30 | 4.45 | 6.25 |

Source: BOM website

**Table 21: Severity of Moonie River flooding**

| River Height Station | First Report Height | Crossing Height | Minor Flood Level | Crops & Grazing | Moderate Flood Level | Towns and Houses | Major Flood Level |
|---|---|---|---|---|---|---|---|
| | m | m | m | m | m | m | m |
| The Deep Crossing | 0.50 | 0.00 (C) | 2.50 | 3.50 | 3.00 | 4.20 | 4.20 |
| Tartha | 1.00 | 1.60 (C) | 2.50 | 4.00 | 4.00 | 5.50 | 5.00 |
| Southwood | 1.00 | 0.80 (C) | 3.50 | - | 4.50 | - | 5.50 |

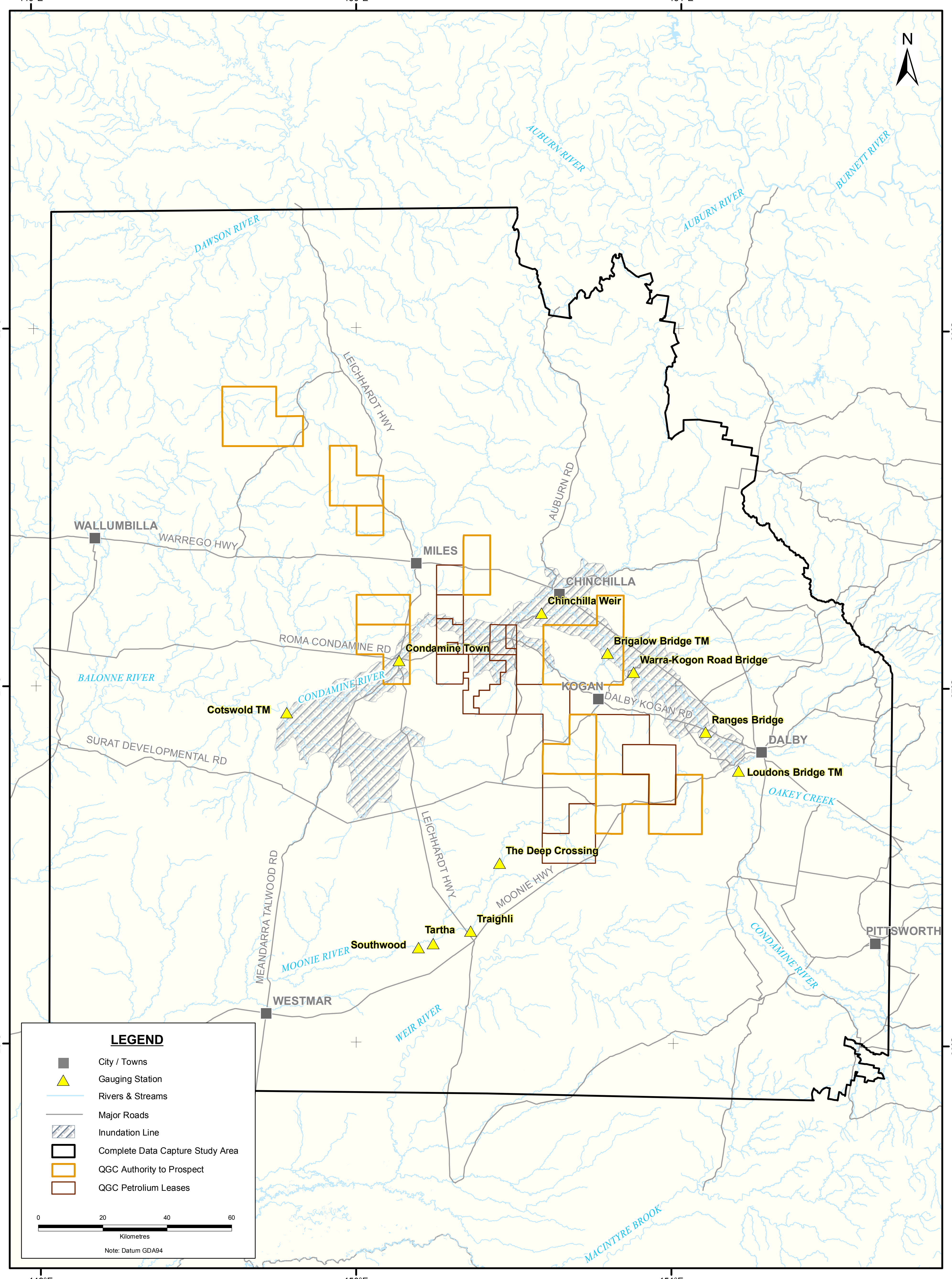
B) = Bridge (A) = Approaches (C) = Causeway (R) = Road (W) = Weir (d/s) = Down Stream Source: BOM website

### 4.8.4 Potential Impact of flooding on infrastructure

Flooding within the Project area may have a number of impacts on infrastructure including:

- damage to infrastructure from high velocity flows and debris
- potential loss of production due to power shut-offs
- access issues due to flooded roads and tracks
- overtopping of evaporation ponds causing environmental harm.

To quantify the potential risks of flooding to infrastructure a hydraulic model would need to be developed for the watercourses within the Project area. The model would assess flood inundation, flow depth and velocity. Development and calibration of the model may be difficult due to the complexity of the watercourse characteristics. Therefore, the use of a detailed, sophisticated modelling platform would be required. The development of a detailed model was not required by the Terms of Reference. The modelling would need to be done at a stage when potential locations for infrastructure had been identified and a layout plan could be provided to the modeller.




Notes:
1. Base map data copyright Mapinfo Australia Pty Ltd
2. Authority To Prospect & Petroleum Leases data and the borehole Locations supplied by Queensland Gas Company (QGC), dated 15-10-2008 and 23-10-2008.

Golder Associates

| | | | |
|---|---|---|---|
| CLIENT | Queensland Gas Company | PROJECT | QGC - LNG EIS Surface Water Studies |
| DRAWN | DK/BQ | DATE | 03-03-09 |
| CHECKED | DS* | DATE | 03-03-09 |
| TITLE | MAY 1996 FLOOD INUNDATION | | |
| SCALE | 1:1,120,000 | PROJECT No | 087633050_014 |
| FIGURE No | 17 | REV No | 1 |
| | A3 | | |



File Location: R:\Env\2008\087633050\GIS\Projects\ArcGIS\087633050_014_R_F0017_Rev1_May1996FloodInundation_A3.mxd
Note: The * beside the typed initials denotes the original drawing issue was signed or initialled by that respective person.

# 5.0 POTENTIAL IMPACTS OF THE PROJECT

The operations of the proposed Project have the potential to impact on the surface water characteristics of the catchments within the vicinity of the Project area. The main surface water characteristics that can be impacted include surface water quantity and quality, surface baseflow to perennial watercourses, and flooding potential.

## 5.1 Surface water quantity and quality changes

Clearing of land for infrastructure development can pose a major threat to the watercourses within the Project area. Increased erosion and sedimentation rates can be a direct result from clearing vegetation, leading to an increase in runoff and stream flow velocity. Overland flow can also pick up existing contamination in the soils which will add to the stream waste loads.

The loss of riparian vegetation by clearing can threaten bank stability. Channel siltation, bank collapse and the loss of larger woody debris may have a major impact on reducing biodiversity values (Wilson & Adams, 2004).

Increased sediment transport into the channels is a primary mechanism for elevated levels of nutrients within the stream systems. This may occur during any runoff or flood event. At the sites surveyed, the levels of nitrate and phosphorous already exceed the ANZECC guidelines. Additional nutrient enrichment could result in eutrophication occurring within the watercourses, potentially reducing oxygen levels and impacting on aquatic organisms and vegetation.

Construction of roads and increased volumes of traffic may also result in an increase in nutrients and hydrocarbons, from vehicle leaks, discharging to watercourses within the Project area. Hydrocarbons generally affect adult fish, eggs and larvae.

Evaporation ponds have the potential to increase salinity levels in surface water by overtopping, wall failure and seepage. Increased levels of salinity in the watercourses within the Project area may affect town water supplies and infrastructure, as well as precluding some crops from irrigation water (Condamine Alliance, 2004). Existing and proposed evaporation ponds are located within the catchments of Cameby, Columboola, Cobbareena, Nine Mile, Wieambilla, Wambo and Sandy Creek which all discharge to the Condamine River. Overtopping, wall failure and/or seepage of the evaporation ponds have the potential to impact on the water quality within these creeks and the Condamine River.

Using treated associated water for irrigation may affect salinity levels, nutrient levels, heavy metals and other contaminants.

Accidental release of CSG water to the surface water drainage system could occur through pipeline leakage and overtopping, wall failure and seepage from evaporation ponds. Such discharge has the potential to change the water composition by increasing salinity levels in surface water. Potential users directly affected by changes to the water quality could include aquatic ecosystems, vegetation and fauna, town water supplies and infrastructure; irrigation water, which could preclude irrigation of sensitive crops; other farming activities such as stockwatering; and domestic water supply users. Those indirectly affected could include recreational water users such as fisherman.

The risk of CSG operations affecting stakeholders will be addressed in the water monitoring program.

## 5.2 Impacts on Baseflow to Perennial Watercourses

Reduction of baseflow to perennial watercourses has the potential to reduce biodiversity, including aquatic and riparian vegetation. However, initial findings and observations from the site visits suggest that baseflow has already been affected by other anthropogenic activities in the Project area.

The Condamine River Alluvium is considered to be a potential source of base flow to the Condamine River. Groundwater levels have been measured in the Alluvium over the past 18 years and are illustrated in Figure 18. The graph displays seasonal trends with distinct drawdown in the summer months. The overall trend in the alluvium is one of declining water levels. The trend is considered to reflect the use of the water in the Alluvium for irrigation purposes. The graph also shows the water levels recorded in the Walloon Coal Measures, the source of the CSG associated water. These levels also show a decline over a similar period of time but this would not be expected to affect baseflow.

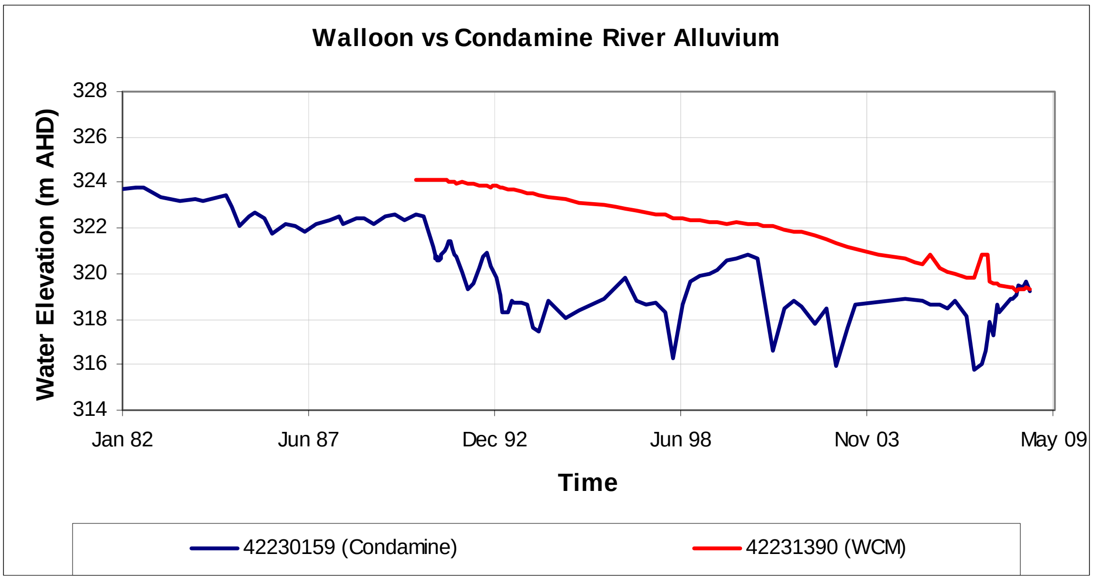



*Figure 18: Water levels in the Condamine River alluvium*

## 5.3 Impacts on flooding potential

Land clearance for infrastructure development has the potential to increase the area of impervious surfaces in a catchment. It is expected that around 8,000 ha of the 26,875 ha that comprise the Condamine River, Moonie River, Wandoan Creek, Woleebee Creek and Horse Creek Catchments will be disturbed, This equates to around 30% disturbance within these catchment areas. This may increase the volume and peak flow of surface water runoff to streams within the Project area. During the early phases of a flood event, impervious ground surfaces that have not become saturated, have the potential to increase flood levels. These potential impacts can be built into surface water models to enable quantification of any extra water that might be added by CSG operations during high rainfall events and floods. It is considered unlikely that this would be a significant volume.

## 5.4 Surface water modelling

To quantify the impact of the Project on surface baseflow to perennial watercourses and flooding within the Project area, detailed modelling would need to be undertaken. The TOR did not require a detailed model to be developed. A basic model was developed so that an understanding of the existing contribution of baseflow to surface flow, and the flooding potential within the Project area would be obtained.

### 5.4.1 Selection of modelling platforms

The Australian Water Balance (AWBM) was the modelling platform chosen for this study. It was used to simulate baseflow and streamflow runoff to watercourses within the Project Area.

### 5.4.2 Model definition

The AWBM is a catchment water balance model that calculates runoff from rainfall for both gauged and ungauged catchments at daily or hourly time increments (Catchment Modelling Toolkit website, Boughton, 2004).

The model uses three surface stores to simulate partial areas of runoff. The surface store represents the volume of water stored in the soil, at or near the surface. The model calculates the moisture balance of each partial area at either daily or hourly time steps. At each time step, rainfall is added to each of the three surface moisture stores and evapotranspiration is subtracted from each store. If the value of moisture in the store becomes negative, it is reset to zero. However, if the value of moisture in the store exceeds the capacity of the store, the moisture in excess of the capacity becomes runoff and the store is reset to the capacity.

When runoff occurs from any store, part of the runoff becomes recharge of the base flow store, if there is base flow in the stream flow. The fraction of the runoff used to recharge the base flow store is BFI*runoff, where BFI is the base flow index. The remainder of the runoff, i.e. (1.0 - BFI)*runoff, is surface runoff. The base flow store is depleted at the rate of (1.0 - K)*BS where BS is the current moisture in the base flow store and Kb is the base flow recession constant of the time step being used.

The surface runoff can be routed through a store if required to simulate the delay of surface runoff reaching the outlet of a medium to large catchment. The surface store acts in the same way as the base flow store, and is depleted at the rate of (1.0 - Ks)*SS, where SS is the current moisture in the surface runoff store and Ks is the surface runoff recession constant of the time step being used (Catchment Modelling Toolkit website).

### 5.4.3 Model development

The model was set-up using rainfall and runoff data available for the most downstream point of the Project area, namely NRW site 422325A, Condamine River at Cotswold. Daily rainfall and runoff data was input into the model along with the catchment area, BFI, Kb, ASS and Ks.

### 5.4.4 Model calibration

The model was calibrated to the recorded river flows at the NRW site 422325A for the period January 1982 to June 2008.

Parameters used to calibrate the model included average surface store capacity (ASS), the baseflow runoff recession constant (Kb), the base flow index – the ratio of baseflow to total flow in the streamflow (BFI) and the surface runoff recession constant (Ks).

Figure 19 below shows the modelled river flows against the recorded river flows. It shows a large difference between recorded and modelled flows. The average daily flow reported by the model was 1833 ML/d, while the recorded average daily flow was 2801 ML/d, indicating only a 65% correlation.

The variation in modelled river flows and recorded river flows is largely because of the simplicity of the model. The model does not take into account: extracted water for irrigation or town supply; capture of overland flow runoff in on-site storages; or groundwater extraction.

The variations of the model calibration result in an under estimation of stream flow. Therefore it is difficult to accurately quantify the potential of flooding in the Project area.

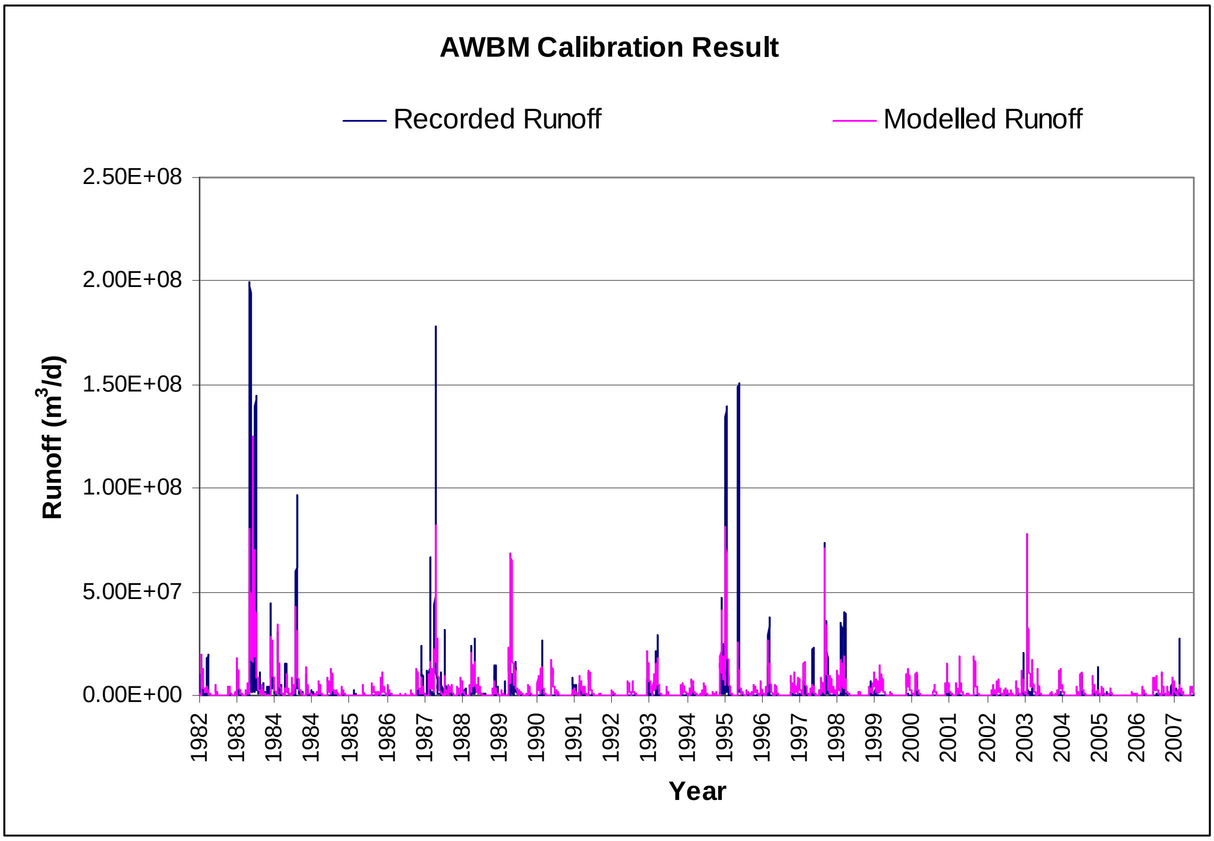



*Figure 19: Calibration of AWBM*

### 5.4.5 Recommended modelling platforms

To successfully model the watercourses within the Project area, a detailed model would need to be developed using a sophisticated model such as the Integrated Quality and Quantity Model (IQQM). An IQQM model has previously been developed for the Middle Condamine catchment from Cecil Plains weir to the Beardmore dam headwater (CSIRO, 2008).

The model was developed by the CSIRO for the CSIRO Murray-Darling Basin Sustainable Yields Project in 2008. The model was used to assess current and expected water availability at the various storages along the Condamine River. It could be used to assess runoff volumes at various locations along the Condamine River within, or adjacent to the Project area.

The model uses 140 nodes – seven medium high security irrigators, 107 unsupplemented access irrigators, five floodplain harvesters, 15 high security town water supplies and six high security stock and domestic nodes. It is operated under two annual accounting schemes (CSIRO, 2008).

Until the completion of a detailed infrastructure plan it was not considered beneficial to develop the detailed surface water hydrological model at this stage. Sophisticated model development should occur when there is greater clarity on present uncertainties such groundwater drawdown and baseflow impact, associated water handling, treatment and reuse, and the siting of infrastructure.

### 5.4.6 Existing surface and baseflow runoff

In lieu of results from a sophisticated modelling package for use during the pre-feasibility stage of the project, the Chapman and Maxwell (1996) method has been used to separate surface and baseflow runoff to the watercourses within the Project area.

The Chapman and Maxwell (1996) equation is as follows:

$$q_b(i) = \frac{k}{1+C} q_b(i-1) + \frac{C}{1+C} q(i)$$

Subject to $q_b(i) \leq q(i)$

where:

*C* = parameter that enables the shape of the separation to be altered

*k* = recession constant of the hydrograph.

*C* and *k* have been estimated from information gained from literature and during the field investigation. Based on the field investigations and BOM records, it is believed that there is minimal water in the majority of the watercourses throughout the Project area during the dry season. This suggests that baseflow is not prominent and this is consistent with Figure 20 to Figure 23. During the field investigation, undertaken towards the end of the dry season, only a small number of watercourses had evidence of groundwater infiltration. These watercourses include Condamine River, Bloodwood Creek, Dogwood Creek, Wallan Creek, Woleebee Creek, Wandoan Creek and Kogon Creek,

Available literature suggested that watercourses within the Project area are predominately surface water fed (Wilson & Adams, 2004 and Australian Wetlands Database). A surface-groundwater connectivity assessment of Condamine-Balonne undertaken by the CSIRO (2008) indicated that the Condamine River is largely “losing” to the groundwater system rather than “gaining” from the groundwater system. A Scoping Study states that “some discharge of groundwater to the local streams within the Upper Condamine is suspected, especially when groundwater levels are high, but no detailed investigations have been undertaken” (REM, 2007). A losing stream is a stream or river that loses water as it flows downstream. The water infiltrates into the ground recharging the local groundwater, because the water table is below the bottom of the stream channel. This is the opposite of a more normal gaining stream which increases in water volume farther down stream as it gains water from the local aquifer.

As the parameters used in this method were chosen based on investigations during the field visit and from the literature review (as discussed above), it should be noted that the resulting surface and baseflow from this method should not be regarded as the true amounts of surface and baseflow from the catchments. The results are merely an indication of the potential ratio of baseflow to surface flow runoff within the catchments.

Figure 20 to Figure 23 indicates the estimated baseflow and surface flow contribution to the Condamine River at various locations. The figures show that the Condamine River regularly dries up and that baseflow only occurs during periods of high rainfall. On average, baseflow represents approximately 17% of the total flow within the Condamine River while surface flow represents approximately 83%.

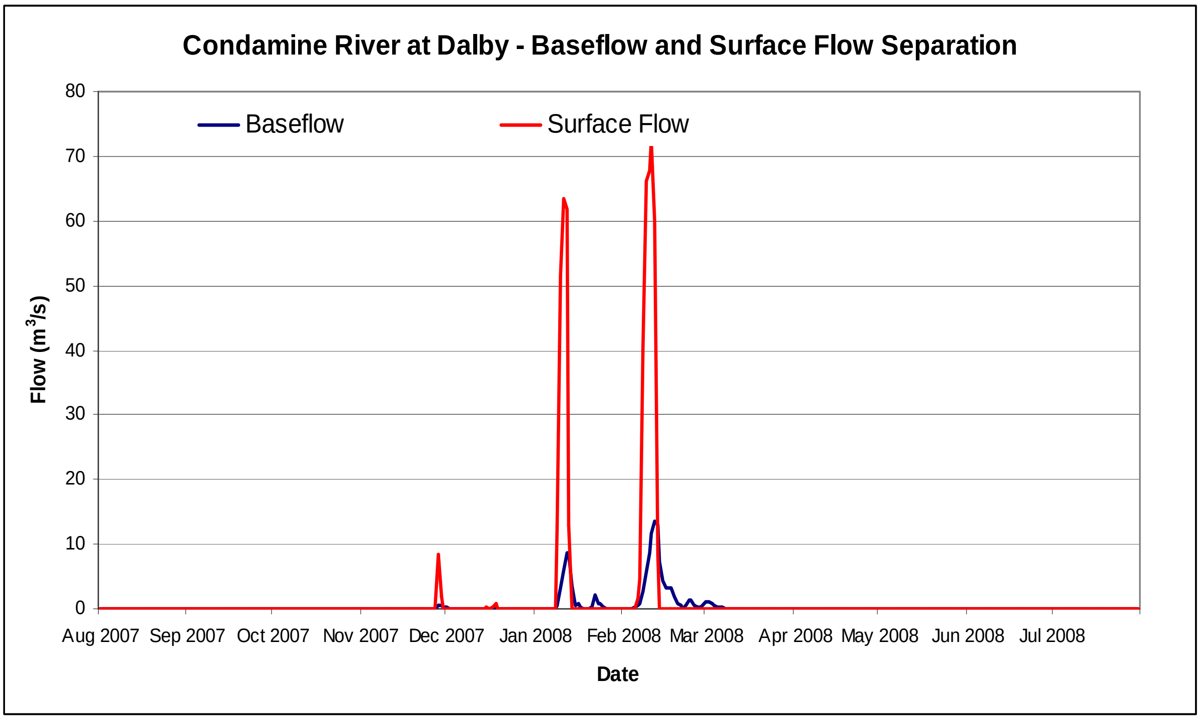



*Figure 20: Baseflow and surface flow separation for the Condamine River at Dalby*

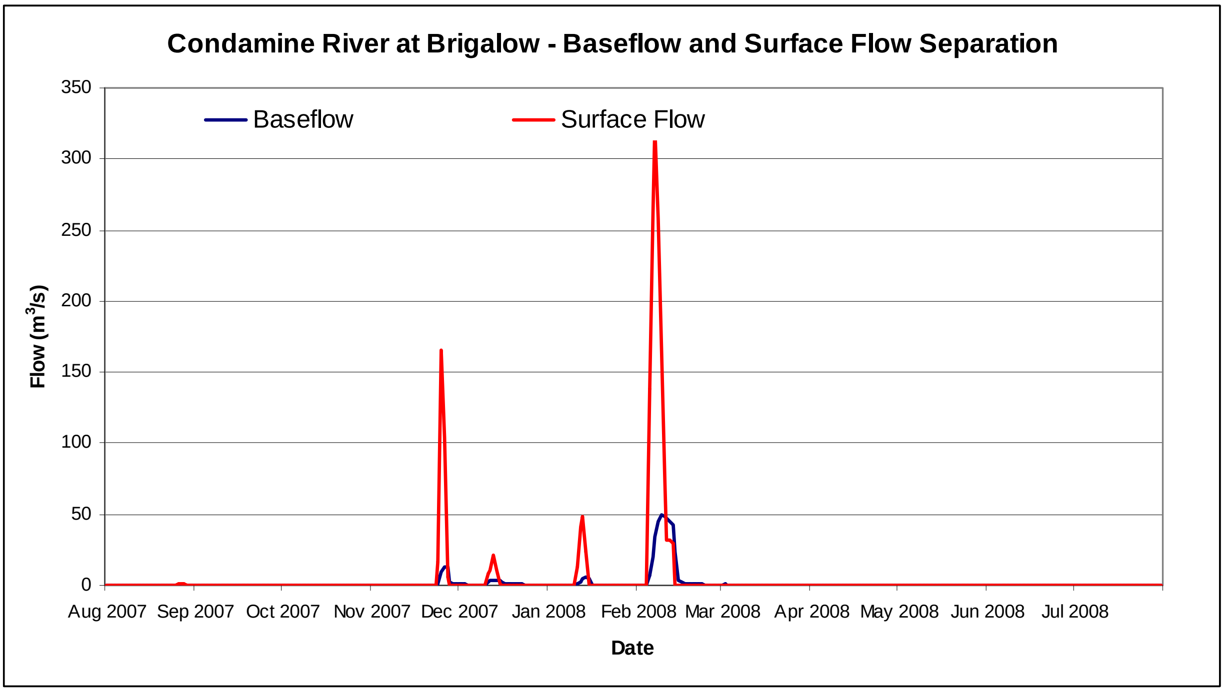



*Figure 21: Baseflow and surface flow separation for the Condamine River at Dalby*

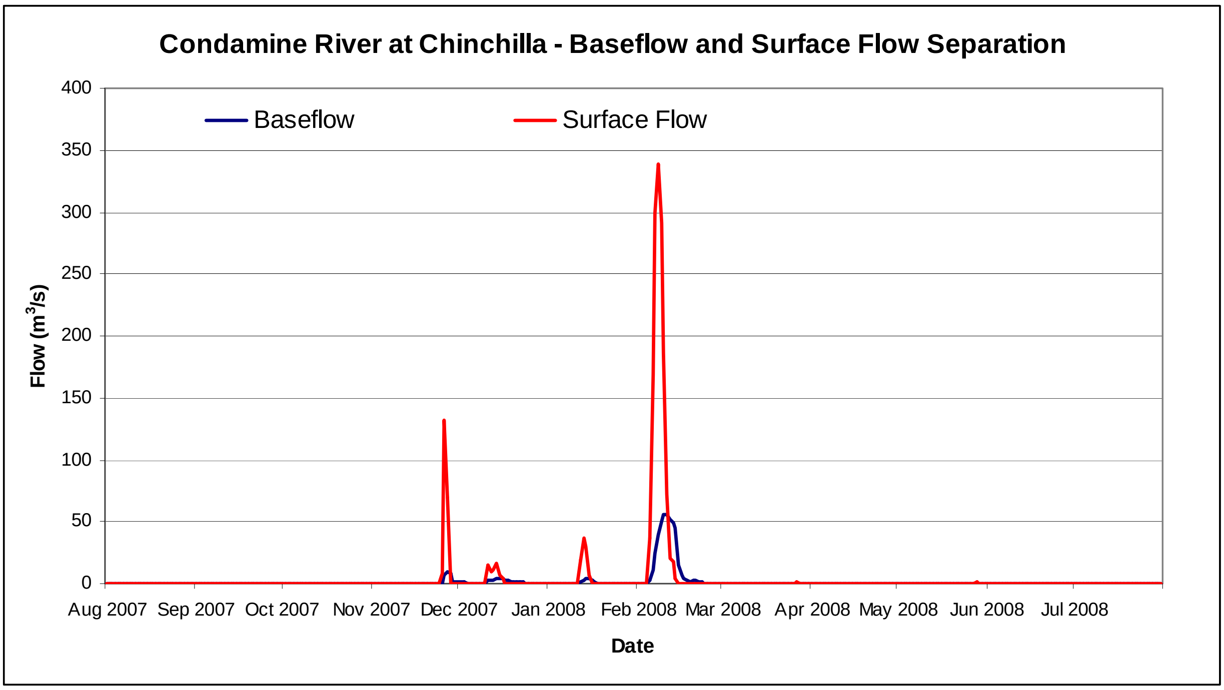



*Figure 22: Baseflow and surface flow separation for the Condamine River at Chinchilla*

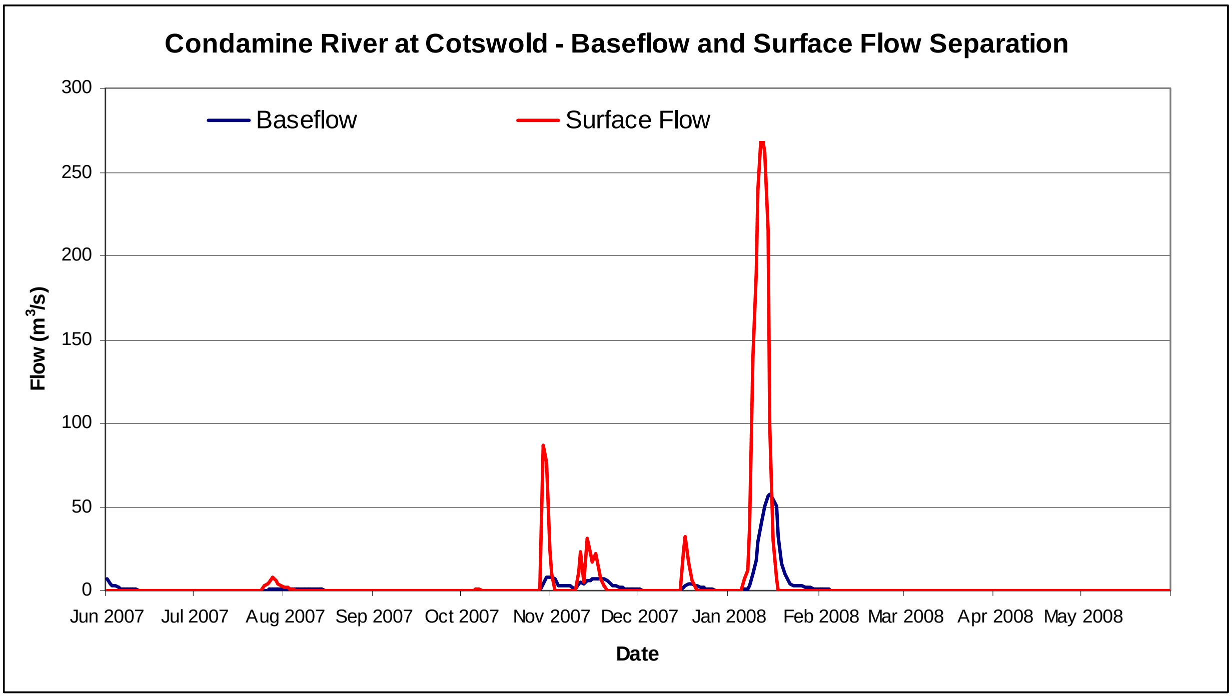



*Figure 23: Baseflow and surface flow separation for the Condamine River at Cotswold*

## 5.5 Water Management Objectives

Potential impacts of the Project on surface water include: increased flooding potential; decreased water quality due to increased sediment runoff; increased nutrient runoff; and a potential increase in salinity from overtopping or seepage of the evaporation ponds. The water management objectives aim to prevent or minimise potential impacts. The objectives include:

- Managing CSG associated water to ensure compliance to legislative requirements
- Managing associated water to ensure no releases occur to surface water regimes
- Minimising the influence of the Project on flood volumes specifically for, but not necessarily confined to, the Condomine and Balonne catchment
- Controlling runoff from disturbed areas to reduce sediment loads specifically in floodplain areas
- Managing sewage treatment plant effluent to mitigate nutrient loads in the catchment
- Intercepting, and where necessary diverting, surface water ensuring that it is kept separated as far as possible from Project activities
- Monitoring surface water to ensure that remediation; management measures; and structures; are adequate for the purpose for which they were designed and built.
- Monitoring will be used as an early warning system for impacts
- Utilising the CSG associated water brought to surface, as far as possible, for beneficial reuse by the company and by other water users.

# 6.0 WATER MONITORING PROGRAM

QGC will need to implement a comprehensive surface water monitoring program with the objective to provide data to understand and manage the potential impacts of the Project on local and regional surface water resources. Monitoring would cover associated water distribution networks, management structures, storage and disposal structures. The monitoring program should ensure that compliance with all legislative requirements and QGC risk management objectives can be measured.

The program is derived from a risk based approach, and is a response to the current expected likelihood and consequence of environmental impacts. Water monitoring is a work in progress, and requires reviewing annually. Reviewing the plan regularly will ensure it is current, complies with any updated EAs or any additional legislative requirements and is adjusted to suit the monitoring results achieved.

The monitoring results will be used:

- to guide ongoing operations and closure design.
- as an early warning system to identify potential impacts.
- for improving CSG water management by utilising the data produced from the monitoring program.

## 6.1 Water legislation drivers for monitoring

The review of the legislation and EAs applicable to QGC operations indicates guidelines for project owners to develop and manage their own monitoring programs. The guidelines do not (in most cases) provide clear and unambiguous direction as to the location, periodicity and parameters for monitoring.

### 6.1.1 The National Water Initiative

The National Water Commission (NWC) has released the National Water Initiative (NWI) and this has a series of requirements which includes the implementation of water accounting. As the NWI water accounting framework is rolled out to the various industry sectors, QGC will need to implement a rigorous water abstraction and water discharge monitoring program. QGC will be required to report to the NWC and to the Bureau of Meteorology, who have been legislated to manage the water resources information.

### 6.1.2 Water Resource (Condamine and Balonne) Plan 2004

The Water Resource (Condamine and Balonne) Plan 2004 defines the availability of water in the plan area and regulates the taking of water from all surface water bodies (rivers, lakes, runoffs). The Plan identifies surface water monitoring requirements relative to the quantity, the quality of the water and its associated natural ecosystems.

Monitoring requirements include (S 54):

- Water monitoring for:
  - Volume, frequency, duration and season of streamflows
  - Taking water
  - Water quality.
- Natural ecosystems monitoring for the condition of riverine habitats including:
  - Waterholes and lake ecosystems

- Stream bed habitats
- Upper and in channel riparian zones
- Floodplains
- Wetlands.

Water infrastructure operators must develop and undertake monitoring programs in the water supply scheme in which they manage the water (S 55).

This includes monitoring for:

- Water quantity (flow of water at gauging stations, volumes of water and the times when the water supply is taken, inflows of water to ponds or weirs, level of the water). Monitoring must also measure the quantity of water released from a pond or weir for consumption, environment, operation of fishways, and any purpose stated by the chief executive
- Water quality (temperature, biological, chemical and physical measurements)
- Operation of outlet works for a pond including multi level off takes.

The monitoring information (S 55) must be given to the Chief Executive as a report (S 56). The report should be annual and should be submitted no longer than 3 months after the beginning of the following year.

### 6.1.3 Environment Protection Act 1994

Conditions (S 98) may be imposed on an environmental authority (petroleum activities) (EA) and this may include carrying out and reporting on a stated monitoring program. There are standard environmental conditions for associated water. This includes the requirement not to release associated water to land or waters other than to an evaporation pond that is constructed and managed according to the conditions. This requirement can be addressed by developing and implementing a water quality, monitoring program for testing and analysing the quality of the associated water. This would allow associated water that is not a hazardous waste to be used for purposes such as livestock watering, agricultural purposes, dust suppression and release to land or surface waters.

If water is to be used for irrigation, a land and water management plan (LWMP) would be required under the Water Act which may have a monitoring component attached.

Dams and evaporation ponds are also covered by conditions by which they must be designed, constructed, operated, maintained and decommissioned according to set objectives.

The holder of the EA (Condition 21) must develop and implement a monitoring program that will demonstrate compliance with the environmental conditions. The monitoring and inspections must be documented. The monitoring program should focus on areas that have potential to cause environmental harm.

### 6.1.4 Environmental Protection (Water) Policy 1997

This regulation has a monitoring component (S 26) relating to monitoring the release of waste water on land or into water. The administering authority would decide on the level of monitoring dependant on the activity, the risk of harm to environmental values, and the frequency needed.

Impact monitoring may also be required (S 27) if an administering authority is making a decision about an activity involving a release or potential release of waste water.

The direct release of water to surface water and to groundwater is regulated under Sections 18 to 20. The release of water to surface water is only permitted after an assessment of the water quality and the impact of mixing the released water with the existing water quality. The Environmental Protection Agency (EPA) may control the releases. The release of water to groundwater is only permitted after an assessment of the impact on the environment and will only be allowed under certain aquifer conditions.

Section 21, which regulates the accidental release of water to the groundwater, requires that infiltration of release water to soil and groundwater is minimised or prevented and any release or potential released monitored against site baseline conditions.

### 6.1.5 EA No 150 386. (Section 124 Environmental Protection Act 1994)

The various EAs outline criteria for dams and evaporation ponds. A list of analytes and criteria are provided in each EA, which outlines the assessment process for the determination if content of dam is hazardous waste. If contents can not comply with the limits in the table, the water within the dam is considered hazardous. All of the analytes listed in Table 1 must be included in the water quality sampling analytical suite.

Monitoring requirements included in the EA are:

- All piezometer installation, plant maintenance and monitoring must be completed by qualified person of appropriate qualifications and experience in the fields of hydrology and ground water monitoring.
- All water sampling must be performed in accordance with the current edition of the Queensland EPA Water Quality Sampling Manual. Sampling methodology records (including anomalies) must be kept.
- Water samples must be analysed by a National Association of Testing Authorities (NATA) accredited laboratory.
- An annual report (for the entire pond operation period) should summarise all monitoring, analysis and interpretations of results. A similar report is to be submitted when a change of greater than 10% (not related to climatic variability) in water level and/or groundwater quality is detected; and/or when requested by the administering authority.
- Their design must ensure that there will be no environmental harm caused to existing groundwater aquifers, contamination of surface waters or significant impact on vegetation. A proposed groundwater monitoring program must be submitted with a risk assessment for proposed evaporation ponds. Existing evaporation ponds must have a monitoring plan already in place. The following must be recorded:
  - quality of water contained in the pond (pH, EC dissolved Na, Mg, K, Ca, $SO_4$, $HCO_3$ and Cl);
  - environmental impact risk analysis, including procedures and structures that are in place to minimise or prevent ground water and land contamination;
  - groundwater and soil monitoring methodology in place. including field and laboratory procedures;
  - signs of water seepage or leakage should be investigated and status of each pond catalogued on the pond register should be recorded and advised to the administrative authority as required under the conditions of the EA;
  - maintenance procedural methodology
  - indicators of land/ground water salinisation must be investigated for each existing evaporation pond and the status for each pond should be recorded and kept on file until requested by the administering authority.

### 6.1.6 PEN 100068707 (Previously EA No 1502 272) (Section 124 Environmental Protection Act 1994)

The monitoring requirements included in the EA are:

- All water sampling must be performed in accordance with the current edition of the Queensland EPA Water Quality Sampling Manual. Soil Sampling must be in accordance with the EPAs Guidelines for the Assessment of Contaminated Land in Queensland.
- Water samples must be analysed by a National Association of Testing Authorities (NATA) accredited laboratory.

### 6.1.7 EA No 150 361. (Section 124 Environmental Protection Act 1994)

The EA applies to ATP47P. This EA covers petroleum activities, but specifically addresses waste disposal within the evaporation dam.

The monitoring requirements included in the EA are:

- Associated water should be monitored and compared to the accepted ANZECC 2000 Water Quality Guidelines or subsequent versions thereof to determine appropriate disposal of alternative uses (i.e., stock and domestic).

## 6.2 Monitoring requirements

The Water Monitoring Plan covers surface water quantity and quality monitoring, water course characteristic assessments and overland flow assessments. In addition to regulatory requirements, a series of monitoring sites are to be located upstream and downstream of the tenements in the major water courses. This is to demonstrate that the project is not having an impact on water quantity and quality in the surrounding water courses.

At the least, monitoring sites should be located directly upstream of the most upstream tenement and directly downstream of the most downstream tenement in each of the major catchment areas being the Condamine River, Moonie River, Wandoan Creek, Horse Creek and Woleebee Creek catchments.

Where major infrastructure is proposed, particularly evaporation ponds, water monitoring sites should be located downstream of the infrastructure and also upstream of the infrastructure if changes in the downstream water quality are noted.

Visual assessment should be undertaken throughout the project area to assess any impacts from overland flow such as gullying, impacts to sediment and erosion control structures and exposure of pipes.

The exact location of the proposed monitoring sites will be decided once the project infrastructure layout plan has been finalised.

Monitoring of the surface water quantity, quality, water course characteristics and overland flow should be undertaken throughout all stages of the project in order to obtain the baseline conditions, as well as assessing the impact of the project on the surface water characteristics. The monitoring should be undertaken on a quarterly, annual and event basis.

### 6.2.1 Surface water quantity monitoring

Water level and flow or velocity measurements should be taken within water courses upstream and downstream of the project site. Water level and flow or velocity measurements may be taken manually on an event basis using instrumentation such as a current meter and gauging staff. Due to the potential for high water levels and velocity during or after flood events, manual gauging may not be appropriate. It is recommended that permanent monitoring equipment is installed.

It is recommended that a permanent flow gauging system connected to a datalogger that is easily accessible, should be used for recording water level and velocity measurements at the project area.

At least two sites within the Condamine River should be monitored and should be located directly upstream of the most upstream tenement and directly downstream of the most downstream tenement,

Baseline data should be characterised by the collection of water quantity readings prior to extensive development being undertaken within the project area. Additional water quantity readings should then be taken throughout the life of the project and compared to baseline data to assess the potential impact of the project on surface water quantity.

### 6.2.2 Surface water quality monitoring

The surface water quality monitoring includes different suites of sampling which are defined as:

- A field suite covering electrical conductivity, pH, redox potential (Eh), temperature, dissolved oxygen and flow to be taken when samples of laboratory analysis are collected.
- A baseline suite including EC, TDS, TSS, pH, total Alkalinity, major cations and anions, Nitrates, Ammonia, Boron, Selenium, Iron, Zinc, Manganese and Aluminium.
- CSG water indicators suite including boron, vanadium, iron, selenium and zinc, fluoride, PAH, TPH, BTEX and cyanide.

The baseline suite and CSG water indicators suite were chosen as the most common trace metals associated with CSG water include manganese, iron, barium, arsenic, selenium, boron, copper, cadmium and zinc as well as nutrients as phosphate and nitrate and ammonia. Coal-derived organic compounds (Polycyclic Aromatic Hydrocarbons (PAHs), phenols, heterocyclic compounds and total petroleum hydrocarbons (TPH)) are also commonly present in low concentrations in CSG water.

The field suite and baseline suite should be monitored on a quarterly basis and on an event basis (whenever 50mm of rain or more is recorded on site). The CSG water should be monitored on a quarterly basis for characterisation of the baseline water quality within the watercourses and then monitored during the project life on a bi-annual basis or when failure of a water storage structure occurs.

The water quality monitoring may be collected manually in accordance with approved sampling procedures. In order to ensure that water quality samples are collected on a quarterly and event basis, it is recommended that instrumentation be installed that records the field suite and baseline suite parameters. Instrumentation that incorporates a datalogger and telemetry would be suitable for the project area as the datalogger may be located in an accessible location above the flood level. This type of system also records all of the field and baseline suites, apart from Nitrate, including total metals.

### 6.2.3 Watercourse characteristics monitoring

A river geomorphology and water course characteristic assessment should be undertaken quarterly and/or after a major flood event has occurred during the initial phases of the project to characterise the baseline conditions. The geomorphology and water course characteristic assessment should then be undertaken on a bi-annual or event basis for the duration of the project. The characteristics to be recorded during these assessments include bank stability, bed and bar stability, channel diversity and habitat types and riparian and aquatic vegetation. These characteristics are to be recorded to assess the impact of the development on the water courses within the project area.

### 6.2.4 Overland flow monitoring

Visual inspection of the areas of disturbance should be performed on an annual basis and after significant rainfall events to assess gullying, damage to erosion control structures; and to assess potential exposure of pipelines supports. Where visual inspection indicates a potential impact; physical testing soil stability may be required and remediation of the areas will be required.

# 7.0 ASSOCIATED WATER MANAGEMENT PROGRAM

## 7.1 Introduction

The associated water management program provides various management options. The risk of each option to impact surface water resources, existing water users, and water related environmental values are considered in this program. CSG associated water extraction may impact the environment, particularly with respect to:

- aquifer drawdown
- stream baseflow
- disposal of the associated water at surface
- surface water and aquifer contamination.

The key factors to be considered in the development of the water management options include the associated water volume, associated water quality, legislative and policy requirements, the water balance and monitoring. These factors are briefly discussed in the following sections.

### 7.1.1 Associated water volume

The CSG extraction process will bring an estimated 150 to 200ML/d of associated water to the surface. To effectively manage the large volumes of associated water, it is most likely that a combination of management approaches will be required. The approach chosen will depend on how effectively it meets the regulations, the technical capability, and the costs of implementation and operation.

The volumes of associated water produced will vary over time and they will, after an initial peak volume decrease over time. This is shown in Figure 24 and the reader is directed to the Groundwater report by Golder (2009) for more details on associated water production. The three production areas, the Northwest development area (NWDA), the Central development area (CDA) and the SE development (SEDA) area are indicated in Figure 2.

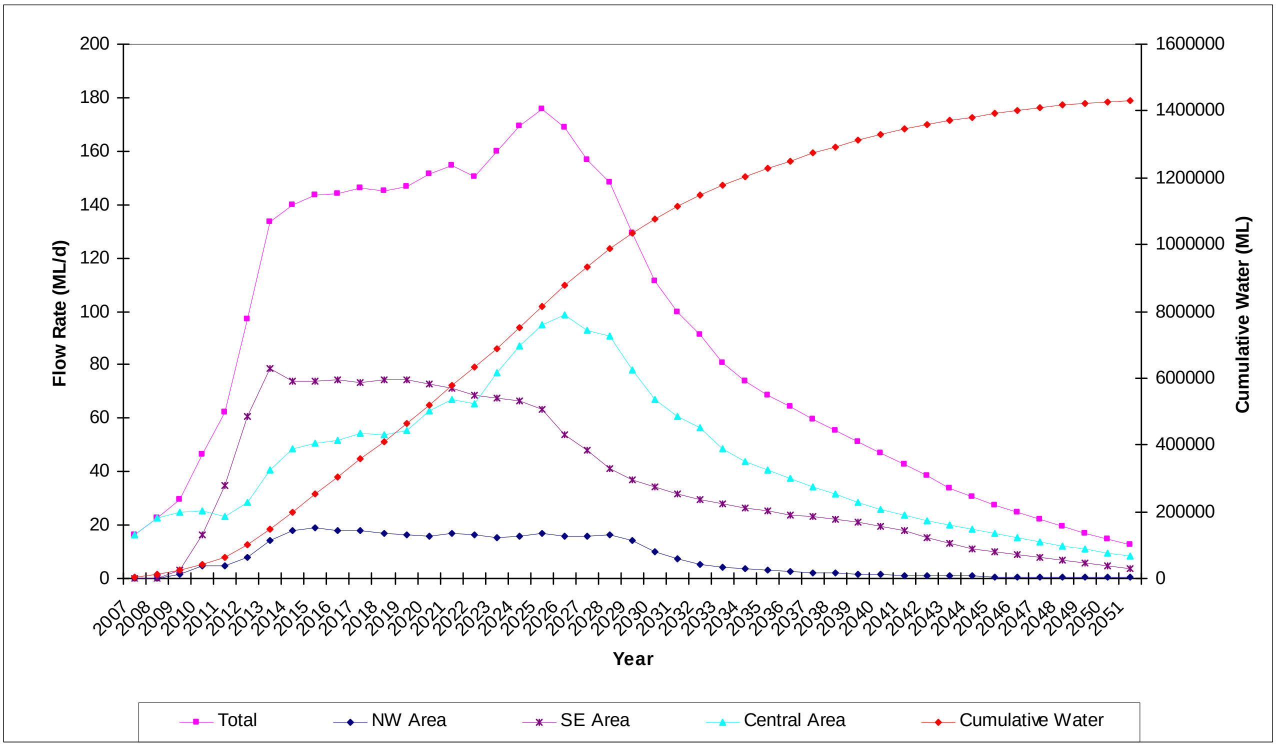



*Figure 24: Graph of associated water production.*

It is possible that entitlements for CSG associated water extraction could be partially offset through reuse of the associated water by current entitlement holders (non-CSG related groundwater entitlements for the WCM account for approximately 11,000 ML/year) assuming that a suitable quality and reliable quantity of water can be supplied to the end user. However, if the current full entitlement in all the of groundwater management units was replaced by CSG associated water; estimated predictions suggest that there will still be a substantial surplus of associated water, relative to local demand.

### 7.1.2 Associated water quality

The quality of the associated water reflects the original depositional environment, depth of burial and coal type. Water quality within the Walloon Coal Measures (WCM) varies across the study area. The quality of groundwater extracted from the WCM is summarised as follows:

- Groundwater from WCM production wells varies from slightly brackish (51% of samples had TDS ranging from 1,000 - 3,000 mg/L) to brackish (46% of samples had TDS ranging from 3,000 – 10,000 mg/L). Only 3% of groundwater samples had TDS concentrations below 1,000 mg/L and therefore, could be classified as fresh water.
- Brackish sodium-chloride type water was observed in the north western portion of the study area, while fresh to slightly brackish, sodium-bicarbonate type water was reported in the south-eastern portion of the production well field.
- With the exception of fluoride, analyses of other trace metals were not available in the NRW bore database. Common trace metals associated with CSG water include manganese, iron, barium, arsenic, selenium, boron, copper, cadmium and zinc as well as nutrients such as phosphate, nitrate and ammonia. Coal-derived organic compounds such as Polycyclic Aromatic Hydrocarbons (PAHs), phenols, and heterocyclic compounds are also commonly present in low concentrations in CSG water.

A detailed summary and discussion of the associated water quality data in the study area is presented in APPENDIX D.

The quality of the associated water will limit opportunities for direct reuse and re-injection. To increase these opportunities water treatment will be required.

### 7.1.3 Legislative and policy requirements

The existing common practice for the management of associated water is disposal to evaporation ponds. The recently released Queensland Government CSG water policy (refer to section 2.2) requires more innovative associated water management approaches that reduce potential environmental impacts. It suggests considering other disposal options such as re-injection, increasing water recycling and other beneficial uses of the water.

### 7.1.4 Water balance

A life of operation water balance is fundamental for assessing and selecting water management options and thus managing water.  The use of a probabilistic water balance model can form the basis of the management control system, which is essential where multiple water uses are likely. The quantity of associated water produced varies over time. It is possible that associated water quality may do the same. Probabilistic water balance models provide the means to optimise the water uses and water treatment requirements needed to achieve the qualities of water for particular use.

The balance can simplify the complex water abstraction system that will be employed for CSG abstraction. Balances can be developed per bore, per tenement, per CSG abstraction area (NW, SE and Central development areas) and for the total CSG field. They provide the means to manage water on a day to day basis or for life of operation.

### 7.1.5 Monitoring

Monitoring has been outlined in the preceding section (section 6). As well as informing water management structure designs, satisfying legislative requirements, providing data for the water account, quantifiying potential or actual impacts etc., and water monitoring data is essential for the water balance and for surface water modelling.

### 7.1.6 Other factors

Other considerations for selecting a water management option are:

- site location
- technical feasibility
- cost – capital and operational
- available infrastructure
- new infrastructure and equipment.

## 7.2 Associated water management options

This section describes a series of water management options. In each section, the option is outlined and the risks identified.

BG QGC are planning for climate change with their design parameters and sizing selection for infrastructure, including storm water structures and evaporation ponds. Any option will be required to consider designing for a 30% increase in rainfall intensity during peak tropical cyclone precipitation events and a 10% increase in runoff. Infrastructure and ponds will need to be located above the maximum expected flood levels. Occasional inundation of roads and access tracks will be accepted.

### 7.2.1 Surface water discharge to a watercourse

Surface discharge involves the release of associated CSG water to natural surface watercourses or surface soil via overland flow. This section considers direct discharge to surface water courses. Overland flow is considered under irrigation (section 7.2.2 below). It can be an efficient and cost-effective water disposal solution.

Direct discharge of CSG water involves delivery to a stream by pipeline or dry drainage where it mixes with the existing stream flow. The method requires monitoring and characterising of the discharged water and the existing stream water; and careful management of discharge quality.

The amount of CSG water that can be managed by surface discharge depends on various factors, such as the assimilative capacity of the stream, quality of the CSG produced water, seasonal requirements of the aquatic ecosystems and downstream user requirements.

The Condamine Balonne river catchment drains into the Murray Darling River system. This river system is under pressure with respect to salt loading due to natural salinity, irrigation and dry land salinity processes (MDBC, 1999). Given the brackish to saline nature of the associated water, direct discharge of untreated CSG water to surface water systems is unlikely to be a viable option. Direct discharge could be considered following treatment of the associated water to a suitable standard. However, other more beneficial uses for treated water (such as municipal supply, stock watering and irrigation) should be considered in preference to stream discharge.

Direct discharge of associated water to surface drainage systems is often used in areas where the quality and quantity of the associated water is compatible with the receiving environment. Surface discharge of lower quality water can result in impacts to the health of the receiving aquatic ecosystem. Excessive volumes of discharge water can alter the morphology of the receiving environment, and even create new habitats that are unsustainable in the long term. The habitats become dependent on continued additional water contributions. Analysis of CSG associated water in the study area indicates that, without treatment, the water quality is unlikely to be compatible with existing surface water. As a result, this is unlikely to be a suitable management option for this area.

### 7.2.2 Irrigation

This option involves discharge by irrigation techniques such as central pivots, drip or flood irrigation.

The most significant impediment of associated water for agricultural purposes is its salt content. The majority of crops cannot tolerate elevated TDS content in irrigation water. Excess salinity in soil water results in plant stress due to a decrease in plant available water. Since associated water from WCM exhibits relatively high sodium concentrations compared to those of calcium and magnesium, the Sodium Adsorption Ratio (SAR) tends to be above the irrigation criteria for most crops. CSG water also has high bicarbonate concentrations. This contributes to SAR due to precipitation of calcium carbonates in the associated water.

Discharge of sodic water to clayey soils will increase the probability of clay dispersion. Clay dispersion can cause reduced soil permeability and infiltration, surface crusting and increased runoff. If over irrigation occurs, the possible impacts are runoff to surface watercourses and infiltration into the groundwater systems.

Direct use of CSG water for irrigation is limited. The associated water would require treatment to reduce salinity and sodium concentrations. Soil conditioning with gypsum may be used to counteract the effect of elevated concentrations of sodium, but at an added cost and inconvenience to the user.

Prior to irrigation, a number of investigations would be required. Studies to determine the suitability of soil types to be irrigated; the compatibility of the receiving waters to the irrigation water; and trials of various crops would need to be undertaken.

### 7.2.3 Stock Watering

Livestock can tolerate a range of TDS concentrations in their drinking water (ANZECC, 2000). Animals can often tolerate elevated levels of TDS if they are gradually acclimatised. Slightly brackish water from CSG production wells is suitable for watering of beef cattle, horses, sheep and pigs. With the exception of poultry, most livestock can adapt to brackish water of up to 6,000 mg/L of TDS without a loss of production. Sheep can tolerate water salinity up to 10,000 mg/L. Considering the prevalence of the stock watering entitlements within the study area, stock watering is considered to be a potential viable reuse option for the associated water.

### 7.2.4 Surface impoundments and evaporation ponds

Evaporation ponds have been widely used as the preferred CSG associated water management approach in Queensland, as the evaporation potential in the region is significantly greater than rainfall in many parts of the state.

Impoundments, such as evaporation and recharge ponds, can be used for associated water management options including:

- disposal by evaporation and/or infiltration
- storage prior to another water management option including re-injection or irrigation
- beneficial use such as fish ponds, livestock watering dams or recreational dams.

Evaporation ponds receiving low quality associated water would require low permeability liner systems to prevent water infiltration to shallow groundwater systems.

It is unknown whether existing evaporation ponds will be permitted to continue operating under the new policy. It should be determined from the Queensland government whether evaporation will be allowed in the future as part of a combined management approach.

The risks from surface water impoundments are leakage or breach of storage basins, releasing the saline associated water to land or waterways. This risk has been specifically addressed in the proposed Queensland Management Policy for CSG associated water which will significantly limit the use of evaporation ponds as a CSG water management option. Discharge of CSG associated water to containment structures may potentially affect the water quality in the shallow aquifer, if seepage occurs.

Evaporation ponds must occupy significant land areas to efficiently manage the large volumes of associated water generated. They result in an accumulation of salt, and without remediation, precludes the land for future alternative land uses.

### 7.2.5 Industrial Applications

A range of potential industrial applications for CSG associated water are available. These may include:

- coal mining process water
- animal production
- cooling tower water
- enhance oil recovery
- aquaculture
- fire protection

For some applications (such as cooling tower water), pre-treatment of the associated water would be required to reduce the potential for scale formation and fouling from the dissolved solids. Additionally, for most industrial applications the reliability of the supply is as important as the water quality. To provide industrial users with confidence in the reliability of supply, a good understanding of the fluctuations in water extraction volumes over the CSG lifecycle would be required. Current ongoing studies should provide a better understanding of the likely water production volumes across the study area over the lifecycle of the CSG extraction program.

Regardless of specific applications, industrial water use within the study area accounts for a very limited proportion of the current licensed entitlements. Hence, industrial reuse options would account for a minor portion of the projected associated water budget.

### 7.2.6 Municipal Water Use

The reliability of supply and quality of water for rural communities in the Surat Basin has been declining over the past decade. To meet municipal demands, many communities have needed to identify additional sources of water. They have been required to increase their water treatment capability to use marginal quality groundwater supplies. The provision of associated water to these communities would provide a short to medium term solution to their municipal water requirements.

Associated water for municipal use may include use for potable and non-potable purposes. Use for potable purposes requires a higher level of treatment than for non-potable uses (such as irrigation and maintenance of community facilities). It is unlikely that existing community raw water treatment plants would be able to accept associated water. The major constraints on use of associated water for municipal purposes will be:

- water quality
- treatment
- transport costs.

According to Australian Drinking water guidelines (ANZECC, 2004), water with salinity of 500 mg/L TDS is generally suitable for drinking. Based on taste, elevated salinity with TDS in the range 500 – 1000 mg/L may be acceptable. Salinity above 1000 mg/L can cause excessive scaling, corrosion and unsatisfactory taste.

As with industrial water applications, the study area is generally characterised by small, decentralised population bases. The current groundwater entitlement for urban water supply is relatively small with a total supply capacity for the towns of Chinchilla, Dalby and Warra of 17.3 ML/d. Supplementing urban water supply with CSG associated water would only account for a minor portion of the projected water budget.

### 7.2.7 Underground injection (re-injection)

Underground injection is potentially an environmentally safe option. Underground injection into deeper aquifers is generally the primary management option for disposal of CSG associated water.

Injection of associated water can be grouped generally as:

- re-injection into a coal seam aquifer
- re-injection into a non-coal seam aquifer.

CSG water could not be re-injected into the producing environment because the production of CSG requires a reduction in the hydrostatic pressure. Re-injection, especially during active production of methane may increase hydrostatic pressure, leading to a decrease in gas production.

Alternatively, injection of CSG water into non-producing deeper or shallower coal aquifers may avoid a detrimental effect on gas production.

Application of underground injection includes both technical and regulatory considerations. The following technical aspects must be considered:

- Formation suitability – requires characterisation of reservoir hydraulic characteristics (porosity, permeability, storage capacity), depth, relative location to producing wells, significance of local fracturing and faulting, and presence of active and abandoned wells within the area.
- Isolation – the receiving formation must be vertically and laterally separated or otherwise confined from utilised groundwater resources, including CSG production formations.
- Reservoir pressure – static pressure within the receiving formation may limit the rate at which fluids can be injected and/or may limit the total volume of injected fluids.
- Water quality – the chemical compatibility of formation water and injected water will also play a part in the feasibility assessment of the injection plan. The quality of the water re-injected should be equal of better than that in the receiving aquifer).

### 7.2.8 Aggregation and disposal

The Queensland CSG Water Management Policy indicates that aggregation and disposal of surplus CSG associated water may be considered for any water that cannot be directly injected into aquifers or that has no feasible beneficial use. However, guidance regarding this management option is still under development, and it is uncertain what conditions will be placed on this option. It is anticipated that there may be a significant financial or regulatory burden associated with this option.

It is unknown whether existing evaporation ponds will be permitted to continue operating under the new policy, but this should be established to determine whether evaporation is available as part of a combined management approach.

## 7.3 Water Treatment Technologies

CSG associated water is generally not suitable for direct beneficial reuse or re-injection without treatment. Various treatment technologies for reducing salinity, sodicity and trace element concentrations in CSG produced water are available. The type and extent of treatment are determined by a variety of factors such as:

- water use or disposal (e.g. freshwater surface water body, underground injection, beneficial use)
- the applicable regulatory requirements and allowable options

- the cost to transport and treat the water
- site-specific factors (e.g., climate, availability of infrastructure)
- the potential for long-term liability
- a company's familiarity with or preference for specific options.

A more detailed evaluation of treatment options and associated costs for CSG associated water is currently being preformed by Golder Associates and will provide a basis for selecting:

- treatment options
- beneficial uses.

Available water treatment technologies are generally limited to treating specific constituents in water (e.g., dissolved solids, organics, etc.). Therefore treatment of CSG associated water may require more than salinity removal. Depending on the potential use and the desired water quality, treatment processes are often coupled to achieve required water use objectives. Treatment technologies should only be considered as a suitable treatment options after thorough research, cost effectiveness analyses, water quality assessment, and identification of beneficial use goals.

The relative effectiveness for each treatment will depend on the water quality of the associated water and the required quality for beneficial use.

The most likely constituents that will require treatment in the CSG associated water are:

- suspended solids
- dissolved solids
- organic constituents.

A variety of treatment technologies are available to deal with these constituents. A summary of available desalination treatment technologies is presented in Table 22. Desalination is a process that removes dissolved salts from saline and hypersaline water. The techniques for desalination may be classified into three categories according to the principle process used:

- process based on a physical change in state of the water – i.e. distillation or freezing
- process using membranes – i.e. reverse osmosis and electrodialysis
- process acting on chemical bonds – i.e. ion exchange.

Reverse osmosis (RO) has proved to be a robust process for treatment of CSG associated water. The RO desalination process requires several steps to condition the water before and after treatment. This treatment depends on the treated water application. In addition, the disposal of the brine generated from the RO process is an environmental and economical issue. Typical pre and post treatment processes for different final water quality targets are presented in Table 22.

**Table 22: Overview of desalination treatment technologies**

| Process | Description | Application | Limitations |
|---|---|---|---|
| Reverse Osmosis | A membrane process capable of separating a chemical (solute) from an aqueous solution by forcing the water through a semipermeable membrane by applying a pressure greater than the osmotic pressure of the solute. | Good track record with sea-water and brackish water.<br>Small footprint.<br>Handles a wide range of TDS concentrations<br>Organics and salts are removed | Membrane failing due to oil films, precipitations, abrasion and poor water recovery<br>Pre-treatment has to be considered depending on water composition<br>Relatively expensive with significant operating and maintenance costs<br>A concentrated waste stream requires disposal |
| Electrodialysis | An electrically-driven membrane separation process that is capable of separating, concentrating, and purifying selected ions from aqueous solutions. Electrodialysis differs from a normal ion exchange process by utilizing both cation and anion selective membranes to segregate charged ions from a water solution. | Applied in number of industries including food, chemicals, & pharmaceuticals.<br>Not commercially used in oil and gas industry<br>Requires a lower level of pre-treatment than RO and lower associated capital costs | Energy costs excessive with influent salt above 15,000 mg/l TDS.<br>Removal of charged ions, does not remove organic contaminants<br>Relatively expensive with significant operating and maintenance costs |
| Ion Exchange | The process of ion exchange historically has been used to soften water for residential purposes by replacing hardness calcium and magnesium with sodium and chloride ions. Ion exchange is also commonly used to deionize water by replacing ions, such as conductive salts with $H^+$ and $OH^-$ | Suitable to remove charged species including heavy metals, radium, nitrates, arsenic, uranium<br>Process is non-polluting and requires low energy input. | Unable to effectively remove organics<br>Preferential removal of divalent ions therefore sodicity adjustment required<br>Relatively expensive with significant operating and maintenance costs |
| Distillation | Distillation involves boiling water into steam, which is then passed through a cooling chamber and subsequently condensed into a purified form. | The distillation process is capable of removing 99.5% of the impurities concentrated in raw water.<br>Used to remove nitrates, bacteria, sodium, hardness, dissolved solids, and heavy metals | For produced waters of low to medium TDS. It is energy intensive compared to ED or RO. |
| Capacitive Desalination (CDI)<br>or Deionization | Salty water flows between paired sheets of aerogel (porous material with high surface area).<br>Electrodes embedded in the aerogel apply a small direct current; positively charged ions attach to the sheet with the negative electrodes, and negatively charged ions cling to the sheet with the positive electrodes | Provides the removal of charged ions<br>No use of cleaning chemicals therefore reduced waste stream | New technology with no commercial record<br>Removal of charged ions only with maximum TDS of 8,000 mg/L |

(modified from Hayes and Arthur, 2004 and PB, 2005)

# 8.0 MITIGATION MEASURES AND RECOMMENDATIONS

This section includes a series of recommendations that can be considered to prevent, minimise and mitigate the potential impacts that could result from the Project concerning:

- The management of CSG associated water after it has been brought to surface
- The affects of other Project activities, such as the construction of infrastructure, on the surface water environment.

## 8.1 Regulatory framework

QGC is committed to meet all legislative requirements in terms of surface water management. There are two main issues that require further investigation and these are considered in the following sections.

### 8.1.1 The use of associated water within the petroleum lease

It is recommended that the best practical, most sustainable and environmentally friendly uses of associated water within the lease area are investigated.

To use associated water outside of the tenement a water licence is required by the Water Act, 2000. It is unlikely that all associated water can be used within the lease area. Therefore, identification of the licencing requirements is recommended. For example the volumes of associated water that may be used outside the tenement areas should also be estimated.

### 8.1.2 The Queensland Government policy on associated water

The Policy requires the phasing out of associated water evaporation ponds over time. It also requires the operator to consider beneficial uses of water, including the treatment of associated water for beneficial use, and the re-injection of associated water. It is recommended that studies into these aspects of associated water be commenced.

## 8.2 Water information management systems

To assist in short and long term water management and to demonstrate proactive stewardship of water resources, the development of a water information management system is recommended. The system would incorporate water monitoring, data collection, laboratory analysis, data base development, data interrogation, information generation and reporting. The purpose of the system is to provide the appropriate level of information to enable informed decisions on water management issues; definition of mitigation measures; the provision of an early warning system indicating potential environmental impacts; and the means to quantify any impacts resulting from Project activities. This system would form part of the larger environmental management system for the Project.

Two key components of a water information system are the water monitoring program and the water balance model discussed in the following sections.

### 8.2.1 Water monitoring program

The basic surface water monitoring program provided in this report should be implemented. A CSG water monitoring plan should be included in the Environmental Management Plan and is required for the Environmental Authority (EA). It is recommended that monitoring the water within the watercourses, upstream and downstream of the Project site is commenced on a monthly basis to define the baseline conditions. Monitoring downstream of proposed Project infrastructure sites, including associated water storage facilities, should commence as early as possible. If there is evidence of increasing pollutant discharge to the watercourses, due to the Project activities, water quality improvement devices may be required to be installed at the locations of concentrated flow discharging off the Project area.

The monitoring program should initially focus on completing the baseline program by sampling and site characterisation for a minimum period of one year. Monthly flow and quality monitoring is recommended for good baseline definition. This can move out to quarterly monitoring or seasonal thereafter.. Existing water monitoring structures can be used.

The water monitoring program will require ongoing development as legislative requirements change. Development of water accounting procedures should be considered to meet the future requirements of the NWI and the Bureau of Meteorology.

As infrastructure plans are finalised a water reticulation plan (water map or schematic representation of water flows in streams pipelines etc.) should be developed. This plan should be used to identify additional monitoring sites.

### 8.2.2 Water balance model

The development of a probabilistic water balance model is considered essential. It should cover the life of Project and post closure. A first order water balance based on assumed water structure layouts should be developed as a minimum and updated as the project progresses.

## 8.3 Hydrological model

Detailed surface hydrological modelling is recommended to confirm and quantify the floodlines. Climate change factors should be incorporated to estimate runoff variations. The contribution of baseflow to surface water streams should also be modelled.

Results of this work will assist in designing overland flow interception systems that divert clean water away from project infrastructure to avoid pollution and reduce flooding impacts.

## 8.4 Associated water uses

An investigation into potential beneficial uses of the associated water is currently being undertaken by QGC. Water use without treatment, with partial treatment combined with blending, and full treatment will need consideration. The potential uses of associated water should be discussed with other CSG producers in the region, other water users, and the government to identify potential synergies from combining facilities to treat and use the water.

### 8.4.1 Water treatment

To identify the water treatment technologies most suited to associated water quality improvement, an evaluation of the costs of different water treatment technologies is required. This should be combined with a cost-benefit analysis assessing the different water treatment options, the various water use options, and other management options such as re-injection of associated water into different aquifers.

A technical assessment of handling, possible use of and the disposal of water treatment brine should occur and a cost benefit analysis of the options should be undertaken.

### 8.4.2 Irrigation

The use of associated water for irrigation requires identification of the areas within tenements that have suitable soil types that can withstand irrigation and produce crops.

### 8.4.3 Re-injection

To use re-injection as a management option for associated water it is recommended that prospective re-injection locations (including specific hydro-stratigraphic zones) be identified. The re-injection locations should be close enough to the CSG operations so that water transport costs are not prohibitive. Target hydro-stratigraphic horizons should be identified that will not interfere with active CSG extraction zones.

It is recommended that detailed pilot studies for feasibility of re-injection in prospective zones, to determine achievable rates of re-injection are conducted.

### 8.4.4 Surface water aggregation and disposal

The Queensland Government has requested industry to be involved in developing a framework for surplus water aggregation and disposal (i.e. associated water that cannot otherwise be reused or reinjected). Discussions with the Queensland Government are required to progress this option.

### 8.4.5 Supply water to existing over-allocated water resources.

The volumes of associated water that will be produced and available for use will be greater than the existing demand for water. However, many surface and groundwater resources are already oversubscribed and water stressed. Investigations into the use of this water to reverse the degradation of water resources and natural ecosystems should be instigated.

## 8.5 Flood reduction and control

Overland flow and stream diversions should be designed to move surface water runoff around infrastructure. To reduce erosion and scouring the diversions should ensure the flow does not exceed 0.5m depth and velocity of 2.0m/s.

Flooding can impact the Project operation by inundating roads and tracks. Where feasible, locating these in elevated areas not prone to flooding may assist in keeping them operational or operational for longer periods of time.

Increased rainfall and storm intensity due to climate change factors will increase runoff. Recommendations to reduce impacts include:

- Ensuring the design of existing evaporation ponds are such that they accommodate greater than the standard design freeboard to reduce the likelihood of overtopping
- Placing infrastructure well above the expected floodlines where possible
- Designing bunding to accommodate greater frequency of intense storm events with special consideration of structures in low lying areas.

## 8.6 Impacts of release of associated water

The accidental release of CSG associated water from pipelines, bore facilities and storage facilities such as evaporation ponds, should be quantified from data collected by the surface water monitoring system. The design and location of associated water management structures should aim to reduce or eliminate the risk of discharge.

Evaporation ponds need to be engineered structures, lined to prevent seepage through the floor and constructed to prevent seepage through the walls. Regular auditing of the facilities is essential. Installation and monitoring of piezometers in the pond walls and in bores around the ponds are required to act as early warning systems for potential pollution incidents, for safety purposes and to quantify the concentration and load of any pollution that may have escaped.

A plan to move away from the use of evaporation ponds is needed to enable compliance with the Queensland Policy on CSG water management. It is recommended that investigations into the beneficial uses of the water presently stored in these ponds should be performed. Other uses of the existing ponds, such as water mixing facilities prior to water treatment should be considered. Any ponds that will be made redundant require rehabilitation plans.

## 8.7 Pollution reduction

Bunding around surface structures and storage containers are a standard environmental control measure required to prevent the escape of pollutants to water resources and provide a level of defence against potential flooding. All facilities should be checked to determine bunding requirements.

## 8.8 Sediment erosion and control

A Sediment and Erosion Control Plan should be developed for the Project site to minimise erosion and sedimentation on the floodplains, and within the watercourses.

Techniques for erosion and sediment control will include where applicable:

- sediment fences and bunding of disturbed areas
- installation of velocity retardation structures in drains to limit flow velocities downstream of disturbed areas
- slope and drain stabilisation using mulching, rip-rap or similar devices
- sediment dams
- early revegetation using defined maximum landform stability criteria
- the application of defined buffer zones and clearing limits
- regular clean out of sediment traps, ponds and drains until erosion stability has been achieved
- visual monitoring to identify active erosion rills and gullies and implementation of remediation measures

To reduce erosion and scouring, where watercourse diversions are installed, the diversions should be designed to ensure that the flow does not exceed 0.5 m deep and 2.0 m/s.

## 8.9 Site investigations

The site survey of surface water systems identified existing degradation of the surface water environments. A full assessment of baseline conditions is required. Regular monitoring and inspections should be commenced to document seasonal variations within the baseline. This is important as the baseline is the condition of surface water resources to which future monitoring will be compared to determine the effectiveness of water management measures and the level of additional impacts.

## 8.10 Standards, policies and procedures

To ensure consistent, acceptable and auditable management of water throughout the life of the Project the development of a water strategy and policy with associated goals and targets is recommended.

Standard procedures and codes of practice in surface water management will provide the guidelines to achieve the water strategic objectives and these should be developed.

To ensure understanding of the strategy and the requirements of standards, an internal water awareness program for corporate, operational and project personnel is recommended.

## 8.11 Audits

As the water management measures are installed in parallel with the phased gas production ramp up, regular water audits are suggested to judge the effectiveness of the monitoring systems and the management measures put in place. Such audits will identify gaps in systems and provide information for improvements and judge progress in water management against targets and controls.

## 8.12 Water management team

Associated water and infrastructure developments for the CSG gas field development pose risks to the environment and therefore business risks to QGC. Regulators and the public are increasingly focusing on water and its management. Therefore it is suggested that the organisational structure should have a well defined water management team with clearly defined roles and responsibilities, and that this is represented by an organogram. This will demonstrate to the regulator and other stakeholders the commitment by QGC to water custodianship.

## 9.0 CONCLUSIONS

There are two main factors that can pose risks to the surface water environment from the development of the Project. Firstly, the volume and the quality of the associated water that has to be handled, once brought to the surface. Secondly, the development of infrastructure can affect surface water flow and water quality.

These two factors pose business risks to QGC's CSG gas field development, and both require an appropriate level of management. Physical risks (including excess “polluted” water at surface and flooding potential), regulatory risks (changing regulatory framework and legislation such as the recent Queensland policy on associated water management) and risks to reputation (increasing demand for water in the area, managing potential contamination in the upper portions of the politically sensitive Murray – Darling Basin and other socio-economic factors), will require the application of significant financial resources towards surface water management to ensure licence to operate.

No fatal flaws, in terms of surface water resources, were identified that would prevent the development of the CSG gas field, based on the analysis of the available information. The potential impacts to surface water resources can be managed to ensure minimal or no impact provided that the suggested recommendations and mitigation measures are followed.

Existing and historical anthropogenic activities have adversely impacted the surface water environment and resources. Key conclusions identified with respect to the existing surface water environment include the following:

- Depletion of stream and river flows in the Condamine and Balonne systems to the extent that these are losing stream systems (normal river systems gain water downstream)
- Little or no base flow contributes to the river systems due, at least in part, to existing and historical over exploitation of the river alluvial aquifers
- Reduction in riparian zone diversity and size
- Increased erosion and sedimentation due to land clearing and agricultural activities have impacted stream flow and quality
- Aquatic habitats and vegetation have been affected and are of poor quality
- Suspended solid loads and concentrations of nitrogen and phosphorous in nearly all streams and rivers sampled are greater than ANZECC guideline values.

Potential beneficial uses of the associated water have been identified. These will require more detailed analysis. Treatment of the water may be required to make it fit for purpose. This aspect also requires further investigation.

Infrastructure development and location will affect surface flow and could also be affected by flooding. Placement of infrastructure will require careful planning to minimise impacts from flooding.

To demonstrate good practice and custodianship of the water a number of aspects of water management will need on going development and implementation as the Project progresses. These include a water information management system, a probabilistic water balance developed for the life of operation, a water monitoring system, installation of erosion and sedimentation control facilities, a comprehensive water strategy, and a management structure that includes a water management component with clearly defined roles and responsibilities.

It will be important that QGC can demonstrate the effectiveness of the management measures that are planned and implemented. A thorough baseline study of the existing surface water resources would provide the yardstick to which the effectiveness of the measures can be compared. However, such comparisons will need to be adjusted to compensate for cumulative affects on surface water resources from other ongoing and future developments.

## 10.0 REFERENCES

Australian and New Zealand Environment and Conservation Council (ANZECC), Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality Volume 1 The Guidelines*.

Australian Wetlands Database, www.environment.gov.au/cgi-bin/wetlands.

Boughton, W (2004) The Australian water balance model. Environmental modelling and Software 19 (2004) 943-956. Elsevier.

Bureau of Meteorology, www.bom.gov.au.

Catchment Modelling Toolkit, www.toolkit.net.au.

CCMA 2001, *Condamine Catchment Strategic Plan, June 2001,* Available at: www.condaminecatchment.com.au/pdf/StrategicPlan.pdf.

Chapman T.G. and A. Maxwell 1996, *Baseflow separation - comparison of numerical methods with tracer experiments*, Institute Engineers Australia National Conference, Publ. 96/05, 539-545.

Condamine Alliance 2004, *Natural Resource Management Plan*.

CSIRO 2008, *Water Availability in the Condamine-Balonne – A Report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*, CSIRO, Australia.

CSIRO 2008, *Water Availability in the Moonie, A Report to the Australian Government from the CSIRO Murray-Darling Basin Sustainable Yields Project*, CSIRO, Australia.

Environment Protection Agency www.epa.qld.gov.au/wetlandmapping.

Department of Environment, Heritage and The Arts Australian Wetlands Database. Website accessed 2008.

Department Local Government and Planning (2003) Runoff and flow coordination framework for the Condamine Floodplains.

Department of Natural Resources 2000, *Draft Water Allocation and Management Plan (Condamine-Balonne Basin)*.

ECOS (2003) Recycling water, up and down to the Darling. January-March, CSIRO.

Environment Australia (2001) A Directory of Important Wetlands in Australia. Third Edition, Environment Australia, Canberra.

Environmental Protection Agency 1999, *Water Quality Sampling Manual*, Queensland Government, Australia.

Environment Australia 2001, *A Directory of Important Wetlands in Australia Third Edition*, Environment Australia, Canberra.

Johnson D.P. 1999, *State of the Rivers Border Rivers and Moonie River Catchments, An Ecological and Physical Assessment of the Condition of Streams in the Border Rivers and Moonie River Catchments*, The State of Queensland, Department of Natural Resources, Australia

Land Resource Assessment and Management Pty Ltd (2002), Draft Condamine Flow Co-Ordination NRM Report Technical Working Paper A, submitted to the Department of Local Government and Planning.

Manen N.V. 2001, *State of the Rivers Maranoa, Balonne and Lower Condamine Rivers and Tributaries, An Ecological and Physical Assessment of the Condition of Streams in the Maranoa, Balonne and Lower Condamine River Catchments*, The State of Queensland, Department of Natural Resources, Australia.

McMahon T.A. & R. Srikanthan 1981, ‘Log Pearson III Distribution – Is it Applicable to Flood Frequency Analysis of Australian Streams’, *Journal of Hydrology*, vol. 52, no. 1-2, pp. 139-147.

MDBC (1999) The salinity audit of the Murray Darling Basin. A 100 year perspective 1999. Murray Darling Basin Commission.

MDBMC 2001, *Audit of Queensland Water Resource Plans,* Report of the Independent Audit Group, Murray-Darling Basin Ministerial Council.

Meecham, J. 2003, *Guidelines for Incorporating Runoff and Flow Coordination into Local Government Planning Schemes on the Condamine Floodplains*, Department of Local Government and Planning, Australia.

Natural Resources and Mines 2006, *Interim Resource Operations Licence for Chinchilla Weir Water Supply Scheme*.

NPWS 2003, *National Parks and Wildlife Service Bioregions*, Available at: www.nationalparks.nsw.gov.au/npws.nsf/Content/Bioregion.

OESR, 2008

Office of the Queensland Parliamentary Counsel 2004, *Water Resource (Condamine and Balonne) Plan 2004.*

Office of the Queensland Parliamentary Counsel 2003, *Water Resource (Moonie) Plan 2003.*

Office of the Queensland Parliamentary Counsel 1997, *Environmental Protection (Water) Policy 1997.*

Office of the Queensland Parliamentary Counsel 2000, *Water Act 2000.*

Office of the Queensland Parliamentary Counsel 2004, *Petroleum and Gas (Production and Safety) Act 2004.*

Patra K.C. 2002, *Hydrology and Water Resources Engineering*, Narosa Publishing House, New Delhi.

Pfankuch D.J. 1975, *Stream Reach Inventory and Channel Stability Evaluation*, USDA Forest Service Northern Region, Montana.

QMDC and SWNRM 2004, *Regional Natural Resource Management Plan 2004 (NRM)*, Queensland Murray Darling Committee Inc.and South West Natural Resource Management Group Inc.

Resource and Environmental Management (REM) (2007), Impacts of Groundwater Affecting Activities on Baseflow Variability and Ecological Response A Scoping Study.

Rosgen D. 1942, *Applied River Geomorphology*, Wildland Hydrology, Colorado.

Taylor B. & J. Meecham 2003, *Runoff and Flow Coordination Framework for the Condamine Floodplains*, Department of Local Government and Planning, Australia.

Wilson G.C. & J.C.Adams 2004, *State of the Catchment Report for the Condamine River System – Water*, CRC for Freshwater Ecology.

# Report Signature Page

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# APPENDIX A

## Surface water site photographs

*Photo 1: RD01 – Condamine River looking DS*

*Photo 2: RD02 – Bloodwood Creek looking US*

*Photo 3: RD03 – Dogwood Creek looking DS*

*Photo 4: RD04 – Wallan Creek looking DS*

*Photo 5: RD05 – Wollobee Creek looking US*

*Photo 6: RD06 – Wandoan Creek looking DS*

*Photo 7: RD07 – Ogle Creek looking DS*

*Photo 8: RD08 – Horse Creek looking DS*

*Photo 9: RD09 – Dogwood Creek looking DS*

*Photo 10: RD10 – Dogwood Creek looking US*

*Photo 11: RD11 – Condamine River looking US*

*Photo 12: RD12 – Condamine River looking US*

*Photo 13: RD13 – Condamine River looking DS*

*Photo 14: RD14 – Wambo Creek looking DS*

*Photo 15: RD15 – Kogon Creek looking DS*

*Photo 16: RD16 – Braemer Creek looking US*

*Photo 17: RD17 – Back Creek looking US*

*Photo 18: RD20 – Condamine River looking US*

*Photo 19: RD22 – Coolumboola Creek looking DS*

*Photo 20: RD23 – Cameby Creek looking DS*

*Photo 21: RD24 – Coolumboola Creek looking DS*

*Photo 22: RD25 – Cobareena Creek looking US*

*Photo 23: RD26 – Wieambilla Creek looking US*

*Photo 24: RD27 – Nine Mile Creek looking US*

*Photo 25: RD28 – Moonie River looking US*

*Photo 26: RD29 – Finch Creek looking DS*

*Photo 27: RD30 – Wilkie Creek looking US*

*Photo 28: RD31 – Condamine River looking US*

*Photo 29: RD32 – Cooranga Creek looking US*

*Photo 30: RD33 – Jingi Jingi Creek looking US*

*Photo 31: RD34 – Condamine River looking DS*

*Photo 32: RD35 – Condamine River looking US*

Photo 33: RD36 – Condamine River at Chinchilla Weir

Photo 34: RD37 – Charley's Creek looking DS

*Photo 35: RD38 – Rocky Creek looking US*

*Photo 36: RD39 – Condamine River looking DS*

# APPENDIX B

## Geomorphologic surface water site results

| Site Number | Stream | Catchment | Latitude | Longitude | Rosgen Stream Type | Stability Value | Stability Rating | Notes |
|---|---|---|---|---|---|---|---|---|
| RD01 | Condamine River | Condamine | -26.8364 | 150.30759 | C4 | 87 | Mod. Stable | ➢ Meandering channel within wide floodplain<br>➢ Low longitudinal slope<br>➢ Predominately gravel/sand bed and banks<br>➢ No flowing water, some pools<br>➢ Extensive deposition in centre of channel (dunes) and point bars at bends<br>➢ Terraced top of bank (right) ~ 1.5m high<br>➢ Alluvial soils, highly erodible<br>➢ Moderately stable banks<br>➢ Location of pipeline crossing<br>➢ Groundwater infiltration, evidence of fringe seepage<br>➢ Fauna = carp Flow = grass banks, woodland overbank areas |
| RD02 | Bloodwood Creek | Condamine | -27.1399 | 150.77814 | C5 | 89 | Mod. Stable | ➢ Location of pipeline crossing<br>➢ No flowing water, some pools<br>➢ Evidence of groundwater infiltration (minor)<br>➢ Channel not well defined<br>➢ Extensive vegetation in creek bed (woodland trees and grass)<br>➢ Sand dunes in channel, 80% vegetated<br>➢ Alluvial soils, sand/gravel<br>➢ Meandering channel |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | | ➢ Wide, flat overbank areas, woodland vegetation at top of banks extending to pastures<br>➢ Fauna = Crustaceans Flora = woodland |
| RD03 | Dogwood Creek | Condamine | -26.65658 | 150.18031 | C6 | 71 | Stable | ➢ Wide channel<br>➢ Designated as Lacustrine system<br>➢ Flowing water, low velocity ~ 0.2 m/s<br>➢ Minimal obstructions in channel<br>➢ Evidence of fringe seepage<br>➢ U/S LOB steep with some signs of erosion, D/S LOB ~ 1 in 5 with little signs of erosion<br>➢ Banks predominately grass with sparse woody trees<br>➢ Some marshy areas<br>➢ Silt-clay banks<br>➢ Wide, flat floodplain<br>➢ Anectodal evidence suggest that creek floods up to top of railway lines (~ 8-10 m high)<br>➢ Camping area/walking paths |
| RD04 | Wallan Creek | Condamine | -26.56568 | 150.14638 | C6 | 78 | Mod. Stable | ➢ Hard to characterise stream type. Combination of E6 and C6<br>➢ Meandering channel with wide, flat floodplain<br>➢ U/S banks fairly stable<br>➢ Extensive debris in channel U/S (fallen limbs)<br>➢ New grass sprouts in U/S creek bed<br>➢ Woodland trees at top of bank and on overbank areas<br>➢ D/S left bank after bridge crossing very eroded |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | | at bend and where head-cut occurs. Root mat overhangs and sloughing evident<br>➢ Silt-clay soils<br>➢ Poplar box trees and Cyprus trees on overbank areas<br>➢ Groundwater infiltration evident D/S |
| RD05 | Wollobee Creek | Wollobee | -26.15392 | 149.85248 | C6 | 74 | Stable | ➢ Low W/D ratio<br>➢ Meandering channel; wide, flat overbank areas<br>➢ Some debris in creek (fallen limbs) though not extensive<br>➢ Very murky water<br>➢ Clay bed and banks<br>➢ Some minor evidence of erosion though banks well vegetated with grass and lined with woodland trees<br>➢ Overbank areas sparsely vegetated with woodland trees and short grass<br>➢ Point bar at bends |
| RD06 | Wandoan Creek | Wollobee | -26.14626 | 149.83907 | C6 | 88 | Mod. Stable | ➢ No flowing water, some pools D/S, evidence of groundwater infiltration<br>➢ Creek bed and banks well vegetated with long grass, reeds, pine trees and woody trees<br>➢ Large volume of debris in channel particularly D/S<br>➢ Low W/D ratio<br>➢ Erosion and scouring D/S @ bend. Steep slopes though well vegetated<br>➢ Silty soils |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| RD07 | Ogle Creek | Wollobee | -26.21651 | 149.82137 | C4 | 66 | Stable | ➢ Small creek, not well defined U/S, very overgrown long grass in creek bed and banks<br>➢ D/S grass short in creek bed<br>➢ Woodland trees within channel and banks<br>➢ Debris in creek bed<br>➢ Sandy silt soil<br>➢ Erosion and slumping at bends though vegetation has been restored<br>➢ Wide, flat overbank areas sparsely vegetated with woodland trees |
| RD08 | Horse Creek | Horse | -26.16094 | 145.56973 | C5 | 100 | Unstable | ➢ Channel not well defined<br>➢ White sand, very unstable bed, poorly vegetated<br>➢ Grass banks, scattered trees on over banks<br>➢ Extensive scouring on D/S left bank at bend |
| RD09 | Dogwood Creek | Condamine | -26.89859 | 149.8273 | C4 | 72 | Stable | ➢ Large channel with steep slopes<br>➢ Suggests sufficient capacity to convey flows<br>➢ Bed appears fairly stable, some build up of sediment where extensive debris and point bars at bends<br>➢ Good riparian vegetation, diverse, good canopy coverage<br>➢ Clay/rocky bed and banks<br>➢ Lots of debris in channel<br>➢ Minimal flowing water, predominately pools<br>➢ Evidence of groundwater infiltration<br>➢ Freshly grown grass within D/S bed, drier U/S |

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|---|---|---|---|---|---|---|---|---|
| RD10 | Dogwood Creek | Condamine | -26.90944 | 149.98785 | C6 | 75 | Stable | ➢ Flowing water, low velocity, differing depths ~ 0.5m – 1.5m<br>➢ Water a greyer colour than at other sites<br>➢ Well vegetated banks – grass and woody trees<br>➢ Some reeds in creek bed<br>➢ Some sediment island within creek bed that are vegetated<br>➢ Some dead tree branches fallen into creek bed |
| RD11 | Condamine River | Condamine | -27.06363 | 149.71503 | C6 | 86 | Mod. Stable | ➢ River not well defined at bridge crossing<br>➢ Numerous sediment islands in bed, well vegetated<br>➢ Steep banks, some raw spots on banks that have not been revegetated<br>➢ Clay soil<br>➢ Debris in creek bed<br>➢ Wide, flat overbank areas<br>➢ Moderate riparian vegetation predominately woody trees |
| RD12 | Condamine River | Condamine | -26.99784 | 150.07863 | C6 | 60 | Stable | ➢ Wide open channel<br>➢ Silt/clay soil, large stable rocks on lower bank ~ 10cm diameter<br>➢ Steep banks, some erosion evident though fairly stable<br>➢ Good vegetation coverage on lower and upper banks<br>➢ Good recreational site<br>➢ Flowing water, low velocity<br>➢ Some sedimentation islands in centre of bed |

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|---|---|---|---|---|---|---|---|---|
| | | | | | | | | causing obstruction to flow<br>➢ Point-bar at bends<br>➢ Riparian vegetation predominately grass and woody trees, about 30m on either side<br>➢ Minimal debris in channel, some fallen trees on banks |
| RD13 | Condamine River | Condamine | -26.92552 | 150.12976 | C6 | 69 | Stable | ➢ Bridge crossing at Condamine<br>➢ Wide open channel, minimal debris<br>➢ Vegetated sedimentation islands blocking flow of water<br>➢ Some flowing water U/S, predominately pools D/S<br>➢ Riparian corridor ~ 50 m, houses built on top of left bank<br>➢ Grass and woody trees on banks<br>➢ Low longitudinal slope |
| RD14 | Wambo Creek | Condamine | -26.9393 | 150.60104 | C6 | 95 | Mod. Stable | ➢ Very overgrown channel, creek bed dry<br>➢ Creek bed vegetated with long grass, reeds and small trees<br>➢ Upper banks vegetated with woody trees<br>➢ Wide, flat overbank areas, well vegetated, minimal disturbance<br>➢ Low W/D ratio, very steep banks<br>➢ Silty/clay soil<br>➢ Extensive scouring and failure on U/S right bank at bend ~ 5m high<br>➢ Debris in channel<br>➢ No evidence of groundwater infiltration though |

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| | | | | | | | | some greener reeds in creek bed, other vegetation extremely dry |
| RD15 | Kogon Creek | Condamine | -27.04237 | 150.76561 | C6 | 94 | Mod. Stable | ➢ Small, incised, meandering channel<br>➢ Wide, flat overbank areas, cleared<br>➢ Riparian corridor minimal ~ 10m wide<br>➢ Long grass and woody trees in riparian corridor<br>➢ Banks slumping and highly eroded at bends, tree roots overhanging out of bank<br>➢ Silty/clay soil<br>➢ Sedimentation islands in centre of channel, well vegetated<br>➢ Water depth low, barely flowing<br>➢ Evidence of groundwater infiltration and fringe seepage<br>➢ Some debris in channel – fallen tree branches and leaves |
| RD16 | Braemer Creek | Condamine | -27.06891 | 150.86758 | C5 | 74 | Stable | ➢ Incised channel<br>➢ Evidence of bank erosion though fairly stable<br>➢ High W/D ratio<br>➢ Good canopy cover, tall woody trees on top of bank at edge of water<br>➢ Moss growing on overbank areas outside at extent of riparian corrider<br>➢ Depth of water ~ 1m, very low velocity<br>➢ Sedimentation island U/S collecting debris<br>➢ Riparian corridor ~ 20m wide, sparsely vegetated though some diversity ie. grass, shrubs, pine trees, woody trees, Tree Pears |

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| | | | | | | | | ➢ Tree pears on overbank areas<br>➢ Wide, flat floodplain |
| RD17 | Back Creek | Condamine | -27.08110 | 150.93311 | C6 | 69 | Stable | ➢ Water depth ~ 1-2m, low velocity<br>➢ Banks well vegetated with grass and woody trees<br>➢ Reeds growing in centre of creek bed<br>➢ Grass, small trees, pine trees and tall woody trees on banks<br>➢ Grass and woody trees on overbank areas<br>➢ Wide, flat floodplain<br>➢ Minimal evidence of erosion or slumping<br>➢ Extensive leaf litter on banks, some debris in channel around bridge piles<br>➢ Wide riparian corridor, minimal clearing |
| RD18 | Condamine River | Condamine | -27.12132 | 151.08994 | C6 | 77 | Stable | ➢ Wide incised channel<br>➢ No water<br>➢ Some evidence of erosion though banks well vegetated and fairly stable<br>➢ Tall trees and grass on lower banks<br>➢ Riparian corridor ~ 40 – 80m<br>➢ Minimal sedimentation in creek bar ie. no obvious point bars<br>➢ No photos |
| RD20 | Condamine River | Condamine | -26.85761 | 150.18536 | C5 | 94 | Mod. Stable | ➢ Sandy bed, silt banks<br>➢ Extensive bank erosion, root mat overhang and sloughing evident<br>➢ Mass sedimentation around bridge due to |

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| | | | | | | | | distortion of channel path<br>➢ Point bars evident<br>➢ Vegetation ~ 90% restored on banks though some raw spots<br>➢ Some pools though no flowing water<br>➢ Evidence of new sedimentation islands due to fresh vegetation<br>➢ Evidence of groundwater infiltration<br>➢ Riparian corridor ~ 70m |
| RD22 | Coolumboola Creek | Condamine | -26.7230 | 150.200 | C5 | 99 | Unstable | ➢ Sandy bed and banks<br>➢ U/S channel not well defined, D/S incised channel<br>➢ Serious erosion and slumping U/S<br>➢ D/S banks well vegetated with minimal raw spots<br>➢ Deposition in bed causing dunes<br>➢ Poor riparian vegetation, predominately grass and sparse woody trees<br>➢ Riparian corridor width ~ 30 – 50m<br>➢ Debris from fallen trees extensive U/S<br>➢ Wide, flat overbank areas |
| RD23 | Cameby Creek | Condamine | -26.7187 | 150.2643 | C6 | 98 | Unstable | ➢ Channel not well defined<br>➢ Poor riparian vegetation, some pine trees and woody trees<br>➢ Riparian corridor ~ 10m<br>➢ Clay soil<br>➢ Bed partly vegetated, recently grown grass |

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| | | | | | | | | obvious<br>➢ Numerous sandy/clay build-ups in channel<br>➢ Near Bellevue evap pond |
| RD24 | Coolumboola Creek | Condamine | -26.7380 | 150.2578 | C6 | 95 | Unstable | ➢ U/S channel not well defined<br>➢ Steep banks, highly eroded<br>➢ Root mat overhangs and sloughing evident<br>➢ Leaf matter prominent in D/S channel, some vegetation in creek bed<br>➢ No flowing water, some small pools<br>➢ Poor riparian vegetation, corridor ~ 15m<br>➢ Near Bellevue evap pond |
| RD25 | Cobareena Creek | Condamine | -26.94395 | 150.39639 | C6 | 104 | Unstable | ➢ U/S channel low W/D ratio<br>➢ Steep eroded banks, not well vegetated<br>➢ Numerous blockages from fallen trees at regular intervals along creek bed<br>➢ Clay/silt soils<br>➢ Poor riparian vegetation<br>➢ No flowing water, some small pools<br>➢ D/S channel not well defined<br>➢ Trees in centre of channel D/S of bridge<br>➢ Mass scouring on D/S right bank at bend<br>➢ Some trees fallen into creek bed D/S where slumping has occurred<br>➢ Near Kenya pond, Wieambilla Ck catchment |

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|---|---|---|---|---|---|---|---|---|
| RD26 | Wiemabilla Creek | Condamine | -26.94997 | 150.43051 | C6 | 71 | Stable | ➢ No flowing water, some small pools<br>➢ Some erosion on banks though vegetation has been restored and banks fairly stable<br>➢ Minimal vegetation in creek bed, some debris from sticks and leaf litter<br>➢ Wide, flat floodplain<br>➢ Banks well vegetated with pine trees and grass<br>➢ Clay soil<br>➢ Near Kenya pond |
| RD27 | Nine Mile Creek | Condamine | -26.93925 | 150.45319 | C6 | 70 | Stable | ➢ U/S channel not well defined, resembles marsh area rather than creek<br>➢ Clay soil<br>➢ No flowing water, pools ~0.3 – 1.0m deep<br>➢ Banks well vegetated with grass and trees<br>➢ Some signs of erosion and sedimentation though not severe<br>➢ Wide, flat, well vegetated overbank areas<br>➢ Riparian corridor ~ 10m on right overbank and 100m on left overbank |
| RD28 | Moonie River | Moonie | -27.41217 | 150.48729 | C6 | 67 | Stable | ➢ Flowing water ~ 1.5 m/s, depth ~ 2-3m<br>➢ Evidence of eddying around trees in centre of creek bed<br>➢ Banks well vegetated with grass and trees<br>➢ Poor riparian vegetation ~ 5m wide<br>➢ Cleared land for agricultural purposes on either side<br>➢ Anecdotal evidence suggests that clearing of left overbank has resulted in a major increase in |

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| | | | | | | | | sediment deposition to river<br>➢ Wide, flat floodplain |
| RD29 | Finch Creek | Moonie | -27.48753 | 150.72115 | C6 | 93 | Mod. Stable | ➢ Flowing water ~ 0.5m/s, depth ~ 1-2m<br>➢ Evidence of erosion at bends, serious scouring D/S right bank ~ 6 – 8m high<br>➢ Silt/clay soil<br>➢ Eddying around trees and reeds in centre of channel<br>➢ Vegetation ~ 60% on banks<br>➢ Well vegetated, wide riparian corridor ~ 4km |
| RD30 | Wilkie Creek | Condamine | -27.56941 | 151.04207 | C6 | 67 | Stable | ➢ Wide channel, high W/D ratio, low bank slope gradient U/S<br>➢ Flowing water U/S ~ 0.5 m/s, 1-2m deep<br>➢ Well vegetated banks - grass, small trees and tall woody trees<br>➢ Some debris build up at bridge<br>➢ Banks fairly stable<br>➢ Silt/clay soil<br>➢ Channel not well defined D/S<br>➢ Marsh area, frog habitat, well vegetated channel<br>➢ Riparian corridor sparsely vegetated ~ 30m wide |
| RD31 | Condamine River | Condamine | -27.22059 | 151.18243 | C6 | 71 | Stable | ➢ Flowing water ~ 2m/s, depth ~ 3m<br>➢ Banks well vegetated with grass, small trees and tall woody trees<br>➢ Some erosion and scouring near bridge though banks have been revegetated<br>➢ Extensive debris at bridge where sediment |

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| | | | | | | | | island has built up<br>➢ Riparian corridor ~ 30 – 70m wide<br>➢ Frog habitat |
| RD32 | Cooranga Creek | Condamine | -26.92888 | 150.91821 | C6 | 68 | Stable | ➢ Flowing water ~ 2m/s, depth ~ 4m<br>➢ Centre of creek well vegetated<br>➢ Wide flat banks, flow in channel nearly overtopping banks<br>➢ Well vegetated banks, predominately grass with trees spaced sparely<br>➢ Poor riparian corridor |
| RD33 | Jingi Jingi Creek | Condamine | -26.88590 | 150.85497 | C6 | 68 | Stable | ➢ Wide shallow channel, high W/D ratio<br>➢ Flowing water overtopping banks ~ 1m deep, low velocity<br>➢ Vegetated bed and banks predominately with long grass and some tall woody trees<br>➢ No evidence of erosion, bank and bed stable<br>➢ Poor riparian corridor, agricultural land on both sides |
| RD34 | Condamine River | Condamine | -26.95252 | 150.86967 | C6 | 68 | Stable | ➢ Incised channel, steep banks ~ 12m high<br>➢ Low W/D ratio<br>➢ Well vegetated banks<br>➢ Flowing water ~ 1m/s, ~ 3m deep<br>➢ Wide, flat overbanks<br>➢ Minimal debris, low turbidity water<br>➢ Some evidence of erosion at bend U/S<br>➢ Banks fairly stable |

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| | | | | | | | | ➢ Riparian corridor ~ 50m on both sides |
| RD35 | Condamine River | Condamine | -26.90547 | 150.78871 | C6 | 85 | Mod. Stable | ➢ Large channel, steep slopes ~ 1 in 3, banks ~ 8m high, low W/D ratio<br>➢ Flowing water ~ 2 m/s, depth ~ 2m<br>➢ Scouring at bends, root mat overhanging and sloughing evident<br>➢ Banks ~ 60% vegetated with grass and tall trees<br>➢ Riparian corridor ~ 60m wide<br>➢ Some debris in channel<br>➢ Silt/clay soil<br>➢ Water rising rapidly |
| RD36 | Condamine River | Condamine | -26.79992 | 150.57695 | C6 | 69 | Stable | ➢ Chinchilla Weir<br>➢ Well vegetated banks, steep slopes ~ 1 in 3<br>➢ Silt/clay soil<br>➢ Some evidence of erosion D/S of weir though fairly stable |
| RD37 | Charley's Creek | Condamine | -26.73645 | 150.62219 | C6 | 70 | Stable | ➢ Flowing water, low velocity, ~ 1m deep, very turbid<br>➢ Steep banks ~ 1 in 2, 5m high, some evidence of erosion though not severe<br>➢ Some tree roots extending through banks<br>➢ Well vegetated banks with grass, bushy trees and tall woody trees<br>➢ Silt soil<br>➢ Wide, flat overbank areas<br>➢ Minimal debris in channel |

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| RD38 | Rocky Creek | Condamine | -26.72784 | 150.60956 | C6 | 76 | Stable | ➢ Flowing water, low velocity, ~1m deep, very turbid<br>➢ Channel ~ 10m wide, banks ~ 5m high, 1 in 5 sides<br>➢ Scouring along banks particularly U/S at bend<br>➢ Bank vegetation diverse and thick |
| RD39 | Condamine River | Condamine | -26.81442 | 150.68904 | C6 | 71 | Stable | ➢ Wide open channel, fairly clear, minimal obstructions<br>➢ Minimal channel vegetation<br>➢ Well vegetated banks<br>➢ Some erosion on lower banks and scouring at bends though fairly stable otherwise<br>➢ Flowing water ~ 1.5 m/s, depth ~ 2m, very turbid<br>➢ Some debris in channel and at bridge (branches)<br>➢ Clay soil<br>➢ Wide, flat overbank areas, well vegetated on right overbank, cleared on left overbank |

| Site | Reach Environs | Bank Stability | Bed and Bar Stability | Channel Habitat Types | Riparian Vegetation | Aquatic Vegetation | Aquatic Habitat | Scenic, Recreation and Conservation Value | Overall Rating |
|---|---|---|---|---|---|---|---|---|---|
| RD01 | Poor | Moderate | Moderate | Poor | Good | Poor | Poor | Moderate | Moderate |
| RD02 | Moderate | Moderate | Moderate | Very Poor | Poor | Very Poor | Poor | Poor | Poor |
| RD03 | Moderate | Good | Good | Poor | Poor | Poor | Poor | Good | Moderate |
| RD04 | Good | Moderate | Moderate | Very Poor | Very Poor | Poor | Very Poor | Good | Poor |
| RD05 | Very Good | Good | Good | Poor | Poor | Very Poor | Poor | Moderate | Moderate |
| RD06 | Moderate | Moderate | Moderate | Poor | Poor | Poor | Poor | Moderate | Moderate |
| RD07 | Poor | Moderate | Moderate | Very Poor | Poor | Very Poor | Very Poor | Poor | Poor |
| RD08 | Moderate | Poor | Very Poor | Very Poor | Poor | Very Poor | Very Poor | Very Poor | Very Poor |
| RD09 | Good | Good | Good | Poor | Very Good | Poor | Poor | Good | Moderate |
| RD10 | Moderate | Good | Moderate | Moderate | Good | Moderate | Moderate | Moderate | Moderate |
| RD11 | Moderate | Moderate | Moderate | Poor | Moderate | Moderate | Poor | Moderate | Moderate |
| RD12 | Moderate | Good | Good | Moderate | Moderate | Poor | Poor | Good | Moderate |
| RD13 | Poor | Good | Good | Poor | Moderate | Poor | Poor | Moderate | Moderate |
| RD14 | Good | Moderate | Moderate | Poor | Good | Poor | Very Poor | Poor | Moderate |
| RD15 | Poor | Poor | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate |
| RD16 | Moderate | Moderate | Moderate | Moderate | Moderate | Poor | Moderate | Moderate | Moderate |
| RD17 | Very Good | Good | Good | Moderate | Moderate | Moderate | Moderate | Moderate | Good |
| RD18 | Moderate | Good | Good | Very Poor | Moderate | Very Poor | Poor | Moderate | Moderate |
| RD20 | Good | Moderate | Moderate | Poor | Moderate | Poor | Poor | Good | Moderate |
| RD22 | Moderate | Poor | Poor | Very Poor | Poor | Very Poor | Very Poor | Poor | Poor |
| RD23 | Poor | Poor | Poor | Very Poor | Poor | Very Poor | Very Poor | Very Poor | Poor |
| RD24 | Poor | Poor | Poor | Very Poor | Poor | Very Poor | Very Poor | Very Poor | Poor |
| RD25 | Poor | Poor | Poor | Very Poor | Poor | Very Poor | Very Poor | Very Poor | Poor |
| RD26 | Moderate | Moderate | Moderate | Poor | Moderate | Very Poor | Very Poor | Poor | Poor |
| RD27 | Moderate | Moderate | Moderate | Poor | Moderate | Poor | Poor | Moderate | Moderate |
| RD28 | Poor | Good | Moderate | Good | Moderate | Moderate | Good | Good | Moderate |
| RD29 | Very Good | Moderate | Moderate | Moderate | Good | Moderate | Poor | Good | Moderate |
| RD30 | Moderate | Good | Moderate | Moderate | Good | Moderate | Good | Good | Good |
| RD31 | Poor | Good | Moderate | Good | Good | Moderate | Good | Good | Good |
| RD32 | Poor | Good | Good | Moderate | Moderate | Good | Good | Good | Good |
| RD33 | Poor | Good | Very Good | Moderate | Poor | Poor | Poor | Moderate | Moderate |

| Site | Reach Environs | Bank Stability | Bed and Bar Stability | Channel Habitat Types | Riparian Vegetation | Aquatic Vegetation | Aquatic Habitat | Scenic, Recreation and Conservation Value | Overall Rating |
|---|---|---|---|---|---|---|---|---|---|
| RD34 | Moderate | Good | Good | Moderate | Moderate | Moderate | Good | Good | Good |
| RD35 | Moderate | Moderate | Moderate | Good | Moderate | Moderate | Moderate | Good | Moderate |
| RD36 | Moderate | Good | Moderate | Moderate | Moderate | Poor | Moderate | Very Good | Moderate |
| RD37 | Moderate | Good | Moderate | Moderate | Moderate | Moderate | Moderate | Good | Moderate |
| RD38 | Good | Good | Moderate | Moderate | Good | Moderate | Moderate | Good | Good |
| RD39 | Moderate | Good | Moderate | Moderate | Good | Moderate | Moderate | Good | Good |

# APPENDIX C

## The Gums Lagoon and Lake Broadwater Wetlands Database Search results

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# Water

## Publications



# A Directory of Important Wetlands in Australia

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## Lake Broadwater - QLD015

**Level of importance:** National - Directory

**Location:** 27 degrees 21' 23" S, 151 degrees 06' 04" E; the site extends c. 3 km from north to south and is up to c. 2 km wide, with its centre c. 25 km southwest of Dalby. It falls within the Condamine-Balonne catchment (Queensland Department of Primary Industries 1993).

**Biogeographic region:** Brigalow Belt South

**Shire:** Wambo.

**Area:** 215 ha.

**Elevation:** 340 m ASL.

**Other listed wetlands in same aggregation:** None.

**Wetland type:** C1, B2, B14, B10, B5

**Criteria for inclusion:** 1, 2, 3, 5,

**Site description:** The lake is situated at the edge of the broad valley of the Condamine River and lies to the west of the associated Long Swamp. Wilkie Creek lies to the east and the lake overflows into this Creek via the Broadwater Overflow. The catchment of the area is the higher land to the southwest of the site and includes Wilkie Creek, Broadwater Gully and the Condamine River, further to the southeast, when in flood. The lake has been enhanced by minor levee construction to a hieight of apporoximately 0.75m.

**Physical features:** Landform: backplain, floodout, drainage depression, stream channel, stream bed, lake and swamp; surrounding uplands are gently sloping flats and low ridges. General geology: the lake and its associated floodplain are Quaternary alluvium. Sandstone ridges (Lower Cretaceous) occur in the catchment to the southwest and east of the lake. Soils: Sandy surface soils with an abrupt transition to a finer textured B horizon. Climate: the site falls within the 610-711 mm isohyets, with rain falling mostly in December-March, and occasionally during winter.

**Hydrological features:** Water supply: principally runoff, floodout and stream flow from the catchment. Water quality is good. The lake is shallow (maximum depth c. 4 m). It fills and occasionally floods with the summer rainfall and recedes thereafter. It may dry out completely, as in 1981-83 and 1986-87.

**Ecological features:** Four wetland communities are recognised as associated with the lake, of which the first two are the most important: (i) open water communities dominated by a range of species including shiny nardoo (Marsilea mutica), swamp lily (Ottelia ovalifolia), native water hyacynth (Monochoria cyanea), wavy marshwort (Nymphoides crenata), ribbonweed (Vallisneria gigantea), Triglochin procera and water primrose (Ludwigia peploides); (ii) lake edge communities dominated by river red gum (Eucalyptus camaldulensis) with an understorey of grasses and sedges including slender canegrass (Leptochloa decipiens), Leptochloa fusca subsp. fusca, rice sedge (Cyperus difformis), Fimbristylis velata and Polygonum spp.; (iii) marsh communities with such dominants as Myriophyllum striatum, Fimbristylis velata and Polygonum spp.; (iv) riparian communities of similar structure to the lake edge communities.

**Significance:** Lake Broadwater is a good example of a semi permanent freshwater lake in an area where these are rare.

**Notable flora:** The seasonally rich aquatic bed and emergent communities.

**Notable fauna:** A varied fauna is associated with the lake and is detailed in the work edited by Scott (1988). Frogs, reptiles and mammals are well represented including appreciable populations of a wide range of waterbirds. The latter includes representatives of a diversity of families together with holarctic breeding species protected under CAMBA and JAMBA.

**Other Fauna:**

**Social and Cultural values:** Significant Aboriginal presence is in evidence in the area.

**Land tenure:** The lake is included in the Lake Broadwater Conservation Park. Conservation park and leasehold.

**Current land use:** Recreation (boating, camping, fishing) and conservation management. Low intensity cattle grazing on native pasture.

**Disturbance or threat:** Past/present: Survey records from 1877 indicate that changes to the lake have been very slow and are likely to continue in this manner, providing that the catchment remains undisturbed. Current disturbance is minimal.

Potential: Irrigation and hydrological changes in the catchment will impact adversely on the lake.

**Conservation measures taken:** Lake Broadwater Conservation Park.

**Management authority and jurisdiction:** Queensland Parks and Wildlife Service.

**References:** Mond, A. (1973); Queensland Department of Lands. (1995); Queensland Department of Primary Industries. (1993); Scott, G. et al. (1988). See Queensland Reference List

**Compiler & date:** Suggit, J. and Wilson, B., 1992. Revised Blackman, J.G. and Craven, S. A., 1995. Edited Miller, G.J. and Worland, J.L., 2004.

**Drainage:**

| | |
|---|---|
| ***AWRC Division*** | MURRAY-DARLING |
| ***AWRC Region*** | CONDAMINE |
| ***AWRC Basin*** | MURRAY-DARLING |
| ***Catchment*** | Condamine River |
| ***Sub-catchment*** | |

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| Australian Government | Australian Water Resources 2005 | Bureau of Meteorology | Murray-Darling Basin Authority | National Water Commission | Water efficiency labelling | Waterwatch |

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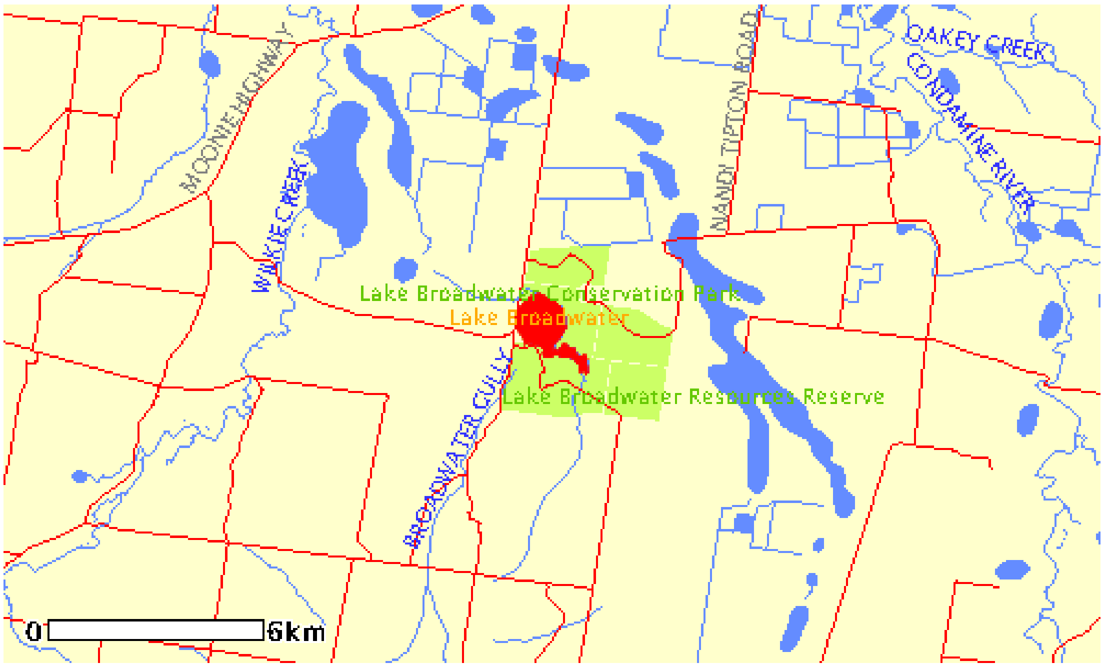
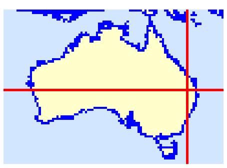
# Lake Broadwater



| Map key |
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| Selected Wetland |
| Ramsar Wetlands |
| Important Wetlands |
| World Heritage |
| Protected Areas |
| Rivers and Lakes |

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| | Roads |
| | Towns |
| | Cwlth Marine Area |

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# Water

## Publications



# A Directory of Important Wetlands in Australia

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## The Gums Lagoon - QLD020

**Level of importance:** National - Directory

**Location:** 27 degrees 20' 06" S, 150 degrees 11' 47" E; the site extends for c. 3 km east-west and is c. 1 km wide, with its centre 26 km southwest of Tara. It falls within the Condamine-Balonne catchment (Queensland Department of Primary Industries 1993).

**Biogeographic region:** Brigalow Belt South

**Shire:** Tara.

**Area:** 343 ha.

**Elevation:** 284 m ASL.

**Other listed wetlands in same aggregation:** None.

**Wetland type:** B10, B14

**Criteria for inclusion:** 1, 3,

**Site description:** A relatively undisturbed wooded swamp, in a small (240 ha) reserve of similarly undisturbed woodlands and open forest; an island in a sea of heavily disturbed (cleared), grazed and cultivated rural land.

**Physical features:** The lagoon is a relatively shallow depression in an otherwise flat plain; Quaternary and recent alluvia with silty clay to clay loam. Surrounding land systems are either Cainozoic sandy sediments with deep uniform loose sands and texture contrast soils or Cainozoic sediments in clay sheets, with very deep grey cracking clays showing strong gilgai formation (Mullins 1980). Climate is transitional between warm humid and semi arid; annual rainfall is 572 mm and evaporation is 1902 mm (Queensland National Parks and Wildlife Service 1986).

**Hydrological features:** The lagoon apparently fills about once every seven to ten years (Queensland National Parks and Wildlife Service 1986). Depending on subsequent seasonal top up it may stay full for more than one year. It is a shallow freshwater feature (< 0.5 m) and water quality is generally good.

**Ecological features:** The lagoon supports a low open forest of river red gum (Eucalyptus camaldulensis) over perennial tussock grasses (probably species such as Chloris spp. and Leptochloa digitata). Ephemeral semi aquatic plants (e.g. Marsilea spp. and Cyperaceae spp.) occur during periods of inundation. Large numbers of waterbirds and fish are known to use the lagoon when it is full.

**Significance:** The significance of this site lies largely in its existence as a relatively undisturbed wetland in a region of extensive habitat modification for agriculture.

**Notable flora:** No declared endangered or vulnerable plants are known from the wetland. River red gum wooded swamps are a relatively rare community in Queensland and the Southern Brigalow Belt biogeographic region. The sparse distribution, small size of remaining swamps, and continued broad scale clearing for agriculture on floodplains, means that The Gums Lagoon is representative of a threatened plant community at the bioregional, if not state level.

**Notable fauna:** No declared endangered or vulnerable fauna are known from the wetland. The lagoon supports large numbers of waterbirds (some breeding) during periods of inundation. Of the 79 species of birds recorded for the reserve area; 23 are wetland birds, and 12 of those have bred on site (Queensland National Parks and Wildlife Service 1986). Several birds listed for the lagoon come under JAMBA and CAMBA (great egret (Ardea alba) - breeding, white-bellied sea-eagle (Haliaeetus leucogaster), rainbow bee-eater (Merops ornatus)).

**Other Fauna:**

**Social and Cultural values:** The Gums Lagoon is a significant recreational site for many local individuals and groups, especially for nature study (scouts, guides, The Gums School) and bird watching.

**Land tenure:** Until recently, a camping and water reserve. It is currently in process of changing to a reserve for natural resource management. Freehold private land, institutional State land (railway reserve and other) and 240 ha in reserve as for on site.

**Current land use:** Recreation: camping, walking, education (schools and community groups). Recreation and education (as above), sand/loam extraction, extensive grazing (native and improved pastures), transport (road and rail) land development (urban extensive).

**Disturbance or threat:** Past/present: Minor disturbances through clearing and selective removal of trees have occurred in the vicinity of the wetland in the past. Feral cats and hares are seen as major animal pests in the area. Many weeds occur in and around the lagoon, and roads around the lagoon perimeter help to spread those weeds.

Potential: Future use of the lagoon and surrounding reserve by travelling stock (e.g. in drought) may be an issue. It is also possible that some urban and industrial development may occur in the future.

**Conservation measures taken:** An environmental park was proposed for the land surrounding the lagoon in 1986 (Queensland National Parks and Wildlife Service 1986). This was subsequently downgraded to a reserve for natural resource management. At present, no conservation measures are taken at the site.

**Management authority and jurisdiction:** Tara Shire Council (Queensland Parks and Wildlife Service and Department of Natural Resources and Mines to have input into management planning); the Education Queensland has a small reserve which extends into the southern end of lagoon.

**References:** Mullins, J.A. (1980); Queensland Department of Primary Industries. (1993); Queensland National Parks and Wildlife Service. (1986). See Queensland Reference List

**Compiler & date:** Ford, G.I., 1995. Edited Miller, G.J. and Worland, J.L., 2004.

**Drainage:**

| | |
|---|---|
| ***AWRC Division*** | MURRAY-DARLING |
| ***AWRC Region*** | CONDAMINE |
| ***AWRC Basin*** | CONDAMINE-CULGOA RIVERS |
| ***Catchment*** | Condamine River |
| ***Sub-catchment*** | |

Go to basic query form | Go to advanced query form | Go to spatial query tool

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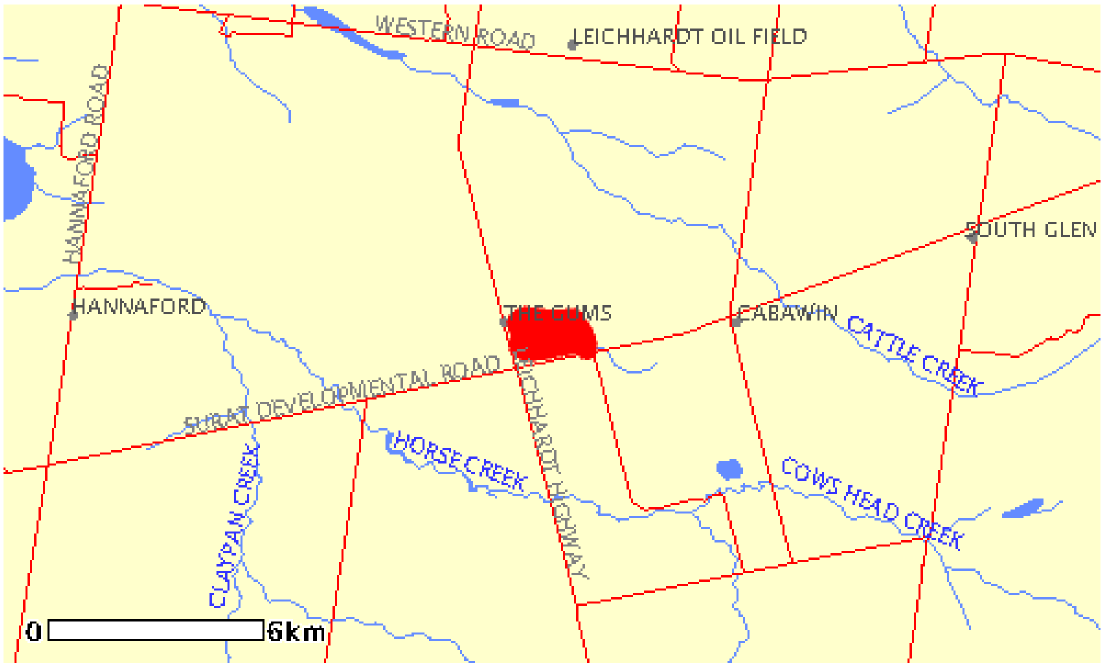
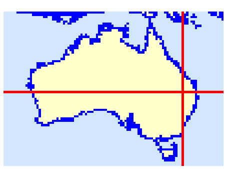
# The Gums Lagoon



**Map key**

| | |
|---|---|
| | Selected Wetland |
| | Ramsar Wetlands |
| | Important Wetlands |
| | World Heritage |
| | Protected Areas |
| | Rivers and Lakes |

| | |
|---|---|
| | Roads |
| | Towns |
| | Cwlth Marine Area |

- Go to search form
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# APPENDIX D

## Surface water quality laboratory results

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Matrix:** | | **Sample Type:** | **REG** | **REG** | **REG** | **REG** | **REG** | **REG** |
| **Workgroup:** | | **ALS Sample number:** | EB0816321001 | EB0816321002 | EB0816321003 | EB0816321004 | EB0816321005 | EB0816321006 |
| **Project name/number:** | | **Sample date:** | 18/11/2008 | 18/11/2008 | 19/11/2008 | 20/11/2008 | 20/11/2008 | 21/11/2008 |
| | | **Client sample ID (1st):** | QGC_SW01 | QGC_SW02 | QGC_SW03 | QGC_SW04 | QGC_SW05 | QGC_SW06 |
| | | **Client sample ID (2nd):** | | | | | | |
| | | **Site:** | | | | | | |
| | | **Purchase Order:** | | | | | | |
| **Analyte grouping/Analyte** | **Units** | **LOR** | | | | | | |
| ***EA005: pH*** | | | | | | | | |
| pH Value | pH Unit | 0.01 | **7.02** | **7.08** | **7.32** | **7.88** | **6.60** | **7.26** |
| ***EA006: Sodium Adsorption Ratio (SAR)*** | | | | | | | | |
| Sodium Absorption Ratio | - | 0.01 | **1.50** | **2.92** | **1.00** | **23.4** | **1.26** | **1.58** |
| ***EA010P: Conductivity by PC Titrator*** | | | | | | | | |
| Electrical Conductivity @ 25°C | µS/cm | 1 | **89** | **115** | **254** | **483** | **82** | **146** |
| ***EA025: Suspended Solids*** | | | | | | | | |
| Suspended Solids (SS) | mg/L | 1 | **90** | **450** | **33** | **200** | **3270** | **1550** |
| ***ED037P: Alkalinity by PC Titrator*** | | | | | | | | |
| Hydroxide Alkalinity as CaCO3 | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Carbonate Alkalinity as CaCO3 | mg/L | 1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Bicarbonate Alkalinity as CaCO3 | mg/L | 1 | **24** | **41** | **104** | **172** | **35** | **51** |
| Total Alkalinity as CaCO3 | mg/L | 1 | **24** | **41** | **104** | **172** | **35** | **51** |
| ***ED040F: Dissolved Major Anions*** | | | | | | | | |
| Sulfate as SO4 2- | mg/L | 1 | **4** | **4** | **2** | **3** | <1 | **3** |
| ***ED045P: Chloride by PC Titrator*** | | | | | | | | |
| Chloride | mg/L | 1 | **10** | **11** | **20** | **58** | **10** | **10** |
| ***ED093F: Dissolved Major Cations*** | | | | | | | | |
| Calcium | mg/L | 1 | **3** | **2** | **18** | **1** | **6** | **6** |
| Magnesium | mg/L | 1 | **2** | **1** | **9** | <1 | **2** | **3** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sodium | mg/L | 1 | **13** | **21** | **21** | **114** | **14** | **19** |
| Potassium | mg/L | 1 | **4** | **2** | **8** | **3** | **4** | **5** |
| ***EK059G: NOX as N by Discrete Analyser*** | | | | | | | | |
| Nitrite + Nitrate as N | mg/L | 0.01 | **0.07** | **0.13** | <0.01 | **0.15** | <0.01 | **2.54** |
| ***EK061: Total Kjeldahl Nitrogen (TKN)*** | | | | | | | | |
| Total Kjeldahl Nitrogen as N | mg/L | 0.1 | **0.5** | **1.2** | **0.8** | **4.5** | **3.9** | **1.3** |
| Total Kjeldahl Nitrogen - Filtered | mg/L | 0.1 | **0.4** | **0.7** | **0.8** | **1.1** | **0.7** | **1.2** |
| ***EK062: Total Nitrogen as N*** | | | | | | | | |
| Total Nitrogen as N | mg/L | 0.1 | **0.6** | **1.3** | **0.8** | **0.9** | **0.6** | **3.8** |
| ***EK062: Total Nitrogen as N (TKN + NOx)*** | | | | | | | | |
| Total Nitrogen as N | mg/L | 0.1 | **1.5** | **0.8** | **3.5** | **2.5** | **0.7** | **3.8** |
| ***EK067G: Total Phosphorus as P by Discrete Analyser*** | | | | | | | | |
| Total Phosphorus as P | mg/L | 0.01 | **0.40** | **0.28** | **0.13** | **0.90** | **1.36** | **0.85** |
| Total Phosphorus - Filtered | mg/L | 0.01 | **0.16** | **0.14** | **0.07** | **0.29** | **0.24** | **0.64** |
| ***EN055: Ionic Balance*** | | | | | | | | |
| Total Anions | meq/L | 0.01 | **0.85** | **1.22** | **2.69** | **5.13** | **0.99** | **1.36** |
| Total Cations | meq/L | 0.01 | **0.95** | **1.16** | **2.72** | **5.10** | **1.18** | **1.47** |
| Ionic Balance | % | 0.01 | | | | **0.27** | | |
| ***EP002: Dissolved Organic Carbon (DOC)*** | | | | | | | | |
| Dissolved Organic Carbon | mg/L | 1 | **11** | **8** | **8** | <1 | **23** | **8** |
| ***EP005: Total Organic Carbon (TOC)*** | | | | | | | | |
| Total Organic Carbon | mg/L | 1 | **17** | **9** | **8** | **12** | **8** | **8** |

## NRW Water Quality Data

| 422333A | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average of Conductivity @ 25C (uS/cm) | 559 | 365 | 350 | 429 | 606 | 529 | 731 | 737 | 680 | 909 | 540 | 341 |
| Average of pH (pH units) | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 7 |
| Average of Total Alkalinity as CaCO3 (mg/L) | 130 | 96 | 110 | 133 | 140 | 127 | 143 | 156 | 140 | 159 | 143 | 89 |
| Average of Hardness as CaCO3 (mg/L) | 162 | 101 | 116 | 152 | 180 | 151 | 196 | 203 | 197 | 239 | 173 | 83 |
| Average of Total Diss. Solids (mg/L) | 324 | 214 | 217 | 277 | 346 | 291 | 375 | 385 | 379 | 471 | 341 | 160 |
| Average of Total Suspended Solids | 440 | 291 | 76 | 27 | 39 | 49 | 46 | 18 | 28 | 22 | 302 | 493 |
| Average of Calcium as Ca soluble (mg/L) | 26 | 19 | 24 | 26 | 31 | 28 | 34 | 37 | 34 | 39 | 28 | 16 |
| Average of Chloride as Cl (mg/L) | 105 | 55 | 52 | 77 | 110 | 84 | 127 | 130 | 138 | 176 | 109 | 26 |
| Average of Magnesium as Mg soluble (mg/L) | 24 | 13 | 14 | 21 | 25 | 20 | 27 | 27 | 27 | 34 | 25 | 10 |
| Average of Nitrate as NO3(mg/L) | 4 | 3 | 4 | 2 | 3 | 3 | 6 | 4 | 3 | 4 | 3 | 5 |
| Average of Potassium as K (mg/L) | 7 | 6 | 6 | 6 | 8 | 6 | 7 | 7 | 6 | 11 | 8 | 5 |
| Average of Sodium as Na (mg/L) | 54 | 37 | 33 | 42 | 57 | 48 | 65 | 69 | 65 | 84 | 60 | 22 |
| Average of Sulphate as SO4 (mg/L) | 14 | 8 | 12 | 6 | 18 | 16 | 17 | 19 | 18 | 28 | 16 | 4 |
| Average of Oxygen (Dissolved) (mg/L) | 5 | 5 | 5 | 3 | 6 | 8 | 9 | 9 | 9 | 8 |  | 5 |

| 422336A | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average of Conductivity @ 25C (uS/cm) | 685 | 335 | 312 | 395 | 494 | 512 | 506 | 601 | 1000 | 833 | 381 | 535 |
| Average of Turbidity (NTU) |  | 89 | 165 | 32 | 33 | 100 | 64 | 49 | 9 | 96 | 743 |  |
| Average of pH (pH units) | 8 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Average of Total Alkalinity as CaCO3 (mg/L) | 200 | 101 | 130 | 122 | 135 | 148 | 133 | 131 | 161 | 130 | 109 | 100 |
| Average of Hardness as CaCO3 (mg/L) | 333 | 99 | 138 | 175 | 165 | 176 | 176 | 180 | 270 | 196 | 122 | 142 |
| Average of Total Diss. Solids (mg/L) | 584 | 209 | 234 | 252 | 302 | 310 | 321 | 336 | 533 | 341 | 239 | 282 |
| Average of Total Suspended Solids | 48 | 233 | 26 | 18 | 65 | 10 | 28 | 50 | 32 | 35 | 630 | 35 |
| Average of Calcium as Ca soluble (mg/L) | 59 | 19 | 26 | 29 | 31 | 36 | 29 | 31 | 38 | 34 | 20 | 23 |
| Average of Chloride as Cl (mg/L) | 240 | 49 | 60 | 78 | 94 | 104 | 111 | 116 | 220 | 129 | 70 | 92 |
| Average of Magnesium as Mg soluble (mg/L) | 45 | 13 | 18 | 25 | 22 | 21 | 26 | 25 | 43 | 27 | 17 | 21 |
| Average of Nitrate as NO3(mg/L) | 2 | 3 |  |  | 3 |  | 3 | 5 | 3 | 5 | 3 | 8 |
| Average of Total Nitrogen (mg/L) |  | 1 |  | 1 |  |  | 2 |  |  | 1 |  |  |
| Average of Oxygen (Dissolved) (mg/L) |  | 6 | 6 |  |  | 10 |  |  |  | 8 | 5 |  |
| Average of Total Phosphorus as P (mg/L) |  | 0 |  | 0 |  |  | 0 |  |  | 0 | 2 |  |
| Average of Potassium as K (mg/L) | 9 | 5 | 5 | 4 | 5 | 3 | 6 | 5 | 8 | 5 | 5 | 6 |
| Average of Sodium as Na (mg/L) | 95 | 31 | 29 | 34 | 46 | 55 | 53 | 55 | 101 | 57 | 38 | 46 |

| 422308C | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average of Conductivity @ 25C (uS/cm) | 399 | 355 | 278 | 291 | 298 | 550 | 484 | 478 | 526 | 542 | 589 | 335 |
| Average of Turbidity (NTU) | 162 | 104 | 311 | 80 | 103 | 157 | 62 | 93 | 26 | 43 | 142 | 422 |
| Average of pH (pH units) | 8 | 7 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| Average of Hydrogen as H (mg/L) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Average of Total Diss. Solids (mg/L) | 191 | 196 | 176 | 174 | 192 | 295 | 252 | 267 | 301 | 311 | 275 | 195 |
| Average of Total Suspended Solids | 146 | 289 | 211 | 305 | 59 | 109 | 47 | 49 | 36 | 41 | 123 | 182 |
| Average of Calcium as Ca soluble (mg/L) | 20 | 20 | 14 | 19 | 19 | 22 | 22 | 27 | 29 | 32 | 24 | 16 |
| Average of Chloride as Cl (mg/L) | 46 | 42 | 50 | 31 | 40 | 74 | 63 | 79 | 92 | 90 | 82 | 44 |
| Average of Magnesium as Mg soluble (mg/L) | 13 | 12 | 9 | 12 | 12 | 15 | 15 | 19 | 21 | 21 | 19 | 11 |
| Average of Nitrate as NO3(mg/L) | 2 | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 1 | 1 | 2 | 2 |
| Average of Total Nitrogen (mg/L) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Average of Oxygen (Dissolved) (mg/L) | 5 | 6 | 6 | 8 | 7 | 7 | 9 | 8 | 7 | 8 | 7 | 8 |
| Average of Total Phosphorus as P (mg/L) | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Average of Potassium as K (mg/L) | 5 | 5 | 5 | 4 | 5 | 6 | 4 | 4 | 5 | 5 | 5 | 4 |
| Average of Sodium as Na (mg/L) | 32 | 33 | 33 | 26 | 29 | 60 | 49 | 44 | 50 | 55 | 50 | 37 |
| Average of Sulphate as SO4 (mg/L) | 5 | 5 | 4 | 5 | 5 | 8 | 7 | 8 | 8 | 9 | 7 | 4 |

| 422333A | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average of Conductivity @ 25C (uS/cm) | 241 | 184 | 309 | 150 | 295 | 298 | 385 | 410 | 404 | 525 | 481 | 56 |
| Average of Turbidity (NTU) | 73 | 119 | 251 | 100 | 250 | 158 | 68 | 65 | 52 | 220 | 72 | |
| Average of pH (pH units) | 8 | 7 | 8 | 8 | 7 | 8 | 8 | 8 | 8 | 7 | 8 | 7 |
| Average of Total Alkalinity as CaCO3 (mg/L) | 84 | 57 | 96 | 51 | 91 | 121 | 91 | 109 | 80 | 101 | 94 | |
| Average of Hardness as CaCO3 (mg/L) | 74 | 48 | 94 | 39 | 94 | 116 | 106 | 129 | 98 | 116 | 102 | |
| Average of Hydrogen as H (mg/L) | | 0 | 0 | | 0 | 0 | | 0 | | 0 | 0 | |
| Average of Total Diss. Solids (mg/L) | 156 | 125 | 178 | 110 | 185 | 200 | 220 | 231 | 186 | 220 | 208 | |
| Average of Total Suspended Solids | 138 | 2012 | 104 | 1800 | 65 | 10 | 54 | 42 | 355 | 156 | 21 | |
| Average of Calcium as Ca soluble (mg/L) | 15 | 11 | 20 | 8 | 18 | 25 | 21 | 24 | 18 | 23 | 18 | |
| Average of Chloride as Cl (mg/L) | 32 | 19 | 41 | 11 | 41 | 51 | 59 | 69 | 56 | 67 | 60 | |
| Average of Magnesium as Mg soluble (mg/L) | 9 | 5 | 11 | 4 | 12 | 13 | 13 | 17 | 13 | 14 | 14 | |
| Average of Nitrate as NO3(mg/L) | 2 | 4 | 2 | 4 | 1 | | 3 | 2 | 1 | 2 | 2 | |
| Average of Total Nitrogen (mg/L) | | 1 | 1 | | | | 1 | | | | 1 | |
| Average of Oxygen (Dissolved) (mg/L) | | 8 | | | 7 | 10 | | | | 7 | | |
| Average of Total Phosphorus as P (mg/L) | | 1 | 1 | | 0 | | 0 | | | | 0 | |
| Average of Potassium as K (mg/L) | 5 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 3 | 4 | 5 | |
| Average of Sodium as Na (mg/L) | 24 | 20 | 28 | 19 | 28 | 33 | 36 | 36 | 29 | 40 | 36 | |
| Average of Sulphate as SO4 (mg/L) | 4 | 11 | 3 | 11 | 5 | | 5 | 7 | 8 | 5 | 5 | |

# APPENDIX E

## Limitations

## LIMITATIONS

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