REPORT:

Arrow Energy Surat Gas Project

Input to the Environmental Impact Statement

SURFACE WATER ASSESSMENT

PART A: Fluvial Geomorphology and Hydrology

November 2011

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Executive Summary

E1 Introduction

This report has been prepared as input to the preparation of the "ARROW ENERGY SURAT GAS PROJECT – Environmental Impact Statement". Surface water aspects of the project have been examined in two parts: Part A: Fluvial geomorphology and hydrology (this report); and Part B: Water quality.

E2 Legislative Context

This section focuses solely on legislative aspects that may have relevance to geomorphology and hydrology as they pertain to the design, construction, operation and decommissioning of the coal seam gas fields associated infrastructure.

E3 Study Method

The assessment approach taken in this study has been the use of sensitivity and magnitude to determine the significance of potential impacts. The significance of impacts has been assessed by considering the sensitivity of identified environmental values and the magnitude of the potential impact, before and after the application of mitigation measures. This has then enabled the effectiveness of the proposed mitigation measures in reducing the predicted impact to be assessed.

E4 Existing Environment – Environmental Values

Specific environmental values for watercourses in the project development area are not defined within the Environmental Protection (Water) Policy Act 2009 (EPP). Environmental values have therefore been developed from the desktop / archival / baseline investigations and field investigation in conjunction with consideration of ANZECC 2000, the National Water Quality Management Strategy (NWQMS), the DERM guideline: Establishing Draft Environmental Values and Water Quality Objectives and the Queensland Water Quality Guidelines 2009.

The following environmental values have in common the overarching primary value of sustainable function and use of ecosystems. Identified environmental values and the objectives for preservation of these values are:

Environmental value 1: Physical integrity, fluvial processes and morphology of watercourses and wetlands of a slightly to moderately disturbed aquatic habitat.

Environmental values objective 1: Maintain the physical integrity, fluvial processes and morphology of watercourses and wetlands as identified in the Queensland Wetlands Programme "Wetland mapping and classification for Queensland" (version 1.3 February 2009) and maintain their values as amenity to the local and broader community.

Environmental value 2: Hydrology of watercourses and wetlands - quantity, duration and timing of stream flows.

Environmental values objective 2: manage the potential adverse impacts from project activities on the hydrology of watercourses and wetlands (such as adverse increases or decreases in quantity, duration, rate or timing of stream flows). This includes: the maintenance of sufficient quantity of surface waters to protect existing beneficial downstream uses of those waters (including the minimisation of impacts on flooding levels and frequency both upstream and downstream of the project development area).

E5 Issues and Potential Pre-mitigation impacts

Project activities that have the potential to result in environmental impacts to hydrology and geomorphology during construction, operation and maintenance, and decommissioning and rehabilitation are:

- Exploration including seismic activities.
- Site selection for project facilities and infrastructure. This would only be an issue if any facilities were to be located below the 1 in 100 year ARI flood level or interfered with watercourses, neither of which is planned.
- Construction activities including installation of wells and construction of processing and compression facilities (FCFs, CGPFs and IPFs).
- Construction of gathering lines and medium and high pressure gas and water pipelines including watercourse crossings and the storage and discharge of hydrotesting water.
- Construction of dams.
- Construction of access roads (including watercourse crossings).
- Operational activities including emergency discharge of associated water and dust suppression (possibly using associated water).
- Decommissioning activities including stockpiling and possible removal of watercourse crossings.

Issues

- Erosion and sediment mobilisation.
- Rainfall and runoff during construction causing sediment movement into watercourses and wetlands.
- Disturbance to natural drainage channels and/or surface flow paths.
- Placement of cut and fill on or within the flood extent of major watercourses
- Disturbance of bed and banks at pipeline and track crossings.
- Clearance of riparian vegetation
- Altered hydraulic conditions.
-

Impacts

- Changes to physical form and morphology.
- Erosion of bed and banks with associated mobilisation and transport of sediment.
- Reduced bank stability from removal of riparian vegetation
- Potential off-site changes to flood flow paths and flood extents

For each project activity the significance of the potential impact on identified environmental values identified, has been determined.

E6 Avoidance, Mitigation and Management Measures

This section provides proposed avoidance, mitigation and management measures for each of the environmental values to be upheld.

Based upon geomorphic watercourse categories and wetland types and erosion risk areas as detailed in Attachment A, generic mitigation measures and measures specific to watercourse categories (river styles) are detailed. Example measures include:

- Where practical, using existing stable crossings.
- Minimising the number of channels to be crossed (where a watercourse has more than one channel or where a tributary joins).
- Crossing on straight sections of channel, at right angles to flow and not on the outside of bends.
- Timing of construction will aim to coincide with the lowest risk of rainfall and runoff (April to October). Construction outside this period will be subject to risk assessment.
- Time waterway crossings to occur during periods of no or low flow.
- Choosing bedrock where available or immediately upstream of bedrock to maximise stability.

Geomorphic features warranting special attention are also identified. Of special note is the nationally significant wetland of Lake Broadwater (within Lake Broadwater Conservation Park) (Environment Australia, 2001). The mitigation measure for the Conservation Park is for no project activities to occur within the Park. Any project activities that may occur within an 800 m buffer of the Park will be subject to a risk assessment relevant to protecting the environmental values of the Park, and development and application of appropriate mitigation measures.

The controlled and uncontrolled discharge of water should primarily be managed by avoidance. The primary avoidance measure for the discharge of associated water will be its beneficial use.

In locations where flooding has been identified as a potential risk, this will be considered as part of engineering design and Arrow's site selection process.

E7 Residual impact assessment

For this assessment, all of the mitigation measures described in Section 6 are assumed to be applied and residual impacts identified. Residual impacts are those still expected to occur after the effective application of mitigation measures. A determination has then been made of the post-mitigated magnitude of each impact in relation to each environmental value. The significance (sensitivity and magnitude) of the residual impacts on the identified environmental values has then been determined. All residual impacts are either low or negligible.

E8 Cumulative impacts

Based on the assumption that all appropriate mitigation measures are applied effectively, the only impacts that could reasonably be considered as having the potential to impact outside the project development area, at a regional level, are those related to the potential emergency discharge of associated water.

E9 Inspection and Monitoring

Inspection and monitoring will be an integral component of construction, operation and decommissioning phases of the project. The aim of the inspection and monitoring program is to track the project's progress in meeting the objectives for managing the environmental values identified above (E4).

E10 Conclusions

With the application of the avoidance, mitigation and management measures detailed in Section 6, the impacts from these project activities can be managed to reduce the residual impact of those activities to a low or negligible level. The only exception is the uncontrolled release of associated water, which if it was to occur could have a moderate impact depending upon the quantity, duration and location of the discharge. However, the risk of such an uncontrolled discharge will be managed by:

- Appropriate level of design, geotechnical investigation and construction.
- Design dams to manage a minimum 1 in 100 ARI rainfall event.
- Implementation of Dam Operating Plans, which will include regular inspections for structural integrity.
- Undertake dam failure assessment, which will include "failure to contain" and "dam break" scenario analysis.

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Acronyms and Glossary

Acronyms

ARI	Average Recurrence Interval
Arrow	Arrow Energy
BOM	Bureau of Meteorology
CSG	Coal Seam Gas
CGPF	Central Gas Processing Facility
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cumec	Cubic metre per second
DERM	Department of Environment and Resource Management
DNRW	Department of Natural Resources and Water
EM Plan	Environmental Management Plan
EPP	Environmental Protection (Water) Policy Act 2009
FCF	Field Compression Facility
GL	Gigalitre (one thousand million litres)
IPF	Integrated Production Facility
LNG	Liquefied Natural Gas
LRAM	Land Resource Assessment and Management Pty Ltd
ROW	Right of way
SGP	Surat to Gladstone Pipeline

Glossary

Fluvial geomorphology	The science that describes explains and predicts the shape and form of waterways.
Indurated	Hardened sedimentary materials, largely due to cementation by mineral matter deposited from solution in water.

1 Introduction and Project Description

1.1 Introduction

This report has been prepared as input to the preparation of the “ARROW ENERGY SURAT GAS PROJECT – Environmental Impact Statement (EIS)”. Surface water aspects of the project have been examined in two parts:

- Part A: Fluvial geomorphology and hydrology (This report).
- Part B: Water quality.

For fluvial geomorphology and hydrology this report provides:

- Legislative context and standards.
- Method of assessment, existing environment and environmental values.
- Relevant project activities and impact assessment.
- Proposed avoidance, mitigation and management measures.
- Residual impact assessment.
- Cumulative impacts.
- Inspection and monitoring.
- Conclusions.
- References.
- Attachments.

Related aspects of the EIS are covered in other reports. These include groundwater, riparian vegetation, aquatic and terrestrial ecology, visual and recreational amenity, and cultural significance. This report focuses solely upon fluvial geomorphology and hydrology.

1.2 Project Description

Project Proponent

Arrow Energy Pty Ltd (Arrow) is an integrated energy company with interests in coal seam gas field developments, pipeline infrastructure, electricity generation and a proposed liquefied natural gas (LNG) projects.

Arrow has interests in more than 65,000 km^2 of petroleum tenures, mostly within Queensland’s Surat and Bowen basins. Elsewhere in Queensland, the company has interests in the Clarence-Moreton, Coastal Tertiary, Ipswich, Styx and Nagoorin Graben basins.

Arrow's petroleum tenures are located close to Queensland’s three key energy markets; Townsville, Gladstone and Brisbane. The Moranbah Gas Project in the Bowen Basin and the Tipton West, Daandine, Kogan North and Stratheden projects in the Surat Basin near Dalby comprise Arrow’s existing coal seam gas production operations. These existing operations currently account for approximately 20% of Queensland’s overall domestic gas production.

Arrow supplies gas to the Daandine, Braemar 1 and 2, Townsville and Swanbank E power stations which participate in the National Electricity Market. With Arrow’s ownership of Braemar 2 and the commercial arrangements in place for Daandine and Townsville power stations Arrow has access to up to 600 MW of power generation capacity.

Arrow and its equity partner AGL Energy have access rights to the North Queensland Pipeline which supplies gas to Townsville from the Moranbah Gas Project. They also hold the pipeline licence for the proposed Central Queensland Gas Pipeline between Moranbah and Gladstone.

Arrow is currently proposing to develop the Arrow LNG Project, which is made up of the following aspects:

- Arrow LNG Plant – The proposed development of an LNG Plant on Curtis Island near Gladstone, and associated infrastructure, including the gas pipeline crossing of Port Curtis.
- Surat Gas Project – The upstream gas field development in the Surat Basin, subject of this assessment.
- Arrow Surat Pipeline Project – (Formerly the Surat Gladstone Pipeline), the 450 km transmission pipeline connects Arrow's Surat Basin coal seam gas developments to Gladstone.
- Bowen Gas Project – The upstream gas field development in the Bowen Basin.
- Arrow Bowen Pipeline – The transmission pipeline which connects Arrow's Bowen Basin coal seam gas developments to Gladstone.

Project Overview
Arrow proposes expansion of its coal seam gas operations in the Surat Basin through the Surat Gas Project. The need for the project arises from the growing demand for gas in the domestic market and global demand and the associated expansion of LNG export markets.

The project development area covers approximately 8,600 km^2 and is located approximately 160 km west of Brisbane in Queensland's Surat Basin. The project development area extends from the township of Wandoan in the north towards Goondiwindi in the south, in an arc adjacent to Dalby. Townships within or in close proximity to the project development area include (but are not limited to) Wandoan, Chinchilla, Kogan, Dalby, Cecil Plains, Millmerran, Miles and Goondiwindi. Project infrastructure including coal seam gas production wells and production facilities (including both water treatment and power generation facilities where applicable) will be located throughout the project development area but not in towns. Facilities supporting the petroleum development activities such as depots, stores and offices may be located in or adjacent to towns.

The conceptual Surat Gas Project design presented in the environmental impact statement (EIS) is premised upon peak gas production from Arrow's Surat Basin gas fields of approximately 1,050 TJ/d. The peak gas production comprises 970 TJ/d for LNG production (including a 10% fuel gas requirement for facility operation) and a further 80 TJ/d for supply to the domestic gas market.

A project life of 35 years has been adopted for EIS purposes. Ramp-up to peak production is estimated to take between 4 and 5 years, and is planned to commence in 2014. Following ramp-up, gas production will be sustained at approximately 1,050 TJ/d for at least 20 years, after which production is expected to decline.

Infrastructure for the project is expected to comprise:

- Approximately 7,500 production wells drilled over the life of the project at a rate of approximately 400 wells drilled per year.
- Low pressure gas gathering lines to transport gas from the production wells to production facilities.
- Medium pressure gas pipelines to transport gas between field compression facilities and central gas processing and integrated processing facilities.
- High pressure gas pipelines to transport gas from central gas processing and integrated processing facilities to the sales gas pipeline.
- Water gathering lines (located in a common trench with the gas gathering lines) to transport coal seam water from production wells to transfer, treatment and storage facilities.
- Approximately 18 production facilities across the project development area expected to comprise of 6 of each of the following:
  - Field compression facilities.
  - Central gas processing facilities.
  - Integrated processing facilities.
- A combination of gas powered electricity generation equipment that will be co-located with production facilities and/or electricity transmission infrastructure that may draw electricity from the grid (via third party substations).

Further detail regarding the function of each type of production facility is detailed below.

Field compression facilities will receive gas from production wells and are expected to provide 30 to 60 TJ/d of first stage gas compression. Compressed gas will be transported from field compression facilities in medium pressure gas pipelines to multi-stage compressors at central gas processing facilities and integrated processing facilities where the gas will be further compressed to transmission gas pipeline operating pressure and dehydrated to transmission gas pipeline quality. Coal seam water will bypass field compression facilities.

Central gas processing facilities will receive gas both directly from production wells and field compression facilities. Central gas processing facilities are expected to provide between 30 and 150 TJ/d of gas compression and dehydration. Coal seam water will bypass central gas processing facilities and be pumped to an integrated processing facility for treatment.

Integrated processing facilities will receive gas from production wells and field compression facilities. Integrated processing facilities are expected to provide between 30 and 150 TJ/d of gas compression and dehydration. Coal seam water received at integrated processing facilities is expected to be predominantly treated using reverse osmosis and then balanced to ensure that it is suitable for the intended beneficial use. Coal seam water received from the field, treated water and brine concentrate will be stored in dams adjacent to integrated processing facilities.

It is envisaged that development of the Surat Gas Project will occur in five development regions: Wandoan, Chinchilla, Dalby, Kogan/Millmerran and Goondiwindi. Development of these regions will be staged to optimise production over the life of the project.

Arrow has established a framework to guide the selection of sites for production wells and production facilities and routes for gathering lines and pipelines. The framework will also be used to select sites for associated infrastructure such as access roads and construction camps. Environmental and social constraints to development that have been identified through the EIS process coupled with the application of appropriate environmental management controls will ensure that protection of environmental values (resources) is considered in project planning. This approach will maximise the opportunity to select appropriate site locations that minimise potential environmental and social impacts.

Arrow has identified 18 areas that are nominated for potential facility development to facilitate environmental impact assessment (and modelling). These are based on circles of approximately 12 km radius that signify areas where development of production facilities could potentially occur.

Arrow intends to pursue opportunities in the selection of equipment (including reserve osmosis units, gas powered engines, electrical generators and compressors) and the design of facilities that facilitates the cost effective and efficient scaling of facilities to meet field conditions. This flexibility will enable Arrow to better match infrastructure to coal seam gas production. It will also enable Arrow to investigate the merits of using template design principles for facility development, which may in turn generate further efficiencies as the gas reserves are better understood, design is finalised, or as field development progresses.

2 Legislative Context

2.1 Relevant Legislation

Legislation relevant to all project activities is extensive and not discussed here. This section focuses solely on legislative aspects that may have relevance to geomorphology and hydrology.

Coal seam gas fields

The design, construction, operation and decommissioning of the coal seam gas fields will be undertaken progressively over the life of the project and will be in accordance with the *Petroleum and Gas (Production and Safety) Act 2004, Petroleum Act 1923,* Environmental *Protection Act 1994, Environmental Protection (Waste Management) Policy 2000* and the *Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland 1998*. Key legislation governing the management of surface water in regards to coal seam gas fields includes:

- *Water Act 2000, (Qld),* which sets out permitting and licencing requirements for taking or interfering with water and other resources. A riverine protection permit is required from the Department of Environment and Resource Management (DERM) where the development will: destroy vegetation in a watercourse; excavate in a watercourse; or place fill in a watercourse. Other measures and conditions may also be established by DERM. A development permit may be required to: take or interfere with water from a watercourse; or take or interfere with overland flow water. A notice for quarry material or development permit may be required for use of materials from a watercourse.
- *Water Supply (Safety and Reliability) Act 2008, (Qld).* A development permit may be required for construction of a referrable dam.
- *Environment Protection Act 1994, (Qld).*
- *Environmental Protection (Water) Policy 1997, (Qld)* and the *Environmental Protection Act 1994 Environmental Protection (Water) Amendment Policy (No 1) 2008*. This amendment allows for the identification of additional environmental values, with respect to water.
- *Petroleum and Gas (Production and Safety) Act, (Qld).*
- *Petroleum Act 1923, (Qld).*
- *Water Resource (Fitzroy Basin) Plan 1999.*
- *Environmental Protection Regulation 2008, the Environmental Protection (Waste Management) Policy 2000 and the Environmental Protection (Waste Management) Regulation 2000.* This legislation is also supported by the former *Environmental Protection Agency's (EPA) 2007* operational policy entitled *Management of water produced in association with petroleum activities (associated water).*
- *Sustainable Planning Act 2009* (Qld). The Sustainable Planning Act (SP Act) provides the framework for Queensland's planning development assessment system and replaces the *Integrated Planning Act 1997* (Qld). A range of approvals may be necessary under the SP Act.

Some additional considerations include:

- The Petroleum and Gas (Production and Safety) Act 2004, Petroleum Act 1923, Water Act 2000 and Water Supply (Safety and Reliability) Act 2008 establish the regime for the taking, use and on-supply of coal seam gas associated water and impose obligations for monitoring and making good any impacts the extraction of associated water has on existing bores licensed under the Water Act 2000. The Environmental Protection Act 1994 deals with the regulation of environmental impacts arising from the use or disposal of associated water.
- The Water Act 2000 also governs the management of certain works (including filling) in waterways. This may be relevant for infrastructure development (including gas transmission infrastructure).
- The Water Resources (Condamine and Balonne) Plan 2004 and the Condamine and Balonne Resource Operations Plan 2008 may be of relevance to the Surat Gas Project.
- The Condamine-Balonne catchments are part of the Murray-Darling system. The Murray-Darling Basin Agreement was signed in 1992. This is given legislative status by the Water Act 2007 (Commonwealth). The agreement was ratified by identical legislation that has been enacted by the parliaments of all the signatory governments. In terms of salinity management, The Queensland government has obligations in the implementation of the Basin Salinity Management Strategy 2001-

2015. According to the strategy, both salinity and water quality outcomes will be delivered within the framework of integrated catchment management and the National Action Plan (NAP) for Salinity and Water Quality. Meanwhile, Queensland has committed itself to accountabilities and responsibilities for implementing this strategy. This may be of relevance with respect to water quality management in parts of the project development area.

- Healthy Headwaters Feasibility study (DERM, 2011), which is analysing the opportunities for, and the risks and practicability of, using CSG water to address water sustainability and adjustment issues in the Queensland section of the Murray–Darling Basin. At the time of preparing this report no further details were available.
- The Guide to the proposed Basin Plan: Overview (Murray Darling Basin Authority, 2010). This was undergoing consultation at the time of preparing this report. Relevant components will need to be considered as the project progresses.
- There are no declared wild rivers in the project area.

Gathering lines
Key legislation applying to the construction of gas gathering lines includes the above, and in particular the Water Act 2000, which sets out permitting and licensing requirements.

Rehabilitation and decommissioning of gas gathering lines will be undertaken in accordance with relevant regulatory requirements, Australian Standards and industry guidelines including the *Petroleum and Gas (Production and Safety) Act 2004*, *Environmental Protection Act 1994*, Australian Pipeline Industry Association *Code of Environmental Compliance – onshore pipelines 1995*; and the Australian Petroleum Production and Exploration Association *Code of Environmental Practice 2008*.

2.2 Approvals Relevant to Surface Water

A list of required approvals relevant to surface water is identified in the table below.

Table 2-1. ***Required approvals relevant to surface water***

Approval Source	Responsible Authority	Relevant Aspect of Project
Environmental Protection Act 1994 (Qld) (Schedule 5). Environmental authority (section s 426, and Schedule 5 Regulation).	DERM (formerly EPA).	An environmental authority is required to carry out an environmentally relevant activity which includes petroleum activities. The environmental authority will also authorise other environmentally relevant activities to be carried out in the area of a petroleum authority granted under the *Petroleum and Gas (Production and Supply) Act, 2004* (PAG Act). If any environmentally relevant activities are undertaken on areas other than those subject to a petroleum authority, then a development approval under the SP Act may be required.
Environmental Protection and Biodiversity Conservation Act 1999 (Commonwealth). The Commonwealth Minister for the Department of Sustainability, Environment, Water, Population and Communities (DSEWPC) decided the project constitutes a controlled action under relevant controlling provisions of the EPBC Act (ss68 and 133).	Commonwealth Minister for DSEWPC	Any aspect of the project which is likely to impact on a relevant matter of national environmental significance.
Sustainable Planning Act 2009 (Qld)	Department of Infrastructure and Planning	The new planning and development laws came into effect on 18 December 2009 with the Sustainable Planning Act 2009 (Qld) replacing the Integrated Planning Act 1997 (Qld). The Project will require an approval under the SP Act for building works that are assessable under the Building Act

Approval Source	Responsible Authority	Relevant Aspect of Project
		1975 (Qld) unless the works are within the petroleum tenure and categorised as incidental activities under the PAG Act. The Project may also require, depending on final project design and construction responsibilities, plumbing and drainage works approvals if the works are not authorised under the PAG Act or are located outside of the petroleum tenure. If operational works are required for waterway barrier works a development approval may be required.
Water Act 2000 (Qld), Sustainable Planning Act 2009 (Qld). Development permit for operational work (Schedule 8, Part 1, Table 4, Item 3(a) and Table 5, Item 3(c)(i).	DERM.	A development permit may be required to: • take or interfere with water from a water course; or • take or interfere with artesian water; or • take or interfere with overland flow water or sub artesian water.
Water Act 2000 (Qld), Sustainable Planning Act 2009 (Qld). Riverine protection permit (section s 266(1)).	DERM.	A riverine protection permit is required to do any or all of the following activities in a watercourse, lake or spring: • destroy vegetation; • excavate; and • place fill.
Water Act 2000 (Qld). Allocation notice for quarry material (section s 815)	DERM.	Quarry material includes stone, gravel, sand, rock, clay, earth and soil, unless it is removed from a watercourse as waste material. The need to obtain an allocation notice will only arise where there is an intention to re-use the material that is taken from a watercourse for another purpose (e.g. building up foundations). This will occur during certain project activities.
Water Supply (Safety and Reliability) Act 2008. *Sustainable Planning Act 2009 (Qld)*. Development permit for removing quarry material from a watercourse.	DERM.	The requirement to obtain the development permit will arise where there is an intention to re-use the material that is taken from a watercourse for another purpose (e.g. building up foundations). This will occur during certain project activities.
Water Supply (Safety and Reliability) Act 2008. *Sustainable Planning Act 2009 (Qld)*. Development permit for operational work being the construction of a referrable dam as defined under the *Water Supply (Safety and Reliability) Act 2008*.	DERM.	A development permit for operational work is required for the construction of a referrable dam as defined under the *Water Supply (Safety and Reliability) Act 2008*. This only applies to dams of a certain size and does not include dams that contain hazardous waste.
Fish Habitat Management Operational Policy FHMOP 008 (revised September 2009).	DEEDI.	The construction or raising of a waterway barrier may require approvals under: • Fisheries Act 1994 • Water Act 2000 • Land Act 1994 A barrier may include any waterway crossing including tracks/roads that include culverts and or raised causeways.

3 Study Method

3.1 Overview

The assessment approach taken in this study has been the use of sensitivity and magnitude to determine the significance of impacts. The significance of impacts has been assessed by considering the sensitivity of identified environmental values and the magnitude of the impact, before and after the application of mitigation measures. This has then enabled the effectiveness of the proposed mitigation measures in reducing the predicted impact to be assessed. Further details of the method for the assessment of significance of impacts is provided in Section 3.2.

The first stage in the assessment was the identification of the existing environment and environmental values, which was undertaken through desktop/archival/baseline investigations followed by targeted field investigations. Field investigations were undertaken in October and December 2009 and targeted watercourses across the project development area with an emphasis on consideration of impacts to and from FCF's, CGPF's, IPF's, wells, gathering lines and access track crossings. The results of the baseline investigations including field investigations are presented as Attachment A.

The results of those investigations were then used to:

- Undertake an assessment of issues and potential impacts (Section 5, page 18).
- Inform and develop management and avoidance, mitigation and management measures (Section 6, page 28).
- Inform the identification of residual impacts (Section 7.1, page 34).
- Inform an assessment of cumulative impacts (Section 8, page 45).
- Provide input to the development of inspection and monitoring strategies, (Section 9, page 47).

With reference to the above process, conclusions have been drawn and are presented in Section 10, page 48.

3.2 Assessment of Significance of Impacts

The significance assessment method was developed by Coffey Environments (Coffey Environments, 2011) specifically for projects of this nature. That method as detailed below has been applied by Alluvium to the assessment of significance of impacts. The results of the application of the method are presented in Sections 5, 6, 7, 8 and 9 as identified above.

Approach

The impact assessment method has been used to determine the potential threat that project activities pose to the environmental values of the study area.

An assessment using sensitivity and magnitude to determine the significance of an impact has been adopted. In this approach, the significance of an impact has been assessed by considering the sensitivity of the environmental value and the magnitude of the impact, before and after the application of mitigation measures. This has enabled the effectiveness of the proposed mitigation measures in reducing the predicted impact to be assessed.

This approach assumes the identified impacts will occur, as this conservative method enables a more comprehensive understanding and assessment of the likely impacts of the project. It focuses attention on the mitigation and management of potential impacts through the identification and development of effective design responses and environmental controls.

The sensitivity of environmental values is determined from its susceptibility or vulnerability to threatening processes or as a consequence of its intrinsic value. The significance of impacts on these environmental values is determined by assessing the magnitude of a potential impact on the environmental values having regard to their sensitivity. (The magnitude of impacts on an environmental value is an assessment of the geographical extent, duration and severity of the impact. This is discussed in more detail later.).

The effectiveness of mitigation measures is indicated by whether the magnitude of potential impacts has been reduced and hence whether the significance of the potential impacts on the environmental value has been reduced.

Sensitivity Criteria

The sensitivity of environmental values has been determined with respect to its conservation status, intactness, uniqueness or rarity, resilience to change and replacement potential. These contributing factors are described below.

- **Conservation Status** is assigned to an environmental value by governments (including statutory and regulatory authorities) or recognised international organisations (e.g., UNESCO) through legislation, regulations and international conventions.

  The nationally significant wetland of Lake Broadwater (within Lake Broadwater Conservation Park) (Environment Australia, 2001) is within the project development area in the Condamine River catchment. There are eight other nationally listed wetlands in the Condamine catchment downstream from the project area. One of these is Narran Lakes, which is a RAMSAR listed wetland on the Narran River, a tributary of the Ballone River and is located in the central north of New South Wales, between Brewarrina and Walget, approximately 340 kilometres southwest of the southernmost point of the project development area.
- **Intactness** (an assessment of how intact the environmental values are). It is a measure (with respect to its characteristics or properties) of its existing condition, particularly its representativeness. Where it was practical to assess intactness or condition, separate categories of watercourse have been mapped. Examples include “chain of ponds”, “chain of ponds channelised” and “chain of ponds incising”, which identifies level of intactness or level of disturbance.
- **Uniqueness or rarity** of environmental values (an assessment of its occurrence, abundance and distribution within and beyond the study area. The extents, in length, have been identified for each geomorphic watercourse type within the study area. An example is the “chain of ponds” geomorphic watercourse type, which is often a rare feature in intact form (at a regional or national scale) since European settlement and land clearance, many have become continuously channelised or trending that way.
- **Resilience to change** of environmental values (an assessment of its ability to cope with change including that posed by threatening processes). This factor is an assessment of the ability of environmental values to adapt to change without adversely affecting intactness, uniqueness or rarity. For each geomorphic watercourse type an assessment of resilience to change is identified. An example is a “confined” watercourse, a robust stream form with a low sensitivity to disturbance.
- **Replacement potential** of environmental values (an assessment of the potential for a representative or equivalent example of an environmental value to be found to replace any losses determines its replacement potential). The extents, in length, have been identified for each geomorphic watercourse type within the Project Development area, which can be used as a good indication of replacement potential.

Details of the watercourse geomorphic types discussed above are provided in Attachments A and C.

The criteria for determining high, moderate and low sensitivity are set out below.

<u>High sensitivity</u>

- Listed on a recognised or statutory state, national or international register as being of conservation significance.
- The environmental value is intact and retains its intrinsic value.
- It is unique to the environment in which it occurs. It is isolated to the affected system/area which is poorly represented in the region, territory, country or the world.
- It is fragile and predominantly unaffected by threatening processes. Small changes would lead to substantial changes to the prescribed value.
- It is not widely distributed throughout the system/area and consequently would be difficult or impossible to replace.

Moderate sensitivity

- May be nominated for listing on recognised or statutory registers.
- The environmental value is in a moderate to good condition despite it being exposed to threatening processes. It retains many of its intrinsic characteristics and structural elements.
- It is relatively well represented in the systems/areas in which it occurs but its abundance and distribution are limited by threatening processes.
- Threatening processes have reduced its resilience to change. Consequently, changes resulting from project activities may lead to degradation of the prescribed value.
- Replacement of unavoidable losses is possible due to its abundance and distribution.

Low sensitivity

- The environmental value is in a poor to moderate condition as a result of threatening processes, which have degraded its intrinsic value.
- It is not unique or rare and numerous representative examples exist throughout the system/area.
- It is abundant and widely distributed throughout the host systems/areas.
- There is no detectable response to change or change does not result in further degradation of the environmental value.
- The abundance and wide distribution of the environmental value ensures replacement of unavoidable losses is assured.

Magnitude Criteria

The magnitude of impacts on environmental values is an assessment of the geographical extent, duration and severity of the impact. These criteria are described below.

- **Geographical extent** is an assessment of the spatial extent of the impact where the extent is defined as site, local, regional or widespread (meaning state-wide or national or international).
- **Duration** is the timescale of the effect i.e., if it is short, medium or long term.
- **Severity** is an assessment of the scale or degree of change from the existing condition, as a result of the impact. This could be positive or negative. The criteria for determining high, moderate and low impacts are set out below.

High magnitude impact

A high magnitude impact is an impact that is widespread, long lasting and results in substantial and possibly irreversible change to the environmental value. Avoidance through appropriate design responses is required to address the impact.

Moderate magnitude impact

A moderate magnitude impact is an impact that extends beyond the area of disturbance to the surrounding area but is contained within the region where the project is being developed. The impacts are short term and result in changes that can be ameliorated with specific environmental management controls.

Low magnitude impact

A localised impact that is temporary or short term and either unlikely to be detectable or could be effectively mitigated through standard environmental management controls.

Assessment of Significance of Impacts

Table 3-1 shows how; using the criteria described above, the significance of impacts has been determined having regard to the sensitivity of the environmental value and the magnitude of the expected change.

Table 3-1. ***Matrix of significance***

	Sensitivity of Environmental Values		
Magnitude of impact	**High**	**Moderate**	**Low**
High	**Major**	**High**	**Moderate**
Moderate	**High**	**Moderate**	**Low**
Low	**Moderate**	**Low**	**Negligible**

A description of the significance of an impact derived using Table 3-1 is set out below.

Major impact
A major impact occurs when impacts will potentially cause irreversible or widespread harm to an environmental value that is irreplaceable because of its uniqueness or rarity. Avoidance through appropriate design responses is the only effective mitigation.

High impact
A high impact occurs when the proposed activities are likely to exacerbate threatening processes affecting the intrinsic characteristics and structural elements of an environmental value. While replacement of unavoidable losses is possible, avoidance through appropriate design responses is preferred to preserve its intactness or conservation status.

Moderate impact
A moderate impact occurs where, although reasonably resilient to change, the environmental value would be further degraded due to the scale of the impacts or its susceptibility to further change. The abundance of the environmental value ensures it is adequately represented in the region, and that replacement, if required, is achievable.

Low impact
A low impact occurs where an environmental value is of local importance and temporary and transient changes will not adversely affect its viability provided standard environmental controls are implemented.

Negligible impact
A degraded (low sensitivity) environmental value exposed to minor changes (low magnitude impact) will not result in any noticeable change in its intrinsic value and hence the proposed activities will have negligible impact. This typically occurs where the activities occur in industrial or highly disturbed areas.

Residual Impact
Residual impacts are those potential impacts remaining after the application of mitigation measures and design response. The extent to which potential impacts have been reduced has been determined by undertaking an assessment of the significance of the residual impacts. This is a measure of the effectiveness of the design response and/or mitigation measures in reducing the magnitude of the potential impacts, as the sensitivity of the environmental value does not change.

4 Existing environment

4.1 Existing Environment Summary

The identification of the existing environment and environmental values was conducted via desktop / archival / baseline investigations followed by targeted field investigations.

The results of the baseline investigations including field investigations are presented as Appendix A with the extent of the project development area shown in Figure A2-1, Page 55 and a summary of the findings is outlined below.

The climate of the project development area can be described as subtropical to semi-arid characterized by a wet summer and lower winter rainfall. Typically, rainfall and runoff occurs in late spring, summer and autumn with flooding most likely to occur between January and February.

The project development area lies within parts of the catchments of:

- Dawson River (Fitzroy River Basin), flowing north before joining the Fitzroy River and flowing east to the Great Barrier Reef lagoon.
- Condamine River (Murray Darling Basin), flowing north west through the project development area before flowing east and joining the Balonne River.
- Macintyre and Weir Rivers (Murray Darling Basin), with tributaries flowing generally south-west through the project development area.
- Moonie River (Murray Darling Basin), flowing south-west.
- Macintyre Brook (Murray Darling Basin), with the tributaries within the project area flowing south to join MacIntyre Brook, which flows south-west.

The project development area has an extensive network of watercourses and wetlands that are largely ephemeral. The hydrology of the surface waters flowing through the project development area has been extensively modified by land clearance, dams, weirs and pumping infrastructure, constructed primarily for irrigation and potable water use. The extent of these modifications varies between catchments. Overland flow characteristics will vary across the project area, with vast areas of very low gradient floodplains or terrace surfaces, many of which are modified for agriculture that will generate little runoff except when saturated and/or under intense rainfall. When runoff is generated vast areas may be inundated. The moderate relief ranges with some steeper slopes have denser watercourse networks limiting overland flow extents.

The project development area has a variety of wetlands and geomorphic stream reach types, which provide geomorphic diversity and contribute to habitat diversity. These geomorphic reach types have been categorised by "River Styles®" (Brierley and Fryirs, 2005), a nationally recognised method that has been applied to provide a values and threats approach to geomorphic assessments. This categorisation is provided in Appendix A, Section 5.2 and Appendix C.

The nationally significant wetland of Lake Broadwater (within Lake Broadwater Conservation Park) is located within the project development area in the Condamine River catchment. The project will not undertake any project activities within Lake Broadwater Conservation Park. Any project activities that may occur within an 800 m buffer of the Park will be subject to a risk assessment relevant to protecting the environmental values of the Park, and development and application of appropriate mitigation measures. Therefore no impacts are expected. Eight additional nationally listed wetlands are situated in the Condamine River catchment, downstream (i.e., outside) of the project development area. One of these is Narran Lakes, which is a RAMSAR listed wetland on the Narran River, a tributary of the Ballone River and is located in the central north of New South Wales, between Brewarrina and Walget, approximately 340 kilometres southwest of the southernmost point of the project development area.

Overall, there are three types of wetland riverine, lacaustrine and palustrine (for details of each of these see Attachment A, section 5.2). Of these, lacaustrine and palaustrine wetlands will be avoided by the project and no impacts are expected. Only riverine wetlands, which are part of the mapped watercourses are considered further. Similarly, the project will avoid dams and no impacts are expected.

A flow chart depicting the geomorphic characters (river styles), including wetlands and other waterbodies, within the project development area is provided in the figure below with detailed information about each river style provided in Attachments A and C.

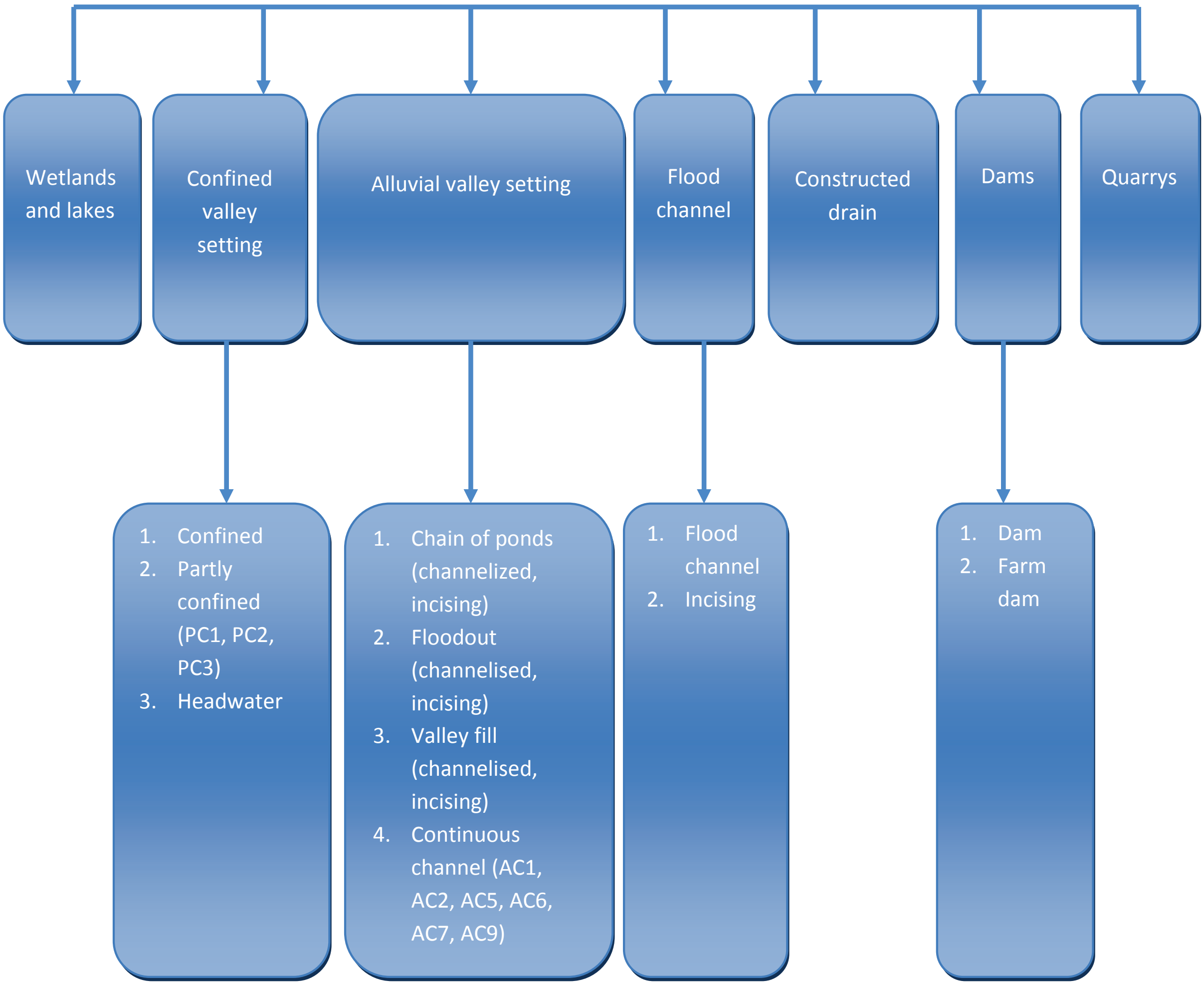

Figure 4-1. ***River styles, including wetlands and other waterbodies within the project development area***

Present and potential water uses for the catchments in the Surat Gas Project development area include agricultural, pastoral, urban, mining and recreational use. There is also the potential for domestic uses for water within and downstream of the development area.

In common with the watercourses in other catchments within Queensland and elsewhere in Australia, the 4,869 km of watercourses mapped in the project development area, exhibit a range of conditions from near pristine to highly disturbed. Much of the riparian zones have been altered since European settlement, primarily for agricultural use (clearing for cropping and grazing) but also for urban development and mining. Disturbance of watercourses has resulted in bed and bank erosion to varying levels throughout the project development area.

4.2 Environmental Values

Specific environmental values for watercourses in the project development area are not defined within the Environmental Protection (Water) Policy Act 2009 (EPP). Environmental values have therefore been developed from the desktop / archival / baseline investigations and field investigation in conjunction with consideration of ANZECC 2000, the National Water Quality Management Strategy (NWQMS), the DERM guideline:

Establishing Draft Environmental Values and Water Quality Objectives and the Queensland Water Quality Guidelines 2009.

All of the following environmental values have in common the overarching primary value of sustainable function and use of ecosystems, consistent with the legislation, studies and plans identified in Section 2.1, page 4. Sustainable function and use of ecosystems is the primary environmental value of watercourses, wetlands and their catchments. Attributes that define the primary environmental value, are themselves values that collectively describe the intrinsic characteristics and properties of the watercourse or wetland and the associated catchment. The following attributes define the environmental values of surface water assets and are consistent with the above Plans.

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

Information about the attributes that define the primary environmental values is set out in the preceding sections, particularly categorisation of stream geomorphology and hydrology (method described in Section 3.2).

There are no declared wild rivers in the project area.

The environmental values of primary and secondary recreation use, and physical and hydrologic character contributing to the cultural and spiritual values are identified here because any change to waterways or wetlands through project activities could have an impact to these values. However:

- For *primary and secondary recreation use*, potential impacts are through disturbance of watercourses at crossings and other infrastructure and siting of facilities and infrastructure. A visual and landscape impact assessment has been conducted as part of this EIS. All other physical and hydrologic impacts are considered as part of environmental values 1 and 2.
- For *physical and hydrologic character contributing to the cultural and spiritual values*, two reports have been prepared to address both Indigenous and non-Indigenous cultural heritage aspects of the potential impacts from project activities.

The impacts and mitigation measures associated with the primary and secondary recreation use and the cultural and spiritual environmental values are reflected in the above mentioned EIS supporting studies and are therefore not identified in this report. As such, this report considers two overarching environmental values for each of the various types of watercoures and wetlands within the project development area as described below.

Environmental value 1: Physical integrity, fluvial processes, form and morphology of watercourses and wetlands.

Environmental value 1 objective: Maintain the physical integrity, fluvial processes, form and morphology of watercourses and wetlands as identified in the Queensland Wetlands Programme "Wetland mapping and classification for Queensland" (version 1.3 February 2009).

Environmental value 2: Hydrology of watercourses and wetlands in the catchment - quantity, duration and timing of stream flows.

Environmental value 2objective: Manage adverse impacts that may result from project activities on the hydrology of watercourses and wetlands (such as adverse increases or decreases in quantity, duration, rate or timing of stream flows). This includes: the maintenance of sufficient quantity of surface waters to protect existing beneficial downstream uses of those waters (including the minimisation of impacts on flooding levels and frequency both upstream and downstream of the project development area.

4.3 Sensitivity of Environmental Values

Given that the exact locations for the various project activities are yet to be determined, an assessment was conducted to determine the sensitivity (as defined in Section 3.2) for the environmental values associated with each of the river styles (summarised in Figure 4-1), found within the project development area. Table 4-1, page 15, summarises the environmental values and associated sensitivity for each of the river styles.

The “lake” river style is the only category in Table 4-1 (by way of Lake Broadwater), to be assigned a conservation status as part of the sensitivity analysis.

The sensitivity of the Murray Darling Basin and Fitzroy Basins and their associated catchments, identified in Section 4.1, are not assessed here but are rather considered in terms of potential cumulative impacts outside the project development area and as such are considered in Section 8 – Cumulative Impacts.

Table 4-1. ***Generic sensitivity of environmental values (EVs) for river styles identified within the project development area***

Valley-setting and River Style	EVs	Intactness	Uniqueness or rarity	Resilience to change	Replacement potential	Sensitivity
Lake The nationally significant wetland of Lake Broadwater (within Lake Broadwater Conservation Park) (Environment Australia, 2001).	1 & 2	Substantially intact.	Unique in the Project Development Area.	Could be resilient to some change	Could not be replaced within the region.	High
Confined valley setting **Confined -** occasional floodplain pockets, frequent bedrock controls.	1	Intact to slightly disturbed.	Not unique or rare in area.	Robust stream form with low sensitivity to disturbance.	Other similar types in the area and region.	Low
Confined valley setting **PC1 - Partly confined bedrock controlled** valley and channel with planform controlled discontinuous floodplain.	1	Intact to slightly disturbed.	Not unique or rare in area.	Robust stream form with low sensitivity to disturbance.	Other similar types in the area and region.	Low
Confined valley setting **PC2 - Partly confined low sinuosity** valley and channel with planform controlled discontinuous floodplain.	1	Intact to slightly disturbed.	Not unique or rare in area.	Robust stream form with low sensitivity to disturbance but has some features that could be susceptible to disturbance.	Other similar types in the area and region.	Low
Confined valley setting **PC3 - Partly confined meandering** channel with planform controlled discontinuous floodplain.	1	Intact to slightly disturbed.	Not unique or rare in area.	Potential for disturbance of alluvial features. May be subject to more rapid rates of erosion on the outside of bends than PC2 watercourses.	Other similar types in the area and region.	Moderate
Confined valley setting **Headwater –** thin alluvial/colluvial deposits in narrow valley floor that is near contiguous with hillslopes, much exposed bedrock/indurated Tertiary sediments.	1	Intact to slightly disturbed.	Not unique or rare in area.	Usually a first order stream in the upper catchment. Generally steeper gradient and stable. Limited potential impacts.	Other similar types in the area and region.	Low

Valley-setting and River Style	EVs	Intactness	Uniqueness or rarity	Resilience to change	Replacement potential	Sensitivity
Alluvial or partly confined valley setting (Discontinuous/absent channel) **AD1 - Chain of ponds**, no continuous defined channel occasional ponds. Two sub categories are mapped **Chain of ponds - channelized** (which is a former chain of ponds that has been deliberately channelized for drainage purposes) and **Chain of ponds - incising** (which is an actively eroding chain of ponds becoming continuously channelised).	1	Intact to slightly disturbed.	Not unique or rare in area.	Can be subject to rapid erosion if disturbed. Often a rare feature in intact form since European settlement and land clearance, many have become continuously channelised or trending that way.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Discontinuous/absent channel) **AD2 - Floodout**, valley width expands to the point where another form of watercourse in the upstream reach floods out**.** There are two sub-categories identified: **Floodout - channelised** (an artificially created channel to aid drainage) and; **Floodout - incising** (incising to become a continuous channel).	1	Intact to slightly disturbed.	Not unique or rare in area.	Is likely to be less susceptible to erosion than a chain of ponds but still vulnerable if disturbed. Many have been channelised into roadside or agricultural drains and many are not mapped watercourses.	Other similar types in the area and region.	Moderate
Alluvial or partly confined valley setting (no channel when intact) **AD4 - Valley fill**, alluvial and colluvial sediments across valley floor with no channel. Two sub-categories are identified: **Valley fill – incising** (where a formerly intact valley fill is undergoing incision usually due to disturbance by land clearance or construction activities.); and **valley fill – channelized** (where a valley fill has been deliberately channelized for drainage purposes.	1	Intact to moderately disturbed.	Not unique or rare in area.	Many valley fills are already incised or incising, developing continuous channels. These watercourse types store large amounts of sediment and play a critical role in sediment and water flux in the landscape. Can be subject to rapid erosion if disturbed and/or flow is concentrated (such as occurs with pipes through roads). Many valley fills are not mapped.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Continuous channel) **AC1 - Low-moderate sinuosity fine grained**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate

Valley-setting and River Style	EVs	Intactness	Uniqueness or rarity	Resilience to change	Replacement potential	Sensitivity
Alluvial valley setting (Continuous channel) **AC2 - Low-moderate sinuosity gravel bed**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Continuous channel) **AC4 - Meandering fine grained**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Continuous channel) **AC5 - Meandering sand bed**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Continuous channel) **AC6 - Meandering gravel bed**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Continuous channel) **AC7 - Multiple channel, sand belt**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Alluvial valley setting (Continuous channel) **AC9 - Anabranching fine grained**	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Flood channel sub-categories: **Flood channel - incising** (an actively eroding channel	1	Intact to moderately disturbed.	Not unique or rare in area.	Susceptible to erosion if disturbed and not adequately treated for erosion protection.	Other similar types in the area and region.	Moderate
Constructed drain	1	N/A	N/A	Limited to localised erosion if disturbed and not adequately treated for erosion protection.	N/A	Low
Quarry	1	N/A	N/A	Limited.	N/A	Low

5 Issues and Potential Impacts

5.1 Project Activities

Project activities that have the potential to result in impacts to the environmental values of watercourses and wetlands are listed below:

- Exploration including seismic activities.
- Site selection for project facilities and infrastructure. This would only be an issue if any facilities were to be located below the 1 in 100 year ARI flood level or interfered with watercourses, neither of which is planned.
- Construction activities including installation of wells and construction of processing and compression facilities (FCFs, CGPFs and IPFs).
- Construction of gathering lines and medium and high pressure gas and water pipelines including watercourse crossings and the storage and discharge of hydrotesting water.
- Construction of dams.
- Construction of access roads (including watercourse crossings).
- Operational activities including emergency discharge and storage of associated water and dust suppression (possibly using associated water).
- Decommissioning activities including stockpiling and possible removal of gas and water pipelines (possibly at watercourse crossings).

5.2 Potential Impacts

Potential impacts from project activities during each phase of the project (construction, operation and maintenance and decommissioning) are described in Table 5-1 below.

Table 5-1. ***Potential issues and subsequent impacts by project phase***

Project activity	Potential issues	Potential impacts
Construction including installation of wells, gathering lines and construction of processing and compression facilities		
Clear and grade	1. Erosion and sediment mobilisation.	1. Reduced bank stability from removal of riparian vegetation.
	2. Rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	2. Changes to physical form and morphology.
Placement of project infrastructure	1. Disturbance to natural drainage channels and/or surface flow paths.	1. Changes to hydrology (direction and discharge points of surface flow paths). 2. Changes to physical form and morphology.
Seismic surveys	1. Ground disturbance resulting in erosion.	1. Reduced bank stability.
Stockpiling and earth moving	1. Sediment movement into watercourses and wetlands.	1. Changes to physical form and morphology.
	2. Erosion.	2. Reduced bank stability.
	3. Placement of cut and fill within the flood extent of major watercourses; erosion.	3. Changes to physical form and morphology.
Watercourse crossings	1. Bed and bank erosion with associated mobilisation and transport of sediment.	1. Changes to physical form and morphology.
	2. Blockages to streams (open-cut crossings).	2. Changes to hydrology - altered timing and duration of flow.
	3. Clearance of riparian vegetation.	3. Reduced bank stability.
Installation of pipelines and production wells	1. Drill mud spillage and seepage resulting in sediment discharge to watercourses.	1. Changes to physical form and morphology.
	2. Wells possibly being located within the flooding extent of major waterways.	2. Changes to hydrology - altered flow regime.
	3. Discharge of hydrotest water.	3. Changes to physical form and morphology - erosion and generation of sediment.
Works in proximity to watercourses and wetlands.	1. Rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	1. Changes to physical form and morphology.
Operation and maintenance including compression and processing facilities, gathering lines and production wells		
Operation of facilities	1. Erosion and generation of sediment from rainfall and runoff.	1. Reduced bank stability.

Project activity	Potential issues	Potential impacts
	2. Changed surface flow paths.	2. Changes to hydrology. Altered hydraulic conditions.
	3. Flooding; alteration of pre-construction hydraulic conditions.	3. Altered hydraulic conditions. Potential off-site changes to flood flow paths and flood extents.
Use and maintenance of access tracks.	1. Erosion and generation of sediment from rainfall and runoff.	1. Changes to physical form and morphology.
	2. Scour and generation of sediment at watercourse crossings.	2. Changes to physical form and morphology.
Emergency discharge of associated water	1. Erosion and generation of sediment.	1. Changes to physical form and morphology.
	2. Changed hydrology for duration of discharge.	2. Changes to hydrology.
Decommissioning including compression and processing facilities, construction camps, capping of production wells, removal of gathering lines		
Stockpiling and earth moving	1. Sediment movement into watercourses and wetlands.	1. Changes to physical form and morphology.
	2. Erosion.	2. Changes to physical form and morphology. Reduced bank stability where banks directly disturbed.
	3. Placement of cut and fill on flood plains or the flood extent of major watercourses; erosion	3. Changes to physical form and morphology, Possible alteration of hydraulic conditions in flood flows.
Watercourse crossings	1. Bed deepening and bank erosion.	1. Changes to physical form and morphology.
	2. Increased sediment.	2. Changes to physical form and morphology.
	3. Blockages to streams (open-cut crossings).	3. Changes to hydrology.
	4. Clearance of riparian vegetation.	4. Changes to physical form and morphology. Reduced bank stability leading to erosion and sediment transport.
Works in proximity to watercourses and wetlands.	1. Rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	1. Changes to physical form and morphology.

5.3 Magnitude and Significance of Potential Impacts

In this section the magnitude of the potential impacts is determined based on the geographic extent, duration and severity of the potential impact.

The significance of a potential impact on the identified environmental values for each category of river style, has then been determined with reference to the significant assessment matrix Table 3-1, page 10. The significance has been identified as negligible, low, moderate or high.

A number of river styles were determined to have a low sensitivity value, which indicates their low vulnerability to change. These are confined valley setting (confined, PC1 and PC2) and headwater as well as quarries and constructed drains. Table 5-2, page 22 provides a summary of the significance assessment for these low sensitivity watercourses.

Table 5-2. *Significance of potential impacts for low sensitivity environmental values*

Project activity	Potential impacts	Environmental Values affected	Magnitude Criteria	Magnitude	Significance
Construction including installation of wells, gathering lines and construction of processing and compression facilities					
Clear and grade	Reduced bank stability from removal of riparian vegetation resulting in erosion and sediment mobilisation.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
	Changes to physical form and morphology of watercourses following rainfall and runoff during construction also causing sediment movement into watercourses and wetlands.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
Placement of project infrastructure	Changes to hydrology, physical form and morphology (direction and discharge points of surface flow paths) from disturbance to natural drainage channels and/or surface flow paths.	1 & 2	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands .	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
	Reduced bank stability from erosion.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
	Changes to physical integrity and morphology from placement of cut and fill within the flood extent of major watercourses resulting in erosion.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
Watercourse crossings	Changes to physical form and morphology from bed and bank erosion with associated mobilisation and transport of sediment. .	1	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Low
	Changes to hydrology - altered timing and duration of flow form blockages to streams (open-cut crossings).	2	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Low
	Reduced bank stability from clearance of riparian vegetation.	1	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Low
Installation of pipelines and production wells	Changes to physical form and morphology from drill mud spillage and seepage resulting in sediment discharge to watercourses.	1	Geographical extent: local Duration: short-term Severity: low	Low	Negligible

Project activity	Potential impacts	Environmental Values affected	Magnitude Criteria	Magnitude	Significance
	Changes to hydrology - altered flow regime. Wells possibly being located within the flooding extent of major waterways.	2	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
	Changes to physical form and morphology - erosion and generation of sediment from discharge of hydrotest water.	1	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form from rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	1 & 2	Geographical extent: local Duration: construction Severity: moderate	Moderate	Low
Operation and maintenance of compression and processing facilities, gathering lines and production wells					
Operation of facilities	Reduced bank stability from erosion and generation of sediment from rainfall and runoff.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Low
	Changes to hydrology. Altered hydraulic conditions from changed surface flow paths..	2	Geographical extent: local Duration: operation Severity: moderate	Moderate	Low
	Altered hydraulic conditions. Potential off-site changes to flood flow paths and flood extents due to alteration of pre-construction hydraulic conditions.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Low
Use and maintenance of access tracks.	Changes to physical form and morphology due to erosion and generation of sediment from rainfall and runoff.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Low
	Changes to physical form and morphology from scour and generation of sediment at watercourse crossings.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Low
Emergency release of associated water	Changes to physical form and morphology from erosion and generation of sediment.	1	Geographical extent: local to out of project development area Duration: operation Severity: moderate	Moderate	Moderate#
	Changes to hydrology from flows for duration of discharge.	2	Geographical extent: local to out of project development area Duration: operation Severity: moderate	Moderate	Moderate#
Decommissioning including: compression and processing facilities, construction camps, capping of production wells, removal of gathering lines					
Stockpiling and	Changes to physical form and morphology from	1	Geographical extent: local	Low	Negligible

Project activity	Potential impacts	Environmental Values affected	Magnitude Criteria	Magnitude	Significance
earth moving	sediment movement into watercourses and wetlands.		Duration: short-term Severity: low		
	Changes to physical form and morphology. Reduced bank stability where banks directly disturbed resulting in erosion and generation sediment.	1	Geographical extent: local Duration: short-term Severity: moderate	Low	Negligible
	Changes to physical form and morphology, Possible alteration of hydraulic conditions in flood flows caused by placement of cut and fill on flood plains or the flood extent of major watercourses; erosion.	1 & 2	Geographical extent: local Duration: short-term Severity: moderate	Low	Negligible
Watercourse crossings	Changes to physical form and morphology from bed deepening and bank erosion.	1	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Low
	Changes to physical form and morphology from increased sediment.	1	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Low
	Changes to hydrology from blockages to streams (open-cut crossings).	2	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Low
	Changes to physical form and morphology. Reduced bank stability leading to erosion and sediment transport from clearance of riparian vegetation.	1	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Low
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form and morphology from rainfall and runoff during construction causing sediment movement into watercourses and wetlands	1	Geographical extent: local Duration: short-term Severity: moderate	Low	Negligible

 # Moderate category assigned due to possibility that emergency discharge of associated water could continue from low sensitivity watercourses downstream to moderate sensitivity watercourses.

The environmental values of the river styles within the alluvial valley setting were all determined to have a moderate sensitivity. This was also the case for one of the confined valley setting river styles (PC3) as well as the flood channel setting. Table 5-3, page 22 provides a summary of the significance assessment for these moderate sensitivity watercourses.

Table 5-3. ***Significance of potential impacts for moderate sensitivity environmental values***

Project activity	Potential impacts	Environmental Values affected	Magnitude Criteria	Magnitude	Significance
Construction including installation of wells, gathering lines and construction of processing and compression facilities					
Clear and grade	Reduced bank stability from removal of riparian vegetation resulting in erosion and sediment mobilisation.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
	Changes to physical form and morphology of watercourses following rainfall and runoff during construction also causing sediment movement into watercourses and wetlands.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
Placement of project infrastructure	Changes to hydrology, physical form and morphology (direction and discharge points of surface flow paths) from disturbance to natural drainage channels and/or surface flow paths.	1 & 2	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
Seismic surveys	Reduced bank stability from ground disturbance activities resulting in erosion.	1	Geographical extent: local Duration: exploration Severity: low	Low	Low
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands .	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
	Reduced bank stability from erosion.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
	Changes to physical integrity and morphology from placement of cut and fill within the flood extent of major watercourses resulting in erosion.	1	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
Watercourse crossings	Changes to physical form and morphology from bed and bank erosion with associated mobilisation and transport of sediment. .	1	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Moderate
	Changes to hydrology - altered timing and duration of flow form blockages to streams (open-cut crossings).	2	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Moderate
	Reduced bank stability from clearance of riparian vegetation.	1	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Moderate

Project activity	Potential impacts	Environmental Values affected	Magnitude Criteria	Magnitude	Significance
Installation of pipelines and production wells	Changes to physical form and morphology from drill mud spillage and seepage resulting in sediment discharge to watercourses.	1	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Changes to hydrology - altered flow regime. Wells possibly being located within the flooding extent of major waterways.	2	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Changes to physical form and morphology - erosion and generation of sediment from discharge of hydrotest water.	1	Geographical extent: local Duration: short-term Severity: moderate	Moderate	Moderate
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form from rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	1 & 2	Geographical extent: local Duration: construction Severity: moderate	Moderate	Moderate
Operation and maintenance of compression and processing facilities, gathering lines and production wells					
Operation of facilities	Reduced bank stability from erosion and generation of sediment from rainfall and runoff.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Moderate
	Changes to hydrology. Altered hydraulic conditions from changed surface flow paths.	2	Geographical extent: local Duration: operation Severity: moderate	Moderate	Moderate
	Altered hydraulic conditions. Potential off-site changes to flood flow paths and flood extents due to alteration of pre-construction hydraulic conditions.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Moderate
Use and maintenance of access tracks.	Changes to physical form and morphology due to erosion and generation of sediment from rainfall and runoff.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Moderate
	Changes to physical form and morphology from scour and generation of sediment at watercourse crossings.	1	Geographical extent: local Duration: operation Severity: moderate	Moderate	Moderate
Emergency release of associated water	Changes to physical form and morphology from erosion and generation of sediment.	1	Geographical extent: local to out of project development area Duration: operation Severity: moderate	Moderate	Moderate
	Changes to hydrology from flows for duration of discharge.	2	Geographical extent: local to out of project development area Duration: operation	Moderate	Moderate

Project activity	Potential impacts	Environmental Values affected	Magnitude Criteria	Magnitude	Significance
			Severity: moderate		
Decommissioning including: compression and processing facilities, construction camps, capping of production wells, removal of gathering lines					
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands.	1	Geographical extent: local Duration: short-term Severity: moderate	Low	Low
	Changes to physical form and morphology. Reduced bank stability where banks directly disturbed resulting in erosion and generation sediment.	1	Geographical extent: local Duration: short-term Severity: moderate	Low	Low
	Changes to physical form and morphology, Possible alteration of hydraulic conditions in flood flows caused by placement of cut and fill on flood plains or the flood extent of major watercourses; erosion.	1 & 2	Geographical extent: local Duration: short-term Severity: moderate	Low	Low
Watercourse crossings	Changes to physical form and morphology from bed deepening and bank erosion.	1	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Moderate
	Changes to physical form and morphology from increased sediment.	1	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Moderate
	Changes to hydrology from blockages to streams (open-cut crossings).	2	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Moderate
	Changes to physical form and morphology. Reduced bank stability leading to erosion and sediment transport from clearance of riparian vegetation.	1	Geographical extent: local Duration: medium-term Severity: moderate	Moderate	Moderate
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form and morphology from rainfall and runoff during construction causing sediment movement into watercourses and wetlands	1	Geographical extent: local Duration: short-term Severity: moderate	Low	Low

6 Avoidance, Mitigation and Management Measures

This section provides proposed avoidance, mitigation and management measures to address the potential impacts that may result from project activities and to meet objectives 1 and 2 (as per Section 4.2) for preservation of each of the environmental values.

Based upon the geomorphic watercourse categories and wetland types and erosion risk areas detailed in Attachment A, the following standard mitigation measures are recommended.

6.1 Site Selection and Planning Considerations

The significance of potential impacts that result from placement of project facilities and infrastructure will be influenced by:

- Adequate consideration of stream processes during site selection, including (but not limited to) the following:
  - Potential for channelisation of alluvial discontinuous reaches if inappropriately disturbed.
  - Recognising watercourses with the potential to avulse.
  - Allowing for possible deepening episodes.
  - Predicting mobile bed phenomena.
- In locations where flooding has been identified as a potential risk, this will be considered as part of engineering design and Arrow's site selection process.
- Design water interception and storage facilities with a minimum for a 1:100 year storm event and to manage an average three month wet season to reduce the risk of failure.
- Locate project infrastructure with consideration of downstream values.

In planning for the most appropriate watercourse crossing locations, the following aspects of the surface water assets should be considered.

1. Landscape Setting

- Hillslope – gullies and valleys where streams are often substantially bedrock controlled. Where bedrock controls exist they provide an opportunity to manage erosion risk by locating pipeline and track crossings at stable points. Where not bedrock controlled, hillslopes can be a point of rapid incision (erosion and generation of sediment) in moderate sensitivity watercourses, particularly chain of ponds and floodouts.

- Plain – broad alluvial plain generally in lower catchment or trunk stream reaches. Usually larger and often less robust watercourse form requiring site specific assessment and mitigation measures if planned to be disturbed.

2. Confinement

- Confined - by bedrock or valley margins, limited alluvial horizontal channel boundaries. Robust watercourse form with limited risk of significant erosion.

- Partly Confined - by bedrock or valley margins but with more extensive alluvial horizontal channel boundaries and some freedom to move in the valley floor. Less robust than confined watercourses but still provides good opportunity for pipeline and track crossing with limited risk of erosion.

- Alluvial - less than 10% of horizontal channel boundaries controlled by bedrock or valley margins. Greater risk of erosion in these watercourse types and are likely to require greater level of site specific assessment and mitigation measures if planned to be disturbed.

Site selection and planning will also be aided by the geomorphic categorisation and identification of the inherent risks associated with each category undertaken as part of the desktop and targeted field assessments for this report and as detailed in Appendix A, Section 5. This includes ArcView format GIS mapping of watercourses and wetlands, which will be used by Arrow during the site selection and planning stages of the project to aid in identifying suitable locations for project infrastructure.

Watercourses are not often static features in the landscape and as such may move in a manner, be it gradually or episodically, which threatens commercial infrastructure. When site selection is undertaken, factors additional to the geomorphic categorisation of a watercourse should be considered, such as prevailing sediment supply and transport conditions, riparian and catchment vegetation coverage, the presence or absence of fire regimes, grazing, impoundments, other infrastructure influences on flows, etc. Such consideration will assist in locating project facilities and infrastructure at a site with a low potential for threatening morphological processes.

Selection of watercourse crossing points should consider the following:

- Where practical, use existing stable crossings.
- Minimising the number of channels to be crossed (where a watercourse has more than one channel or where a tributary joins).
- Crossing on straight sections of channel and not on the outside of bends.
- Minimising the disturbance of bed banks and riparian vegetation.
- Avoiding permanent pools.
- Choosing bedrock where available or immediately upstream of bedrock to maximise stability.
- For scour protection, where bedrock is not present at the surface and where feasible, consider placing pipeline crossings in consolidated material or bedrock below the level of unconsolidated sands, gravel or cobbles. For minor crossings this can be determined during construction.
- Alluvial islands (vegetated and stable) in the middle of the active channel. These should be avoided where possible.

6.2 Generic Management Measures for each Project Phase

Most geomorphic and hydrological risks from the identified project activities can be managed by:

- Undertaking construction during the periods of lowest rainfall and channel flow (April to October) where practicable.
- Selecting appropriate crossing and other infrastructure locations that minimise erosion risks.
- Implementing appropriate erosion control measures (as detailed in section 6.2.2) both during and after construction.
- Managing the discharge of hydrotest water used for testing the integrity of the pipelines once installed, prior to commissioning.
- Ensuring a high level of quality of stabilisation measures implemented as part of the construction process.
- Rigorously undertaking maintenance as required.

Additional control strategies to mitigate potential impacts from project activities are summarised below for each of the project phases: construction, operation and maintenance, and decommissioning and rehabilitation.

6.2.2 Construction

Construction of watercourse crossings

The following standard mitigation measures should be applied for watercourse crossings:

- Assessment and management of scour potential.
- Where bedrock is present, installation of pipelines in a bedrock trench with a stable backfill cover.
- Horizontal directional drilling crossings should be given a minimum of one active channel width offset from top of stream bank.
- A recommended depth below invert should be provided for major water crossings based on mobile sediment conditions, which may require scour depth computations, to be determined on a site by site basis. It is recommended where possible that pipelines be installed in situ, consolidated or indurated material below mobile bed sediment.
- Adequate stream bank protection and revegetation should be put in place.

- Timing watercourse crossings to be constructed during periods of no or low flow, where practicable.
- Monitoring the weather with reference to rainfall, runoff and river levels to minimise risks of adverse weather conditions.
- All crossings should be constructed and reinstated so as not to impede or pond water in watercourses. Where temporary damming of flow is necessary for construction then flow will be maintained where required by diversion or piping to minimise disruption to flows and allow fish movement.
- To the greatest extent possible, delaying clearance of adjacent slopes until the watercourse crossing is due to be constructed.
- Ensuring that if the watercourse bed material needs to be stockpiled in the watercourse channel adjacent to the construction ROW, then the watercourse is dry and the stockpile is sited to avoid impacts on riparian vegetation, in-stream features and waterholes.
- Stockpiling coarse armouring material (cobbles and gravels) if layer/s overlay unconsolidated alluvial material, and then re-laying the material at the original depth of the bed-level as part of the crossing construction.
- Conducting rehabilitation of banks as soon as practicable after construction, including riparian vegetation.
- Preparation of detailed watercourse crossing designs pertinent to the geomorphic category to be crossed (including site specific rehabilitation measures) will be prepared once crossing locations are confirmed. Watercourse crossing risks can be mitigated through good design, location, construction techniques and timing of construction. Where significant disturbance to the bed or banks of a watercourse, wetland or spring is to occur the works must be designed in accordance with the DERM "*Guideline - activities in a watercourse, lake or spring associated with mining operations*". The main types of crossing techniques that will be considered are:
  - Horizontal direct drilling (HDD) – for environmentally sensitive waterways.
  - Blasted trench – for confined watercourse with rock in the bed and banks.
  - Blasted trench and open cut – for watercourses with rock bed and alluvial banks.
  - Open cut – for alluvial watercourses.
  - Open cut within a reduced Right of Way (ROW).

<u>Features warranting special attention:</u>

Discontinuous geomorphic categories Chain of Ponds, Floodout and Valley Fill, are often sensitive to disturbance and concentration of flow can lead to continuous channelisation and loss of the environmental values (regionally and nationally high due to most of them having become channelised since European settlement). The primary mitigation measure will be to avoid disturbing them by identifying them at the planning stage and seeking alternative locations for project activities where possible. If project activities such as pipeline and track crossings must be located such that they will cross or disturb these features the following generic measures need to be considered, together with site specific assessment and development of mitigation measures.

- Avoid concentrating flows such as occurs at culverts and drains. Concentration of flow can initiate headward erosion.
- In chain of ponds do not cross through pools.
- Implement site specific erosion control including rock protection if appropriate, soft engineering techniques (such as stabilisation matting) and immediate revegetation of disturbed areas.
- Frequent monitoring (after each rainfall and runoff event) until shown to be stable.

<u>Ancillary Construction activities</u>

Construction activities that may have an indirect impact upon watercourses (i.e., those activities not undertaken directly in watercourses but that have the ability to impact on watercourses if adequate management measures are not implemented), include disturbance of banks or adjacent land that could result in sediment discharge to a watercourse. The following mitigation and management measures are proposed as standard measures to be carried out, regardless of where the construction activities are undertaken within the project development area:

- Stockpiles of soil should be located away from watercourses and wetlands so as to minimise potential for sediment runoff to enter the watercourse or wetland.
- Sediment traps (or an equivalent control measure) should be constructed around the lower slopes of stockpiles and regularly maintained.
- Soil should be graded away from watercourses.
- Sediment and erosion control measures should be implemented on slopes approaching watercourses and wetlands to prevent sediment discharge to watercourses. This may include the use of sediment traps, vegetation and diversion berms, etc., all of which should be appropriately maintained.
- Trenches should be protected by the installation of diversion banks on the slopes approaching watercourses to reduce scour risk.
- Additional scour protection should be assessed on a site by site basis once final locations for project facilities and infrastructure are selected.
- The use of gabions should be avoided whenever practical as they are unsuitable for the watercourses of this area. Where erosion protection other than vegetation is required, soft engineering techniques will be preferred and graded rock used where a higher level of protection is required.
- Where practical, and in consultation with landholders, stock access and crossing use other than for construction and maintenance should be excluded.
- As far as practical re-use hydrotest water on adjacent pipeline sections.

6.2.3 Operation and maintenance

By undertaking the measures identified above during construction, the need for implementation of additional management measures during the operation and maintenance phase is expected to be minimal. The key management activity for the operation and maintenance phase will be to monitor locations where project activities have had an impact during construction, principally at watercourse crossings and at points where other activities have occurred that may have an impact upon watercourses or wetlands.

Further details of monitoring are provided in Section 9, Inspection and Monitoring, page 9.

6.2.4 Decommissioning and rehabilitation

The following should be considered in decommissioning:

- Restore disturbed sites to a state that is as close as reasonably practical to the preconstruction condition or better, or to the satisfaction of landowners.
- Dewatering of dams at a rate and location that will not result in erosion (additional erosion protection measures should be implemented if required).
- Removal of infrastructure should not result in adverse changes in overland or flood flows by ensuring that where infrastructure such as dams is to be removed, material will be removed from areas where such an impact would occur.

Rehabilitation will require ongoing monitoring and maintenance until monitoring shows that:

- rehabilitation works are successful, and
- no further maintenance is required.

6.3 Generic Mitigation Measures for Special Features and Processes

Some particular erosion features/processes across the project development area that need to be considered as potential threats to environmental values and project infrastructure. They may occur in both low and moderate sensitivity river styles and are as described below (also discussed in more detail with photographic examples in Appendix A).

6.3.1 Meander cutoff

This feature occurs when a channel across the inside of a meander bend becomes the main channel. This usually occurs through a series of floods but can be an artificial channel cut across a meander/s to shorten the river channel (observed to be associated with creation of ring tanks, mostly located on the Condamine River and North branch). The risk associated with these features is a shortening of channel length, together with increased gradient and increased risk of bed deepening and bank instability. The rate of erosion will be determined by the frequency and magnitude of high flows.

Mitigation measures:

- These features are rare in the project development area but should be avoided where this risk occurs.

6.3.2 Gully erosion

This feature occurs when a gully is actively incising and widening, often with a head cut migrating upstream through alluvial discontinuous watercourses. Could threaten project infrastructure over time. Could also be exacerbated by project infrastructure if not appropriately treated.

Mitigation measures:

- The most cost effective management is to avoid locating infrastructure in zone of potential influence of existing gullies.
- If management required site specific methods would need to be designed but could include rock grade control measures and soft engineering techniques including, revegetation.
- Requires field assessment and site specific mitigation measures.

6.3.3 Gully erosion and dispersive soils

This is often manifest as multiple gullies in a network or "amphitheatre" usually with large areas of bare soil. As per gully erosion but potentially more difficult to manage. Hard to stabilise and can threaten project infrastructure over time. Could also be exacerbated by project infrastructure.

Mitigation measures:

- The most cost effective management is to avoid locating infrastructure in zone of potential influence.
- If management required site specific methods would need to be designed but could include rock grade control measures and soft engineering techniques including, revegetation.
- Requires field assessment and site specific mitigation measures.

6.3.4 Avulsion

This is the process where a new main channel is created and the former main channel abandoned or becomes a flood channel. Usually through scour in a flood or series of floods. Natural process in anabranching systems. The risk associated with this feature is that a pipeline crossing may become exposed or damaged if the new main channel erodes rapidly as a result of the avulsion. This is more of a risk to project infrastructure rather than an environmental risk although there could be some additional erosion caused by scour around project infrastructure.

Mitigation measures:

- Avoid crossings near risk reaches.

6.4 Uncontrolled Discharges of Water

Point locations where emergency discharges could occur will be identified during the planning and design stage. Where practical, the planning and design stage should seek to avoid geomorphic types identified as being a greater risk of erosion (Valley fill and chain of ponds in particular). Assessments should consider the risk of scour and adverse hydrological impacts both at the point of discharge and downstream. The location of discharge points from emergency releases should be planned to be on watercourses with inherent robustness where extended flows will not result in increased erosion. As a minimum, scour protection should be implemented at the potential discharge point. Any requirement for additional protective works further downstream should be evaluated through field assessment.

The risk of catastrophic failure of ponds will be managed through the dam safety provisions for referrable dams under the *Water Act 2000*. A dam failure assessment will be undertaken for all referrable dams as required under the Act. This includes determining the number of people whose safety could be at risk should a dam fail.

The impacts of an emergency release are severe erosion and flooding. Downstream extent will depend upon watercourse style (and consequently its ability to resist erosion) and magnitude of the event.

Measures for uncontrolled emergency releases include:

- Design dams to a minimum 1 in 100 ARI rainfall event.
- Undertake dam failure assessment, which includes “failure to contain” and “dam break” scenario analysis.
- Develop Emergency Response Plans with dam release scenarios.
- Siting assessment in consideration of downstream values.

6.5 Wetlands

Wetlands need to be considered when planning facility locations. The data used to identify wetlands in the project development area is from the Queensland Wetlands Programme (version 1.3 – February 2009), which identifies wetland classifications as occurring in the Surat Gas Project development area as shown in Figure A5-11, page 98. In addition to the wetland classifications further information is provided including the degree to which these wetlands have been modified. The digital data layers are available to assist Arrow with planning. Riverine wetlands will be crossed by pipelines and tracks but will be addressed by applying the same mitigation measures detailed for watercourses. The mitigation measure for the disturbance of lacustrine and palustrine wetlands is to avoid them and so they are therefore not considered further in this report.

Of special note is the nationally significant wetland of Lake Broadwater (within Lake Broadwater Conservation Park) (Environment Australia, 2001). The mitigation measure for the Conservation Park is for no project activities to occur within the Park or an 800 m buffer of the Park. Should any project activities be planned within the catchment of Lake Broadwater they will require particular attention at the planning stage and beyond to ensure that any risks are minimised from project activities to the watercourses that flow to Lake Broadwater.

6.6 Measures for Each River Style

Section 7 Table 7-1 identifies the various project activities, and recommended specific mitigation measures for each river style. This table assumes that the appropriate generic mitigation measures as detailed in Section 6.1.2 are also applied. This assessment is based upon the assumption that the primary activity will be pipeline and/or track crossings of watercourses. Dams and other infrastructure would also require site specific investigations and assessments in addition to the generic mitigation measures shown. Routine discharge of associated water to watercourses is not Arrow’s preferred water management strategy. However, for completeness, generic mitigation measures related to emergency discharges of associated are included.

7 Residual Impacts and Constraints

7.1 Residual Impact Assessment

In this section all of the mitigation measures described in Section 6 are assumed to be applied. The residual impacts described below are those still expected to occur after the application of mitigation measures and a determination has been made of the post-mitigated magnitude of each impact in relation to each environmental value (as per the method described in Section 3.2, page 7). The significance (sensitivity and magnitude) of the residual impacts on the identified environmental values has then been determined with reference to Table 3-1, page 10.

The assessment of residual impact is shown in Table 7-1, page 35, for low sensitivity environmental values and in Table 7-2, page 39, for moderate sensitivity environmental values.

When considering the residual impacts that the project activities may have upon the watercourses and wetlands of the project development area it is assumed that the good industry practices and the mitigation measures identified in this report are applied.

Table 7-1. ***Significance of residual impacts for low sensitivity environmental values***

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
Construction including installation of wells, gathering lines and construction of processing and compression facilities						
Clear and grade	Reduced bank stability from removal of riparian vegetation resulting in erosion and sediment mobilisation.	1	Application of generic mitigation measures. Minimise extent of clearance necessary for construction activity.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
	Changes to physical form and morphology of watercourses following rainfall and runoff during construction also causing sediment movement into watercourses and wetlands.	1	Application of generic mitigation measures. Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
Placement of project infrastructure	Changes to hydrology, physical form and morphology (direction and discharge points of surface flow paths) from disturbance to natural drainage channels and/or surface flow paths.	1 & 2	Flood assessment to be undertaken at the planning stage. Infrastructure to be located to avoid or minimise changes to natural drainage lines.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
Seismic surveys	Reduced bank stability from ground disturbance activities resulting in erosion.	1	None required.	Geographical extent: local Duration: exploration Severity: low	Low	Negligible
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands.	1	Generic mitigation measures only required.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
	Reduced bank stability from erosion.	1	Generic mitigation measures only required.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
	Changes to physical integrity and morphology from placement of cut and fill within the flood extent of major watercourses resulting in erosion.	1	Generic mitigation measures only required.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
Watercourse crossings	Changes to physical form and morphology from bed and bank erosion with associated mobilisation and transport of sediment.	1	Assessment of scour potential recommended for crossings. Application of generic mitigation measures.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
	Changes to hydrology - altered timing and duration of flow form blockages to streams (open-cut crossings).	2	Maintain flows and fish passage during construction by diversion or piping.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
	Reduced bank stability from clearance of riparian vegetation.	1	Application of generic mitigation measures. Site specific erosion control measures to be developed for all watercourse crossings larger than 2nd order (see Attachment A, Section 5 where watercourse orders are detailed).	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
Installation of pipelines and production wells	Changes to physical form and morphology from drill mud spillage and seepage resulting in sediment discharge to watercourses.	1	Application of good industry practice for the management of drill mud.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
	Changes to hydrology - altered flow regime. Wells possibly being located within the flooding extent of major waterways.	2	Assess location at planning stage. Locate above 1 in 100 year Average Recurrence Interval where possible. If not possible, provide flood protection measures.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
	Changes to physical form and morphology - erosion and generation of sediment from discharge of hydrotest water.	1	Site specific erosion control measures will be identified when discharge sites are known.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form from rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	1 & 2	Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: construction Severity: low	Low	Negligible
Operation and maintenance of compression and processing facilities, gathering lines and production wells						
Operation of facilities	Reduced bank stability from erosion and generation of sediment from rainfall and runoff.	1	Application of generic mitigation measures.	Geographical extent: local Duration: operation Severity: low	Low	Negligible
	Changes to hydrology. Altered hydraulic conditions from changed surface flow paths.	2	Infrastructure to be located to avoid or minimise changes to natural drainage lines and flow paths.	Geographical extent: local Duration: operation	Low	Negligible

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
				Severity: low		
	Altered hydraulic conditions. Potential off-site changes to flood flow paths and flood extents due to alteration of pre-construction hydraulic conditions.	1	Assess location and hydraulic conditions at planning stage. Locate above 1 in 100 year Average Recurrence Interval where possible. If not possible, provide flood protection measures.	Geographical extent: local Duration: operation Severity: low	Low	Negligible
Use and maintenance of access tracks.	Changes to physical form and morphology due to erosion and generation of sediment from rainfall and runoff.	1	Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: operation Severity: low	Low	Negligible
	Changes to physical form and morphology from scour and generation of sediment at watercourse crossings.	1	Application of generic mitigation measures. Monitor stability following each flow event.	Geographical extent: local Duration: operation Severity: low	Low	Negligible
Emergency release of associated water	Changes to physical form and morphology from erosion and generation of sediment.	1	The location of discharge points from emergency releases planned to be on watercourses with inherent robustness where extended flows will not result in increased erosion. Extent of impact would depend upon duration and quantity of flows.	Geographical extent: local Duration: operation Severity: Low	Moderate	Low
	Changes to hydrology from flows for duration of discharge.	2	Prevention is the only mitigation option.	Geographical extent: local Duration: operation Severity: Moderate	Moderate	Low
Decommissioning including: compression and processing facilities, construction camps, capping of production wells, removal of gathering lines						
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands.	1	Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
	Changes to physical form and morphology. Reduced bank stability where banks directly disturbed resulting in erosion and generation sediment.	1	Application of generic mitigation measures.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
	Changes to physical form and morphology, Possible alteration of hydraulic conditions in flood flows caused by placement of cut and fill on flood plains or the flood extent of major watercourses; erosion.	1 & 2	Application of generic mitigation measures. The key measure will be the timing of construction to avoid periods of highest risk of out of channel flow (April to October).	Geographical extent: local Duration: short-term Severity: low	Low	Negligible
Watercourse crossings	Changes to physical form and morphology from bed deepening and bank erosion.	1	Application of generic mitigation measures.	Geographical extent: local Duration: medium-term Severity: low	Low	Negligible
	Changes to physical form and morphology from increased sediment.	1	Application of generic mitigation measures.	Geographical extent: local Duration: medium-term Severity: low	Low	Negligible
	Changes to hydrology from blockages to streams (open-cut crossings).	2	Timing of construction to coincide with periods of lowest flow (April to October). Flows to be maintained during construction by diversion or piping, whilst maintaining fish passage.	Geographical extent: local Duration: medium-term Severity: low	Low	Negligible
	Changes to physical form and morphology. Reduced bank stability leading to erosion and sediment transport from clearance of riparian vegetation.	1	Application of generic mitigation measures.	Geographical extent: local Duration: medium-term Severity: low	Low	Negligible
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form and morphology from rainfall and runoff during construction causing sediment movement into watercourses and wetlands	1	Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: short-term Severity: low	Low	Negligible

Table 7-2 identifies the Significance of residual impacts for moderate sensitivity environmental values. In this table it is assumed that the best mitigation measure is to avoid disturbance of bed and banks of moderate sensitivity river styles (see Table 4-1) wherever possible by identification and avoidance at planning stage. Where it is not possible to avoid disturbance of these river styles, specific mitigation and management measures are provided.

Table 7-2. ***Significance of residual impacts for moderate sensitivity environmental values***

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
Construction including installation of wells, gathering lines and construction of processing and compression facilities						
Clear and grade	Reduced bank stability from removal of riparian vegetation resulting in erosion and sediment mobilisation.	1	Where not possible to avoid, apply generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: construction Severity: low	Low	Low
	Changes to physical form and morphology of watercourses following rainfall and runoff during construction also causing sediment movement into watercourses and wetlands.	1	Application of generic mitigation measures. Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: construction Severity: low	Low	Low
Placement of project infrastructure	Changes to hydrology, physical form and morphology (direction and discharge points of surface flow paths) from disturbance to natural drainage channels and/or surface flow paths.	1 & 2	Where not possible to avoid, apply generic mitigation measures and develop site specific mitigation measures, which may include avoiding concentration of surface flows such as occurs at culverts and drains. Apply additional erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: construction Severity: low	Low	Low
Seismic surveys	Reduced bank stability from ground disturbance activities resulting in erosion.	1	None required.	Geographical extent: local Duration: exploration Severity: low	Low	Low
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands.	1	Generic mitigation measures only required.	Geographical extent: local Duration: construction Severity: low	Low	Low
	Reduced bank stability from erosion.	1	Where not possible to avoid, apply generic mitigation measures and develop site specific mitigation measures, which may include erosion	Geographical extent: local Duration: construction	Low	Low

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
			protection through hard and soft engineering techniques.	Severity: low		
	Changes to physical integrity and morphology from placement of cut and fill within the flood extent of major watercourses resulting in erosion.	1	Where not possible to avoid, apply generic mitigation measures. Avoid concentration of surface flows where possible.	Geographical extent: local Duration: construction Severity: low	Low	Low
Watercourse crossings	Changes to physical form and morphology from bed and bank erosion with associated mobilisation and transport of sediment.	1	Where not possible to avoid, apply generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Changes to hydrology - altered timing and duration of flow form blockages to streams (open-cut crossings).	2	Where not possible to avoid: • apply generic mitigation measures • develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques. • Maintain flows and fish passage during construction by diversion or piping.	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Reduced bank stability from clearance of riparian vegetation.	1	Where not possible to avoid, apply generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques. Site specific erosion control measures to be developed for all levels of stream order.	Geographical extent: local Duration: short-term Severity: low	Low	Low
Installation of pipelines and production wells	Changes to physical form and morphology from drill mud spillage and seepage resulting in sediment discharge to watercourses.	1	Application of good industry practice for the management of drill mud.	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Changes to hydrology - altered flow regime. Wells possibly being located within the flooding extent	2	Assess location at planning stage. Locate above 1 in 100 year Average Recurrence Interval where possible. Provide flood protection	Geographical extent: local Duration: short-term	Low	Low

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
	of major waterways.		measures where not possible to locate above 1 in 100 year ARI zone. Additional erosion protection measures may be required: avoid concentration of flows that may initiate erosion; apply additional hard or soft engineering techniques to mitigate erosion.	Severity: low		
	Changes to physical form and morphology - erosion and generation of sediment from discharge of hydrotest water.	1	Where not possible develop site specific mitigation measures, which may include discharge to dam to rock protection where discharged directly to a watercourse.	Geographical extent: local Duration: short-term Severity: low	Low	Low
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form from rainfall and runoff during construction causing sediment movement into watercourses and wetlands.	1 & 2	Application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: construction Severity: low	Low	Low
Operation and maintenance of compression and processing facilities, gathering lines and production wells						
Operation of facilities	Reduced bank stability from erosion and generation of sediment from rainfall and runoff.	1	Where avoidance is not possible, site specific erosion measures should be implemented. Monitoring undertaken more frequently than for low sensitivity river styles.	Geographical extent: local Duration: operation Severity: low	Low	Low
	Changes to hydrology. Altered hydraulic conditions from changed surface flow paths.	2	Where avoidance is not possible, alterations to hydraulic conditions minimised at planning stage. Infrastructure to be located to avoid or minimise changes to natural drainage lines and flow paths. Assess and develop site specific additional erosion mitigation measures as required. Minimise concentration of flows and apply erosion control measures.	Geographical extent: local Duration: operation Severity: low	Low	Low
	Altered hydraulic conditions. Potential off-site changes to flood flow paths and flood extents due to alteration of pre-construction hydraulic conditions.	1	Where avoidance is not possible assess location and hydraulic conditions at planning stage. Locate above 1 in 100 year Average Recurrence Interval where possible. Provide flood protection measures where not possible to locate above 1 in	Geographical extent: local Duration: operation Severity: low	Low	Low

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
			100 year ARI zone to ensure no offsite adverse impacts. Assess and develop site specific additional erosion mitigation measures as required.			
Use and maintenance of access tracks.	Changes to physical form and morphology due to erosion and generation of sediment from rainfall and runoff.	1	Where avoidance is not possible application of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: operation Severity: low	Low	Low
	Changes to physical form and morphology from scour and generation of sediment at watercourse crossings.	1	Where avoidance is not possible Application of generic mitigation measures. Monitor stability following each flow event.	Geographical extent: local Duration: operation Severity: low	Low	Low
Emergency release of associated water	Changes to physical form and morphology from erosion and generation of sediment.	1	The location of discharge points from emergency releases planned to be on watercourses with inherent robustness where extended flows will not result in increased erosion. Extent of impact would depend upon duration and quantity of flows.	Geographical extent: local Duration: operation Severity: Moderate	Moderate	Moderate
	Changes to hydrology from flows for duration of discharge.	2	Prevention is the only mitigation option.	Geographical extent: local Duration: operation Severity: Moderate	Moderate	Moderate
Decommissioning including: compression and processing facilities, construction camps, capping of production wells, removal of gathering lines						
Stockpiling and earth moving	Changes to physical form and morphology from sediment movement into watercourses and wetlands.	1	Application Of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Changes to physical form and morphology. Reduced bank stability where banks directly disturbed resulting in erosion and generation sediment.	1	Application of generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: short-term Severity: low	Low	Low
	Changes to physical form and morphology, Possible alteration of hydraulic conditions in flood flows caused by placement of cut and fill on flood plains or the flood extent	1 & 2	Application of generic mitigation measures. Avoid concentration of surface flows where possible. The key measure will be the timing of construction to avoid periods of highest risk of out of channel	Geographical extent: local Duration: short-term Severity: low	Low	Low

Project activity	Potential impacts	EVs affected	Mitigation and management measures	Residual Magnitude Criteria	Residual Magnitude	Significance of residual impact
	of major watercourses; erosion.		flow (April to October).			
Watercourse crossings	Changes to physical form and morphology from bed deepening and bank erosion.	1	Application of generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: medium-term Severity: moderate	Low	Low
	Changes to physical form and morphology from increased sediment.	1	Application of generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: medium-term Severity: moderate	Low	Low
	Changes to hydrology from blockages to streams (open-cut crossings).	2	Timing of construction to coincide with periods of lowest flow (April to October). Flows to be maintained during construction by diversion or piping, whilst maintaining fish passage.	Geographical extent: local Duration: medium-term Severity: moderate	Low	Low
	Changes to physical form and morphology. Reduced bank stability leading to erosion and sediment transport from clearance of riparian vegetation.	1	Application of generic mitigation measures and develop site specific mitigation measures, which may include erosion protection through hard and soft engineering techniques.	Geographical extent: local Duration: medium-term Severity: moderate	Low	Low
Works in proximity to watercourses or wetlands or within drainage channels	Changes to physical form and morphology from rainfall and runoff during construction causing sediment movement into watercourses and wetlands	1	Application Of good industry practice for the management of sediment from disturbed areas.	Geographical extent: local Duration: short-term Severity: low	Low	Low

7.2 Constraints

For the perspective of the geomorphology and hydrology of watercourses within the project development area, no constraints were identified through the assessment of residual impacts.

As stated in Section 5, Lake Broadwater and wetlands should be avoided by project activities where possible.

8 Cumulative impacts

8.1 Cumulative impacts

The potential impacts to fluvial geomorphology and hydrology that have been identified are listed in Table 8-1 together with their potential to have a cumulative impact at a regional level. Based on the assumption that all appropriate mitigation measures are applied, the only impacts that could reasonably be considered as having the potential to impact outside the project development area, at a regional level, are those related to the potential emergency discharge of associated water. Other major projects that could potentially contribute to the discharge of associated water are:

- Australia Pacific LNG Project (Origin Energy and Conoco Philips).
- Gladstone LNG Project (Santos Ltd).
- Queensland Curtis LNG Project (QGC Pty Ltd (BG Group Business).

Table 8-1. ***Potential impacts and likely cumulative impacts***

Potential impact	Likely cumulative impact – post-mitigation
Direct disturbance of watercourses from waterway access track and gathering line crossings.	Localised impacts only. There are no anticipated impacts to geomorphic or hydrologic processes from any project activities and therefore no cumulative impacts.
Erosion and the generation of sediment from construction and maintenance activities.	Localised impacts only. There are no anticipated impacts to geomorphic or hydrologic processes from any project activities and therefore no cumulative impacts.
Erosion and the generation of sediment from discharge of hydrotesting water.	Localised impacts only. There are no anticipated impacts to geomorphic processes. The uncontrolled discharge of associated water, if it occurs will be of short duration temporally and spatially with no impacts outside of the project development area although at the time of preparing this report the location, if any, of discharge points was not known. Reassessment should be undertaken once any locations of potential discharge points, if any, are known. No cumulative impacts are expected.
Erosion due to uncontrolled discharge of associated water.	Possible impacts to geomorphology in the form of erosion risk. The extent of impacts would be determined by quantity and duration of release and the geomorphic type of watercourses affected.
Altered hydrology from uncontrolled discharge of associated water.	Has the potential to have impacts outside the project development area and the potential to have a cumulative impact if other coal seam gas projects in the region also discharge associated water. If an uncontrolled release was to occur, hydrologic impacts would be of a short duration and possibly to extend beyond the project development area. However, it is not possible to estimate the extent of such a potential impact until design details known. Following the application of mitigation measures detailed in Section 6, the risk of such discharges is identified as being negligible and therefore the opportunity for any cumulative impact is also negligible.
Altered flood flows if dams, IFCF's, CGPF's & IPF's or other infrastructure are located in areas subject to inundation during flooding. This is also a potential issue in terms of risk to that infrastructure during flood events.	This infrastructure is small scale development and is only expected to have localised impacts on flood flows, if any at all. This will require site specific modeling as appropriate where such infrastructure is proposed to be located in an area with a flood risk.

The application of saline water, potentially used to suppress dust,	Not considered to have any potential impacts upon the hydrology or geomorphology of watercourses or wetlands. It could have impacts upon water quality, which is considered in the Surface Water Assessment Report – Part B: Water Quality.

9 Inspection and Monitoring

Site-specific monitoring plans will be developed to ensure that the below environmental value objectives will be achieved through each project phase.

Environmental value 1 objective: Maintain the physical integrity, fluvial processes, form and morphology of watercourses and wetlands as identified in the Queensland Wetlands Programme "Wetland mapping and classification for Queensland" (version 1.3 February 2009).

Environmental value 2 objective: Manage adverse impacts that may result from project activities on the hydrology of watercourses and wetlands (such as adverse increases or decreases in quantity, duration, rate or timing of stream flows). This includes: the maintenance of sufficient quantity of surface waters to protect existing beneficial downstream uses of those waters (including the minimisation of impacts on flooding levels and frequency both upstream and downstream of the project development area.

The monitoring plans will be developed once site selection for the project facilities and infrastructure is conducted and will include, but not be limited to the following:

- Inspections and assessments of water discharge locations, should discharge of water occur. Monitoring will include assessment of erosion and effectiveness of management measures.
- Monitoring of flows into receiving waters.
- Monitoring and/or inspections of stream crossings following significant rainfall and runoff events (i.e. events that have the ability to initiate erosion and mobilise sediment) during and post construction, until disturbed areas at crossings have stabilised.
- Monitoring of third party complaints associated with surface waters.

Detailed operation and decommissioning monitoring plans will be developed to achieve the above objectives. Monitoring plans will identify monitoring locations, parameters and responsibilities and include measurable performance criteria against which, project activities can be monitored.

10 Conclusions

Project activities that have the potential to result in environmental impacts to hydrology and geomorphology during construction, operation and maintenance, and decommissioning and rehabilitation are:

- Site selection for project facilities and infrastructure. This would only be an issue if any facilities were to be located below the 1 in 100 year ARI flood level or interfered with watercourses, neither of which is planned.
- Construction activities including installation of wells and construction of processing and compression facilities (FCFs, CGPFs and IPFs).
- Construction of gathering lines and medium and high pressure gas and water pipelines including watercourse crossings and the storage and discharge of hydrotesting water.
- Construction of dams.
- Construction of access roads (including watercourse crossings).
- Operational activities including emergency discharge and storage of associated water and dust suppression (possibly using associated water).
- Decommissioning activities including stockpiling and possible removal of gas and water pipelines (possibly at watercourse crossings).

Unmitigated impacts include:

- Erosion and generation of sediment during construction, operation and decommissioning.
- Bed scouring in flow events.
- Bank erosion in flow events.
- Incision of unchannelised reaches/upstream causing migration of erosion heads
- Bank erosion due to localised rainfall and overland flow entry (this is linked to the first point but also includes risk of insufficient vegetation establishment due to stock access or insufficient maintenance).
- Emergency release of associated water.
- On site and off site flooding.

With the application of the avoidance, mitigation and management measures detailed in Section 6, the impacts from these project activities can be managed to reduce the residual impact of those activities to a low or negligible level. The only exception is the emergency release of associated water, which if it was to occur could have a moderate to low impact depending upon the quantity, duration and location of the discharge. However, the risk of such an emergency discharge will be managed by:

- Appropriate level of design, geotechnical investigation and construction.
- Design dams to manage a minimum 1 in 100 ARI rainfall event.
- Undertake dam failure assessment.

11 Terms of Reference Cross-reference Table

Final Terms of Reference component	Relevant section in report
Water resources (TOR section 4.5)	
4.5.1 Description of environmental values	4.2
4.5.1.1 Surface waterways	
• Description of surface watercourses (including drainage patterns)	Attachment A
• Geomorphic condition of watercourses	Attachment A5 & Attachment C
• Overland flow and quantity of water (hydrology)	Attachment A4
• Wetlands	Attachment A5.2
• Flooding (likelihood and history)	Attachment A4
• Mapping of watercourses and catchments	Attachment A4.4 Attachment A3.2
4.5.2 Potential Impacts and mitigation measures	
• Potential impacts	5, 7 & 8
• Mitigation measures	6
• Monitoring	9
4.5.2.1 Surface water and watercourses	
• Potential impacts	5,7 & 8
• Stream diversions	N/A
• Controlled and uncontrolled discharges of water	6.1.4
• Application of saline water for dust suppression	Table 8-1
• Climate extremes and dam capacity	6.4
• Water flows to and from the project area.	Attachment A4
• Need for licencing of dams.	6.1.4
• Options for mitigation of sediment.	6.1

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Attachment A
Regional context, existing environment and identification of environmental issues that could arise as a consequence of the project

1 Introduction

1.1 Structure

The purpose of this Appendix is to provide the following supporting information for the Surat Gas Project: – Surface Water Assessment Part A: Fluvial Geomorphology and Hydrology:

- Introduction.
- Brief overview of the project development area and project activities.
- Regional setting.
- Hydrology.
- Fluvial geomorphology.

The information gathered and prepared for this report has been collated and presented such that it can be used by Arrow Energy as a framework to aid in site selection and management of environmental, construction and operational risk. Maps are provided identifying risks together with options for control strategies and monitoring. Mapping data is also available in ESRI ArcView digital format to support Arrow Energy planning.

1.2 Baseline data and information

Data used as the baseline to define and assess the hydrology and geomorphology of the project development area included:

- Stream and wetland layers from the Queensland Wetlands Programme “wetland mapping and classification for Queensland” (Version 1.3 – February 2009). The “Hyd_stream” layer was modified by Alluvium to improve its usefulness for this project assessment. Modifications included creating a traceable stream network and applying strahler stream ordering, a useful tool to assist resource projects that may impact upon watercourses (Further details are provided in Attachment A).
- A 1:100,000 scale digital elevation model (DEM) created by Alluvium from the Geosciences Australia 1:100,000 digital map sheet contours (20m intervals).
- Aerial imagery supplied by Coffey Environments / Arrow.
- Geology and contours (5m intervals) for some of the project development area provided by Arrow Energy.
- Flow data from the Department of Environment and Resource Management (DERM).

1.3 Assessment method

The methods used to undertake the assessment of risks are detailed below.

Hydrology:

- Examination of climate data from Bureau of Meteorology.
- Examination of flow data and flood risk data from DERM “Watershed”, the surface water data archive of the former Department of Natural Resources and Water (NRW), which includes gauging station information and streamflow data summaries.
- Search of relevant reports and data on flooding and flood risk for the project area.
- Overview of water use and surface water extraction.

Geomorphology:

- Modification of the Queensland Wetlands Programme “Hyd_stream” digital layer to include the application of the River Styles geomorphic categorisation utilising aerial photography, topography and geologic information.
- Access and use of the Queensland Wetlands Programme “Hyd_wetland” digital layer to identify wetland location and types.
- Field assessment of selected locations.

- Review of relevant reports and data of the geomorphic character and condition of the project development area streams.

2 Brief overview of the project development area, project activities and potential impacts

The Arrow Energy Surat Gas Project development area covers 8,661.6 km^2 in southeast Queensland as shown in Figure A2-1, page 55.

The project will ultimately be comprised of a number of facilities, infrastructure and activities that could potentially impact upon the hydrology and geomorphology of the project development area. These are listed in Table A2-1.

Table A2-1. ***Facilities, infrastructure and activities that could potentially impact upon hydrology and geomorphology***

Facility/activity	Potential Impacts to/from hydrology and fluvial geomorphology
FCF's, CGPF's and IPF's	Depending upon site location: potential impact to facilities from flooding and potential to affect flood flows; also have the potential to interfere with watercourses.
Pipelines	Potential to result in erosion to watercourses at crossings and for damage to the pipeline by erosion and scour.
Wells	Potential to be inundated by flooding. Potential to be located where they may affect watercourses and wetlands.
Tracks and gathering lines associated with wells, FCF's, CGPF's and IPF's.	Potential to result in erosion to watercourses at crossings and for damage to pipelines by erosion and scour. Potential to impact upon wetlands.
Discharge of associated water.	Whilst the discharge of associated water is not expected to occur (at the time of preparing this report it was understood that treatment and beneficial use of water and/or alternative disposal strategies were being examined), it is never-the-less wise to consider issues related to accidental or emergency discharge or disposal if water quality is suitable and licencing to discharged granted. Issues include erosion risk at the point of discharge and altered hydrology from discharge, which may result in unseasonal and extended flows occurring in ephemeral watercourses.

The desktop investigations and field studies for this assessment were undertaken with consideration to potential impacts during planning, construction, operation and decommissioning of the above facilities and infrastructure.

Field investigations were undertaken in October and December 2009 and targeted watercourses across the project development area with an emphasis on consideration of impacts to and from FCF's, CGPF's, IPF's, wells, gathering lines and access track crossings.

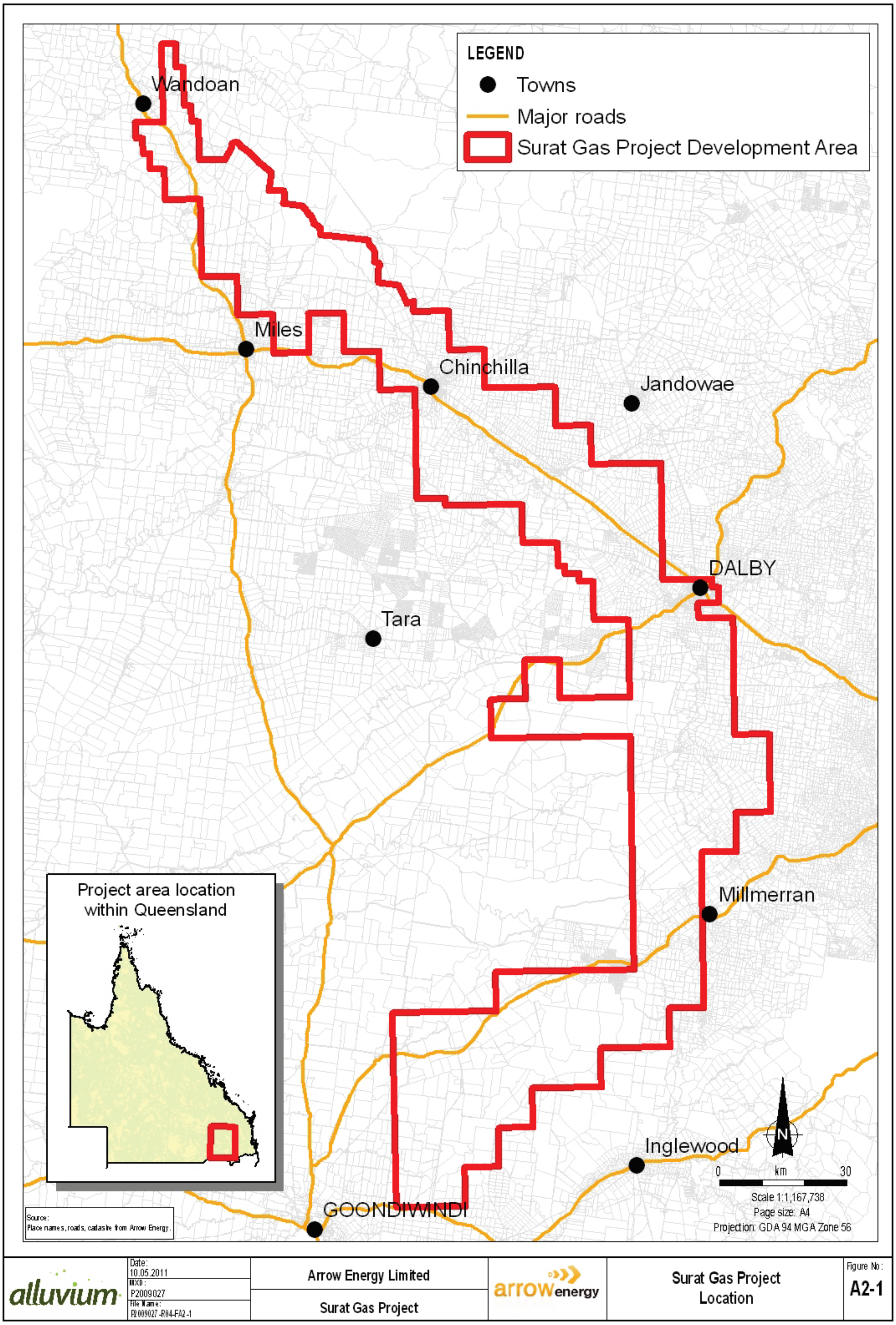


Figure A2-1. ***Location of the Surat Gas Project development area***

3 Regional setting

3.1 Regional setting

Drainage divisions, basins and sub-basins

The project area covers 8,493.8 km^2 across two of Australia's twelve drainage divisions[1]; primarily the Murray-Darling Division and part of the Northeast Coast Division. These Drainage Divisions are further divided into basins and sub-basins, which are shown in Table A3-1, and Figure A3-1, page 57. At a finer scale, the sub-basins can be further divided by catchment and sub-catchment, which is discussed in the following section.

Table A3-1. ***Areas of Drainage Divisions, Basins and Sub-basins falling within the project development area***

Drainage Division	Basin	Sub-basin	Total Sub-basin area (km^2)	Area of project development area within sub-basin (km^2)	% of project development area within sub-basin	Project development area as a % of the sub-basin
Murray-Darling (IV)	Condamine Culgoa(22)	Balonne	38,400.98	1,122.62	13.22%	2.92%
		Condamine	30,442.86	4,492.75	52.89%	14.761%
	Borders Rivers (16)	Macintyre Brook	4,316.47	286.56	3.37%	6.64%
		MacIntyre and Weir Rivers	15,438.75	2,113.81	24.89%	13.69%
	Moonie (17)	Moonie	14,846.01	59.68	0.70%	0.40%
North East Coast (I)	Fitzroy Basin (30)	Dawson	51,304.53	418.38	4.93%	0.82%

[1] Australia's drainage divisions and river basins were formally defined by the Australian Water Resources Council in the early 1960s and, with minor modifications resulting from improved mapping of the inland arid zone area, have been the basis for the study of Australian hydrology since then. The 12 drainage divisions were defined by both the major topographic features of the continent and the main climatic zones to give broadly homogeneous hydrologic regions. Within the drainage divisions the 245 river basins are defined by the major watershed lines (Australian Government, Bureau of Meteorology (http://www.bom.gov.au/hydro/wr/basins/index.shtml, accessed 12th October 2009)).

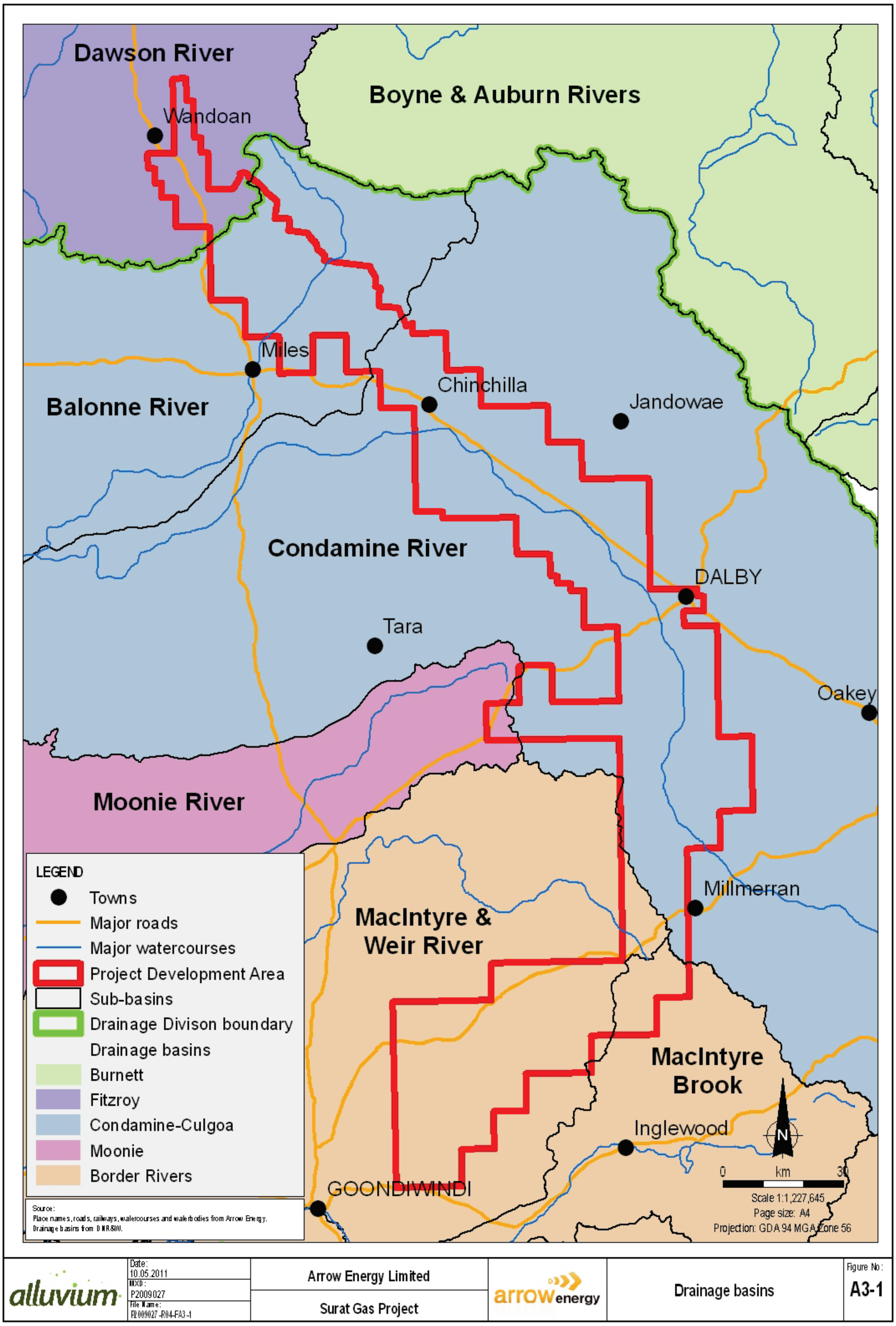


Figure A3-1. ***Location of the Surat Gas Project development area in relation to surrounding catchments***

3.2 Catchments and sub-catchments

As stated in Section 3.1 of Attachment A, at a finer scale, the sub-basins can be further divided by catchment and sub-catchment. The identification of catchments and sub-catchments is useful for a number of purposes including: identification of major streams for the assessment of water quality and aquatic ecology; and to contribute to the geomorphic assessment of watercourses. The Australian drainage basin sub-basins (as described in section A3.1) were used as the basis for the identification of sub-catchments[2] together with the following:

- Streams layer from the Queensland Wetlands Programme “wetland mapping and classification for Queensland” (Version 1.3 – February 2009). This layer was modified by Alluvium to improve its usefulness for this project assessment. Further details are provided in Attachment B.
- A 1:100,000 scale digital elevation model (DEM) created by Alluvium from the Geosciences Australia 1:100,000 digital map sheet contours (20m intervals).
- Aerial imagery supplied by Coffey Natural Systems / Arrow Energy.
- Stream names from the Geosciences Australia 1:250,000 digital map sheets.

The identification and digitising of catchments and sub-catchments was undertaken manually at a scale of approximately 1:50,000 with consideration given to identifying a size of sub-catchments that would provide the most useful tool to aid the projects various assessments. The sub-basins were only examined from the most upstream extent of catchments above the project development area, downstream to the point immediately below the project development area. This was done to focus resources only on the geographic extent of most use to aid the project assessments.

The sub-catchments are shown in Figure A3-3, page 63 and are listed by sub-basin, catchment, sub-catchment and name in Table A3-2, page 60.

Limitations of sub-catchment identification

The digitised sub-catchments are useful for the purposes for which they were prepared. At finer scales the accuracy of the catchment boundaries is limited by the quality of the data used to define them. In particular, the drainage and direction of runoff is not possible to determine accurately at the scales used and with the limited topographic data.

The sub-catchment boundaries are considered to be reasonably accurate in the upper catchments but the lower catchment boundaries are not considered accurate where the topography is low relief (particularly on the Condamine River and Weir River catchment floodplains) and agricultural development extensive. Catchment boundaries in these lower areas should be considered nominal and treated with caution. An example of the boundaries in the lower catchments between the Condamine River floodplain, Myall Creek, Ashall Creek and Oakey Creek and is shown in Figure A3-2, page 59.

[2] The State of Queensland (Department of Natural Resources Mines and Water) Land Vegetation & Water 2006 “Drainage Sub Basins” digital data set was used as the basis for this mapping.

Figure A3-2. ***Example of sub-catchment boundaries***

Table A3-2. ***Project development area drainage basins, catchments and sub-catchments***

Drainage Basin	Sub-basin	Catchment	Sub-catchment 1	Sub-catchment 2	Sub-catchment name (Label)
Border Rivers	Weir River				Weir River
Border Rivers	Macintyre River	Macintyre Brook			Macintyre Brook
Border Rivers	Weir River	Western Creek	Paddy Creek	Bora Creek	Bora Creek
Border Rivers	Weir River	Western Creek	Paddy Creek		Paddy Creek
Border Rivers	Weir River	Western Creek	Scrubby Creek		Scrubby Creek
Border Rivers	Weir River	Western Creek			Western Creek
Border Rivers	Macintyre River	Canning Creek	Pariagara Creek		Pariagara Creek
Border Rivers	Macintyre River	Canning Creek	Cattle Creek		Cattle Creek
Border Rivers	Macintyre River	Canning Creek	Nicol Creek		Nicol Creek
Border Rivers	Macintyre River	Canning Creek	Boola Creek		Boola Creek
Border Rivers	Macintyre River	Canning Creek	un-named		un-named
Border Rivers	Macintyre River	Canning Creek			Mosquito Creek
Border Rivers	Macintyre River	Canning Creek			Canning Creek
Border Rivers	Weir River	Western Creek	Buli Creek		Buli Creek
Border Rivers	Weir River	Wyaga Creek			Wyaga Creek
Border Rivers	Weir River	Yarrill Creek			Yarrill Creek
Border Rivers	Weir River	Commoron Creek			Commoron Creek
Border Rivers	Weir River	Muri Muri Creek			Muri Muri Creek
Border Rivers	Weir River	Wondalli Creek			Wondalli Creek
Condamine-Balonne	Condamine	Condamine			Condamine
Condamine-Balonne	Condamine	Wilkie Creek	Mormanby Creek		Mormanby Creek
Condamine-Balonne	Condamine	Wilkie Creek	Back Creek		Back Creek
Condamine-Balonne	Condamine	Wilkie Creek			Wilkie Creek
Condamine-Balonne	Condamine	Wilkie Creek	Clayhole Creek		Clayhole Creek
Condamine-Balonne	Condamine River	Crawlers Creek			Crawlers Creek

Drainage Basin	Sub-basin	Catchment	Sub-catchment 1	Sub-catchment 2	Sub-catchment name (Label)
Condamine-Balonne	Condamine River	Willis Creek			Willis Creek
Condamine-Balonne	Condamine River	Honeysuckle Creek			Honeysuckle Creek
Condamine-Balonne	Condamine River	Leonard (Back Ck) Gully			Leonard (Back Ck) Gully
Condamine-Balonne	Condamine River	un-named creek			un-named creek
Condamine-Balonne	Condamine	Braemar Creek			Braemar Creek
Condamine-Balonne	Condamine	Kogan Creek			Kogan Creek
Condamine-Balonne	Condamine	Jingi Jingi Creek			Jingi Jingi Creek
Condamine-Balonne	Condamine	Cooranga Creek			Cooranga Creek
Condamine-Balonne	Condamine	Jimbour Creek			Jimbour Creek
Condamine-Balonne	Condamine	Condamine River	Myall Creek		Myall Creek
Condamine-Balonne	Condamine	Condamine River	Oakey Creek		Oakey Creek
Condamine-Balonne	Condamine	Ashall Creek			Ashall Creek
Condamine-Balonne	Condamine	Wambo Creek			Wambo Creek
Condamine-Balonne	Condamine	Charley's Creek			Charleys Creek
Condamine-Balonne	Condamine	Charley's Creek	Rocky Creek		Rocky Creek
Condamine-Balonne	Condamine	Charley's Creek	Branch Creek		Branch Creek
Condamine-Balonne	Condamine	Charley's Creek	un-named creek		un-named creek
Condamine-Balonne	Condamine	Condamine River			Condamine River
Condamine-Balonne	Balonne				Balonne River
Condamine-Balonne	Balonne	Dogwood Creek	Bottle Tree Creek		Bottle Tree Creek
Condamine-Balonne	Balonne	Dogwood Creek	Bottle Tree Creek	L Tree Creek	Bottle Tree Creek
Condamine-Balonne	Balonne	Dogwood Creek	Rocky Creek		Rocky Creek
Condamine-Balonne	Balonne	Dogwood Creek	Hellhole Creek		Hellhole Creek
Condamine-Balonne	Balonne	Dogwood Creek	un-named creek		un-named creek
Condamine-Balonne	Balonne	Dogwood Creek	Punch-bowl Creek		Punch-bowl Creek
Condamine-Balonne	Balonne	Dogwood Creek	Columboola Creek		Columboola Creek
Condamine-Balonne	Balonne	Dogwood Creek	un-named creek		un-named creek

Drainage Basin	Sub-basin	Catchment	Sub-catchment 1	Sub-catchment 2	Sub-catchment name (Label)
Condamine-Balonne	Balonne	Dogwood Creek	Eleven Mile Creek		Eleven Mile Creek
Condamine-Balonne	Balonne	Dogwood Creek			Dogwood Creek
Fitzroy River	Dawson River				Dawson River
Fitzroy River	Dawson River	Juandah Creek	Downfall Creek		Downfall Creek
Fitzroy River	Dawson River	Juandah Creek	Weringa Creek		Weringa Creek
Fitzroy River	Dawson River	Roche Creek			Roche Creek
Fitzroy River	Dawson River	Juandah Creek			Juandah Creek
Moonie River		Moonie River			Moonie River
Moonie River		Durabilla Creek			Durabilla Creek
Moonie River		Dunmore Creek			Dunmore Creek
Moonie River		Kurrawa Creek			Kurrawa Creek
Moonie River		Moonie River			Moonie River

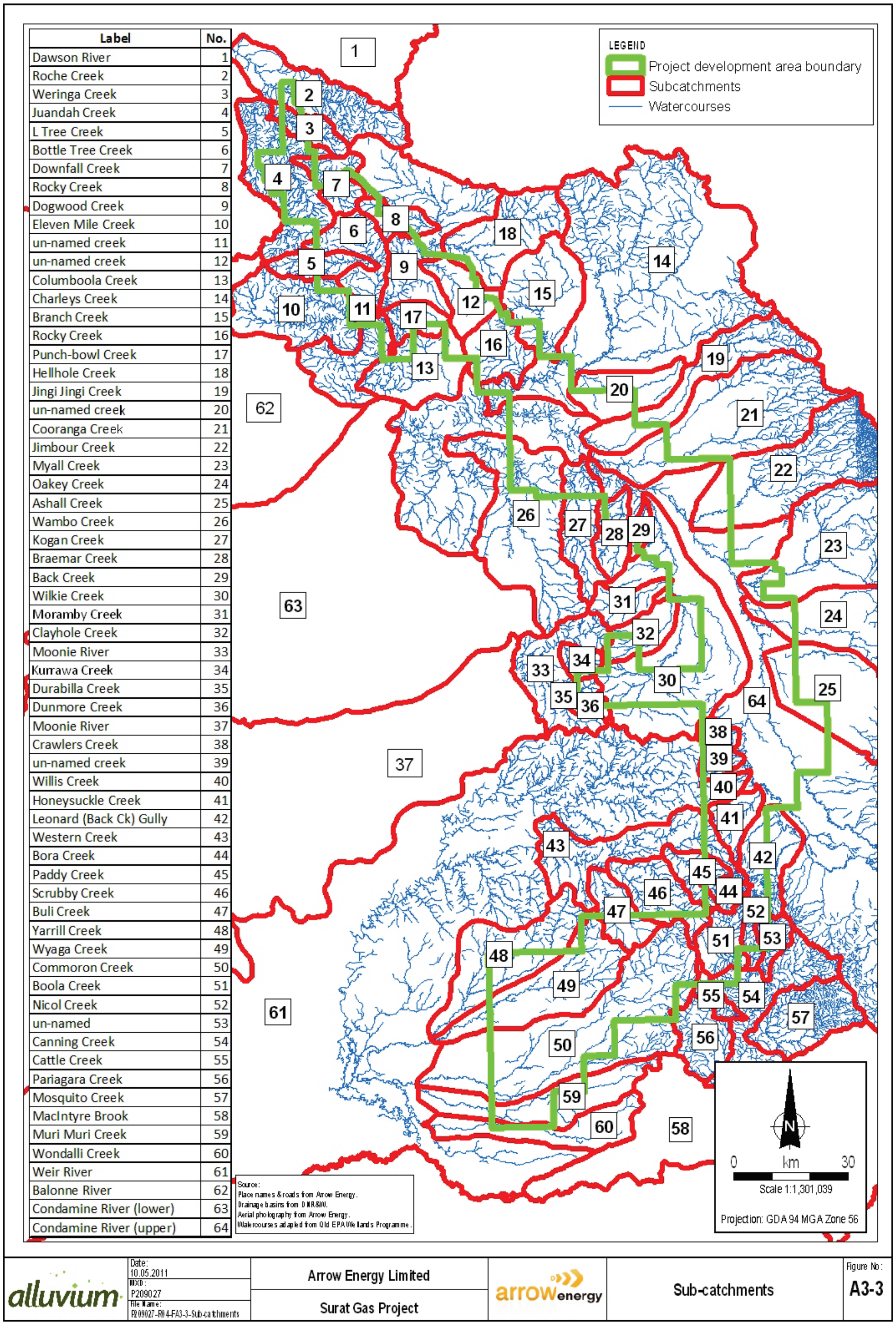
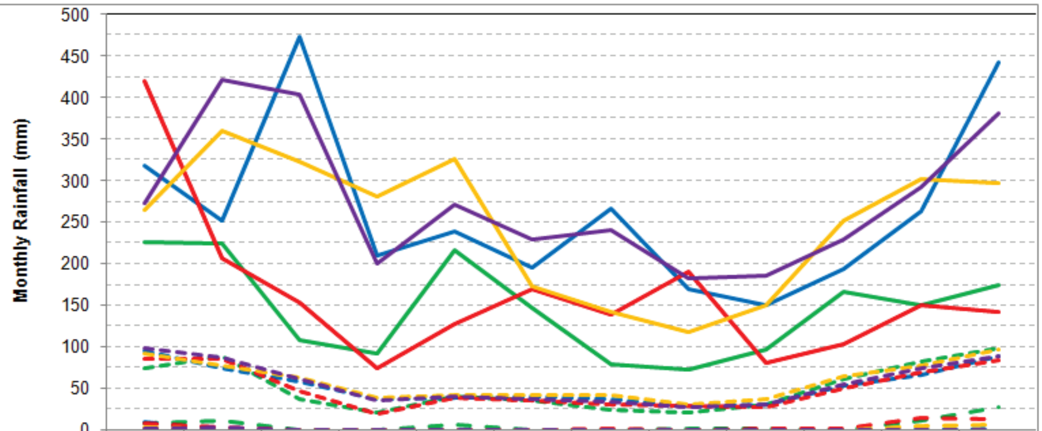


Figure A3-3. ***Project development area sub-catchments***

4 Hydrology

4.1 Climate

The climate of the area can be described as subtropical characterized by a wet summer and lower winter rainfall. Typically rainfall and runoff occurs in late spring, summer and autumn with flooding most likely to occur between January and February. Project development area rainfall averages are shown in Figure A4-1.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dalby AP - Maximum	226.4	224.8	107.6	91.2	216.2	146.6	77.6	71.8	96.2	166.4	150.6	174.4
Dalby AP - Minimum	7.4	11.2	0.6	0	5.8	0.4	0	1.2	1.2	0.4	10.4	26.8
Dalby AP - Average	73.9	89	36.9	20.8	39.4	35.4	23.5	20	30.4	61.2	83.2	98.8
Miles PO - Maximum	317.5	251.8	472.9	211	239.6	195.6	267	170.6	150.6	194.4	262.6	442.5
Miles PO - Minimum	9.7	0.3	0	0	0	0	0	0	0	0.4	0	1.5
Miles PO - Average	95.1	74.9	58.2	36.6	39.1	39.6	37.3	29.1	31	54	66	89
Goondiwindi AP - Maximum	420	207	153.2	74.8	128.4	170	139.2	191	81.8	104.1	150.6	143.2
Goondiwindi AP - Minimum	7.4	2.8	0	0	0.4	0	1	0	1	2.2	14.6	12.4
Goondiwindi AP - Average	84.8	84.3	46.3	19.7	39	35.2	31.2	30	27.4	49.7	69.3	83.3
Pittsworth - Maximum	264.8	359.7	321.8	281.2	325.4	172.7	141.8	117.4	148.9	251	302	297.5
Pittsworth - Minimum	2.4	0.8	0	0	0	0	0	0	0	0	4.9	5.7
Pittsworth - Average	92.1	77	61.8	38.5	40.6	41	40.6	30	36.7	63.7	76.8	96.4
Taroom PO - Maximum	273.1	421.1	403.1	200	270.1	228.6	240.8	181.9	185.7	228.7	292	380.9
Taroom PO - Minimum	1.8	2.6	0	0	0	0	0	0	0	0	0.2	0
Taroom PO - Average	97.8	86.6	61.4	35.1	40.6	36.6	33.8	27.6	31.2	55.5	74.4	88.6

Figure A4-1. ***Project development area rainfall averages*** **(data provided by Coffey Natural Systems)**

4.2 Hydrology overview

Dawson River catchment

The Dawson River catchment forms part of the Fitzroy River basin in central eastern Queensland. The confluence of the Dawson and MacKenzie Rivers leads to the formation of the Fitzroy River, which enters the Coral Sea north of Rockhampton. Stream networks in the Dawson River catchment are generally ephemeral with major streams including the Dawson River, Hutton Creek, Baffle Creek and Juandah Creek, among others. Summer rainfall (November to March) dominates with little or no flow during winter when the streams are reduced to a series of pools, the exception being Dawson River downstream of Dawson's Bend where springs maintain a perennial stream.

Numerous water storages and weirs are located on the Dawson River and its tributaries providing water for irrigation and recreational purposes (Australian Government ANRA). Water allocations are primarily for agriculture with cattle grazing forming the major land use in the catchment while forestry and cropping activities are also widespread.

Extensive clearing of native vegetation has been undertaken to facilitate agricultural and grazing activities that has resulted in considerable land degradation in the form of sheet, rill and gully erosion. Increased sediment loads entering streams has reduced channel capacity and led to an increase in the frequency of overbank flooding.

The catchment of Juandah Creek is mostly undulating with isolated rocky points with cattle grazing being the dominant land use in cleared country while forests remain on the steeper slopes of the upper catchment.

Condition assessments across the catchment generally reflect the extent of vegetation clearing and grazing while variations from poor to good condition appear to reflect the intensity of land use and grazing management (State of the Rivers (2009) – Dawson River).

Condamine River catchment
Forming the northern headwaters of Australia's longest and an important river system, the Murray Darling, the hydrology of the Condamine River and its tributaries is of national significance.

The hydrology of the Condamine River has been greatly altered since European settlement, initially through clearance of vegetation but also later through the construction of weirs, dams and extraction of water, primarily for irrigation. A study by the Independent Audit Group[3] states that for the Condamine-Balonne River system "information on median and mean flows indicates significant impacts of development under moratorium conditions compared to those under predevelopment conditions. The mean flow at the Queensland – New South Wales border is 50% while the median flow is 26% of pre-development flows". Similarly, the CSIRO in June 2008[4] reported for the Condamine Balonne region "Average surface water availability under the historical climate is 1,363 GL/Year. Average surface water use at current level of development is 722 GL/year or 53% of the available water. This is an extremely high level of use". The report also states that "The recent climate (1997 to 2006) was similar to the long-term average climate and that the best estimate of climate change by 2030 would reduce surface water availability by 8% and decrease surface water diversion within the region by 4%". Average periods between flood events are expected to increase and annual flood size and flood volume are predicted to reduce.

Lake Broadwater, which is a designated conservation park and wetland of national importance, is also located within the project development area. The lake is situated at the edge of the broad valley of the Condamine River and is connected to Wilkie Creek via the Broadwater Overflow; and also connected to the Condamine River, when in flood.

Moonie River catchment
Commencing near Dalby, the Moonie River is a tributary of the Barwon River and forms part of the Murray-Darling Basin (Sternberg *et al*, 2008) with less than 5% of the catchment in New South Wales. In its semi-arid climate, rainfall in the region is variable both spatially and temporally with an average annual fall of 500-600mm and annual evaporation of 1800-2200mm (Cottingham, 1999; Sternberg *et al*., 2008). This climatic regime results in the Moonie River being reduced to isolated pools for much of the year and then responding to seasonal rains with well-defined flow events (Sternberg *et al*, 2008). The Moonie River is subject to water use through weirs and off-channel storages and some pumping of water for unregulated stock and domestic use (Sternberg *et al*, 2008).

Portions of the catchment are flat with low relief hills bordering floodplains. The majority of floodplain and lowland areas have been cleared for grazing and cropping practices. Local heavy rainfall can cause major flooding downstream resulting in the inundation of much low lying land and roads. Land uses include dryland pastures for

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[3] Section 5, page 7 of "Audit Report on Draft Condamine-Balonne Water Resource Plan", February 2004.

[4] Page 1, of CSIRO Murray Darling Basin Sustainable Yields Project – a report to the Australian Government.

grazing and irrigated crops for cereals, cotton, pasture and hay. The Moonie catchment is one of the most heavily cleared in Queensland with approximately a quarter of remnant vegetation present.

Border Rivers catchment

Most of the catchment of the Weir River & Macintyre River is within Queensland though the Macintyre River originates in New South Wales. Macintyre Brook is a major tributary of the Macintyre River which eventually joins the Weir River near Talwood, Queensland (BOM, 2009b). Different land uses within the catchment have resulted in substantial land clearing, changes in vegetation and increased erosion, all of which influence catchment hydrology. Many streams in the Border Rivers basin are unregulated with water use being governed by natural flows (Australian Government ANRA).

The most common land use throughout the catchments is grazing on cleared land or in thinned native vegetation (State of the Rivers – Border Rivers and Moonie River). Water consumption in the catchment is dominated by irrigation with other major land uses including cotton production in the lower catchment and grapes, salad crops and orchard fruits in the upper catchment (Queensland Government (NR&W), 2008).

Riparian vegetation in the Upper Weir River subcatchment has been rated as good-to-very good while the Macintyre River and Macintyre Brook subcatchments rated as poor-to-very poor (State of the Rivers (2009) – Border Rivers and Moonie River). Ecological condition assessments rated the Lower Weir River and Upper Weir River subcatchments as good-to-very good while the Macintyre River subcatchment was rated as very poor. The Macintyre Brook subcatchment also received a low rating for bed stability due to high stream sediment loads resulting from bank erosion and agricultural uses.

4.3 Stream gauging

The rivers and their major tributaries which traverse the project development area are listed in the table below. The presence and number of gauging stations, from which daily historical stream flow data is available within the vicinity of the project development area, is also noted.

Table A4-1. ***Major Rivers and Tributaries in the project development area***

Major River (Catchment)	Tributary	Stream Flow Gauge	No. of Stations within or near Project Area
Condamine River (Condamine/Balonne)	Main Channel	✓	6
	Oakey Creek	✓	1
	Myall Creek	X	-
	Jimbour Creek	X	-
	Wilkie Creek	X	-
	Canal Creek[2]	✓	1
	Back Creek	X	-
	Braemar Creek	X	-
	Kogan Creek	X	-
	Cooranga Creek	X	-
	Charley's Creek	✓	1
	Dogwood Creek	✓	1
	North Condamine[1]	✓	2
MacIntyre & Weir Rivers (Border Rivers)	Main Channel	✓	-
	Bora Creek	X	-
	Paddy Creek	X	-
	Yarrill Creek	X	-
	Wyaga Creek	X	-

Major River (Catchment)	Tributary	Stream Flow Gauge	No. of Stations within or near Project Area
	Tin Hut Creek	X	-
	Commoron Creek	X	-
	Murri Murri Creek	X	-
	Wondalli Creek	X	-
	Bethecurriba Creek	X	-
	Wondalli Creek	X	-
	Hogan Creek	X	-
Macintyre Brook (Border Rivers)	Main Channel[2]	✓	2
	Nicol Creek	X	-
	Boola Creek	X	-
Dawson River (Dawson River)	Main Channel[2]	X	-
	Juandah Creek	✓	1
	Downfall Creek	X	-
Moonie River (Moonie)	Main Channel[2]	X	-
	Durabilla Creek	X	-
	Dunmore Creek	X	-

[1]North Condamine is an anabranch of the Condamine River
[2]Not within project development area

4.4 Flood History

A review of historical flood information available from the Bureau of Meteorology (BOM) has been undertaken for major waterways within the project development area. A brief summary of the flood potential for each catchment and the maximum gauge heights of significant floods are provided below. Flood definitions as used by BOM are:

- *Major Flooding*: This causes inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuation of many houses and business premises may be required. In rural areas widespread flooding of farmland is likely.
- *Moderate Flooding*: This causes the inundation of low lying areas requiring the removal of stock and/or the evacuation of some houses. Main traffic bridges may be closed by floodwaters.
- *Minor Flooding*: This causes inconvenience such as closing of minor roads and the submergence of low level bridges and makes the removal of pumps located adjacent to the river necessary.

A complete list of moderate to major flood events on BOM record for each major waterway within the project development area catchments is provided in Attachment D.

Dawson River Catchment

The Dawson River is a major tributary of the Fitzroy River and while the project development area does not include the main channel of the Dawson River, it crosses Juandah and Downfall Creeks, which form part of the Dawson River catchment.

BOM reports that average catchment rainfalls in excess of 200mm in 48 hours may cause significant moderate to major flooding, particularly in the middle to lower reaches of the Dawson River catchment. Average catchment rainfalls in excess of 300mm in 48 hours may cause significant major flooding

Condamine River Catchment

The headwaters of the Condamine River are in the Border Ranges and flow approximately 1,200 km through Queensland before entering New South Wales. Throughout this length the mean annual rainfall distribution varies from 1,000 mm in the headwaters to 500-700 mm per year at Chinchilla.

Flood records for the Condamine River extend back to 1862. Major floods occur regularly, on average every 2 years and generally in the months of late spring, summer and autumn. Significant floods were reported in 1942, 1956, 1976, 1983, and 1996.

Table A4-2. ***Recent floods at river stations along the Condamine River***

BOM River Height Station	Feb 1942	Jan/Feb 1956	Feb 1976	May 1983	May 1996	Feb 2001	Jan 2004
Warwick (McCahon Bridge)	5.72	6.10	9.10	6.25	6.5	5.03	-
Pratten	-	7.32	10.50	8.4	8.5	6.5	-
Tummaville	10.08	10.59	11.11	10.2	10.26	6.2	-
Centenary Bridge	-	-	8.20	7.45	7.61	6.5	6.65
Cecil Plains	-	8.84	9.17	8.5	8.39	6.0	5.5
Tipton Bridge	-	7.32	11.36	10.5	10.18	7.21	6.3
Loudon Bridge	-	10.67	10.89	10.28	10.32	-	8.4
Ranges Bridge	-	10.52	11.05	9.75	9.7	5.85	7.2
Warra-Kogan Road Bridge	-	14.00	-	13.71	13.53	5.5	8.25
Brigalow Bridge TM	-	-	13.99	-	13.4	6.11	8.88
Chinchilla Weir	-	13.87	13.9	13.51	13.32	3.44	7.41

All heights are in metres on flood gauges.

On the basis of historical rainfall and flood height information, BOM has assessed the flood potential of the Condamine River. Major flooding requires large scale rainfall over the Condamine River catchment to Cotswold. Their findings are that average catchment rainfalls in excess of 25 mm, with isolated 50 mm falls, in 24 hours may result in stream rises and the possibility of minor flooding and local traffic disruptions extending downstream. Average catchment rainfalls in excess of 50 mm, with isolated 75 to 100 mm falls, in 24 hours may result in significant stream rises with the possibility of moderate to major flooding developing with local traffic disabilities and extending downstream (BOM, 2009). The table below shows the flood classifications adopted by BOM for selected river height stations in the Condamine River catchment.

Table A4-3. ***Flood Classifications adopted by BOM for river height stations along the Condamine River***

BOM River Height Station	First Report Height	Crossing Height	Minor Flood Level	Crops & Grazing	Moderate Flood Level	Towns and Houses	Major Flood Level
Warwick (McCahon Bridge)	2.0	7.0 (B)	5.0	6.0	6.0	6.2	7.0
Pratten	3.0	4.3 (B)	5.0	5.0	6.0	-	7.0
Tummaville	2.0	4.3 (B)	5.0	8.0	8.0	10.4	9.0 (d/s)
Centenary Bridge	4.0	6.8 (A)	5.0	6.0	6.0	7.3	7.0
Cecil Plains	4.5	6.9 (B)	6.0	7.0	7.0 (d/s)	-	8.0
Tipton Bridge	3.0	8.4 (B)	5.0	5.0	6.0 (d/s)	-	7.0 (d/s)
Loudon Bridge	3.0	9.1 (A)	5.0	5.0	7.0	-	9.0
Ranges Bridge	3.0	7.5 (B)	6.0	8.0	6.5 (d/s)	-	7.0 (d/s)
Warra-Kogan Road Bridge	3.0	9.1 (B)	7.0	-	8.0	-	9.0
Brigalow Bridge TM	-	-	7.5	-	9.0	-	10.5
Chinchilla Weir	6.0	10.0 (R)	6.0	8.0	8.0	-	10

All heights are in metres on flood gauges. (B) = Bridge, (A) = Approaches, (R) = Road, (d/s) = Downstream

Moonie River Catchment
The project development area extends over Durabilla and Dunmore Creeks, which are small tributaries of Moonie River. There are two active streamflow gauging stations on the Moonie River at Flinton and Nindigully; however, both are a significant distance downstream from the project development area. The largest tributary of Moonie River is Teelba Creek, which flows into the Moonie River, approximately 30 km downstream of Flinton and approximately 125 km south-west of the project development area.

BOM reports that this tributary, along with local streams running into the Moonie River upstream of Flinton, can contribute to major flooding downstream following local heavy rainfall. Rainfall of 50 mm in 24 hours over isolated areas, with lesser rains of 25 mm over more extensive areas will cause stream rises and the possibility of minor flooding. If lesser rainfalls have been recorded in the previous 24 to 72 hrs, then moderate to major flooding may develop. Isolated flooding can occur if 50 mm of rain falls within 24 hours in the immediate area of the heavy rain. Rainfall events of 50 mm or heavier within 24 hours over a wide area will most likely cause major flooding, particularly in the middle to lower reaches.

Border Rivers (Macintyre and Weir) Catchment
The Border Rivers Catchment includes the Macintyre, Weir and Severn Rivers. The project development area traverses the headwaters of the Weir River and lies to the north of Macintyre Brook which forms the headwaters of the Macintyre River. Flood heights and warning levels adopted for the river stations closest to the project development area are listed in the tables below.

Table A4-4. ***Recent floods at river stations along Macintyre Brook and Weir River***

BOM River Height Station	Jan/Feb 1956	Feb 1976	May 1996	Jul/Aug 1998	Sept 2010	Oct 2010
Macintyre Brook						
Woodspring	9.57	8.53	6.30	5.70	3.01	2.98
Inglewood Bridge	12.50*	11.73	9.75	9.15	-	-
Bengalla	11.82	11.90	9.82	8.80	7.47	5.94
Goondiwindi	10.27	10.50	10.60	10.48	8.83	8.93
Weir River						
Retreat Bridge	14.95	-	10.65	9.30	-	6.95
Gunn Bridge	-	-	6.52	-	-	5.44

All heights are in metres on flood gauges.
[*] These heights have been taken at old gauge sites and may not relate to existing gauge sites.

A4-5. ***Classifications adopted by BOM for river height stations along the Macintyre Brook***

BOM River Height Station	First Report Height	Crossing Height	Minor Flood Level	Crops & Grazing	Moderate Flood Level	Towns and Houses	Major Flood Level
Macintyre Brook							
Woodspring	3.0	7.00 (B)	3.5	-	5.5	-	7.0
Inglewood Bridge	3.0	10.40 (B)	5.0	9.0	9.0	10.1	10.0
Bengalla	3.0	2.70 (B)	4.0	-	6.0	-	10.0
Goondiwindi	4.0	12.20 (B)	4.0	3.5	6.0 (d/s)	-	8.5 (d/s)
Weir River							
Retreat Bridge	-	12.50 (B)	6.0	-	8.0	-	10.0
Gunn Bridge	-	5.90 (B)	5.0	-	6.0	-	7.0

All heights are in metres on flood gauges. (B) = Bridge, (d/s) = Downstream

BOM's assessment of the flood potential for the Macintyre and Weir River Catchment is similar to that outlined for the Condamine in that it generally requires a large scale rainfall event across the catchment. It is estimated that 50 mm in 24 hours over isolated areas, with lesser rains of 25 mm over more extensive areas will cause stream rises and the possibility of minor flooding. If lesser rainfalls have been recorded in the previous 24 to 72 hours, then moderate to major flooding may develop. Rainfall in excess of 50 mm in 24 hours will cause isolated flooding in the immediate area of the heavy rain. General 50 mm or heavier falls in 24 hours over a wide area will most likely cause major flooding, particularly in the middle to lower reaches of the Macintyre, the Macintyre Brook and Weir River (BOM, 2009).

4.5 Streamflow data

The DERM operates a network of hydrographic monitoring sites throughout Queensland. These monitoring sites collect time series data on streamflow that is available to the public for download online through the DERM website. A summary of the streamflow gauging stations within or near the project development area and their period of record is provided in Table A4-6, page 71. The station locations with regard to the project development area boundary are shown on Figure A4-2, page 72.

The Condamine River, being the largest watercourse in the region and a major irrigation area, is monitored extensively with four gauging stations located on the main channel within the project development area; and a near continuous flow record of 38 to 63 years. For the Condamine River and its tributaries, there are a total of 12 gauging stations within or near the project development area. In addition, there are two stations on the Macintyre Brook in the Border Rivers catchment and a station on Juandah Creek in the headwaters of the Dawson River.

Maximum daily flow data has been obtained for each of the gauging stations listed. Table A4-7 to Table A4-9 list the maximum daily flow for each water year (October – September) of record, ranked by magnitude for each station. For the Condamine River and Juandah Creek at the headwaters of the Dawson River, the recent flood event in December 2010 ranks as one of the highest on record. This data has been used as the basis for the flood frequency analysis outlined in Section 4.6.

Table A4-6. ***Summary of Available Daily Stream Flow Data within or near to the project development area***

STATION NUMBER	LOCATION DESCRIPTION	EASTING	NORTHING	YEARS OF DATA	VERIFIED DAILY FLOW DATA	UNVERIFIED FLOW DATA
			CONDAMINE / BALONNE RIVER CATCHMENT			
Condamine River						
422344A	Condamine River at Bedarra	236086.7	7028328.2	3	12/06/2007 – 28/02/2011	1/03/2011 – 3/05/2011
422308C	Condamine River at Chinchilla	258930.3	7033393.8	55	02/10/1955 – 4/10/2010	5/10/2010 – 2/04/2011
422336A	Condamine River at Brigalow	279820.5	7022227.7	38	01/10/1972 – 16/02/2011	17/02/2011 – 3/05/2011
422333A	Condamine River at Loudons Bridge	320338.5	6987319.8	41	24/03/1969 – 16/02/2011	17/02/2011 – 3/05/2011
422316A	Condamine River at Cecil Weir	322500	6953000	63	25/10/1947 – 3/10/2010	4/10/2010 – 3/05/2011
422323A	Condamine River at Tummaville	353476.1	6916245.5	49	03/08/1961 – 17/10/2010	18/10/2010 – 3/05/2011
Condamine River Anabranch						
422345A	North Condamine River at Lone Pine	336938.3	6938358	31	14/10/1978 – 27/04/2009	–
422347B	North Condamine River at Pampas	344761.9	6925783.4	21	26/03/1988 – 03/06/2009	–
Condamine River Tributaries						
422202D	Dogwood Creek at Gilweir	219324.0	7042351.0	61	02/10/1949 – 13/02/2011	14/02/2010 –3/05/2011
422343A	Charleys Creek at Chinchilla	261731.1	7039881.4	8	27/06/2003 – 13/02/2011	14/02/2010 –3/05/2011
422350A	Oakey Creek at Fairview	329594	6978775	30	17/10/1980 – 3/10/2010	4/10/2010 – 3/05/2011
422338A	Canal Creek at Leyburn	360939.1	6898429	38	26/10/1972 – 5/10/2010	6/10/2010 – 03/05/2011
			BORDER RIVERS CATCHMENT			
MacIntyre River						
416402C	Macintyre Brook at Inglewood	310900	6854958	29	03/02/1981 – 15/02/2011	16/02/2010 – 3/05/2011
416415A	Macintyre Brook at Booba Sands	289267.7	6837575.1	23	18/02/1987 – 29/04/2010	30/04/2010 – 3/05/2011
			FITZROY RIVER CATCHMENT			
Dawson River Tributary						
130344A	Juandah Creek at Windamere	788431	7118180	36	28/06/1974 – 18/01/2011	19/02/2011 – 3/05/2011

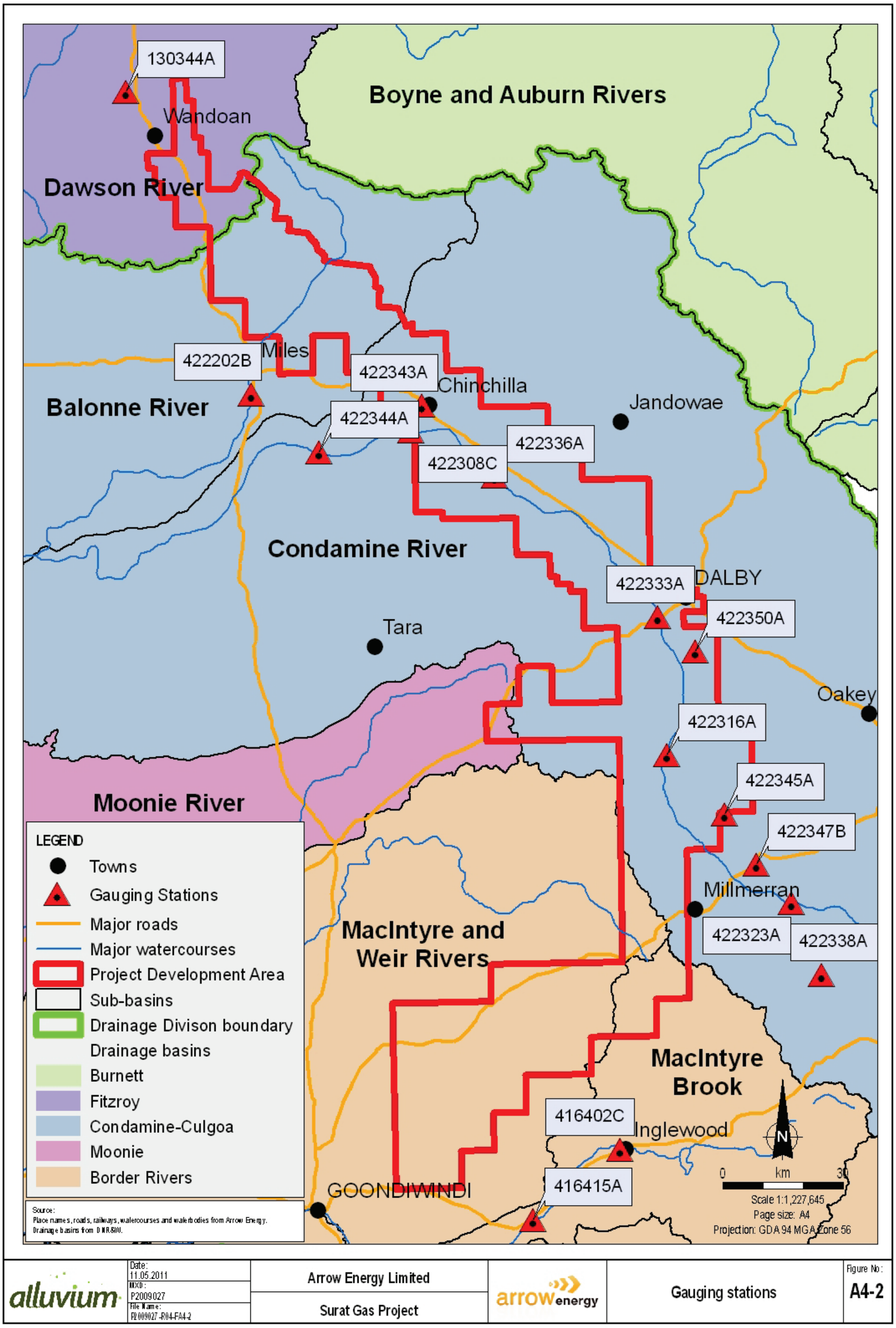


Figure A4-2 . ***Location of streamflow gauging stations within or near the project development area***

Table A4-7. ***Maximum daily flow for each year of record for Condamine River, ranked by magnitude***

Condamine River Stations (m3/s)										
RANK	**Tummaville**		**Cecil Weir**		**Loudon Bridge**		**Brigalow**		**Chinchilla**	
1	Feb-1976	1788	Feb-1976	2024	***Dec-2010***	***3124***	***Dec-2010***	***4817***	***Dec-2010***	***4347***
2	***Dec-2010***	***1761***	***Dec-2010***	***1926***	Feb-1976	1630	Feb-1976	2781	Apr-1988	2855
3	Apr-1988	1415	Apr-1988	1695	Apr-1988	1477	Apr-1988	2620	May-1983	2252
4	May-1983	1236	May-1983	1501	May-1983	1206	Jan-1974	2105	May-1996	2024
5	May-1996	1198	May-1996	1427	May-1996	1163	Feb-1981	2105	Feb-1976	1786
6	Jan-1974	979	Jan-1956	1278	Feb-1981	812	May-1996	2030	Jan-1956	1782
7	Oct-1972	958	Oct-1972	1250	Oct-1972	804	Jul-1984	1116	Feb-1981	1546
8	Jan-1968	924	Feb-1971	1114	Jan-1974	650	Nov-1972	1108	Jan-1974	1504
9	Feb-1971	901	Jan-1974	1098	Jul-1984	598	Mar-1999	532	Jul-1984	1420
10	Mar-1964	790	Jun-1950	1049	Feb-1971	587	Mar-2010	394	Nov-1972	1322
11	Feb-1981	725	Jul-1984	958	Feb-1991	487	Feb-1991	386	Feb-1971	1278
12	Feb-1991	602	Mar-1999	908	Mar-1999	466	Feb-2008	367	Mar-1999	502
13	Feb-1980	600	Feb-1991	872	Mar-1982	330	Mar-1977	291	Dec-1956	479
14	Jul-1984	577	Feb-1951	777	Jan-2004	311	Sep-1998	290	Dec-1971	470
15	Mar-1999	407	Oct-1954	743	Mar-1975	310	Mar-1975	257	Jun-1958	460
16	Jun-1967	387	Mar-1964	678	Nov-2008	309	Feb-1994	253	Feb-1959	446
17	Jul-1965	346	Jan-1968	678	Feb-1994	294	Sep-1978	248	Mar-2010	393
18	Feb-1975	297	Jun-1948	561	Sep-1978	286	Jan-2004	247	Feb-2008	383
19	Dec-2008	296	Dec-1956	536	Dec-1971	255	Apr-1989	226	Feb-1991	365
20	Feb-2001	275	Mar-1963	516	Feb-1980	254	Nov-2008	216	Apr-1963	345
21	Nov-1976	260	Mar-1982	492	Nov-1976	246	May-1990	169	Mar-1964	330
22	Mar-1982	231	Feb-1959	478	Aug-1998	240	Feb-1980	161	Dec-1965	322
23	May-1990	182	Jul-1965	448	May-1990	239	Feb-2001	121	Nov-1959	313
24	Mar-1963	180	Feb-1975	446	Mar-1989	185	Nov-1999	102	Sep-1998	306
25	Sep-1978	179	Dec-1965	418	Jan-1992	137	Jan-1992	94	Jun-1967	291
26	Jan-2008	176	Feb-1980	402	Feb-2001	124	Feb-1997	79	Mar-1977	282
27	Apr-1962	172	Feb-1981	385	Mar-2010	115	Jun-1979	76	Jan-1968	268
28	Jan-1992	158	Mar-1962	334	Nov-1999	110	Dec-2001	74	Mar-1975	259
29	Nov-1999	157	Aug-1998	314	Feb-2008	80	Nov-1984	49	Feb-1994	258
30	Apr-1989	151	Jan-2004	310	Nov-1978	74	Feb-1995	45	Apr-1989	258
31	Dec-1965	148	Nov-1976	288	Dec-2001	70	Jan-2006	44	Jan-1962	257
32	Feb-1995	137	Jun-1967	282	Nov-2005	68	Oct-1985	37	Sep-1978	252
33	Nov-2005	120	May-1990	275	Feb-1995	59	Feb-2003	36	Jan-2004	244
34	Jan-2004	106	Sep-1978	262	Feb-1997	58	Aug-1987	31	Mar-1982	230
35	Feb-1997	96	Mar-1989	235	Nov-1984	46	Jun-2005	19	Jul-1965	215
36	Aug-1969	85	Feb-2001	204	Aug-1987	45	Jun-2007	6	Nov-2008	208
37	Mar-1979	77	Feb-1994	159	Nov-1969	33	Sep-1983	6	May-1990	174
38	Dec-1971	73	Oct-1952	154	Dec-1985	18	Jan-1993	5	Feb-1980	153
39	Aug-1998	64	Jan-1992	144	Feb-2003	10			Mar-1961	150
40	Nov-2001	57	Nov-1959	143	Jan-1993	3			Feb-1997	109
41	Feb-2010	47	Nov-1999	142	Oct-2004	0			Feb-2001	103
42	Jan-1987	42	Dec-2008	129	Oct-2006	0			Jan-1992	91
43	Nov-1984	41	Mar-2010	117					Nov-1999	86
44	Nov-1969	27	Jun-1952	110					Dec-2005	75
45	Dec-1985	18	Feb-2008	104					Nov-1978	69
46	Mar-1994	16	Feb-1954	101					Sep-1969	56
47	Dec-2004	13	Feb-1961	97					Dec-2001	54
48	Feb-2003	10	Nov-1978	85					Nov-1984	51
49	Dec-1992	8	Feb-1995	83					Feb-1995	47
50	Dec-2006	5	Aug-1969	70					Nov-1969	37
51			Nov-2005	68					Jan-1987	36
52			Feb-1997	64					Oct-1985	32
53			Aug-1987	61					Oct-1992	4
54			May-1949	50					Mar-2003	2
55			Nov-1984	41					Jul-2007	1
56			Feb-2003	33					Oct-2004	0
57			Nov-1969	30						
58			Nov-2001	30						
59			Apr-1972	29						
60			Mar-1958	20						
61			Oct-1985	8						
62			Jan-1993	5						
63			Dec-2004	4						
64			Oct-2006	0						

Table A4-8. ***Maximum daily flow for each year of record for Condamine River tributaries, ranked by magnitude***

RANK	Dogwood Creek @Gilweir		Oakey Creek @ Fairview		Canal Creek @Leyburn		Charleys Creek @ Chinchilla	
1	Jan-1956	883	Nov-1995	418	Feb-1976	558	***Jan-2011***	***424***
2	May-1983	733	Apr-1988	405	Mar-1982	519	Dec-2005	144
3	***Dec-2010***	***699***	Feb-1981	401	Apr-1988	464	Mar-2010	109
4	Jul-1954	603	May-1983	383	May-1983	452	Jun-2005	69
5	Jan-1996	599	Jul-1984	343	***Dec-2010***	***310***	*Mar-2004*	47
6	Aug-1998	532	***Jan-2011***	***302***	May-1996	251	Feb-2008	41
7	Feb-1971	499	Nov-2008	282	Oct-1972	230	Jun-2007	18
8	Feb-1959	473	Feb-1999	251	Mar-1999	153	Oct-2008	0
9	Feb-1950	453	Nov-1989	146	Mar-1989	147		
10	Jan-1984	413	Dec-1981	105	Nov-1999	146		
11	May-1955	301	Feb-1994	95	Jul-1984	103		
12	Dec-1956	275	Nov-1984	78	Nov-1976	81		
13	Mar-2010	273	Dec-2001	77	Dec-1989	74		
14	Feb-1981	259	Feb-2001	76	Jan-2004	69		
15	Dec-1971	240	Nov-1997	69	Aug-1987	69		
16	Mar-1994	192	Apr-1989	65	Feb-2008	66		
17	Dec-2005	173	Feb-1991	58	Nov-1979	65		
18	Feb-1991	166	Dec-1991	57	Nov-2008	58		
19	May-1977	160	Feb-2004	47	Feb-1975	52		
20	Nov-1998	159	Feb-2008	34	Jan-2003	50		
21	Jun-1958	150	Feb-1995	32	Sep-1978	49		
22	Apr-2003	147	Feb-1997	31	Feb-1995	44		
23	Mar-1982	135	Mar-2010	31	Mar-2002	42		
24	Nov-1989	126	Dec-1985	26	Aug-1998	39		
25	Jan-2000	107	Dec-1999	4	Jan-1992	34		
26	Jan-1962	103	Jan-2006	4	Jan-1979	32		
27	Apr-1988	96	Dec-2002	2	Dec-1980	29		
28	Jan-1997	94	May-1993	2	Dec-2005	26		
29	Feb-1992	85	Oct-1986	1	Aug-2010	23		
30	Feb-1966	78	Jun-2007	1	Feb-1991	16		
31	Nov-1959	70	Dec-2004	1	Nov-1973	12		
32	Feb-1961	70			Nov-1984	10		
33	Feb-1995	67			Dec-1996	9		
34	Dec-1975	66			Feb-2001	4		
35	Nov-1950	58			Feb-1986	1		
36	Jan-1974	53			Oct-1992	0		
37	Jan-1973	52			Oct-1993	0		
38	Mar-1985	38			Oct-2004	0		
39	Mar-2002	38			Oct-2006	0		
40	Jun-1967	38						
41	Jan-1968	38						
42	Apr-1989	36						
43	Jan-1975	34						
44	Sep-1978	33						
45	Jan-2004	32						
46	Mar-1952	32						
47	Mar-1964	27						
48	Jul-2005	25						
49	Dec-1962	18						
50	Mar-1970	15						
51	Mar-1979	15						
52	Oct-1952	14						
53	Oct-1964	11						
54	Jan-1987	10						
55	Dec-1979	9						
56	Aug-2007	5						
57	Jan-2009	4						
58	Feb-2008	2						
59	Oct-1985	2						
60	Jan-1969	0						
61	Oct-1992	0						
62	Oct-2000	0						

Table A4-9. *Maximum daily flow for each year of record for Macintyre Brook and Juanda Creek, ranked by magnitude*

RANK	Macintyre Brook @ Inglewood		Macintyre Brook @ Booba Sands		Juandah Creek @ Windamere	
1	Apr-1988	1398	Apr-1988	1160	***Dec-2010***	***1057***
2	May-1996	938	May-1996	839	May-1983	891
3	May-1983	836	Jul-1998	589	Feb-1991	828
4	***Jan-2011***	***815***	Apr-1990	389	Aug-1998	815
5	Jul-1998	728	Mar-1999	375	Jan-1996	637
6	Jul-1984	651	Sep-2010	351	Mar-2010	558
7	Apr-1990	595	Feb-1992	271	May-1977	454
8	Mar-1999	520	Nov-1999	263	Dec-2005	448
9	Feb-1992	430	Mar-1989	218	Apr-1990	441
10	Sep-2010	421	Feb-2001	199	Jun-1981	421
11	Nov-1999	343	Feb-1991	149	Jul-1984	362
12	Mar-1989	246	Dec-2005	147	Mar-1997	254
13	Feb-2001	226	Jan-2004	141	Feb-1999	238
14	Mar-1982	171	Nov-2008	133	Feb-1995	174
15	Feb-1991	154	Mar-2002	126	Dec-1993	162
16	Nov-2008	129	Feb-1994	49	Dec-1975	134
17	Jan-2004	127	Feb-2003	46	Sep-1978	126
18	Dec-2005	107	Oct-1996	45	Feb-1980	122
19	Mar-2002	41	Feb-2008	44	Nov-2001	110
20	Oct-1996	41	Dec-2004	42	Feb-1992	107
21	Feb-1994	39	Feb-1995	10	Dec-2004	104
22	Feb-2008	36	Feb-1993	4	Apr-2003	101
23	Feb-2003	34	Nov-2006	4	Oct-1985	77
24	Nov-1984	31			Feb-1975	76
25	Jan-2005	16			Mar-1979	73
26	Feb-1995	13			Mar-1982	69
27	Feb-1986	11			Feb-2004	65
28	Feb-1987	8			Jan-1988	58
29	Dec-1992	5			Feb-2008	58
30	Jan-2007	4			Apr-1989	51
31					May-2009	49
32					Feb-2007	47
33					Oct-2000	41
34					Jan-2000	35
35					Oct-1984	6
36					Nov-1992	4
37					Jan-1987	3

4.6 Flooding Frequency and Extent

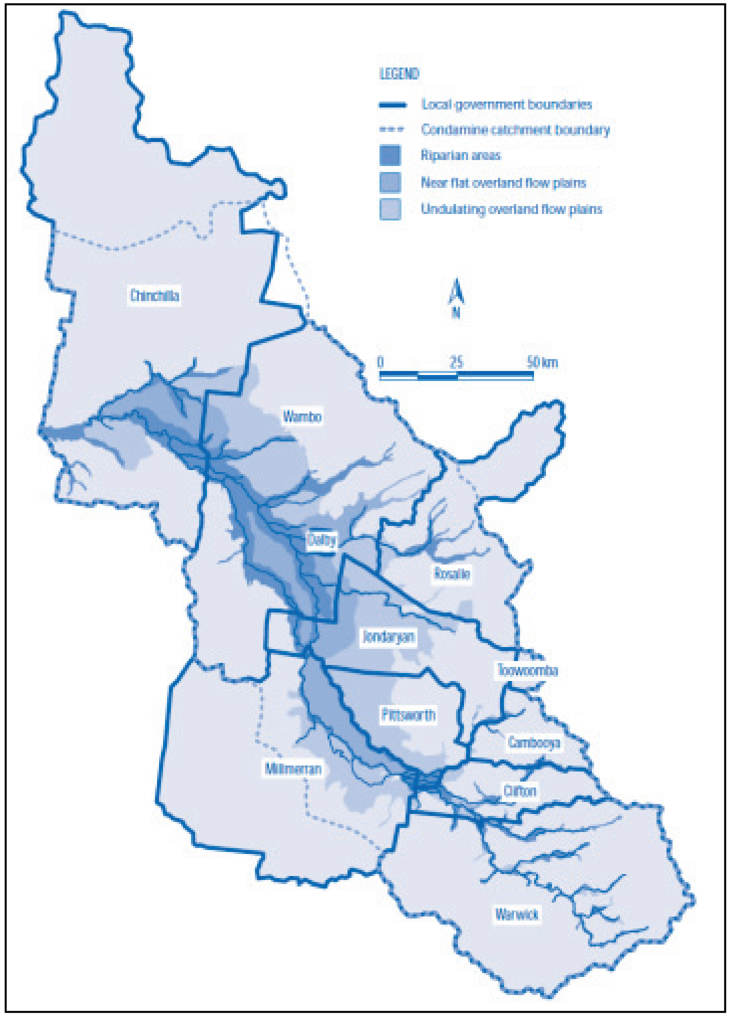
Flood levels and qualitative descriptions of minor, moderate and major flood history have been obtained from the Bureau of Meteorology as outlined previously. There is limited flood modelling information in the public domain, outside of local council town areas. There is no publically available flood mapping for the areas of the catchments covered by the project development area, except for parts of the Condamine River.

Condamine River overland flow modelling was undertaken by Land Resource Assessment and Management Pty Ltd (LRAM). The project reportedly mapped overland flow paths, estimated the extent of flooding and provided tools for use in GIS to assist with Local Government planning. Attempts to obtain the modelling through government agencies or through LRAM have been unsuccessful. However, the delineation of the Condamine River floodplain as prepared by LRAM Pty Ltd was published in *Guidelines for Incorporating Runoff and Flow Coordination into Local Government Planning Schemes on the Condamine Floodplains* (DLGP, 2003). This is reproduced in Figure A4-3 along with GIS information on provided by DERM to the assessment team. It should be noted that the flood plain mapping is at a coarse scale and incomplete for some sections. Therefore, they should only be considered only as a guide when compared to the Project Area.

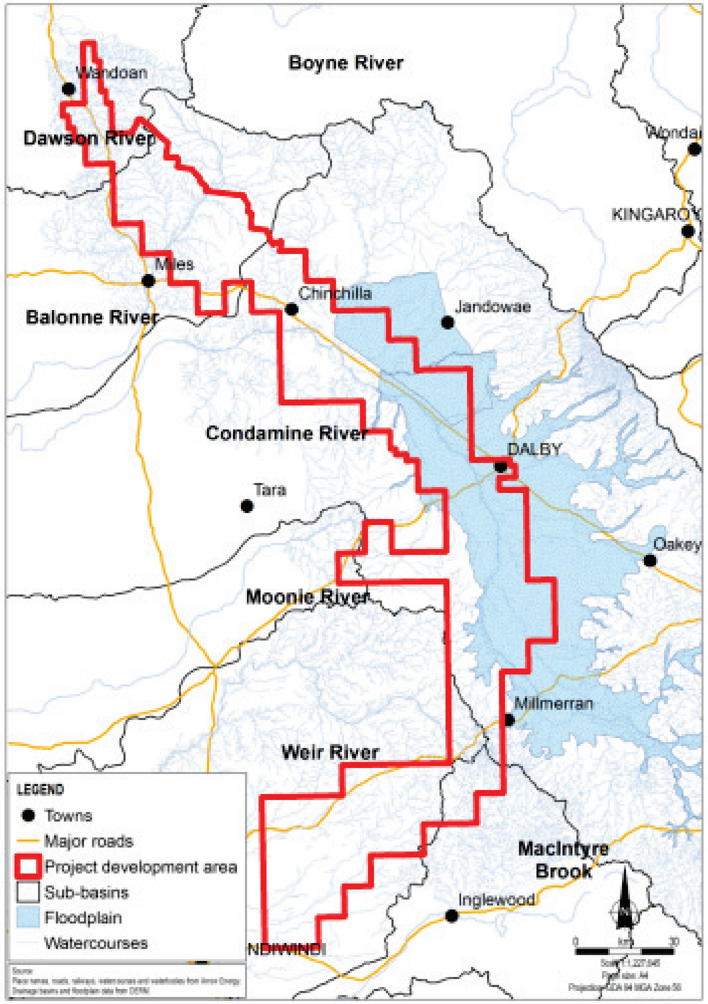
A flood frequency analysis has been undertaken for major watercourses within the Project Area with sufficient stream flow data available. These include the Condamine River (5 gauge locations), the Condamine River tributaries of Dogwood Creek, Oakey Creek and Canal Creek, Macintyre Brook (2 gauge locations) and Juandah Creek, a tributary of the Dawson River. The results of the flood frequency analysis are summarised in Table A4-10, page 78.

Given the extent of the project development area, the number of weirs, off-channel storages and the complexity of modelling overland flow paths, the statistical analysis of flood frequency based on stream flow alone is limited in its usefulness. However, a comparison of peak flows for the recent floods in December 2010 and January 2011, provides an estimate of their average recurrence interval (ARI). The flood frequency analysis for the Condamine River and a comparison to the recent flood events is presented graphically in Figure A4-4, page 79.

Table A4-11 and Table A4-12 summarise the estimates of ARI at each gauging station for the December and January floods, respectively.



(a) Prepared by LRAM Pty Ltd (DLGP, 2003, pg 12)



(b) GIS flood plain information provided by DERM

Figure A4-3. ***GIS Mapping of Condamine River Floodplain published (a) and provided to the assessment team by DERM (b)***

Table A4-10. ***Annual Series flood frequency analyses for major project watercourses with gauged streamflow data available***

Station Number	Location Description	2 Year ARI	5 Year ARI	10 Year ARI	20 Year ARI	20 Year ARI	50 Year ARI	75 Year ARI	100 Year ARI
CONDAMINE / BALONNE RIVER CATCHMENT									
Condamine River									
422323A	Condamine River at Tummaville	237	571	879	1265	1537	1939	2314	2615
422316A	Condamine River at Cecil Weir	301	693	1034	1441	1718	2115	2474	2756
422333A	Condamine River at Loudons Bridge	223	562	903	1359	1696	2216	2721	3140
422336A	Condamine River at Brigalow	245	744	1295	2091	2716	3729	4763	5650
422308C	Condamine River at Chinchilla	288	740	1211	1860	2351	3124	3890	4532
Condamine River Tributaries									
422202D	Dogwood Creek at Gilweir	92	234	370	546	672	862	1043	1190
422350A	Oakey Creek at Fairview	80	191	287	401	479	590	691	770
422338A	Canal Creek at Leyburn	58	151	244	369	461	604	743	857
BORDER RIVERS CATCHMENT									
Macintyre River									
416402C	Macintyre Brook at Inglewood	192	468	712	1003	1202	1489	1750	1955
416415A	Macintyre Brook at Booba Sands	152	352	536	766	927	1166	1389	1568
FITZROY RIVER CATCHMENT									
Dawson River Tributary									
130344A	Juandah Creek at Windamere	157	362	552	789	956	1202	1431	1614

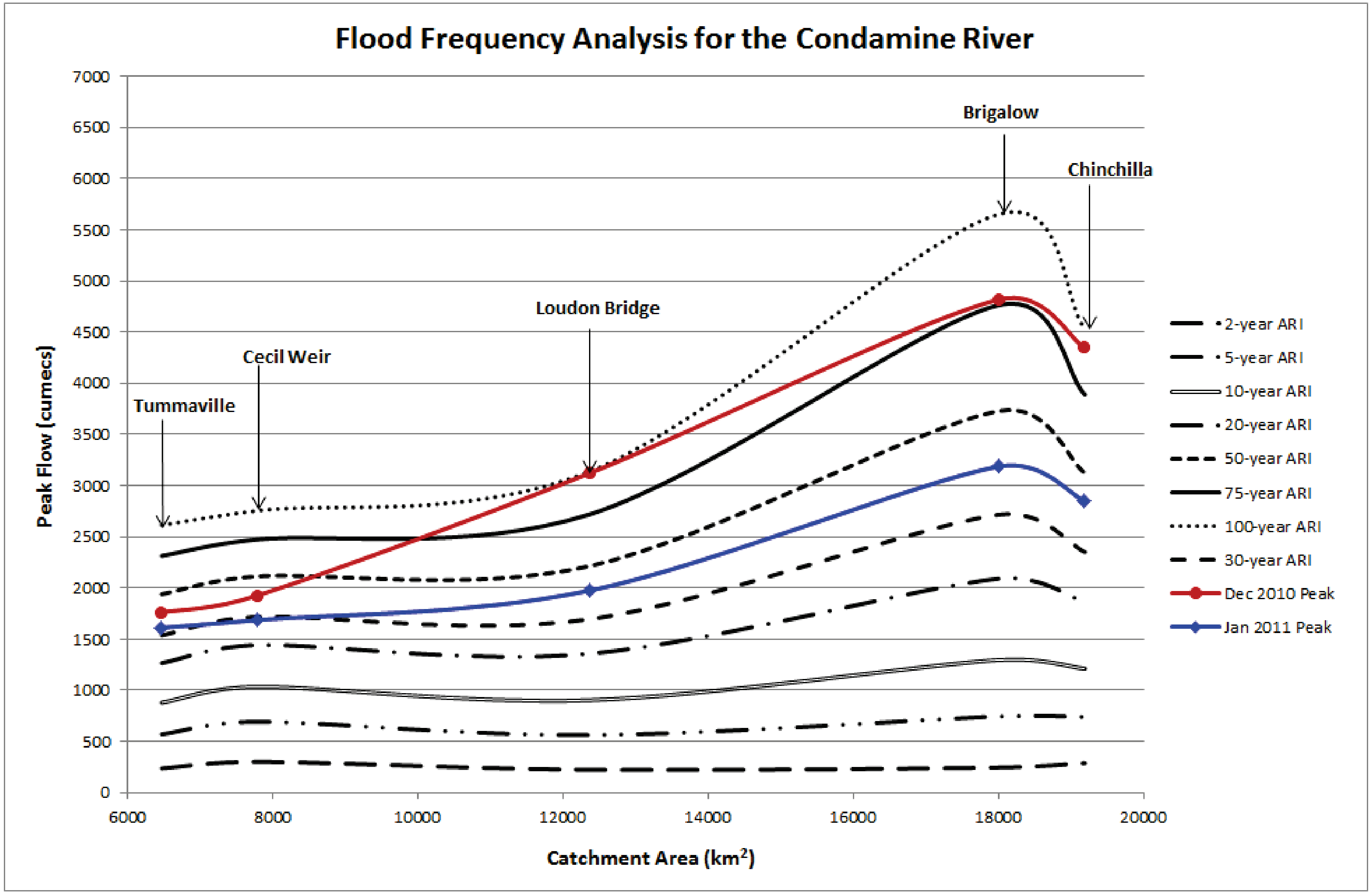


Figure A4-4. ***Graphical presentation of annual series flood frequency analysis for the Condamine River***

Table A4-11. ***Estimated ARI for December 2010 flood event***

Station ID	Location Description	December 2010		
		Date	Peak (cumecs)	ARI (years)
422323A	Condamine River at Tummaville	27/12/2010	1761	30 - 50
422316A	Condamine River at Cecil Weir	26/12/2010	1926	30 - 50
422333A	Condamine River at Loudons Bridge	29/12/2010	3124	~ 100
422336A	Condamine River at Brigalow	30/12/2010	4817	75 - 100
422308C	Condamine River at Chinchilla	31/12/2010	4347	75 - 100
422202B	Dogwood Creek at Gilweir	28/12/2010	699	~ 30
422350A	Oakey Creek at Fairview	28/12/2010	302	10 - 20
422238A	Canal Creek at Leyburn	28/12/2010	310	10 - 20
416402C	Macintyre Brook at Inglewood	28/12/2010	750	~ 10
416415A	Macintyre Brook at Booba Sands	29/12/2010	431	5 - 10
130344A	Juandah Creek at Windamere	27/12/2010	1057	30 - 50

Table A4-12. ***Estimated ARI for January 2011 flood event***

Station ID	Location Description	January 2011		
		Date	Peak (cumecs)	ARI (years)
422323A	Condamine River at Tummaville	12/01/2011	1611	30 - 50
422316A	Condamine River at Cecil Weir	13/01/2011	1687	~ 30
422333A	Condamine River at Loudons Bridge	13/01/2011	1976	30 - 50
422336A	Condamine River at Brigalow	14/01/2011	3186	30 - 50
422308C	Condamine River at Chinchilla	15/01/2011	2849	30 - 50
422202B	Dogwood Creek @Gilweir	13/01/2011	209	~ 5
422350A	Oakey Creek @ Fairview	12/01/2011	302	10 - 20
422238A	Canal Creek @Leyburn	11/01/2011	254	~ 10
416402C	Macintyre Brook at Inglewood	11/01/2011	815	10 - 20
416415A	Macintyre Brook at Booba Sands	12/01/2011	667	10 - 20
130344A	Juandah Creek at Windamere	-	-	-

For the Condamine River, it appears the December 2010 flood event is estimated to be a 30 to 50 year ARI event for the Project area upstream of Dalby. From Loudons Bridge (immediately upstream of the Condamine Rivers' confluence with Myall Creek and downstream of Dalby) to Chinchilla, it is estimated as a 75 to 100 year ARI flood event.

For the Condamine River tributaries of Dogwood Creek (near Miles), Oakey Creek (south of Dalby) and Canal Creek (southwest of Millmerran), it was less than a 30 year ARI event. For Juandah Creek, north of the project area, it was estimated as a 30 to 50 year ARI. For the Macintyre Brook gauging stations, located south of the project area, the event was estimated to be only a 5 to 10 year ARI.

Figure A4-5, page 81, presents the GIS flood extents on 31 December 2010 derived from the NASA operated TERRA MODIS satellite and provided by Geosciences Australia. These flood extents are a snap shot of the flooding, not the maximum extent of flooding for the December 2010 event. However, the satellite image is near to the peak flood level for the Condamine River at Brigalow and Chinchilla and provides an indication of area of inundation in this area for a flood event of 75 to 100 year ARI.

Maximum daily flows for the Condamine River over the December and January flood events are shown in Figure A4-6. The maximum daily flow recorded on 31 December 2010 for each station and its magnitude in relation to the peak flood level is shown in Table A4-13.

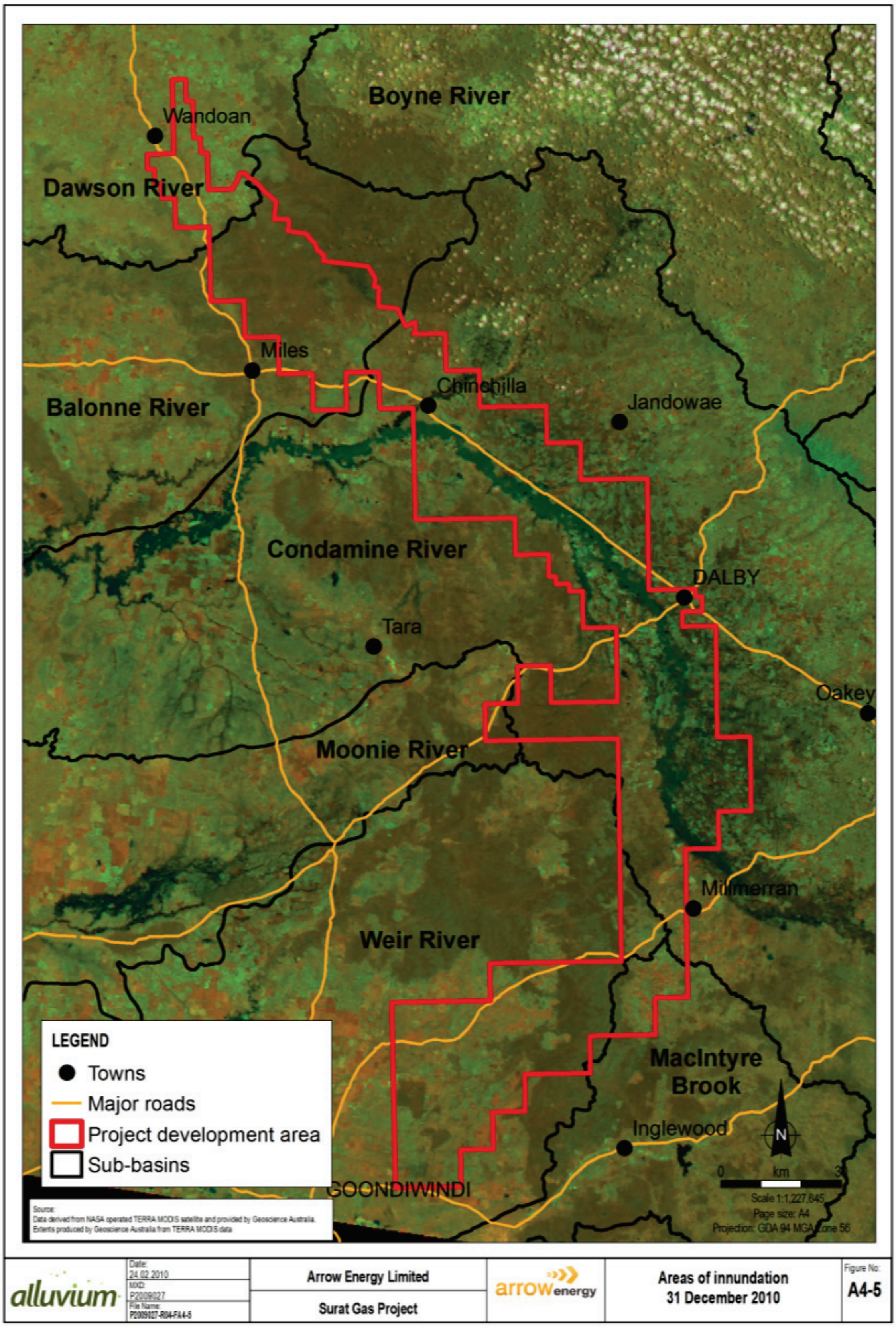


Figure A4-5. ***Flood extents on 31 December 2010 derived from NASA operated TERRA MODIS satellite***

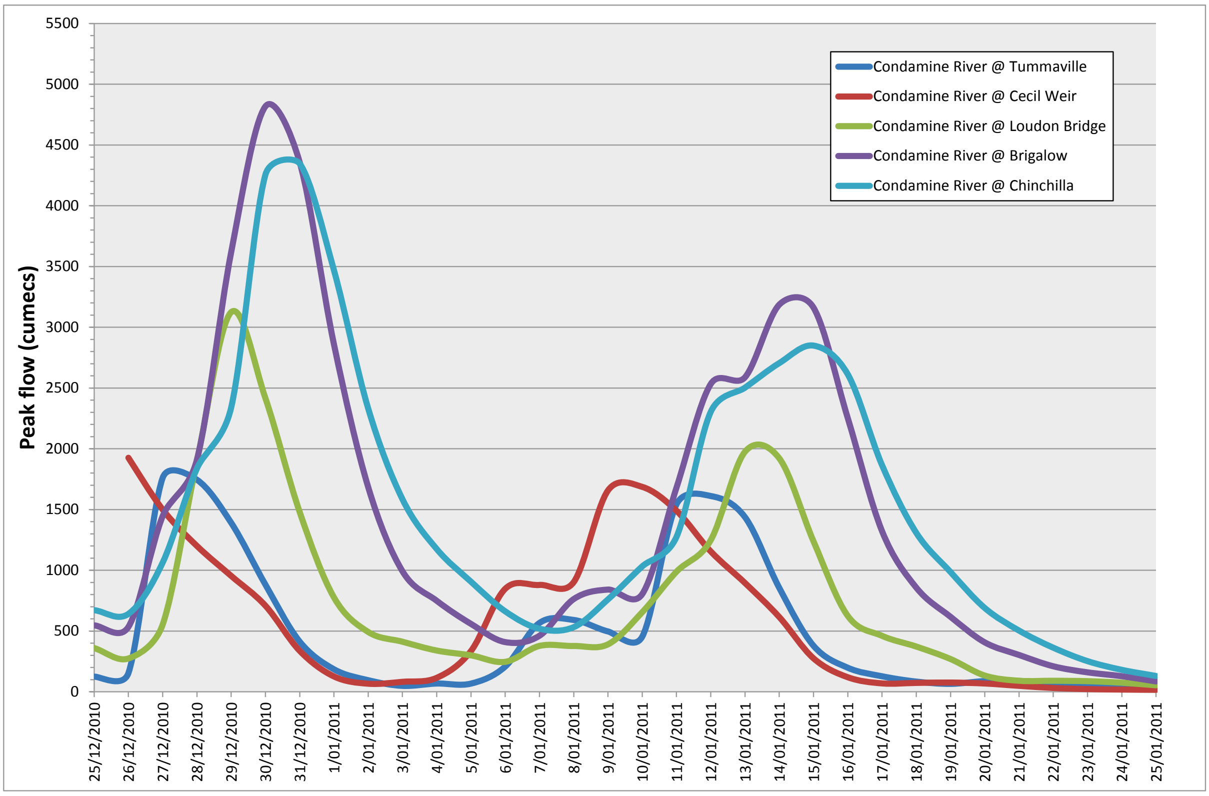


Figure A4-6. ***Maximum daily flows for the Condamine River for December 2010 and January 2011 flood events***

Table A4-13. ***Flow on 31 December 2010 as a percentage of peak flow***

Station ID	Location Description	31 Dec-2010 Flow (cumecs)	Peak flow (cumecs)	% of Peak
422323A	Condamine River at Tummaville	413	1761	23%
422316A	Condamine River at Cecil Weir	337	1926	18%
422333A	Condamine River at Loudons Bridge	1479	3124	47%
422336A	Condamine River at Brigalow	4358	4817	90%
422308C	Condamine River at Chinchilla	4347	4347	100%
422202B	Dogwood Creek @Gilweir	300	699	43%
422350A	Oakey Creek @ Fairview	25	302	8%
422238A	Canal Creek @Leyburn	2	310	1%
416402C	Macintyre Brook at Inglewood	19	750	3%
416415A	Macintyre Brook at Booba Sands	40	431	9%
130344A	Juandah Creek at Windamere	14	1057	1%

From the data in Table A4-13 and the extent of flooding shown in Figure A4-5, page 81, it appears that a significant part of the project development area will be inundated by flood waters. It is recommended that if project infrastructure is to be located on the floodplain, or considered at risk from flooding or to influence flood flows, in the absence of better information, a detailed flood assessment is to be undertaken. Modelling of overland flow paths for the immediate area is to be included in this assessment. The hydrological information gathered as part of this study can assist in calibrating and validating such a model.

5 Fluvial geomorphology

5.1 Summary of geomorphic assessment and sensitivity

Across each of the catchments assessed, the geomorphic category of Chain of Ponds has been found in two different conditions: 1 - intact; and 2 - having undergone or is currently undergoing incision. This particular category of watercourse is of high environmental value in the landscape due to the aquatic habitat it provides, the attenuation of peak flows, long term sediment storage and the fact that the majority of them in eastern Australia have undergone degradation due to sensitivity to disturbance.

Dawson River catchment

The project development area that intersects the Dawson catchment is largely within one of its major tributaries, Juandah Creek. Most of the catchment has been cleared, including headwater reaches and steeper slopes. Many of the first order streams have been categorised as Headwater reaches rather than valley fills due to thinner colluvial/alluvial sediments in the valley floor and steeper gradients than for much of the Condamine system in the project development area.

Some of the small tributaries to Juandah Creek floodout on the valley floor/floodplain margin while others maintain a continuous channel due to greater discharge or energy conditions.

Juandah Creek is carrying moderate sand loads and in general has a low channel capacity within a reasonably broad floodplain (alluvial reaches). Where the valley constricts, channel capacity increases and bedrock occurrence is more frequent (partly confined reaches).

Condamine-Balonne River catchment

The watercourses of the project development area within the Condamine River catchment are dominated by low gradients and hence generally low energy conditions. The main channels through the catchments of the project development area are set within broad floodplains dominated by fine grained, often cohesive alluvium. Rates of planform change of watercourses are low. Potential for incision of the bed of watercourses is limited by low gradients and varying occurrences of bedrock or indurated/cemented Tertiary sediments.

There are reaches where varying depths of mobile bed sediment is present over firmer strata, in these instances pipelines should be located below the mobile sediment into the firmer strata. There are also instances where bank sediments are dominated by non-cohesive fine sediments and are subject to more rapid rates of planform shift than in general across the project area. Certain geomorphic categories of watercourses have multiple channels where the risk of avulsion is present. In all of these instances careful assessment of pipeline crossing locations is required to reduce the risk of pipe exposure and damage in the future.

There are some areas of relief within the project development area, though in general not steep, where there is active erosion of the waterways occurring in particular geologic units with dispersive soils in combination with increased gradients and disturbance in the form of clearing, grazing and infrastructure. In some of these valleys there are waterways that still have unchannelised valley fill or chain of ponds. These are particularly sensitive to disturbance, evidenced by the many that are already undergoing incision or have become fully channelised. In their unchannelised state these watercourses are of high environmental value due to the habitat they provide, the role they play in attenuating flows (reducing flood peaks and extending base flows in major downstream watercourses) and acting as long term sediment stores.

The Condamine River has a dominant main channel and often several flood channels. One of these is known as an anabranch but this river is not an actively anabranching system. The anabranch channel is well decayed, if it was a former main channel, and sits at a much higher level in the floodplain. There may be potential for channel development in some of the flood channels, particularly where floodplain width constricts and/or development such as dams (ring tanks) have a substantive influence on flood hydraulics.

The Condamine River distributes flood flows into watercourses such as Wilkie Creek during large flood events; these too could be considered anabranches/flood channels with the potential for long term avulsion. However, given the low energy conditions of the system and the infrequency of overbank events, there is low potential for this to occur over decades to a century.

Dogwood Creek is a major tributary of the Condamine-Balonne River with its upper catchment in the project development area. It is notably different to the rest of the project development area in that the majority of it is largely uncleared for grazing or cropping. There may be forestry activity but woody vegetation remains dense. In this subcatchment aerial photo interpretation of geomorphic characteristics is difficult, particularly for lower order reaches. The sites viewed at road crossings in the field have played a significant influence in determining the geomorphic category. The majority of first order streams have been categorised as Headwater with thin alluvial/colluvial deposits in very narrow valley floors that are almost continuous with hill slopes.

Given the steeper terrain and geology, most of the second order and greater reaches are partly confined with widespread bedrock/indurated Tertiary sediment controls.

Toward the southern extent of the Dogwood Creek catchment in the project development area, gradients reduce considerably and there are some reaches where it is thought there are substantive reaches of intact chain of ponds (high environmental value).

Moonie River catchment
The project development area covers a very small upper catchment extent of the Moonie River catchment. This area is mostly forested and of reasonably low gradient. The valleys are broad and all the watercourses are alluvial, valley fills for first order and meandering sand bed for higher order.

Border Rivers catchment
The Border Rivers includes the sections of Weir River and Macintyre Brook catchments that intersect the project development area.

The project development area intersects a small upper catchment section of the Macintyre Brook catchment south of Millmerran. The majority of this area is cleared. The majority of the watercourse network is made up of alluvial discontinuous watercourses, many of them being in narrower valleys such as first order valley fills. Most of these first order watercourses have been influenced by contour banks for cropping and grazing of hillslopes. Some have channelised, though many have not due to the thin, fine grained cohesive soils in the valley floors. The second and third order watercourses include substantive reaches of chain of ponds, many of which have been channelised or are still undergoing incision. The higher order watercourses are then either alluvial continuous or partly confined, more often by a regional terrace than hillslope.

The southern extent of the project development area is within the Weir River catchment. The upper catchment areas are mostly forested, coinciding with the steeper areas, with watercourses having substantive shallow bedrock controls (both horizontal and vertical). Most are mapped as Headwater, Confined or Partly Confined in that area. Downstream to the west, gradients reduce to very flat and all the watercourses are unconfined in broad alluvial plains. In large flow events many of these watercourses will be interconnected. These flood channels have been mapped, most are inactive and some are becoming chain of ponds. Some of the main channels through this area have channel boundaries dominated by sand and in particular where vegetation has been disturbed, there is active bank erosion and excess in channel mobile sand. Pipe location and depth in these areas will require careful consideration. Erosion control techniques, should be consistent with the inherent geomorphic character and behaviour.

5.2 Assessment outcomes

Using the method described in Section 1.3 of Attachment A, assessments have been undertaken to help:

- guide the development of environmental values;
- assist in the identification of significant environmental issues;
- provide input to assist planning decisions and
- provide a baseline to assist in the monitoring of impacts on hydrology and geomorphology from project activities.

Stream ordering
Stream ordering provides an indication of the relative size of a watercourse within a climatic and geomorphic setting.

Strahler's (1952) stream order system is a simple method of classifying stream segments based on the number of tributaries upstream. A stream with no tributaries (headwater stream) is considered a first order stream. A segment downstream of the confluence of two first order streams is a second order stream. Thus, a n^{th} order stream is always located downstream of the confluence of two $(n-1)^{th}$ order streams[5].

An example is shown in Figure A5-1 below and the stream orders for the project development area catchments are shown in Figure A5-2, page 86. Stream lengths and Strahler stream orders are also presented for the project development area in Table A5-1, page 87.

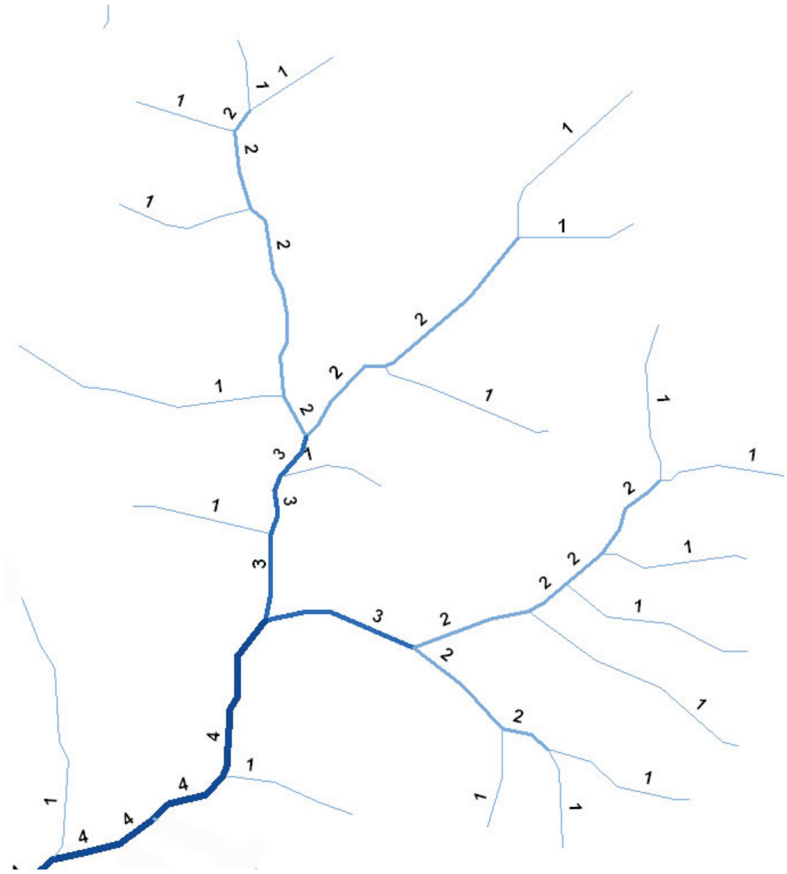


Figure A5-1. ***Strahler stream ordering***

[5] http://www.geog.soton.ac.uk/users/WheatonJ/Definitions/QD0109.htm - accessed 6 November 2009. Strahler, A. N. (1952). Dynamic basis of geomorphology. Geological Society of America Bulletin, 63, 923-938.

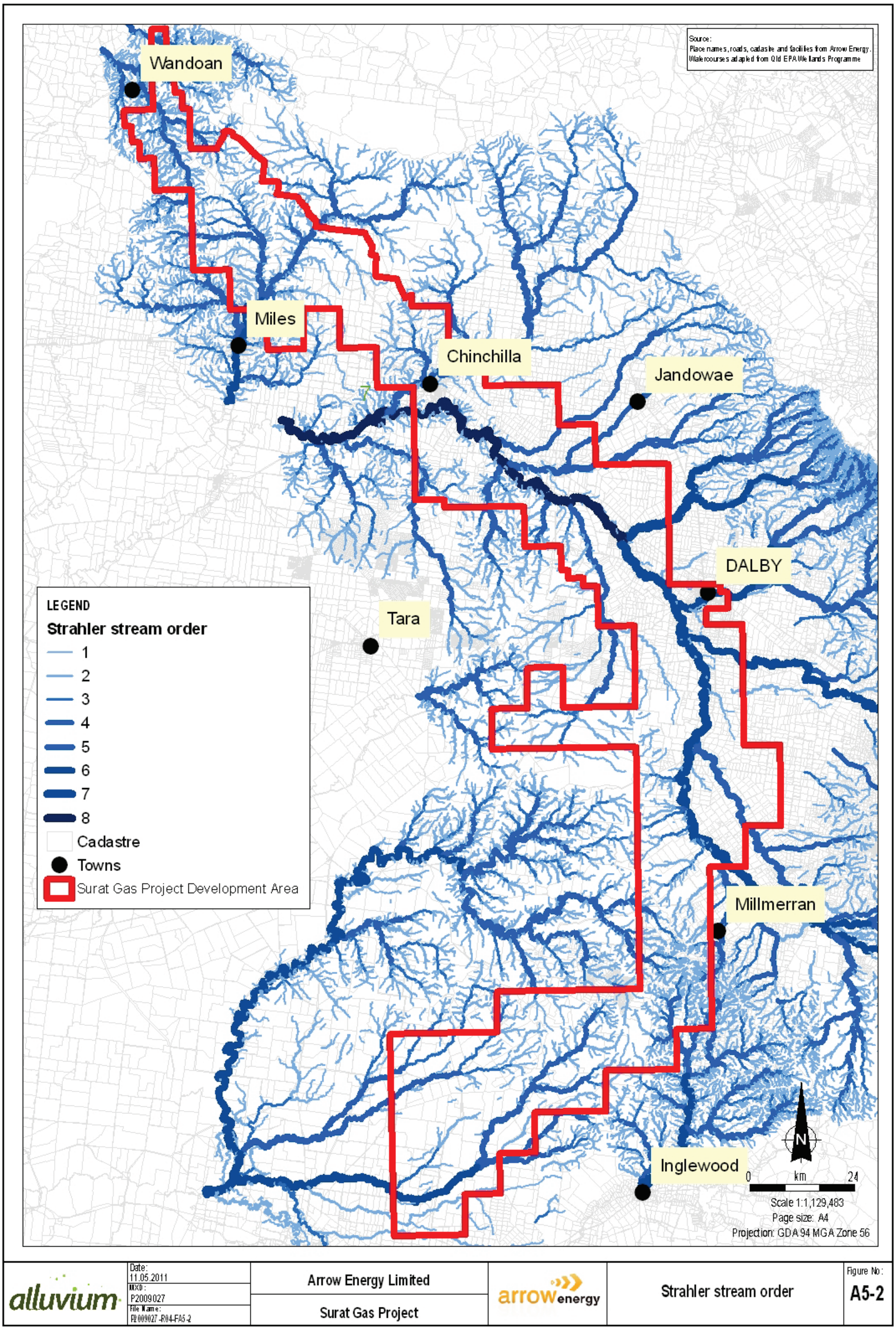


Figure A5-2. ***Strahler stream orders for the project development area***

Table A5-1. ***Watercourse lengths and Strahler stream orders within the project development area***

Strahler stream order	km	%
1	2,461.3	50.6
2	1,077.5	22.1
3	437	9.0
4	337.5	6.9
5	220.8	4.5
6	75.1	1.5
7	155.9	3.2
8	103.9	2.1
TOTAL	**4,869.0**	**100.0**

First and second order watercourses make up nearly three quarters of the mapped watercourse network within the project development area. This is reasonably consistent across other eastern Australian catchments assessed by the authors. The cartographic mapping that makes up the mapped watercourse network does not include all minor watercourses and many of the unincised/unchannelised watercourses.

Geomorphic categorisation

A desktop and field based geomorphic categorisation of the watercourses of the project development area was undertaken to assist in identifying environmental values and potential risks to watercourses from project activities. This information can also be used to guide planning decisions to locate project infrastructure due to risks from watercourse processes. The categorisation was based on the River Styles® framework of geomorphic categorisation developed by Brierley and Fryirs (2005) and undertaken by an Accredited River Styler®. The identified geomorphic categories are shown in Figure A5-4, page 92. Examples of each of these types identified during field assessments are provided as Attachment C.

Additional references were considered as part of the overall categorisation and assessment of risks as follows:

Table A5-2. ***Reports considered as part of the geomorphic assessment***

Report	Comments
Brennan, S. & Gardiner, E. (2004) Geomorphic Assessment of Rivers Series: Condamine Balonne Catchment. Department of Natural Resources and Mines and Energy, Brisbane.	The most useful of all the reviewed publications. This report does not cover all the streams within the project development area but does include a geomorphic assessment of the Condamine River, Myall Creek and Oakey Creek. This work was used to assist the more detailed geomorphic categorisation undertaken for this assessment.
Clayton, P.D., Fielder, D.P., Barratt, P.J. and Hill, C. (2008). Aquatic Conservation Assessments (ACA), using AquaBAMM, for freshwater wetlands of the Condamine River catchment. Published by the Environmental Protection Agency, Brisbane.	Presents an overall assessment of the conservation values of wetlands. Used the bank and bed stability assessments from the State of the Rivers Report (Phillips, N. and Moller, G. (1995)) as input to the assessment process. Provides the most recent available assessment of wetland ecological values.
Geoff Titmarsh and Lucy Larkin (2007) *Condamine Catchment Water Erosion Monitoring*, prepared for the National Land & Water Resources Audit, Canberra.	This study undertook assessments and provides management recommendations for sheet, gully and streambank erosion. A risk map was produced predicting gully erosion, which may be a useful support tool, however, the authors state that "the low confidence level attached to it, its use would have caveats attached". Streambank erosion assessments were limited and reference made to reliance upon the State of the Rivers Report (Phillips, N. and Moller, G. (1995)).

Report	Comments
Phillips, N. and Moller, G. (1995) *State of the Rivers. An Ecological and Physical Assessment of the Condition of Streams in the Upper Condamine River Catchment.* Department of Natural Resources and Mines, Brisbane.	Provides an assessment of health for the Upper Condamine upstream from the confluence with Myall Creek. It found that overall most (72 %) banks were stable or very stable with only 11 % being unstable or very unstable. Beds were generally less stable than banks, with only 50 % of stream lengths having stable or very stable beds. Agricultural practices were considered to be the main factor affecting stability.

The geomorphic categories identified from the desktop and field assessments and implications for project planning are shown in Table A5-3 and Figure A5-4, page 92. Examples of each category (River Style) and further details are provided in Attachment C.

Table A5-3. ***River styles of the project development area***

Valley-setting and River Style	Implications for project planning
Confined valley setting **Confined -** , occasional floodplain pockets, frequent bedrock controls	Robust stream form with low sensitivity to disturbance. Bedrock controls can be used where practical in planning for stable pipeline crossing locations.
Confined valley setting **PC1 - Partly confined bedrock controlled** valley and channel with planform controlled discontinuous floodplain	Robust stream form with low sensitivity to disturbance. Bedrock controls can be used where practical in planning for stable pipeline crossing locations.
Confined valley setting **PC2 - Partly confined low sinuosity** valley and channel with planform controlled discontinuous floodplain	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. Depth of cover may need to allow for scour. Bedrock controls will be present and should be utilised to advantage for crossings.
Confined valley setting **PC3 - Partly confined meandering** channel with planform controlled discontinuous floodplain	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. May be subject to more rapid rates of erosion on the outside of bends than PC2 watercourses. Depth of cover may need to allow for scour. Bedrock controls will be present and should be utilised to advantage for crossings.
Confined valley setting **Headwater –** thin alluvial/colluvial deposits in narrow valley floor that is near contiguous with hillslopes, much exposed bedrock/indurated Tertiary sediments	Usually a first order stream in the upper catchment. Generally steeper gradient and stable. Not likely to require significant erosion protection works at crossings.
Alluvial or partly confined valley setting (Discontinuous/absent channel) **AD1 - Chain of ponds**, no continuous defined channel occasional ponds. Two sub categories are mapped **Chain of ponds - channelized** (which is a former chain of ponds that has been deliberately channelized for drainage purposes) and **Chain of ponds - incising** (which is an actively eroding chain of ponds becoming continuously channelised).	Can be subject to rapid erosion if disturbed. Often a rare feature in intact form since European settlement and land clearance, many have become continuously channelised or trending that way. Avoid where possible, careful rehabilitation required to minimise potential for flow concentration and initiation of incision (incision is commonly observed as gully erosion).
Alluvial valley setting (Discontinuous/absent channel) **AD2 - Floodout**, valley width expands to the point where another form of watercourse in	Is likely to be less susceptible to erosion than a chain of ponds but still vulnerable if disturbed. Many have been channelised into roadside or agricultural drains and many are not mapped watercourses.

Valley-setting and River Style	Implications for project planning
the upstream reach floods out**.** There are two sub-categories identified: **Floodout - channelized** (an artificially created channel to aid drainage) and; **Floodout - incising** (incising to become a continuous channel).	
Alluvial or partly confined valley setting (no channel when intact) **AD4 - Valley fill**, alluvial and colluvial sediments across valley floor with no channel. Two sub-categories are identified: **Valley fill – incising** (where a formerly intact valley fill is undergoing incision usually due to disturbance by land clearance or construction activities.); and **valley fill – channelized** (where a valley fill has been deliberately channelized for drainage purposes.	Many valley fills are already incised or incising, developing continuous channels. These watercourse types store large amounts of sediment and play a critical role in sediment and water flux in the landscape. Can be subject to rapid erosion if disturbed and/or flow is concentrated (such as occurs with pipes through roads). Careful rehabilitation required. Many valley fills are not mapped.
Alluvial valley setting (Continuous channel) **AC1 - Low-moderate sinuosity fine grained**	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. Depth of cover to allow for potential scour events during floods.
Alluvial valley setting (Continuous channel) **AC2 - Low-moderate sinuosity gravel bed**	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. Depth of cover to allow for potential scour events during floods.
Alluvial valley setting (Continuous channel) **AC4 - Meandering fine grained**	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. Depth of cover to allow for potential scour associated with planform changes or scour events during floods.
Alluvial valley setting (Continuous channel) **AC5 - Meandering sand bed**	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. Pipelines may be subject to scour due to mobile bed material during high flows. Analysis of scour potential is recommended if pipelines are to be located in this stream type.
Alluvial valley setting (Continuous channel) **AC6 - Meandering gravel bed**	Locate crossing on straight sections of watercourse and not on bends, which are more likely to be subject to erosion. Depth of cover to allow for potential planform changes or scour during floods. Analysis of scour potential is recommended if pipelines are to be located in this stream type.
Alluvial valley setting (Continuous channel) **AC7 - Multiple channel, sand belt**	Locate crossing on straight sections of watercourse where possible. The character of these watercourses (potential to change channels (avulsion) and erosion potential is such that an assessment by a suitably qualified geomorphologist/waterway engineer is recommended at the planning stage to identify preferred pipeline crossing locations.
Alluvial valley setting (Continuous channel) **AC9 - Anabranching fine grained**	This watercourse type has multiple channels. Locating a pipeline or track crossing should generally seek out a location with the least number of channels to cross and cross on straight sections. Active channels should be assessed by a suitably qualified geomorphologist/waterway engineer at planning stage.
Flood channel sub-categories: **Flood channel - incising** (an actively eroding channel	A channel on the floodplain that only receives water occasionally in flood events or from overland flow. Usually a low risk of erosion due to infrequent flows.
Dam and **Farm Dam** (two categories the difference being the scale of the dam and its constructed purpose.)	To be avoided by pipelines and tracks.
Constructed drain	A former natural watercourse that has been channelized for the purpose of drainage and paddock management. Unlikely to be an issue in terms of

Valley-setting and River Style	Implications for project planning
	infrastructure crossing but if encountered will need to be assessed on a site by site basis.
Lake	Usually to be avoided by project infrastructure. An individual assessment will be required to determine potential impacts in the case of ephemeral wetlands. Due to the inaccuracy of the Queensland Wetlands Programme mapping, on-ground assessment of mapped wetlands will be required if project infrastructure is to be considered at the planning stage to be located in a mapped wetland area.
Quarry	Minor reaches that are unlikely to be crossed by Arrow infrastructure.

In total, 4,869 kms of watercourses were assessed within the project development area. The watercourse lengths by geomorphic category are shown in Table A5-4 below and in descending order of total length in Figure A5-3, page 91.

Table A5-4. *Geomorphic Category and watercourse length*

Geomorphic Category	Watercourse Length (km)	% of total length within project development area
Anabranching fine grained	20.6	0.4
Chain of ponds	223.7	4.5
Chain of ponds - channelised	15.4	0.3
Chain of ponds - incising	107	2.2
Confined	176.0	3.6
Constructed drain	15.2	0.3
Dam	9.6	0.2
Farm Dam	71.7	1.5
Flood channel	192.2	3.9
Flood channel - incising	2.0	0.0
Floodout	45.4	0.9
Floodout - channelised	3.2	0.1
Floodout incising	17.1	0.4
Headwater	652.0	13.4
Lake	4.9	0.1
Low-moderate sinuosity fine grained	251.6	5.2
Low-moderate sinuosity gravel bed	6.6	0.1
Meandering fine grained	346.2	7.1
Meandering gravel bed	28.4	0.6
Meandering sand bed	319.6	6.6
Multiple channel sand belt	40.3	0.8
PC1 - Partly confined bedrock controlled	65.0	1.3
PC2 - Partly confined low sinuosity	470.4	9.7
PC3 - Partly confined meandering planform	286.5	5.9
Quarry	2.4	0.0
Valley fill	1,047.8	21.5
Valley fill - channelised	59.7	1.2
Valley fill - incising	394.5	8.1
TOTAL	**4,869.0**	**100**

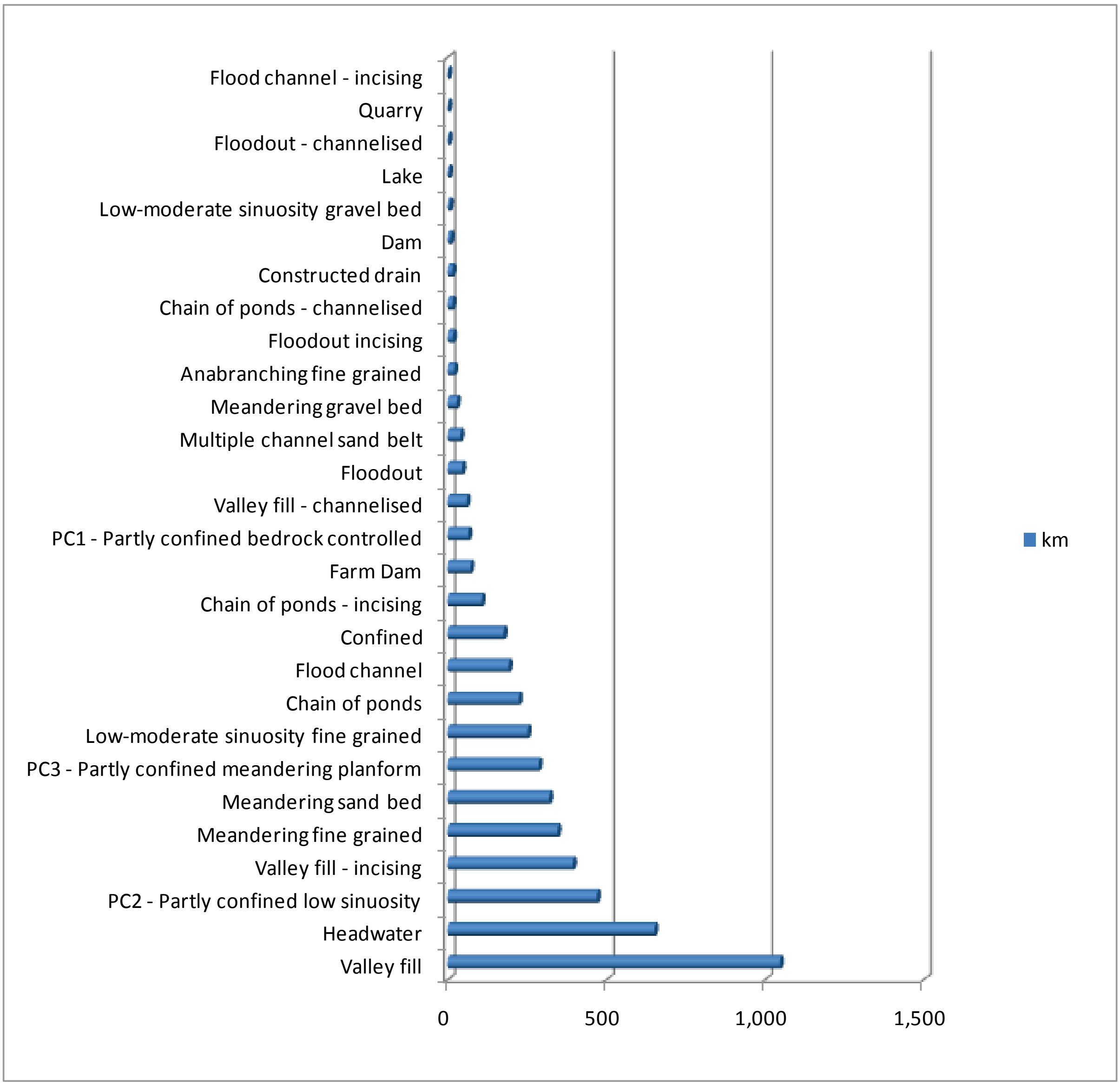


Figure A5-3. ***Geomorphic category in descending order by length***

As can be seen, Valley fill (which includes Valley fill – incising and channelised) comprises 1,502 kms or 30.8% of the total watercourses within the proejct development area. Headwaters comprise 652 km or 13.4% of the total watercourses within the project development area. Both of these geomorphic categories are almost solely found in first and second order watercourses.

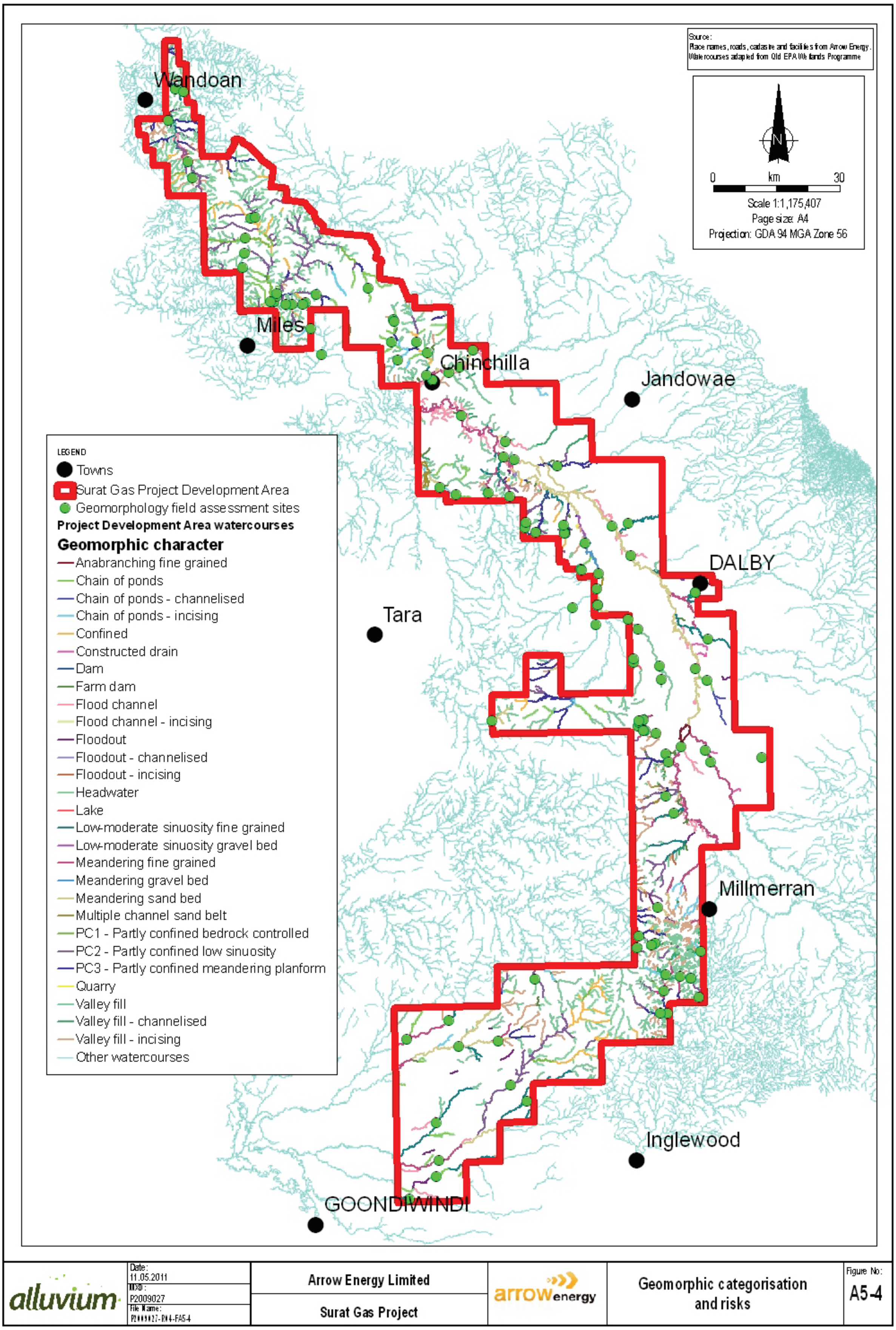


Figure A5-4. ***Geomorphic categorisation of water coursed within the project development area***

Some examples of particular erosion features/processes have been included as Table A5-5 below to assist in recognition in the field by project staff. These have not been mapped across the project development area. These are features/processes that are considered potential threats to environmental values and project infrastructure:

Table A5-5. ***Erosion features/processes and potential risks***

Features	**Potential risk**
Meander cutoff – channel across the inside of a meander bend becomes the main channel. Usually occurs through a series of floods but can be artificial channel cut across a meander/s to shorten the river channel (observed to be associated with creation of ring tanks, mostly located on the Condamine River and North branch).	The risk associated with these features is a shortening of channel length. Increased gradient and increased risk of bed deepening and bank instability. The rate of erosion will be determined by the frequency and severity of high flows. An example is shown in Figure A5-5, page 94.
Gully erosion - A gully actively incising and widening, often with a head cut migrating upstream through alluvial discontinuous watercourses.	Could threaten project infrastructure over time. Could also be exacerbated by project infrastructure if not appropriately treated. Will reduce environmental values.
Gully erosion and dispersive soils – Often manifest as multiple gullies in a network or "amphitheatre" usually with large areas of bare soil.	Difficult to stabilise and can threaten project infrastructure over time. Could also be exacerbated by project infrastructure. The best action is, whenever possible, to avoid locating project infrastructure in these risk areas. Will reduce environmental values.
Avulsion – the process where a new main channel is created and the former main channel abandoned or becomes a flood channel. Usually through scour in a flood or series of floods. Natural process in anabranching systems.	The risk associated with this feature is that a pipeline crossing may become exposed or damaged if the new main channel erodes rapidly as a result of the avulsion. This is more of a risk to project infrastructure rather than an environmental risk although there could be some additional erosion caused by scour around project infrastructure.
Erosion head – a steep drop at the head of gully erosion through alluvial or colluvial material. Mechanism for upstream migration of gully incision.	Erosion heads can advance quickly and cause uncovering of pipelines. They can also be triggered by disturbance of watercourse by infrastructure, particularly where flows become concentrated.
Active bank erosion – found across many of the geomorphic categories	Bank erosion that could affect project infrastructure or where locating project infrastructure could accelerate erosion.

Figure A5-5. ***Example of a meander cutoff on the Condamine River (north branch)***

Figure A5-6. ***Example of gully erosion***

Figure A5-7. ***Example of gullying and dispersive soils***

Figure A5-8. ***Example of potential cut off***

Figure A5-9. ***Example of an erosion head on a watercourse south of the existing Tipton West gas field incising through an alluvial discontinuous watercourse (Valley fill)***

Figure A5-10. ***Example of active bank erosion following incision of a chain of ponds***

Wetland characterisation
Wetlands need to be considered when planning facility locations. The data used to identify wetlands in the project development area is from the Queensland Wetlands Programme (version 1.3 – February 2009), which identifies the following wetland classifications as occurring in the Surat Gas Project development area as shown in Figure A5-11, page 98:

- **Riverine wetlands** describe all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created; they periodically or continuously contain moving water, or form a connecting link between two bodies of standing water.
- **Lacustrine wetlands** are large, open, water-dominated systems (for example, lakes) larger than 8 hectares. This definition also applies to modified systems (for example, dams), which possess characteristics similar to lacustrine systems (for example, deep, standing or slow-moving waters).
- **Palustrine wetlands** are primarily vegetated non-channel environments of less than 8 hectares. They include billabongs, swamps, bogs, springs, soaks etc, and have more than 30 percent emergent vegetation.

In addition to the wetland classifications further information is provided including the degree to which these wetlands have been modified. The digital data layers are available to assist Arrow Energy with planning. In general: riverine wetlands can be crossed by pipelines and tracks by addressing potential erosion risks; disturbance of lacustrine and palustrine wetlands should be avoided where practical and if deemed necessary to cross with project infrastructure, the area should be investigated at the early stages of planning so that the wetland value and any risks associated with disturbance can be assessed.

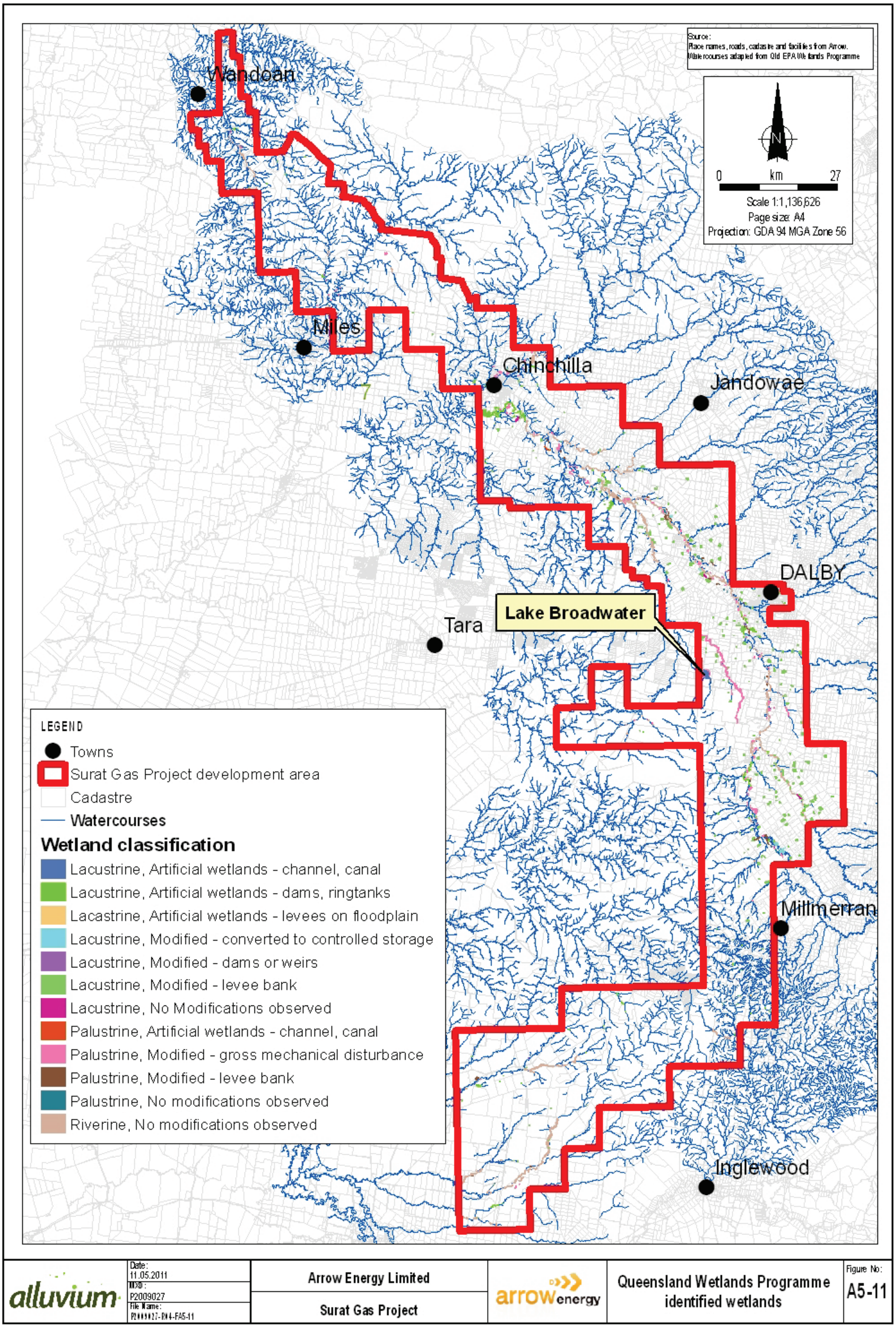


Figure A5-11. ***Wetlands identified by the Queensland Wetlands Programme***

Attachment B
Digital data and metadata

METADATA:

METADATA for Personal Geodatabase "Project_basins_catchments_and_streams_V3.0"

A component of

ARROW ENERGY SURAT GAS DEVELOPMENT PROJECT SURFACE WATER ASSESSMENT

for the Voluntary Environmental Impact Statement

March 2010

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1. Context and datasets

1.1 Arrow Energy Surat Gas Development Project

This digital data has been prepared to assist in the assessment of surface water aspects of the Arrow Energy Surat Gas Development Project EIS.

1.2 Datasets

Dataset TITLE, CUSTODIAN, VERSION

ArcView personal geodatabase “Project_basins_catchments_and_streams_V3.0.mdb” – version V3.0

The database contains the following files:

Table 1: Datasets

Shapefile	Description	Custodian
Project_Area_GDA1994z56	A project boundary provided by Arrow Energy that defines the geographic extent of the Project Development Area.	Arrow Energy
Project_streams_GDA1994z56_V6	A stream layer created by modifying the Queensland Wetlands Programme layer HYD_stream” “wetland mapping and classification for Queensland” (Version 1.3 – February 2009).	Alluvium Consulting (Queensland) modified from Environmental Protection Agency (now DERM)
Project_streams_GDA1994z56_clipped_V6	The above stream layer clipped by the Project Development Area.	Alluvium Consulting (Queensland) modified from Environmental Protection Agency (now DERM)
Project_Subcatchments_100k_GDA1994z56_V1	A layer manually digitised to provide a breakdown of subcatchments within the Project Development Area. The subcatchments were chosen based on a scale that was considered useful for analysis of various tasks including identification of Water Quality field sampling locations.	Alluvium Consulting (Queensland) modified from (formerly) Department of Natural Resources and Water (2006) data currently Department of Environment and Resource Management (2009)
QLD_BASINSUBAREA_100k_GDA1994z56	Queensland drainage basin sub-basins.	Formerly Department of Natural Resources and Water (2006) data currently Department of Environment and Resource Management (2009)
QLD_DRNDIVISION_100k_G	Queensland drainage	Formerly Department of Natural Resources and Water (2006) data

Shapefile	Description	Custodian
DA1994z56	divisions.	currently Department of Environment and Resource Management (2009)
HYD_Wetland_clipped_GDA1994z56	A wetland layer clipped by the Project Development Area from the Queensland Wetlands Programme layer HYD_Wetland" "wetland mapping and classification for Queensland" (Version 1.3 – February 2009).	Environmental Protection Agency (now DERM)

Dataset JURISDICTION

Queensland.

Description ABSTRACT

These data sets have been complied as part of the voluntary Environmental Impact Statement for the Arrow Energy Surat Gas Project. They relate to the assessment of surface water resources in the project area.

Description SEARCH WORD(S)

Surface water

Streams

Wetlands

Water

Catchments

Description (GEOGRAPHIC BOUNDARY)

Parts of the sub-basins of: Condamine-Balonne Rivers; Dawson River, Moonie River, MacIntyre Brook and Weir River.

Dataset CURRENCY

Beginning November 2009. Ending March 2010.

Dataset STATUS

Final.

Dataset PROGRESS

Final.

Dataset MAINTENANCE AND UPDATE FREQUENCY

Complete as at March 2010.

Access STORED DATSET FORMAT(S)

DIGITAL: ESRI Personal Geodatabase

DATUM: Geocentric Datum of Australia 1995 (GDA1994)

PROJECTION: Projected

Access AVAILABLE FORMAT TYPE(S)

ESRI Personal Geodatabase

Access CONSTRAINTS

For use only for the Arrow Energy Surat Gas Project unless otherwise authorised by Arrow Energy.

Data Quality LINEAGE, POSITIONAL ACCURACY and ATTRIBUTE ACCURACY

The individual data sets vary in their scale and quality. A description of how they were prepared and their limitations is provided in the Sections 2 and 3. It is also recommended that EPA metadata is reviewed in relation to the datasets "HYD_wetland" and "HYD_Stream".

Data quality LOGICAL CONSISTENCY

All polygons and polylines visually checked at scale of approximately 1:50,000 and inconsistencies manually checked and rectified.

Data Quality COMPLETENESS

The data sets are complete as at March 2010.

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Metadata date METADATA DATE

March 2010.

Additional Metadata ADDITIONAL METADATA

HYD_wetland: http://www.epa.qld.gov.au/register/p01769aa.pdf
HYD_Stream:http://www.epa.qld.gov.au/wetlandinfo/site/MappingFandD/WetlandMandDBackground.html

2.1 Drainage divisions, basins and sub-basins

The project area covers 8,661.64km^2 across two of Australia's twelve drainage divisions[1]; primarily the Murray-Darling Division but also part of the Northeast Coast Division. These Drainage Divisions are further divided into basins and sub-basins, which are shown in Table 2, and Figure 1, Page 8. At a finer scale, the sub-basins can be further divided by catchment and sub-catchment, which is discussed in the following section.

Table 2: Areas of Drainage Divisions, Basins and Sub-basins falling within the project boundary.

Drainage Division	Basin	Sub-basin	Total Sub-basin Area (km^2)	Area of Project Area within Sub-basin (km^2)	% of Project Area Within Sub-basin	Project Area as a % of the sub-basin
Murray-Darling (IV)	Condamine Culgoa(22)	Balonne	38,400.98	1,275.93	14.73%	3.32%
		Condamine	30,442.86	4,507.28	52.04%	14.81%
	Borders Rivers (16)	Macintyre Brook	4,316.47	286.56	3.31%	6.64%
		Weir	15,438.75	2,113.81	24.40%	13.69%
	Moonie (17)	Moonie	14,846.01	59.68	0.69%	0.40%
North East Coast (I)	Fitzroy Basin (30)	Dawson	51,304.53	418.38	4.83%	0.82%

[1] Australia's drainage divisions and river basins were formally defined by the Australian Water Resources Council in the early 1960s and, with minor modifications resulting from improved mapping of the inland arid zone area, have been the basis for the study of Australian hydrology since then. The 12 drainage divisions were defined by both the major topographic features of the continent and the main climatic zones to give broadly homogeneous hydrologic regions. Within the drainage divisions the 245 river basins are defined by the major watershed lines (Australian Government, Bureau of Meteorology (http://www.bom.gov.au/hydro/wr/basins/index.shtml, accessed 12th October 2009)).

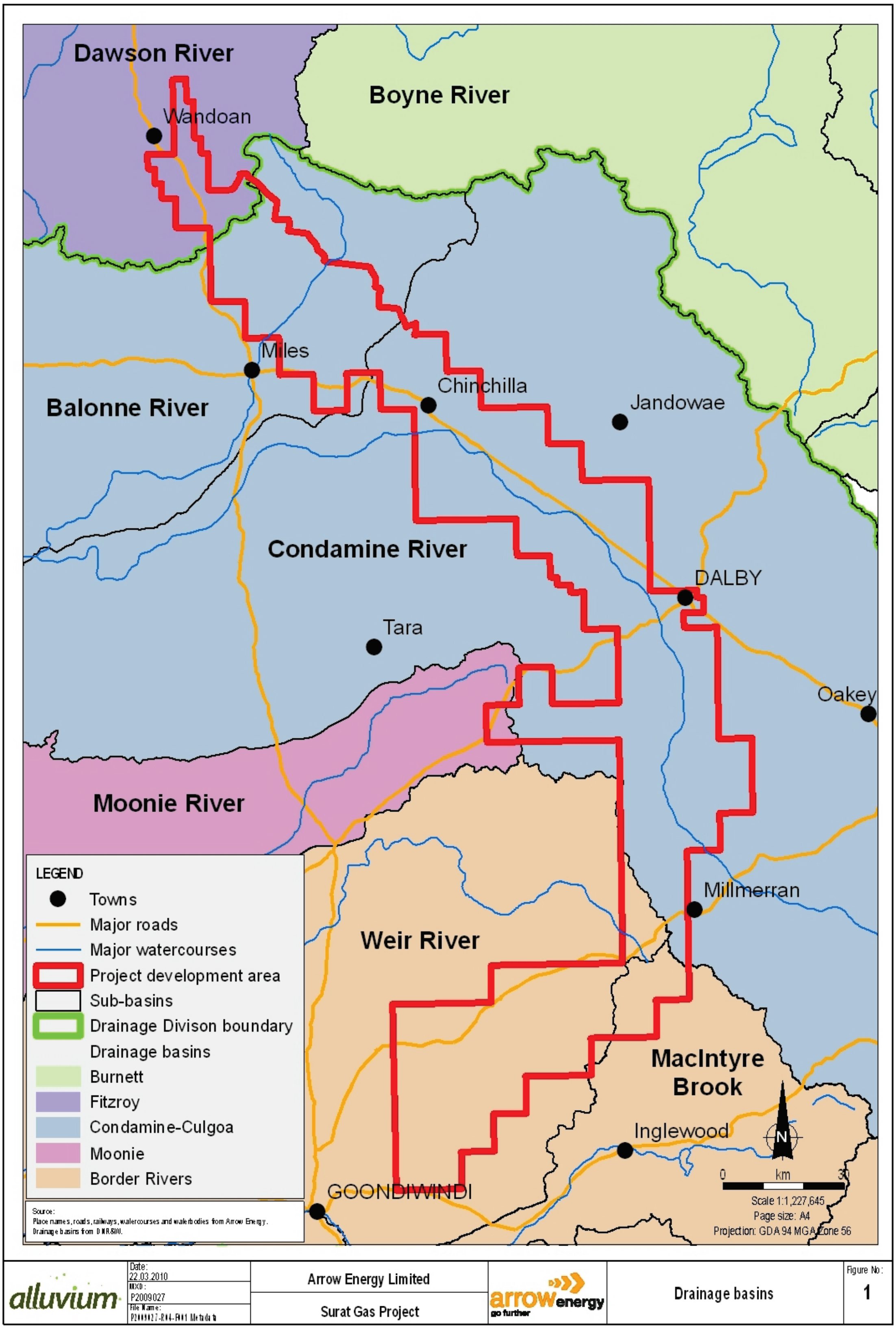


Figure 1: Location of Drainage Divisions, Basins and Sub-basins within the project boundary

2.2 Catchments and sub-catchments

As stated in Section 2.1, at a finer scale, the sub-basins can be further divided by catchment and sub-catchment. The identification of catchments and sub-catchments is useful for a number of purposes including: identification of major streams for the assessment of water quality and aquatic ecology; and to contribute to the geomorphic assessment of watercourses. The Australian drainage basin sub-basins (as described in section 2.1) was used as the basis for the identification of sub-catchments[2] together with:

- Streams layer from the Queensland Wetlands Programme “wetland mapping and classification for Queensland” (Version 1.3 – February 2009). This layer was modified by Alluvium to improve its usefulness for this project assessment. (Further details are provided in Section 1.3.)
- A 1:100,000 scale digital elevation model (DEM) created by Alluvium from the Geosciences Australia 1:100,000 digital map sheet contours (20m intervals).
- Aerial imagery supplied by Coffey Natural Systems / Arrow Energy.
- Additional Aerial imagery from Google Earth.
- Stream names from the Geosciences Australia 1:250,000 digital map sheets.

The identification and digitising of catchments and sub-catchments was undertaken manually at a scale of approximately 1:50,000 with consideration given to identifying a size of sub-catchments that would provide the most useful tool to aid the projects various assessments. The sub-basins were only examined from the most upstream extent of catchments above the project area, downstream to the point immediately below the project area. This was done to focus resources only on the geographic extent of most use to aid the project assessments.

The sub-catchments are shown in Figure 3, page 14, and are listed by sub-basin, catchment, sub-catchment and name in Table 3, page 11.

Limitations of sub-catchment identification

The digitised sub-catchments are useful for the purposes for which they were prepared. At finer scales, the accuracy of the catchment boundaries is limited by the quality of the data used to define them. In particular, the drainage and direction of runoff is not possible to determine accurately at the scales used and with the limited topographic data.

The sub-catchment boundaries are considered to be reasonably accurate in the upper catchments but the lower catchment boundaries are not considered accurate where the topography is low relief (particularly on the Condamine River floodplain) and agricultural development extensive. Catchment boundaries in these lower areas should be considered nominal and treated with caution. An example of the boundaries in the lower catchments between the Condamine River floodplain, Myall Creek, Ashall Creek and Oakey Creek and is shown in Figure 2, page 10.

[2] The State of Queensland (Department of Natural Resources Mines and Water) Land Vegetation & Water 2006 “Drainage Sub Basins” digital data set was used as the basis for this mapping.

Figure 2: Example of sub-catchment boundaries

Table 3: Project area drainage basins, catchments and sub-catchments

Drainage Basin	Sub-basin	Catchment	Sub-catchment 1	Sub-catchment 2	Sub-catchment name (Label)
Border Rivers	Weir River				Weir River
Border Rivers	MacIntyre River	MacIntyre Brook			MacIntyre Brook
Border Rivers	Weir River	Western Creek	Paddy Creek	Bora Creek	Bora Creek
Border Rivers	Weir River	Western Creek	Paddy Creek		Paddy Creek
Border Rivers	Weir River	Western Creek	Scrubby Creek		Scrubby Creek
Border Rivers	Weir River	Western Creek			Western Creek
Border Rivers	MacIntyre River	Canning Creek	Pariagara Creek		Pariagara Creek
Border Rivers	MacIntyre River	Canning Creek	Cattle Creek		Cattle Creek
Border Rivers	MacIntyre River	Canning Creek	Nicol Creek		Nicol Creek
Border Rivers	MacIntyre River	Canning Creek	Boola Creek		Boola Creek
Border Rivers	MacIntyre River	Canning Creek	un-named		un-named
Border Rivers	MacIntyre River	Canning Creek			Mosquito Creek
Border Rivers	MacIntyre River	Canning Creek			Canning Creek
Border Rivers	Weir River	Western Creek	Buli Creek		Buli Creek
Border Rivers	Weir River	Wyaga Creek			Wyaga Creek
Border Rivers	Weir River	Yarrill Creek			Yarrill Creek
Border Rivers	Weir River	Commoron Creek			Commoron Creek
Border Rivers	Weir River	Muri Muri Creek			Muri Muri Creek
Border Rivers	Weir River	Wondalli Creek			Wondalli Creek
Condamine-Balonne	Condamine	Condamine			Condamine
Condamine-Balonne	Condamine	Wilkie Creek	Mormanby Creek		Mormanby Creek
Condamine-Balonne	Condamine	Wilkie Creek	Back Creek		Back Creek
Condamine-Balonne	Condamine	Wilkie Creek			Wilkie Creek
Condamine-Balonne	Condamine	Wilkie Creek	Clayhole Creek		Clayhole Creek

Drainage Basin	Sub-basin	Catchment	Sub-catchment 1	Sub-catchment 2	Sub-catchment name (Label)
Condamine-Balonne	Condamine River	Crawlers Creek			Crawlers Creek
Condamine-Balonne	Condamine River	Willis Creek			Willis Creek
Condamine-Balonne	Condamine River	Honeysuckle Creek			Honeysuckle Creek
Condamine-Balonne	Condamine River	Leonard (Back Ck) Gully			Leonard (Back Ck) Gully
Condamine-Balonne	Condamine River	un-named creek			un-named creek
Condamine-Balonne	Condamine	Braemar Creek			Braemar Creek
Condamine-Balonne	Condamine	Kogan Creek			Kogan Creek
Condamine-Balonne	Condamine	Jingi Jingi Creek			Jingi Jingi Creek
Condamine-Balonne	Condamine	Cooranga Creek			Cooranga Creek
Condamine-Balonne	Condamine	Jimbour Creek			Jimbour Creek
Condamine-Balonne	Condamine	Condamine River	Myall Crek		Myall Creek
Condamine-Balonne	Condamine	Condamine River	Oakey Creek		Oakey Creek
Condamine-Balonne	Condamine	Ashall Creek			Ashall Creek
Condamine-Balonne	Condamine	Wambo Creek			Wambo Creek
Condamine-Balonne	Condamine	Charley's Creek			Charleys Creek
Condamine-Balonne	Condamine	Charley's Creek	Rocky Creek		Rocky Creek
Condamine-Balonne	Condamine	Charley's Creek	Branch Creek		Branch Creek
Condamine-Balonne	Condamine	Charley's Creek	un-named creek		un-named creeek
Condamine-Balonne	Condamine	Condamine River			Condamine River
Condamine-Balonne	Balonne				Balonne River
Condamine-Balonne	Balonne	Dogwood Creek	Bottle Tree Creek		Bottle Tree Creek

Drainage Basin	Sub-basin	Catchment	Sub-catchment 1	Sub-catchment 2	Sub-catchment name (Label)
Condamine-Balonne	Balonne	Dogwood Creek	Bottle Tree Creek	L Tree Creek	Bottle Tree Creek
Condamine-Balonne	Balonne	Dogwood Creek	Rocky Creek		Rocky Creek
Condamine-Balonne	Balonne	Dogwood Creek	Hellhole Creek		Hellhole Creek
Condamine-Balonne	Balonne	Dogwood Creek	un-named creek		un-named creek
Condamine-Balonne	Balonne	Dogwood Creek	Punch-bowl Creek		Punch-bowl Creek
Condamine-Balonne	Balonne	Dogwood Creek	Columboola Creek		Columboola Creek
Condamine-Balonne	Balonne	Dogwood Creek	un-named creek		un-named creek
Condamine-Balonne	Balonne	Dogwood Creek	Eleven Mile Creek		Eleven Mile Creek
Condamine-Balonne	Balonne	Dogwood Creek			Dogwood Creek
Fitzroy River	Dawson River				Dawson River
Fitzroy River	Dawson River	Juandah Creek	Downfall Creek		Downfall Creek
Fitzroy River	Dawson River	Juandah Creek	Weringa Creek		Weringa Creek
Fitzroy River	Dawson River	Roche Creek			Roche Creek
Fitzroy River	Dawson River	Juandah Creek			Juandah Creek
Moonie River		Moonie River			Moonie River
Moonie River		Durabilla Creek			Durabilla Creek
Moonie River		Dunmore Creek			Dunmore Creek
Moonie River		un-named creek			un-named creek
Moonie River		Moonie River			Moonie River

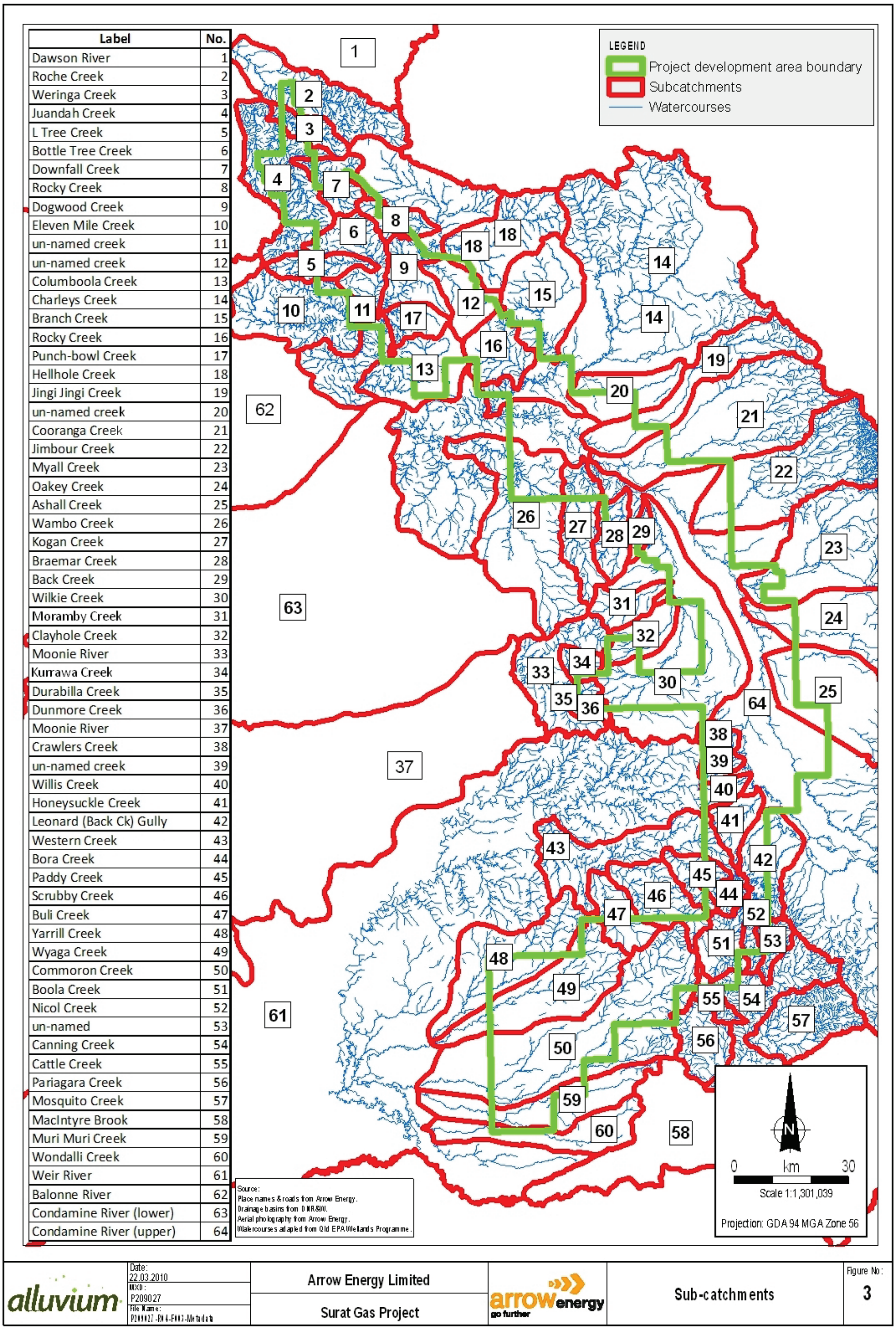


Figure 3: Project area sub-catchments

3. Watercourses and wetlands

The streams and wetlands data from the Queensland Wetlands Programme "wetland mapping and classification for Queensland" (Version 1.3 – February 2009) has been used as the basis for the assessment of watercourses and wetlands. The streams digital data layer was modified by Alluvium to improve its usefulness for this project assessment. The process for that modification was as follows.

Base layers

The digital stream layers "HYD_Stream" and HYD_Wetland" from the Queensland Wetlands Programme "wetland mapping and classification for Queensland" (Version 1.3 – February 2009) were used as the basis for the assessment of watercourses and wetlands. The stream layer required modification to make it more relevant and useful for this project assessment. Details are provided in the main report in Section A1.2.

The wetland layer, whilst having some limitations was not modified for the project and used as provided. It is considered by the project team to be more accurate than the wetland areas identified in the "HYD_Stream" layer and whilst inaccurate at finer scales is the best information available for this project assessment.

Modifications to stream layer

Removal of former channels

The digital stream network is a number of years old (Metadata provided "wetland mapping and classification for Queensland" does not specify the date of capture for the project area but is believed to be at least the early 1990's) and many watercourses have been channelized for agricultural development since that original stream network was created. Some rectification of the streams has been undertaken by Alluvium but resources did not allow for extensive reworking or creation of a new network. An example is shown in Figure 4, page 15. In this example a reach of watercourse and a wetland has been channelized into an agricultural drain since the mapping was completed. Another wetland can also be seen to have been modified. In this case Alluvium has removed these segments as they no longer represent the current location of these features.

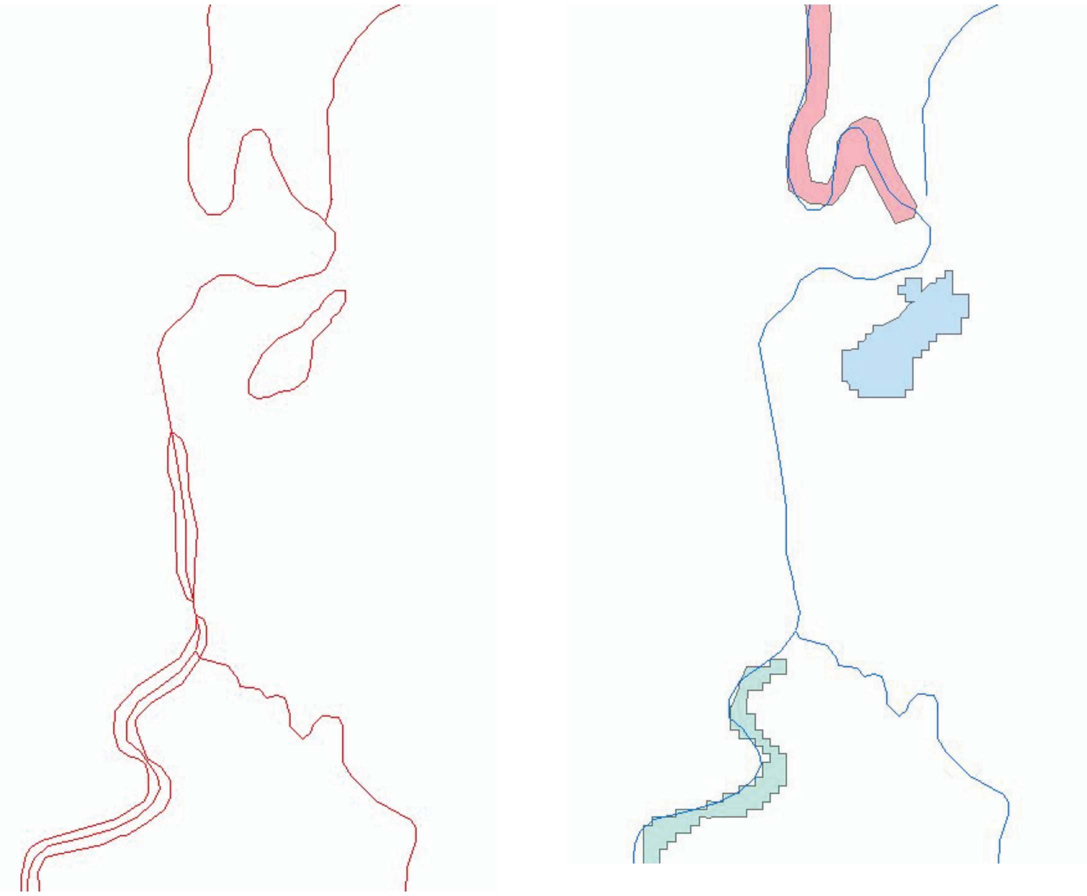
Outdated "HYD_Stream" layer wetlands and channels

Modifications for the project stream layer together with "HYD_Wetland" layer

Figure 4: Example 1 "HYD_Stream" and layer and modified project stream layer

Removal of associated wetlands

As explained previously, the wetland layer, whilst having some limitations was not modified for the project and was used as provided. It is considered by the project team to be more accurate than the wetland areas identified in the “HYD_Stream” layer. The wetlands shown in the HYD_Stream” layer were therefore removed for this assessment. A second example is shown in Figure 5, page 16. In this example an off-stream wetland has been removed and two digitised in-stream pools have been removed.



“HYD_Stream” layer — Modified stream layer and HYD_Wetland layer

Figure 5: Example 2 “HYD_Stream” and layer and modified project stream layer

Traceable stream network and Strahler stream order

The final processes that were applied to the stream layer were to make it a traceable network (it flows in one direction from top of catchment downstream) and to apply the Strahler stream order to the network. This was done in order to provide a more useful tool for geomorphic assessments and risk analysis.

The processes applied were:

- Joining all disconnected streams where appropriate. In this step the “HYD_Stream” layer, with wetlands removed, had all disconnected segments snapped to the neighbouring segment. This was necessary because: in some cases the base data being manually created was not complete; and following the removal of in-stream pools there were some gaps between tributaries and downstream segments.

- After the above step, there were still some streams disconnected from the network. This in some cases was due to a stream flooding out of a defined channel and is therefore a disconnected stream. In those cases the stream was left disconnected. In other cases the stream had not been completed in the “HYD_Stream” layer. Where this was an obvious omission, the stream was digitised and connected appropriately. However, the project has limited resources and so this was only done in the project area where good aerial photography was available to complete the task. Outside the project area, upstream this task was limited to streams that could be readily identified using Google Earth Imagery at a scale of approximately 1:50,000.
- Once the preceding tasks were completed, the Strahler stream order was applied to the network. Strahler's (1952) stream order system is a simple method of classifying stream segments based on the number of tributaries upstream. A stream with no tributaries (headwater stream) is considered a first order stream. A segment downstream of the confluence of two first order streams is a second order stream. Thus, a n^{th} order stream is always located downstream of the confluence of two $(n-1)^{th}$ order streams[3].

  An example from the Condamine catchment is shown in Figure 6 below.

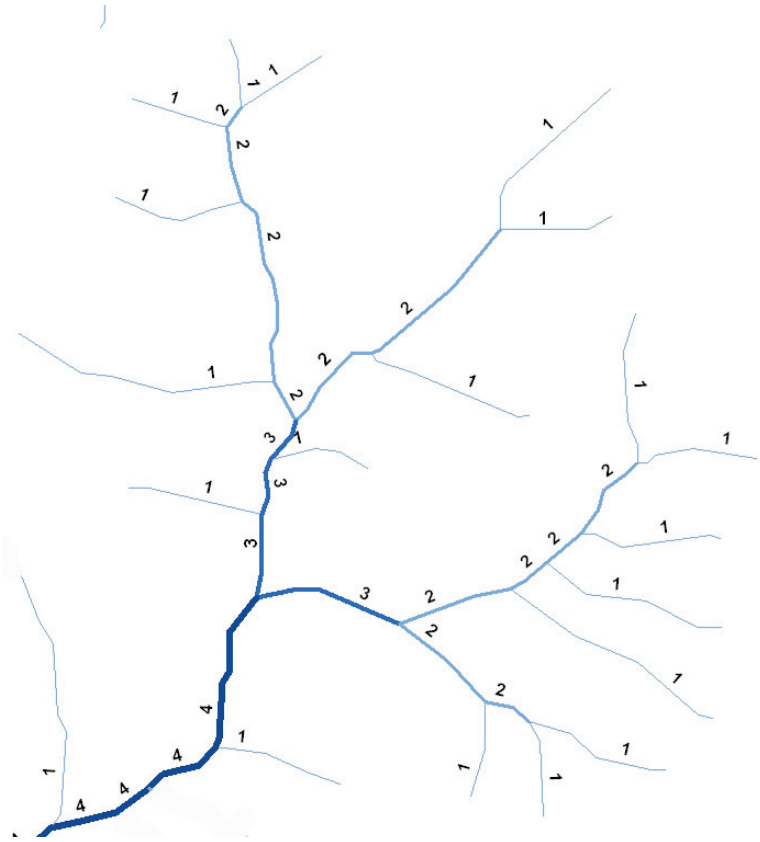


Figure 6: Strahler stream order

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[3] http://www.geog.soton.ac.uk/users/WheatonJ/Definitions/QD0109.htm - accessed 6 November 2009. Strahler, A. N. (1952). Dynamic basis of geomorphology. Geological Society of America Bulletin, 63, 923-938.

Attachment C
Geomorphic categorisation

1 Geomorphic categorisation

The assessment of the geomorphic character and behaviour of the watercourses in the study area has been compiled using the River Styles framework. The assessment has been a desktop exercise using aerial photography, topography and geology. Limited targeted field work has been conducted in the scope of this exercise. A more detailed river styles assessment would include field work assessing at least a reach, generally close to reference, of each of the river styles identified in the desktop assessment. This would then provide for typical cross section and planform sketches illustrating geomorphic unit assemblages as well as ground photos.

The River Styles framework (Brierley & Fryirs, 2005) provides a set of procedures from which to integrate catchment-scale geomorphic understanding of river forms, processes and linkages. The framework allows for the description and explanation of the within-catchment distribution of river forms and processes. River Styles record the character and behaviour of rivers throughout a catchment.

The approach is hierarchical, and can be implemented at the desired range of scales. For this assessment, all watercourses mapped for this study have been assessed. A key component of the technique is the relationship of the watercourse and any associated floodplains to the valley or landscape setting in which they occur. Key distinctions are confined valley, partly confined valley and alluvial unconfined settings.

1. **Confined valley** settings are defined by >90 % of the channel being in contact with the valley side or margin. In these situations there is minimal floodplain, and rivers in this setting are often steep.
2. **Partly confined** valley settings are defined by 10-90 % of the channel abutting the valley margin. Floodplains are common in these settings but often they are broken into discrete pockets or sections as the channel crosses from one side of the valley to another. The shape of the valley (i.e. straight vs curved and irregular in width), and the wavelength of the channel crossing the valley floor combined to dictate the length of the floodplain pockets. Lower sinuosity channels will cross from one side of the valley to the other less frequently than a more sinuous channel.
3. **Alluvial** settings are defined by the channel being in contact with the valley margin for less than10 % of its length. Floodplains are usually continuous along both sides of the channel in these settings. There are two main sub-groupings within the alluvial setting, which are defined on the nature of the channel. ***Alluvial discontinuous*** River Styles are characterised by channel forms that are not continuous. These categories are not robust and have low resilience (high sensitivity) to changes in catchment conditions, hence are often found in an incised or channelised state and behave more like an Alluvial Continuous stream. ***Alluvial continuous*** River Styles contain channel/s that are continuous. This is the broadest and most diverse of the three main groups. The numerous sub-groups within this type are defined on the:

    - number of channels;
    - the sinuosity of the channel/s, and
    - the dominant grain size in the channel bed.

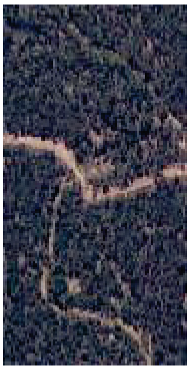
    Thus a fine grained single channel that has a moderate to high sinuosity is called *Fine grained meandering*.

Table C1-1. ***Confined – Confined valley with occasional floodplain pockets***

Example waterways and position in catchment	Back Creek. Usually second to fifth order streams in steeper terrain in relatively straight valleys.	
Channel Geometry	Varies between symmetrical and asymmetrical and generally compound cross section. Variable width to depth ratio. Generally shallow channel on bedrock becoming deeper downstream below geologic timescale headcuts (waterfalls).	
Channel Pattern	Single. Valley walls dictate planform, low sinuosity, occasional discontinuous shallow narrow floodplain pockets at wider sections of valley.	
Geomorphic Units	Channel zone: Bedrock steps, riffle/cascade, short backwater or plunge pools.	Floodplain zone: benches on the inside of valley spur controlled bends.
Geomorphic Behaviour	Moderate to steep slope, bedrock or coarse bedload dominated. Fines in pools. Bends not free to migrate downstream or laterally (i.e. is laterally fixed). Reworking of bars and floodplain pockets on inside bends. May slowly erode valley wall if not composed of bedrock.	
Sediment Transfer Behaviour	Transfer in balance over the long-term, but floodplain pockets accumulate slowly and flush over short interval.	
Additional field comments	Waterfall approximately 1.5 m in height in Back Creek. Upstream track crossing and trenched pipeline in indurated material.	

Back Creek - Location: E 294965 N 7004084

Bedrock/indurated sediment step (waterfall)



Aerial view example (not tracks)

Dense in channel vegetation

Table C1-2. ***Headwater***

Example waterways and position in catchment	Usually first order streams in steeper terrain. Two major clusters, southwest of Millmerran and southeast of Wandoan.	
Channel Geometry	Generally shallow channel on bedrock/indurated sediments that is near contiguous with abutting hillslopes.	
Channel Pattern	Single. Valley walls dictate planform, occasional discontinuous shallow narrow floodplain pockets (colluvial deposits) at wider sections of valley.	
Geomorphic Units	Channel zone: Bedrock steps, riffle/cascade, short backwater or plunge pools.	Floodplain zone: none.
Geomorphic Behaviour	Moderate to steep slope, bedrock dominated.	
Sediment Transfer Behaviour	Transfer in balance over the long-term, but colluvial/alluvial deposits accumulate slowly and flush over short interval.	

Location: E232745 N7058376 unincised into laterite (southwest of Wandoan)

Aerial view example

Table C1-3. ***PC1 - Partly-confined bedrock controlled discontinuous floodplain***

Example waterways and position in catchment	Usually second to fifth order streams in steeper terrain in spurred irregular/non-linear valleys. Mostly found between Wandoan and Miles.	
Channel Geometry	Compound, symmetrical on straights, asymmetrical on bends. Often deeply incised below floodplain pockets and narrow.	
Channel Pattern	The valley is spurred and can be moderately sinuous, the channel planform follows this. The channel abuts the valley margin for 50 – 90 % of its length. The floodplain is discontinuous.	
Geomorphic Units	Channel: pools, riffles, runs, benches, cascades.	Floodplain: generally featureless.
Geomorphic Behaviour	Moderate to steep gradients. Bed material dominated by bedrock or mobile coarse sediment veneer. Rates of change dependent on sediment characteristics and gradient. Bedrock will limit larger scale rates of change. Alluvial banks and floodplains subject to rapid erosion in large flow events where disturbed.	
Sediment Transfer Behaviour	A transfer zone. In balance over the long term unless oversupply from catchment disturbance induced erosion.	

Deep channel confined by hillslope and terrace

Frequent bedrock controls in stream bed and lower banks

Aerial view example

Table C1-4. ***PC2 - Partly-confined with low sinuosity planform controlled discontinuous floodplain***

Example waterways and position in catchment	Oakey Creek. Found throughout the project areas where there is moderate or greater relief.	
Channel Geometry	Compound, symmetrical on straights, asymmetrical on bends. Often deeply incised below floodplain pockets and narrow.	
Channel Pattern	The valley is relatively straight or irregular and the valley planform controls the channel planform. The single channel has low sinuosity and abuts the valley margin for 10 – 50 % of its length. The floodplain is discontinuous and may be terraced.	
Geomorphic Units	Channel: pools, riffles, runs, benches, point bars.	Floodplain: generally featureless, occasional shallow depression wetlands.
Geomorphic Behaviour	Moderate to low slopes. Bed material can be fine grained cohesive, indurated sediments, bedrock or mobile coarse sediment veneer. Rates of change dependent on sediment characteristics and gradient. Bedrock will limit larger scale rates of change.	
Sediment Transfer Behaviour	In balance over the long term unless oversupply from catchment disturbance induced erosion.	

Oakey Creek: E 329104 N 6978752

Channel abutting hillslope

Aerial view example

Commoron Creek E 282188 N 6872967

Table C1-5. ***PC3 - Partly-confined with meandering planform controlled discontinuous floodplain***

Example waterways and position in catchment	Cooranga Creek. Found throughout the project area at transitions from hillslope and valley to floodplain	
Channel Geometry	Compound, symmetrical on straights, asymmetrical on bends. May be shallow and regularly engages floodplain.	
Channel Pattern	Valley can be straight or irregular and channel meanders independent of valley planform. Rate of meander migration dependent on sediment size and cohesiveness. Moderate sinuosity.	
Geomorphic Units	Channel: pools, riffles, runs, benches, point bars.	Floodplain: flood/abandoned channels.
Geomorphic Behaviour	Moderate to low slopes. Bed material can be fine grained cohesive, indurated sediments, bedrock or mobile coarse sediment veneer. Rates of change dependent on sediment characteristics and gradient. Bedrock will limit larger scale rates of change.	
Sediment Transfer Behaviour	In balance over the long term unless oversupply from catchment disturbance induced erosion.	

Braemer Creek Location: E 288226 N 7004135

Impingement on indurated Tertiary sediments controlling lateral movement

Aerial view example

Table C1-6. ***AD1 - Alluvial Discontinuous – Chain of Ponds***

Example waterways and position in catchment	Throughout in both broad and partly confined valley settings. Generally not named watercourses.	
Channel Geometry	When intact there are discrete arcuate ponds, elongated in flow direction separated by swampy valley fill. Flows would be distributed across the valley floor. Chain of Ponds have been excavated (often close to one valley margin) or may have incised to a continuous channel in short sections.	
Channel Pattern	Often sinuous flow paths associated with the ponds when intact and incised.	
Geomorphic Units	Channel zone: No continuous channel when intact, discrete ponds and swampy valley fill flow path connecting. When incised, pools and runs, erosion heads.	Floodplain zone: Broad featureless valley floor when intact. Now cultivated, with drains, paddock levelling, levee banks and infrastructure.
Geomorphic Behaviour	Low energy system. Under pre-settlement conditions, as with valley fills, subject to episodic disturbance associated with fire, drought and flood where channel may experience scour then recover. Now, channelised or confined by valley floor alterations, which may increase flow depth and scour potential, hence continuous channel development and maintenance.	
Sediment Transfer Behaviour	Slow rates of accretion over the long term.	

Minor watercourse E 299077 N 6995354

Minor watercourse E 312462 N 6958115

Aerial view example

High environmental value, large scale ponds E 269116 N 7013278

Table C1-7. ***AD 2 - Alluvial Discontinuous – Floodout***

Example waterways and position in catchment	Unnamed watercourse – mid-catchment and plains at point of valley widening. Often a terminal fan on distributaries. Long Swamp is a form of floodout.	
Channel Geometry	Irregular channels or gullies before upstream end. No channels on floodout. No valley confinement.	
Channel Pattern	Diverging channels (distributaries) or gullies before upstream end dissipating onto a fan and/or swamps (on top of floodplain). Wide variation in size depending upon stream and valley size. Channels may re-form & converge downstream of fan.	
Geomorphic Units	Channel zone: No channel but may have discontinuous scour features.	Floodplain zone: Seepage swamps with sand sheet(s), typical in a fan-shape or splay.
Geomorphic Behaviour	Sand and mud dominated. Sediment supplied from upstream is stored in floodout. A new distributary forms when an old one is blocked by sediment and/or debris. These lobes shift over the floodout surface.	
Sediment Transfer Behaviour	Sediment accumulation zone.	

Long Swamp E 317475 N 6972401

Minor watercourse E 296813 N 6986348

Aerial view example

Table C1-8. ***AD4 - Alluvial Discontinuous – Valley Fill***

Example waterways and position in catchment	Many first and second order un-named waterways in upper catchment. Generally un-named watercourses.	
Channel Geometry	Whole valley floor is 'channel'. Valley margins are 'banks'. Fill is flat or slightly higher in centre than at valley margins.	
Channel Pattern	When intact there is no channel, hence valley is planform. When incised may meander within valley constraints and behave like PC3.	
Geomorphic Units	Channel zone: none where intact. When channelised, include runs and erosion heads.	Floodplain zone: the whole valley floor is the flow path when intact.
Geomorphic Behaviour	Slow accretion of valley floor if undisturbed. Highly sensitive to disturbance.	
Sediment Transfer Behaviour	Slow accumulation of fine sediment. Very important stores of sediment in the landscape. Major source if incising.	
Additional field notes	Valley fill intact, very low grade, recently cleared.	

Minor watercourse – intact valley fill, recently cleared. E 312187 N 6958315

Minor watercourse – incising valley fill, at erosion head E 312742, N 6959437

Minor watercourse – intact valley fill E 296813 N 6986348

Minor watercourse – incised valley fill downstream of erosion head E 312742, N 6959437

Aerial view example – valley fill incising

Table C1-9. ***AC1 - Alluvial Continuous – Low-moderate sinuosity fine grained***

Example waterways and position in catchment	Condamine River, Myall Creek, Jimbour Creek. Located in mid-lower catchments in broad floodplains.	
Channel Geometry	Symmetrical, with low to moderate width-depth ratio.	
Channel Pattern	Narrow single channel, low to moderate sinuosity, continuous floodplain.	
Geomorphic Units	Channel zone: benches, small pools, small bars if any.	Floodplain zone: flat floodplain, levees, swamps, flood channels.
Geomorphic Behaviour	Very low rates of change in cohesive sediments. May have inset low flow channel meandering between paired benches.	
Sediment Transfer Behaviour	Slow accretion of banks and levees. Subject to aggradation if increased inputs of coarser material from catchment.	

Myall Creek downstream from Dalby, E 490512 N 7857150

Condamine River below Cecil Plains weir E 322733 N 6953255

Jimbour Creek E 310030, N 7006346

Wilkie Creek E 303110, N 6994376

Aerial view example

Table C1-10. ***AC2 - Alluvial Continuous – Low-moderate sinuosity gravel bed***

Example waterways and position in catchment	Third order and greater reaches in mid to upper catchment zones with steeper gradients than other alluvial reaches but not enough confinement to be partly confined. Wilkie Creek is an example.	
Channel Geometry	Symmetrical straights, asymmetrical bends, moderate to high width-depth ratio.	
Channel Pattern	Single channel, low to moderate sinuosity, continuous floodplain.	
Geomorphic Units	Channel zone: riffles, bars, pools, benches,	Floodplain zone: levees, swamps, flood channels.
Geomorphic Behaviour	Low rates of change with cohesive bank material and armoured bed.	
Sediment Transfer Behaviour	Slow accretion of banks and levees. Subject to aggradation if increased inputs of coarser material from catchment (not occurring in reaches inspected).	

Aerial view example

Table C1-11. ***AC4 - Alluvial Continuous – Meandering fine grained***

Example waterways and position in catchment	Wilke Creek – mid/lower-catchment or upstream of floodout zones on smaller catchments.	
Channel Geometry	Variable asymmetrical/symmetrical often low capacity.	
Channel Pattern	Single channel with highly variable sinuosity and continuous floodplains along both margins.	
Geomorphic Units	Channel zone: pools riffles, small fine grained point bars and mid-channel bars (if any), occasional benches, chute channels and islands.	Floodplain zone: continuous floodplains with levees, paleochannels, many recent billabongs and back swamps. Often higher floodplain level or terrace.
Geomorphic Behaviour	Active cut bank erosion and concomitant point bar deposition in sand dominated alluvium. Low rates of vertical change.	
Sediment Transfer Behaviour	Throughput in balance or gradually accumulating fine grained sediments.	

Minor watercourse – laterally active, cut bank erosion. E 314075 N 6957026

Wilkie Creek E 299777 N 7001665

Aerial view example

Table C1-12. ***AC5 - Alluvial Continuous – Meandering sand bed***

Example waterways and position in catchment	Wilkie Creek – mid catchment reaches.	
Channel Geometry	Symmetrical in straights, asymmetrical on bends. Moderate sinuosity and continuous floodplains. Low flow channel may locally divide around islands and bars.	
Channel Pattern	Single channel with moderate to high sinuosity and continuous floodplains. Low flow channel may locally divide around sand bars.	
Geomorphic Units	Channel zone: pool-run sequences (large woody debris riffles), large sandy points and bank attached bars, chute channels, islands.	Floodplain zone: multi-surfaced floodplains with cut-offs, flood channels. Back swamps on distal floodplains. Ridges and swales. Terraces.
Geomorphic Behaviour	Laterally active with eroding outside bends (particularly when the mud drape is stripped) and sand depositing inside bends, reworking sand/silt floodplain. Rate of lateral movement governed by vegetation. Floodplain building laterally.	
Sediment Transfer Behaviour	Gradual accretion, prone to aggradation if increased sediment inputs from catchment disturbance	

Wilkie Creek

Wilkie Creek

Aerial view example

Table C1-13. ***AC6 - Alluvial Continuous – Meandering gravel bed***

Example waterways and position in catchment	Wilkie Creek – mid catchment.	
Channel Geometry	Asymmetrical or compound channel with steep outer bend banks and moderate width-depth ratio.	
Channel Pattern	Moderate to high sinuosity within the meander belt. Continuous floodplains.	
Geomorphic Units	Channel zone: pool-riffle sequences, point and bank attached bars, scroll bars, islands, benches.	Floodplain zone: multi-surfaced (lower active floodplain and higher level inactive terrace), cut offs, flood channels, abandoned channels.
Geomorphic Behaviour	Low rates of lateral activity where vegetation reasonably intact. Vertical change limited by occasional bedrock controls. Potential for neck cut offs.	
Sediment Transfer Behaviour	Gravel transfer in balance or gradually accumulating.	

Wilkie Creek mid catchment

Wilkie Creek mid catchment

Aerial view example

Table C1-14. ***AC7 - Alluvial Continuous – Multiple channel sand belt***

Example waterways and position in catchment	Wilkie Creek – mid catchment	
Channel Geometry	Multiple channels within a channel belt. Asymmetrical cross section associated with planform location.	
Channel Pattern	Multiple variable sinuosity channels.	
Geomorphic Units	Channel zone: bars, pools, runs, benches, chutes, cutoffs.	Floodplain zone: floodplain surfaces within channel belt and outside have few features.
Geomorphic Behaviour	Anastomosing channels within channel belt. Sand dominated sediments allow for active channel change which can be accelerated by disturbance.	
Sediment Transfer Behaviour	Sand transfer in balance, or gradually accumulating fine grained sediments. Subject to aggradation if increased sediment inputs.	
Additional field comments	A pipeline crossing less than 12 months old trenched and on the outside of a bend. This could be a good monitoring and evaluation site for trenching.	

Wilkie Creek Location: E 302755 N 6990875

Existing pipeline crossing cross section view same location

Aerial view example

Table C1-15. ***AC9 - Alluvial Continuous – Anabranching – fine grained***

<table>
<tr><td>Example waterways and position in catchment</td><td colspan="2">Mid to lower catchment zones on main stems in broad floodplains. Condamine River downstream Cecil Plains.</td></tr>
<tr><td>Channel Geometry</td><td colspan="2">Variable asymmetrical/symmetrical; often low capacity.</td></tr>
<tr><td>Channel Pattern</td><td colspan="2">Multiple channels with highly variable sinuosity and continuous floodplains. One channel often at floodplain margin.</td></tr>
<tr><td>Geomorphic Units</td><td><u>Channel zone</u>: pools riffles, small fine grained point bars and mid-channel bars (if any), occasional benches, chute channels and islands.</td><td><u>Floodplain zone</u>: continuous floodplains with levees, paleochannels, many recent billabongs and back swamps. Often higher floodplain level or terrace.</td></tr>
<tr><td>Geomorphic Behaviour</td><td colspan="2">Active cut bank erosion and concomitant point bar deposition in sand dominated alluvium. Anabranches developing in highly sporadic nature depending on flood event sequences.</td></tr>
<tr><td>Sediment Transfer Behaviour</td><td colspan="2">Throughput in balance or gradually accumulating fine grained sediments. Deposition in decaying channels, scour in developing channels.</td></tr>
</table>

Aerial view

Table C1-16. ***AC10 – Flood channel***

Example waterways and position in catchment	Prior channels in the floodplain of major watercourses such as the Condamine River.	
Channel Geometry	Symmetric, "u" shaped infilled channels, depth dependent on scale of watercourse and degree of infilling/decay.	
Channel Pattern	Low to high sinuosity. May be set within a terrace or floodplain.	
Geomorphic Units	Channel zone: occasional benches.	Floodplain zone: within terrace or floodplain of main channel.
Geomorphic Behaviour	Invert levels generally much higher than main channel, hence rarely engaged by flood flows (as opposed to anabranches).	
Sediment Transfer Behaviour	Generally infilling at slow rates. Occasional instance where a local tributary to the flood channel is maintaining an active low flow channel set within the flood channel.	

Location: E282998 N7022462. Flood channel of Condamine River with active incising low flow channel from a local tributary

Inactive section of flood channel of Condamine River Same location upstream of crossing

Infilled prior channel, now a flood channel behaving like a chain of ponds. Un-named watercourse E 280854 N 7025737

Aerial view

Attachment D
List of moderate to major flood events in the project development area

1 History of flooding

Though rainfall in the catchment is variable, flooding occurs regularly throughout the project development area. The following table shows the history of flooding in the major watercourses in the vicinity of the project development area as recorded by the Bureau of Meteorology (BOM).

Table D1-1. ***History of flooding in major watercourses***

Year	Month	Town	Major watercourse	BOM summary
1863	Feb	Warwick	Condamine River	One of the most disastrous floods ever experienced in the district occurred on the night of 20 February and caused much damage. The Condamine rose and flooded the flats; Rosenthal Creek in flood; wash-pools and bridges destroyed; 4 feet of water around telegraph posts at the Warwick Post Office.
1863	Feb	Taroom	Dawson River	Plenty of rain in the district; Dawson River flooded, and for some days impassable; bridge under water. A few hundred sheep lost through flood.
1863	Feb	Surat	Dogwood Creek	Floods on the Dogwood Creek; great losses.
1863	Feb	Ellangowan	Condamine River	Condamine River rose for some days several feet above the bridge at Ellangowan. Great number of sheep swept away by the flood.
1863	Mar	Goondiwindi	Macintyre River	McIntyre River: Long, continued spell of wet weather; floods experienced on all the rivers to the westward.
1863	July	Warwick	Macintyre Brook	Highest flood known for many years in the McIntyre Brook occurred; the water rose to a great height in the neighbourhood of Pike's Creek.
1864	Feb	Goondiwindi	Condamine River	Rain poured down incessantly. The river rose, overflowed its narrow limits, rushed down the streets, and flooded the houses. It remained at its height for two days, then slowly abated.
1864	Mar	Brown River	Dawson River	Higher floods in the Dawson, Mimosa, and Brown Rivers than ever known before; Dawson 11 feet higher than previous flood.
1864	Mar	Lower Condamine	Condamine River	Steady and continuous rain; creeks flooded.
1864	Mar	Leyburn	Condamine River	Heavy rain again set in; Condamine River and the creeks re-flooded; plains near Ellangowan entirely under water; heavy rain at Callandoon.
1864	Mar	Warwick	Condamine River	The Condamine at Warwick rose 20 feet. The whole of that part of the town called "The Flat" under water, and the people forced to move elsewhere. Great devastation occurred.
1864	Mar	Dalby	Condamine River	The Condamine River and Canal and Thaw Creeks are in flood, and for several days communication between the eastern and western portions of the town has been cut off whilst the principal street has been converted into a canal. Eye witnesses declared the Condamine to be 2 miles wide in places
1864	Mar	Moonie River		The Moonie and Balonne joined and formed a sheet of water over 25 miles wide.
1866	Dec	Kogon	Condamine River	Tremendous storm at The Kogan, about 35 miles north west of Dalby; rain fell in torrents; road covered with water; creeks impassable; Condamine River within 6 inches of the underside of bridge.

Year	Month	Town	Major watercourse	BOM summary
1868	June	Taroom	Dawson River	Rains flooded the Dawson.
1870	Mar	Dalby	Condamine River	Steady rain; the Condamine and creeks all flooded and the railway dam burst; roads very bad.
1870	Aug	Warwick	Condamine River	Condamine bank and Burnett's Bridge considerably under water.
1870	Aug	Condamine	Condamine River	Water 3 feet deep on bridge over the Condamine; current running strongly.
1870	Aug	Inglewood	Macintyre Brook	Heavy rain caused one of the greatest floods in the Macintyre for many years
1873	Dec	Condamine	Condamine River	Great floods at Condamine and throughout the Western district; all traffic stopped
1874	Apr	Condamine	Condamine River	Floods in the Condamine district stopped traffic. New dam at Dalby destroyed by flood (July).
1875	Mar		Dawson River	The water on the Dawson River rose 16 feet above the 1864 flood, the railway was submerged for miles and the loss of life in all parts of the colony was too great to note.
1876	July	Dalby	Condamine River	Myall Creek bridge at Dalby was almost destroyed, and part of the railway near Gowrie was swept away.
1879	Aug	Dalby	Condamine River	In Dalby many were forced to leave their houses.
1887	Feb	Warwick	Condamine River	Heavy flood came down the Condamine at 3 a.m. on 22 February; water rose 2 feet 6 inches higher than the floor of the Post Office; meteorological instruments in yard were submerged, and embedded in mud. No observations made with these instruments from 21 to 25 February.
1893	Feb	Warwick/ Dalby	Condamine River	Floods occurred at Warwick and Dalby.
1908	Mar	Miles	Dogwood Creek	Dogwood Creek rose up to 30 feet during month and at the end of the month was still 3 feet high.
1908	Mar	Chinchilla	Condamine River	Heavy floods from 17 to 27 March.
1909	Feb	Chinchilla	All watercourses in the vicinity	Creeks all in flood at Chinchilla.
1916	Dec	Goondiwindi		Many interior rivers and creeks flooded. Flood at Goondiwindi only 1 foot lower than record flood of 1890.
1917	Jan		Macintyre/Weir Rivers	Floods in Macintyre and Weir Rivers.
1916	Nov	Chinchilla	All watercourses in the vicinity	Floods in Chinchilla and Goondiwindi districts. Loss of stock, and damage to property in latter area.
1916	Dec	Warwick		Many creeks and rivers in south-eastern quarter flooded. Strong floods in Warwick and Yandilla districts. Floods in Gulf country.
1918	Jan		Dawson River	High floods experienced in all tributaries of Fitzroy and Burdekin Rivers, especially the Dawson, Mackenzie, Comet and Nogoa Rivers.
1919	Mar		Condamine River	Flooding in Macintyre and Condamine Rivers.
1921	June	Goondiwindi	Condamine River	Water was just under one metre deep in the main street of Goondiwindi, where the level was the highest since 1890.
1921	July	Goondiwindi	Condamine River	Serious inundations in many districts, especially at Goondiwindi where the river was a little higher than in the June flood. There were heavy losses of stock in the Goondiwindi area, 5000 head of sheep being drowned in one district, and 2000 in another. On 12 July a flood occurred in the Chinchilla district.

Year	Month	Town	Major watercourse	BOM summary
				From 20 to 26 July most rivers flooded in the south-eastern part of the State. Goondiwindi experienced its third big flood in about 5 weeks. This third event was a little higher than the two earlier inundations, and only 50 mm lower than the record flood of March 1890. Lower portions of Warwick and the eastern part of Roma were submerged.
1921	Dec	Chinchilla	Condamine River	During the period 26 to 31 Dec all coastal rivers and the Condamine, Macintyre, Maranoa and Warrego rivers flooded to some extent. The town of Chinchilla was submerged and considerable damage done to property.
1921	Dec	Dalby	Condamine River	Most of Mitchell and parts of Dalby were inundated.
1923	Dec	Dalby	Condamine River	On 26 Dec there was flooding in Dalby.
1923	Mar	Taroom	Dawson River	the Dawson River overflowed the bridge at Taroom
1928	Apr/May		Dawson River	More serious inundations in the Dawson river and streams in the Dawson Valley. Floods were of a disastrous and probably unprecedented nature.
1933	Jan	Warwick		From 15 to 31 Jan local flooding in various parts of the South Coast district and eastern Downs. Between Toowoomba, Clifton and Pittsworth crops were destroyed, sheep drowned, many fences washed away and floodwaters entered the main streets of Clifton, Warwick and Oakey.
1933	Oct	Goondiwindi	Macintyre River	Bridges in the Warwick district were submerged and the Severn River was well over the bridge at Ashford. The Macintyre River flooded at Goondiwindi.
1934	Dec		Condamine River/ Macintyre River	From the 22 to 31 Dec there was flooding in many localities, particularly in the Condamine and Macintyre rivers.
1935	Jan	Dawson Valley	Condamine River/ Macintyre River	Local flooding in Goondiwindi, Inglewood, Dalby and Taroom. Bridges were washed away in the Dawson Valley and rail lines submerged in the Inglewood area. Dalby streets were inundated and a boy drowned near Goondiwindi.
1937	Jan	Goondiwindi	Macintyre River	Floods in the Goondiwindi district on 13 Jan.
1937	Mar	Goondiwindi	Macintyre Brook	From 15 to 20 Mar widespread flooding occurred over the southern parts of the State. There were serious inundations in many localities, heavy losses of sheep in the Goondiwindi district and destruction of crops in several areas.
1939	Mar		All watercourses in the vicinity	From 11 to 17 Mar there was much local flooding in the South Coast, Downs and Maranoa districts and adjacent parts of the Central and South-west districts. Districts most affected on the Downs and surrounding districts were Dalby, Tara, Chinchilla, Greenmount, Yandilla, Nobby, Millmerran, Goondiwindi, Thallon, Dirranbandi, Surat, Tambo, Blackall and Beta-Jericho.
1942	Feb	Chinchilla/ Warra/ Surat/ St.George	Condamine River	There were local stock losses and damage in the Condamine, Macintyre, Balonne and Downs streams. Warra town was evacuated and Chinchilla experienced the highest flood on record. Some station reports were the highest since records began.
1945	Feb	Downs	All watercourses in the vicinity	Local flooding and general stream rises were reported on the Downs.
1945	Feb	Condamine/ Dirranbandi	Condamine River	The Condamine River and southern border streams were still carrying run-off from late January rains and local

Year	Month	Town	Major watercourse	BOM summary
				flooding was caused in the lower reaches early in the month from 2 to 11 Feb. Heights above local flood level were reported from Dirranbandi and Condamine.
1947	Nov		All watercourses in the vicinity	There were stream rises on the Downs and south coast. Apart from local district flooding in low lying areas, by the end of the month heavy aggregate rains had steadily increased general stream flows, and by 2 December some moderate flood heights were reported from the Condamine and Macintyre basin.
1947	Dec		All watercourses in the vicinity	With the persistent rains in the south eastern quarter during the first half of the month, all streams commenced to carry a considerable run-off and flooding of low lying areas was fairly extensive. Main streams affected or reaching flood height reporting stage included Balonne, Condamine, Macintyre, Brisbane, Dawson and parts of the upper Mackenzie rivers.
1948	June		Condamine River	Some wheat planting was affected on the Darling Downs and in a few cases there was a total loss. In the Downs area local flooding was also reported along the Condamine River basin. Millmerran was isolated until after 18 June due to floodwater being over the road and rail bridges. Traffic approaches to Dalby were also cut off with the Condamine River over Loudoun Bridge on 19 June and Ranges Bridges on 21 June. The lower reaches of the Condamine were still carrying considerable run-off and rising slowly at the end of the month.
1949	Mar	Boolburra	Dawson River	The Mackenzie and Dawson experienced severe flooding with peaks at St. Aubins (Mackenzie) on 4 March and Boolburra (Dawson) on 5 March. These streams were fairly high again on the 28 March and 29 March.
1950	Jan	Pratten	Condamine River	Following the heavy rains in the middle of the month, temporary dislocation of road and rail traffic occurred from low lying flooding on the coastal belt and the south-east Downs. There were stream rises and some flooding in the headwaters of the Condamine.
1950	Feb		All watercourses in the vicinity	Sharp flooding over all headwaters of the Condamine River reached record or near record levels in the northern tributaries.
1950	June	Condamine	All watercourses in the vicinity	In view of the very rapid rises in the headwaters of the Condamine and Macintyre rivers there apparently must have been heavier falls on the upper catchments of these streams. Flooding in the upper reaches of the Condamine River was the highest on record, the stream reaching a width of 5 to 8 kilometres. Warwick recorded a record peak on 23 June. Tummaville recorded a record peak on 24 June. As flood waters moved downstream Condamine recorded the second highest height on record on 2 July. The Macintyre River at Goondiwindi peaked on 27th June.
1950	July		All watercourses in the vicinity	Following the heavy rains of the previous 5 to 6 months, the persistent wet weather and record rainfalls during the month caused State wide flooding reports except in the Carpentaria and far western border areas. Flooding was most severe in the Maranoa, Macintyre, Condamine and Balonne rivers with record or near record levels.
1950	Oct		All watercourses in the vicinity	Resulting from the heavy rain period of 8th to 11th October, strong stream rises were reported in the Dawson, Mackenzie , Condamine , Balonne , Macintyre , Paroo and Bulloo river systems. Heaviest flooding was reported in the

Year	Month	Town	Major watercourse	BOM summary
				Dawson, Condamine and Macintyre river systems where low level flooding and traffic dislocation was considerable.
1953	Feb	Goondiwindi	Macintyre River	The Macintyre River at Goondiwindi reached a near record height on 23rd February. Fairly heavy stock losses were reported in the Macintyre basin where aircraft food drops were made for sheep and where rail traffic was still held up at the close of the month.
1954	Jan	Taroom	Dawson River	Moderate flooding occurred in the Dawson. The Dawson was well over the bridge at Taroom.
1954	Aug		Condamine River	The heavy rains of 12th and 13th August on the headwaters of the Dawson and Condamine rivers caused some flooding and traffic disability in the upper reaches of these streams. The Dawson River peaked at Taroom on 14th August. The Condamine River peaked at Condamine on 17th August.
1954	Oct		Condamine River / Macintyre River	Heavy flooding in the Condamine and Macintyre river systems. The flood on the Condamine River peaked at Pratten on 19th October [second highest on record]. The crest of the flood had moved slowly downstream and passed Surat, where the peak height was reported at the end of the month. Thunderstorm rains of 25 to 50 mm on 28 produced fresh flows and renewed flooding in the Macintyre River, the peak reaching Goondiwindi on 30th October.
1954	Nov	Goondiwindi	Macintyre River	Heavy 25 to 75 mm rains on the southern Downs during the 3rd and 4th November renewed the flooding in the Macintyre River which was still carrying considerable run-off from the October rains. The resultant sharp rises on 4th, 5th and 6th November gave the third flood for that stream in 5 weeks. A peak at Goondiwindi on 6th November resulted in moderate flooding and temporary dislocation of traffic.
1955	Mar	Condamine	Condamine River	Sustained and widespread flooding occurred throughout practically the whole of the States river systems during the month. The western edge of the cyclonic rains caused sharp rises in the upper Condamine River.
1955	June	Condamine	Condamine River	Moderate flooding occurred in the lower reaches of the Condamine River.
1956	Jan	Darling Downs	All watercourses in the vicinity	Unprecedented floods were experienced in the Condamine and Macintyre rivers. Heavy rain [e.g. Inglewood 275 mm in 16 hours, Leyburn 150 mm in 4 hours] gave general 250 to 325 mm falls over the central Downs for the 72 hours ending 0900 23rd January. Record river levels were reported at Goondiwindi on 22nd Riverton on 21st Ranges Bridge on 22nd Miles on 22nd Tummaville on 22nd and Inglewood on 22nd January Macintyre Brook at Inglewood rose more than 3 m above the level previously thought by engineers to be the flood extreme. Near record flooding was also reported at Condamine, Texas and Surat with a large volume of water moving downstream into New South Wales. The most devastated area was in the Inglewood-Yelarbon region.
1956	Feb	Darling Downs	All watercourses in the vicinity	Serious floods in the Dawson catchment. Theodore reached a record height on 14th February and Taroom recorded the highest level since 1890 on 11th February. The catchment areas of the Condamine and Macintyre rivers, where streams were still in a swollen state from the record January floods, experienced a succession of flood rains. Highland districts received up to 750 mm in 3 weeks, completely water logging the country and resulting in 100

Year	Month	Town	Major watercourse	BOM summary
				% run-off. Three floods in the Macintyre catchment gave peak heights at Goondiwindi on 7th, 11th and 20th February This last reading and a peak at Texas on 19th February broke all existing records, but resulted from only 25 to 100 mm of rain over the catchment. The succession of 4 major floods in 4 weeks [including the January flood], was also a record. Roads and bridges were severely damaged, and a 50 m gap torn in the bank of the Bonshaw Weir. Food drops were made necessary due to a general breakdown of transport.
1956	June	Darling Downs	All watercourses in the vicinity	Rain totals of 50 to 100 m over the Darling Downs on 23rd and 24th June caused serious flooding in the Dumaresq and lower Macintyre rivers. Goondiwindi peaked at near record levels on 27th June. A number of residents were evacuated from homes in this town, which experienced its fifth major flood that year. Flooding in the Condamine and Moonie rivers was less serious but traffic disabilities occurred.
1956	July	Darling Downs	All watercourses in the vicinity	The month's rain maintained high levels in most streams. Slight to moderate flooding was reported in the Condamine, and Macintyre rivers.
1957	Mar	Downs	All watercourses in the vicinity	Local flooding was reported on the south-west Downs on 11th and 12th March when Oakey Creek at Limevale reached a record height after 125 mm of rain overnight in the headwaters. Water flowed 2 m deep through the main street of the town and 4 women and 8 children were evacuated to a nearby hill. Slight flooding was reported in the Macintyre River where Goondiwindi reached a peak on 14th March. In the Balonne River a fresh peak was reported from 12th to 15th March.
1959	Feb	Downs	All watercourses in the vicinity	Following 235 mm at the Head, [mostly overnight rain], the Condamine River reached a width of 3 km at Killarney. Water reached a height of 3 m in the business section of the town, the highest in memory. Two bridges were swept away and the total damage cost in the town was very high. Allora reported its biggest flood for 50 years, bridges were damaged, people evacuated from homes and kilometers of fencing washed away. The flood crest flattened as it moved down the Condamine and Balonne rivers, giving mostly moderate flooding. Peaks reported were Warwick on 18th February, Tummaville on 20th Ranges Bridge on 20th St. George on 24th and Dirranbandi on 27th February. Slight flooding with little damage was reported in the Macintyre, Moonie , Maranoa and Warrego rivers at this time.
1961	Feb		All watercourses in the vicinity	The most severe local flooding occurred in the upper reaches of the Condamine River. Water entered the town of Allora to a depth of 1 metre, and parts of Killarney were flooded, damaging crops on the river flats. The river peaked at Killarney on the morning of 19th February.
1961	Mar		All watercourses in the vicinity	With continuing widespread rains in the south-east in the first ten days of the month, reports were received of flooding in the Dawson, Mackenzie, Condamine, Macintyre, Moonie and Weir rivers. Traffic disruptions were widespread, and in some cases prolonged, the worst affected areas being along the Condamine, Moonie and Weir rivers. The bridge at Riversdale was cut by the Moonie River for six days, while Yandilla township was isolated for two days by the Condamine River.
1961	June	Darling Downs	All watercourses in the vicinity	Coastal streams south of Bundaberg, together with the Condamine River, experienced considerable flooding during

Year	Month	Town	Major watercourse	BOM summary
				the month. The rain influence also extended west to the fringe of the Darling Downs, where falls averaging 50 mm produced minor flooding in the upper reaches of the Condamine River. Further drenching rain fell in the same districts on 21st and 22nd June, and again on 26th and 27th June but flooding was generally at a lower level than earlier in the month. The exception was in the Condamine basin, where the rain was more widespread than earlier and resulted in moderate flooding at Loudoun Bridge. At the end of the month flood reports were still being received from stations on the middle and lower Condamine River and the Balonne River. Flood reports were also received during the month for the Macintyre River.
1969	Nov		All watercourses in the vicinity	Major flooding was experienced in the Moonie River and minor to moderate flooding occurred in the lower Balonne and Macintyre rivers on 15th to 22nd November.
1970	Sep		Macintyre River	Three individual floods occurred in the lower Macintyre River. The peaks at Goondiwindi were on 18th September [minor flooding downstream], 25th September [moderate flooding downstream], 30th September downstream]. It has been reported that 2,000 sheep drowned during the second flood, downstream of Goondiwindi.
1970	Dec		All watercourses in the vicinity	Major flooding occurred in the Dawson, Condamine, Macintyre and Weir Rivers.
1971	Jan		All watercourses in the vicinity	Major flooding continued in the Dawson, Condamine, Macintyre and Weir Rivers.
1972	Jan		Macintyre/ Dawson River	Moderate flooding occurred in the Macintyre and Diamantina rivers and upper reaches of the Dawson River.
1972	Oct	south-east Queensland	All watercourses in the vicinity	Major flooding was caused in the Macintyre River mainly downstream from Goondiwindi. In the Condamine River there was widespread flooding in most tributaries upstream from Tummaville. As a result, the combined run-off produced major flooding downstream from Tummaville and extensive crop losses.
1972	Nov		All watercourses in the vicinity	Flood levels continually fluctuated in the Condamine, Balonne and Macintyre rivers during the month. The flooding attained major proportions in the lower reaches of the Condamine River and Macintyre River below Goondiwindi.
1974	Feb		All watercourses in the vicinity	Major flooding on the Condamine River.
1974	Nov		Macintyre River	During the month, rains caused general stream rises in south-east Queensland, with flood conditions being reached as follows : From 4th to 6th November minor to moderate flooding, downstream from Goondiwindi in the Macintyre River, and in the Macintyre Brook and Dumaresq River. A peak of 5.57 m was recorded at Goondiwindi on 5th November. From 19th to 26th November moderate flooding downstream from Goondiwindi and in the Macintyre Brook and Dumaresq River, with a Goondiwindi peak of 7.90 m on 22nd November.
1975	Feb		All watercourses in the vicinity	Minor to moderate flooding occurred in the Macintyre, Diamantina and Georgina rivers, and minor flooding occurred in the upper Bremer River and Warrill Creek, Barker Creek, lower Tully, upper Fitzroy tributaries, Mackenzie, Dawson, Condamine and Balonne systems. Though stream rises and traffic disabilities occurred in

Year	Month	Town	Major watercourse	BOM summary
				numerous other rivers during the month, no significant property damage, or stock losses, was reported.
1975	Mar		All watercourses in the vicinity	A feature of the month has been that the Macintyre and Dumaresq catchments flooding, which varied from minor to moderate flood levels receding during the first week, to major flooding during the last week, continued into the following month. Though flooding of major proportion was occurring in the Macintyre River again towards the close of the month, there were few if any reports of damage to property or stock. Condamine - minor to moderate levels, fluctuating throughout the middle reaches from Ranges Bridge to Surat, during most of the month.
1975	Sep		Macintyre River	Minor to moderate flooding occurred along the Macintyre River downstream from Goondiwindi between 3rd and 5th September.
1975	Oct		All watercourses in the vicinity	Minor flooding of short duration occurred in the latter half of the month along the middle reaches of the Condamine River in the Dalby area. Major flooding occurred on the Macintyre River about the same time, with a peak height of 8.53 m at Goondiwindi at about midnight on 24th October. No significant property damage, or stock losses, was reported.
1975	Dec		All watercourses in the vicinity	Widespread moderate to heavy flood rains in the last half of the month brought major flooding to some catchments with minor to moderate flooding in many others. Major flooding occurred in the Condamine River, where the highest levels were reported since 1956 at a number of stations. Major flooding also occurred in the Bulloo River where Quilpie was isolated for several days. Widespread moderate to minor flooding occurred in the following streams: Macintyre, Fitzroy, Warrego, Paroo, Thomson and Diamantina rivers and Cooper Creek. This caused widespread traffic disabilities.
1976	Jan		All watercourses in the vicinity	Moderate to major flooding continued to ease in the Warrego, Bulloo, Paroo, Thomson and Diamantina rivers, Cooper Creek, Condamine and Balonne rivers and the Fitzroy Basin during the early part of the month, following the heavy rains and subsequent flooding in December.
1976	Feb		All watercourses in the vicinity	During the first week of the month moderate to minor flooding eased in the Fitzroy River basin and the Condamine and Balonne rivers. By mid-month, major flooding was occurring in most streams in the Brisbane Valley, the Albert and Logan rivers, the Macintyre, Moonie and Weir rivers, the Condamine, Balonne, Bulloo and Paroo rivers, the Warrego, Thomson and Barcoo rivers, and Cooper Creek, plus Diamantina and Georgina rivers and Eyre Creek. Major flooding in these rivers was caused by the low pressure system formally Cyclone "Alan". Record flood levels and near record flood levels were recorded in many streams between Warwick and Mungindi and many houses were inundated at Warwick, Inglewood, Stanthorpe, Texas, Mungindi and smaller settlements along the main rivers. A number of houses were also inundated on the Logan River at Waterford. At the end of the month major flooding was still occurring in the Balonne River following the extensive flooding in the Condamine River.
1976	Nov		All watercourses in the vicinity	Storm rains on the Darling Downs produced minor to moderate flooding in the Condamine River during the first and third weeks of the month. Minor local flooding was

Year	Month	Town	Major watercourse	BOM summary
				recorded in the Macintyre River downstream from Goondiwindi, and the Dawson River near Taroom.
1977	Mar		All watercourses in the vicinity	During the second week, major flooding developed in most coastal streams on the North Tropical Coast and Ingham was seriously flooded. In the middle of the month flooding extended into the Fitzroy, Kolan, Upper Burnett, Condamine-Balonne, Lower Macintyre, Bulloo, Paroo and Warrego rivers. Major flooding occurred in the Warrego and Balonne rivers.
1977	Apr		Macintyre River	Moderate flooding occurred in the Macintyre River for a few days from the 9th April.
1977	May		All watercourses in the vicinity	Flooding occurred in the south-east of the State from about the middle of the month and continued into the last week. The major streams involved were the Macintyre, Balonne, Dawson and Mackenzie rivers. Flooding on the Macintyre eventually reached major levels downstream of Goondiwindi, with the Balonne River reporting moderate floods. The Dawson River reached major flood levels at Taroom and the Mackenzie River reached moderate levels, with other streams of the Fitzroy basin also causing traffic disabilities for short periods.
1978	Jan	Goondiwindi	Macintyre River	Heavy rain in the Macintyre catchment late in the month brought major flooding to the Macintyre River downstream of Goondiwindi.
1978	Feb		Macintyre River	Heavy flood rains in late January and early February brought major flooding the Macintyre river.
1978	Sep		All watercourses in the vicinity	Following the substantial rainfall over the Southern Border districts and Central Highlands during the first week of the month , minor to moderate flooding developed firstly in the Macintyre River on 6th September, and gradually extended to the Dumaresq, Condamine, Dawson, Weir, Moonie and Balonne rivers by the 10th September.
1978	Nov		All watercourses in the vicinity	Heavy rainfall early in the month caused some moderate to minor flooding in the Macintyre River downstream of Goondiwindi, to the upper Condamine River in the Pratten and Cecil Plains area, and the Paroo River downstream of Eulo. No damage has been reported.
1978	Dec	Goondiwindi	Macintyre River	Moderate flooding on the Macintyre River, downstream of Goondiwindi on the last 2 days of the month.
1979	Oct		Macintyre River	Minor to moderate flooding for 3 to 4 days occurred in the Macintyre River after local heavy rainfall on 20th October.
1980	Jan		Condamine River	Later in the month , localized minor to moderate flooding occurred on the Condamine River between Tipton and Ranges bridges from 28th to 30th January.
1981	Feb	Dalby	All watercourses in the vicinity	The heavy January rainfall in North Queensland continued into February and again brought stream rises to the Carpentaria and North Coast streams. However the first floods of the month occurred on 7th and 8th February in the Condamine and the Brisbane - Bremer river systems. The most serious incident for the month occurred in the Condamine system when heavy rainfall over the Myall Creek catchment brought record floods to Dalby. The major flooding also extended to property along the course of the Balonne River as the heavy rainfall drained into New South Wales over the following 3 weeks.
1982	Mar		All watercourses in	Moderate flooding was confined to the Macintyre River downstream from Goondiwindi. Renewed flood warnings

Year	Month	Town	Major watercourse	BOM summary
			the vicinity	were issued for the Balonne River on 9th March and moderate rainfall extended this warning the next day to include the Maranoa River. Further rain in this area once again extended the flood warnings on 11th March to include the Macintyre River basin and Condamine River. The final warnings for the Condamine and Balonne rivers were issued on 12th March. The Macintyre River continued with major flooding downstream from Goondiwindi on 13th March. The final Queensland flood warning was issued on 19th March for the Macintyre River with major flooding expected at Mingindi on 26th March .
1983	May		All watercourses in the vicinity	The Condamine and Balonne rivers recorded major flooding. Charley's Creek caused major flooding in the Chinchilla area on 6. Flood warnings were also issued on 4th May for the Moonie and Weir rivers with moderate to major flooding till 13th May.
1983	June		All watercourses in the vicinity	Flood warnings continued from the previous month for the Fitzroy River basin, the Bulloo and Paroo rivers, Barcoo River and Cooper Creek, the Condamine and Balonne rivers and the Macintyre, Weir and Moonie rivers. The final flood warning for the Balonne River was issued on 10th June. Widespread rain in the southeast quarter on 21st June resulted in flood warnings for rivers and streams in this area , with warnings continuing till 30th June for the Balonne River , minor flooding to ease in the Dawson River, and minor to moderate flooding to continue to the New South Wales border in the Moonie River for the next few days.
1983	Sep		Macintyre River	Widespread light to moderate rain in the southeast inland caused minor flooding in the Macintyre River on 6th September with moderate flooding the next day, rising to major flooding on 8th September downstream from Goondiwindi. Final flood warnings for the Macintyre were issued on 13th September, with peak height at Riverview and expected to be maintained for the next 48 hours. The peak at Mungindi was expected on 21st September.
1983	Oct		Macintyre River	Widespread light to moderate rain in the southeast resulted in minor flooding in the Macintyre River on the 13th October, increasing to moderate flooding the next day and continuing till 27th October.
1983	Nov		All watercourses in the vicinity	Minor flooding commenced in the Condamine River system and minor to moderate flooding in the Moonie and Weir rivers on 21st November. Final flood warnings were issued for the Moonie River on the 28th November but moderate to major flooding continued in the Condamine/Balonne river systems to 30th November. During the afternoon of 30th November moderate flooding started in the Paroo River.
1983	Dec		All watercourses in the vicinity	Moderate flooding continued from 30th November in the Paroo River till 4th Nov. Moderate to major flooding also continued in the Balonne River till 8th November. Moderate flooding commenced in the upper Dawson River on 5 and continued till 7 Dec.
1984	Jan		All watercourses in the vicinity	Downstream from Goondiwindi the Macintyre River was in minor flooding from 18th till 24th January. Moderate to major flooding occurred in the Diamantina River from 25th till 27th January. Flooding also commenced in the Macintyre River with moderate flooding on 29th January, the Condamine River

Year	Month	Town	Major watercourse	BOM summary
				with minor flooding on 30th January and the Balonne River with major flooding on 30th January,- all continuing into February.
1984	Feb		All watercourses in the vicinity	Flooding continued from January for the following rivers: Major flooding in the Macintyre River till 8th February. Minor to moderate flooding in the Moonie River till 8th February. Major flooding in the Balonne River till 13th February. Moderate flooding commenced again in the Flinders River on 17th till 19th February and moderate flooding in the Macintyre River from 19th till 29th February.
1984	July		All watercourses in the vicinity	Widespread moderate to local heavy rain from the 23rd to 27th July caused flooding in the southeast quarter from 25th July. Minor flooding commenced in the Macintyre River on the 25th July, and minor flooding in the Moonie River the following day. Stream rises in the upper Dawson River closed the bridge at Taroom, the night of 26th July. On 27th July, flooding became more widespread. Moderate flooding in the Macintyre River increasing to major flooding on 29th July downstream from Goondiwindi and continued till the end of the month. Minor flooding in the Weir River became moderate to major flooding on 30th July and continued the next day. Moderate flooding in the Balonne River increased to major flooding on the 30th July. Moderate to major flooding in the Dawson River became major flooding on 28th July and eased on the 30th July, with minor flooding till the 31st July. Moderate flooding in the Condamine River became major flooding on 30th till 31st July, downstream from Chinchilla. Moderate flooding in the Moonie River continued till 31st July downstream from Flinton. Minor flood levels occurred in the Bremer River and Warrill Creek on 28th July.
1984	Aug		All watercourses in the vicinity	Flooding continued from July for the following rivers: • Moderate to major flooding in the Moonie River till the 5th August. • Moderate flooding in the Weir River till the 5th August. • Minor flooding occurred in the Dawson River till the 3rd August. • Major flooding in the Macintyre River reached a peak at Mungindi on the 10th August. • Major flooding in the Balonne River with flood peaks recorded at Surat on 7th St. George on 12th , Dirranbandi on 15th August , and finally at Hebel on 22nd August.
1988	Jan		All watercourses in the vicinity	Showers and thunderstorms with local heavy falls produced minor flooding in Myall Creek in the Dalby area on 20th January. The same day minor flooding occurred in the Macintyre and Weir rivers and continued in the Macintyre from 21st till 26th January as minor to moderate flooding.
1988	Feb		All watercourses in the vicinity	A severe thunderstorm over Cooyar Creek catchment on the evening of Friday 12th February caused the highest flood since European settlement in the township of Cooyar. Several houses and buildings were washed away and two

Year	Month	Town	Major watercourse	BOM summary
				lives were lost. As a result of the storm rains over the Darling Downs near Cooyar on the 11th and 12th February, moderate flooding occurred in Myall and Oakey creeks. Minor flooding occurred in Dalby. The tributary inflows to the Condamine River combined to cause major flooding downstream from Tummaville. This extended downstream to Surat over the following two weeks. Further storm rainfalls in the Surat - Mitchell area in the last week of the month contributed to flood levels in the Balonne River causing major flooding from Surat to St George and south to the New South Wales border. Major flooding was also recorded in the Macintyre River at Goondiwindi during the middle of the month.
1988	Apr	Darling Downs	All watercourses in the vicinity	This was the second most active flood warning month in Queensland since the 1974 floods, after the May 1983 floods. The total flood warnings issued were 161 with a maximum daily issue of 21warnings on 6th April. Widespread major flooding occurred in inland river systems on the Darling Downs, and in the Condamine-Balonne, Macintyre-Weir and Moonie river systems. Crop losses have been reported in the press as in excess of $50 m. Extensive cash crop losses were sustained on Laidley Creek and Lockyer Creek flood plains.
	May		All watercourses in the vicinity	Moderate rainfall during the last few days of April caused minor to moderate flooding in the Macintyre, Weir and Moonie rivers during the first three days in May.
	July		All watercourses in the vicinity	Widespread moderate with local heavy rainfall in the Moreton South Coast and East Darling Downs during 4th to 6th July caused general minor to moderate flooding to develop in the Mary, Bremer, Albert, Logan, Condamine, Macintyre and Dumaresq rivers. Major flooding occurred along Warrill Creek and some reaches of the Condamine River. Moderate flooding extended into the Balonne River system upstream from Beardmore Dam by 11th July, with areas downstream from Beardmore Dam to the New South Wales border experiencing minor to moderate flooding during the latter half of July.
	Sep	Goondiwindi	Macintyre River	Moderate rainfall in the southeast inlands produced minor to moderate flooding in the Macintyre River from the afternoon of 13th September below Goondiwindi and continued till the 19th September.
1989	June		All watercourses in the vicinity	Widespread light to moderate rainfall in the southeast inland on the 5th and 6th caused minor to moderate flooding in the Upper Dawson River from 7th till 11th and minor to moderate flooding in the Balonne River from 10th to 15th June, due to releases from Beardmore Dam.
	Oct	Darling Downs	Balonne/Dawson Rivers	From 25th October, minor flooding in the Balonne River till the 31st October, and minor to moderate flooding in the Dawson River till 30th October. Local heavy rains in the southern Central Highlands and adjacent Maranoa and Darling downs to 9 am on the 25th October.
	Dec		Macintyre River	Local heavy rain in the southern Granite Belt on 13th and 14th December caused minor to moderate flooding in the Dumaresq and Macintyre rivers on the 15th, continuing till 20th December.
1990	Apr		All watercourses in the vicinity	Major flooding also occurred in the Thomson River and Cooper Creek, the Bulloo and Paroo rivers, Nebine, Wallam and Mungallala creeks, Balonne, Macintyre, Nogoa,

Year	Month	Town	Major watercourse	BOM summary
				Dawson and Belyando rivers, with heights approaching record levels in a number of these streams.
1990	May		All watercourses in the vicinity	At the commencement of May, flood warnings remained current for many inland Queensland river systems following the extensive April flooding. Major flooding continued in the lower parts of the Balonne River, Warrego and Paroo rivers. Minor to moderate flooding also continued in the Macintyre River and in the Condamine-Balonne systems during the last week of May.
1994	Feb		All watercourses in the vicinity	In mid-February heavy localized rainfall caused moderate to major flooding in the lower reaches of the Moonie and Weir rivers but there were no reports of significant flood damage. At the same time, heavy falls of 50 to 150 mm in the lower reaches of the Condamine system initially caused minor flooding.
1995	Feb		All watercourses in the vicinity	Isolated heavy rainfall also caused significant flooding along the Dawson River with major flooding at Taroom and minor flooding down the lower reaches. Minor flooding also occurred in the Moonie River between 19th and 28th February.
1995	Nov	Taroom	Dawson River	In the Dawson River, moderate flooding occurred in the upper reaches around Taroom about 21st November and minor to moderate flooding extended downstream until the 24th November.
1995	Dec		All watercourses in the vicinity	Moderate flooding developed in the Weir and Moonie rivers which extended into early December. The floods in the Condamine-Balonne systems were the highest recorded for several years and widespread moderate to major flooding occurred from Warwick to St George. Beardmore Dam on the Balonne River filled during this event which extended into early December in the lower Balonne River. There were no reports of significant damage recorded during these floods but there were road traffic problems in the western rivers for an extended period.
1996	Jan		All watercourses in the vicinity	The influence of tropical Cyclone Barry which developed in the Gulf of Carpentaria in early January spread from the Gulf to the south east corner of Queensland and produced widespread rainfall and flooding. Flood warnings were issued for the Gulf, Thomson, Barcoo, Warrego, Dawson, Burnett, Mary, Condamine, Balonne, Weir, Macintyre and Moonie rivers. The flooding in the Condamine-Balonne system was the highest since 1988 with areas between Condamine Town and the NSW border remaining above major flood level for nearly two weeks. There were few reports of houses being inundated but many towns and properties were isolated for nearly two weeks because of the extensive flooding of roads and bridges. The Macintyre River at Goondiwindi had three major floods in three weeks with the third peak of 12.61 m on 25th January being the highest level on record. The flood was contained by the town levee but isolated the town for several days. Some properties downstream of Goondiwindi were isolated for nearly three weeks. Major flooding also occurred along the Moonie and Weir rivers during the whole of January, isolating many rural properties and smaller towns.

Year	Month	Town	Major watercourse	BOM summary
1996	May	Dalby	Myall Creek	Myall Creek experienced heavy rainfalls from Wed 1st to Saturday 4th, which caused considerable flooding in the Dalby area, rising to a height of 2.90 m on the Patrick St gauge. This was the highest recorded flood level since 1984 when a flood height of 3.10 m was reached. During the peak of the flood all major roads to Dalby were cut, several businesses were affected by the floodwaters, and a local caravan park required evacuation.
1996	May	Warwick	Condamine River	The Condamine catchment upstream of Warwick was relatively dry at the beginning of May, however with average rainfalls of over 200 mm during the first week, the catchment soon became saturated and river levels began rising. By Friday 3rd May, river levels in the Killarney area had risen about 3 m, Connolly Dam had commenced spilling and river levels were rising quickly in the Warwick area. Further rainfalls with isolated 24 hour totals between 75 mm and 100 mm were reported during the next few days causing major flooding. The Killarney flood peak of 6.15 m on Monday 6th May was similar to the February 1976 level. The river broke its banks at Killarney and inundated the main street with water up to 1 m deep. Several businesses suffered flood damage. Major flooding of the Condamine River also affected rural properties upstream of Warwick. The Condamine River at Warwick rose during Monday 6th May and finally peaked at Warwick (McCahon Bridge) at a height of about 6.6 m by Monday evening. This caused major flooding in the Warwick area, requiring the evacuation of 23 premises. Many of these properties experienced flooded yards and one house suffered above floor flooding. The Warwick flood peak of 6.6 m was the highest since the record flood of February 1976 when the Condamine River at McCahon Bridge rose to a height of 9.10 m causing major residential flooding in the Warwick area. Major flooding continued down the Condamine - Balonne River system, with the main flood peak reaching the NSW border area during the last week of May. St George reached a peak of 10.11 m on 21st May. The Border Rivers area also experienced major flooding as a result of May rainfalls. The Macintyre River at Goondiwindi peaked at 8.74 m on the 8th May, well below the record January flood.
1997	Jan		Weir River	Moderate flooding which commenced in the Weir River in January continued into the middle of February. Further heavy rain towards the middle of the month resulted in renewed rises and moderate to major flooding in the catchment.
1997	Feb		All watercourses in the vicinity	Macintyre River: Heavy rainfall in the headwaters of the Macintyre River in NSW resulted in moderate flooding at Goondiwindi in late February. Moonie River: Major flooding commenced in the Moonie River around 17th Feb and continued to the end of the month.
1998	Feb		Dawson/ Condamine-Balonne Rivers	Dawson River: Moderate to heavy rain falls in Juandah Creek in the upper Dawson River catchment at the beginning of the month caused river rises in that area and minor to moderate flooding from Taroom to Beckers over the following week. Condamine-Balonne system: Heavy rain in the area between Morven and Mitchell around 10th Feb resulted in minor flooding in the Maranoa River and

Year	Month	Town	Major watercourse	BOM summary
				minor to moderate flooding in Mungallala Creek. Further heavy falls caused similar rises in the southerly streams of the Balonne River between Miles and Roma. The main floodwaters in the Balonne River which caused major flooding downstream of St George, were a result of the Maranoa River floods. However high flood levels were maintained for several days by the upper Balonne River floods passing through. An initial warning was issued on 10th Feb and finalised on 24th Feb.
1998	Apr	Taroom	Dawson River	Dawson River: Moderate to heavy rain falls in Juandah Creek and in the upper Dawson River catchment resulted in rapid rises in river levels in the upper Dawson River and moderate flooding at Taroom. Major flooding also occurred in Mimosa Creek and resulted in moderate to major flooding in the Dawson River downstream to Beckers. Further downstream, minor flooding was recorded but only extended as far as Newlands. An initial flood warning for the Dawson River was issued on 23rd April and finalised on 1st May as minor flooding eased.
1998	May		Dawson/ Condamine-Balonne Rivers	Dawson River: An initial flood warning was issued on 5th May following widespread rainfall above Taroom. Minor to moderate flooding was experienced in the Dawson River between Taroom and Moura. Local runoff and floodwaters from Mimosa Creek combined to produce major flooding in the Dawson River between Baralaba and Beckers and minor flooding at Newlands. A final flood warning for the Dawson River was issued on 10th May as minor flooding eased. Condamine-Balonne System: An initial flood warning was issued on 6th for the Condamine River, following isolated rainfall over several days which caused rises to minor flood level downstream of Loudoun Bridge with minor to moderate flooding extending from Loudoun Bridge to Surat. The flood waters approached a peak at Surat on 11th May and produced minor to moderate flooding downstream to Whyenbah.
1998	July	Goondiwindi	Border Rivers	Border Rivers: An initial flood warning was issued for the Macintyre River on 20th July following rainfall in the upper reaches of the catchment. Moderate flooding occurred at Goondiwindi the next day, but further rainfall on the following day caused renewed rises although only to minor flood level. As a result of this rain, minor to moderate flooding occurred downstream of Goondiwindi. As the flooding eased at Goondiwindi, widespread heavy rainfall of up to 65 mm occurred on 27th and 28th July and resulted in rapid river rises in the Macintyre Brook, Dumaresq, Macintyre , Weir and Moonie rivers. Moderate to major flooding occurred in Macintyre Brook, Dumaresq and Macintyre rivers, with a flood peak of 10.47 m occurring at Goondiwindi on the evening of the 30th July. This flood is the third highest recorded flood. Major flooding was predicted to develop between Goondiwindi and Riverview during August. Minor flooding occurred in the Weir and Moonee rivers.
1998	Aug	Downs	All watercourses in the vicinity	Condamine-Balonne River: Heavy rain in the Condamine River catchment on the 27th August between Tummaville and Condamine and on the 28 August in the Charleys Creek and Dogwood Creek catchments resulted in minor to moderate flooding in the Condamine River downstream of Cecil Plains and major flooding in Dogwood Creek. Flood

Year	Month	Town	Major watercourse	BOM summary
				levels peaked in Dogwood Creek on the 29th and 30th August with major flooding, and major flooding starting to develop downstream in the Condamine and Balonne rivers with the floodwaters from Dogwood Creek. Flooding in the upper Condamine River, upstream of Cotswold was less significant although minor to moderate flood levels were reached. The main floodwaters had reached the Warkon area by the end of the month with major flooding. Border Rivers: Flood warnings were current at the beginning of the month for the Macintyre and Weir rivers with major flooding easing at Goondiwindi and major flooding developing downstream. There was also minor to moderate flooding in the lower reaches of the Weir River. Further heavy rainfall of up to 40 mm occurred on 5th and 6th August and resulted in renewed rises in the Macintyre Brook and the Macintyre River. The Macintyre River at Goondiwindi peaked at 7.5 m on 9th August with moderate flooding. Widespread rainfall on 23rd and 24th August resulted in river rises in the Macintyre Brook, Dumaresq and Macintyre rivers. An initial flood warning was issued on 24th with river levels peaking at Goondiwindi on the 26th August at 8.84 m, [above the major flood level]. Further heavy rain around Goondiwindi overnight on the 26th resulted in further renewed rises in the Macintyre River and another peak at Goondiwindi of 9.41 m, on the 29th August. The rain on 26th August affected the Weir River catchment and river rises started to be recorded from the 27th Aug. Moderate to major flooding developed from Retreat Bridge downstream to Talwood. Flood levels peaked at Retreat Bridge on 29th August at moderate flooding, with the floodwaters reaching downstream of Giddi Giddi South by the end of the month, causing major flooding. The first flood warning for the Weir River was issued on the 27th August. Moonie River: Minor flooding occurred downstream of Nindigully. An initial flood warning was issued on the 27th following the heavy rainfall in the catchment from 26th to the 27th August.
1999	Feb	Condamine	Condamine/Balonne River	Condamine/Balonne River: On 2nd February following heavy isolated rainfall, major flooding occurred at the Warra Kogan Road Bridge. Moderate flooding developed downstream of Warra Kogan Road Bridge and major flooding occurred in the Balonne River at Warkon. Minor to moderate flooding extended downstream to Dirranbandi where a peak was reached on 15th February.
1999	Mar	Downs	All watercourses in the vicinity	Border Rivers: Heavy rainfalls in the Macintyre River and Macintyre Brook catchments overnight on 2nd March resulted in minor to moderate flooding in Macintyre Brook, the lower Dumaresq River and the Macintyre River around Goondiwindi. Flood levels peaked at Goondiwindi at 8.4 m on 6th March, just below the major flood level. Minor to moderate flooding continued downstream to Mungindi, with the main floodwaters peaking at Mungindi on 21st March. Major flooding also occurred in the upper reaches of the Weir River at Retreat Bridge and in Yarrill Creek at Medpark Bridge as a result of the rainfall at the beginning of the month. Minor to moderate flooding continued downstream to Talwood during the month with the main floodwaters

Year	Month	Town	Major watercourse	BOM summary
				reaching Talwood on 14th March with minor flooding. Moonie River: River rises with moderate flooding between The Deep Crossing and Tartha in the upper Moonie River catchment were recorded on the 4th March. Minor to moderate flooding continued downstream to Fenton on the New South Wales border over the next two weeks. Condamine-Balonne River: Heavy rainfall occurred in the Condamine River catchment, upstream of Cecil Plains, at the beginning of the month and resulted in rapid river rises throughout the catchment. Minor to moderate flooding occurred upstream of Warwick with river levels peaking at Warwick at 5.63 m on 4th March causing minor flooding. Minor to moderate flooding continued downstream to Cecil Plains with moderate to major flooding developing further downstream to St George. The main floodwaters peaked at Condamine Town on the Condamine River on the on 12th May and Surat on the Balonne River on 19th May with moderate flooding. Moderate flood levels were maintained at St George from 10th May to the 23th May before easing. Minor to moderate flooding continued downstream of St George to the New South Wales boundary until the end of the month.
1999	Oct		Border Rivers	Border Rivers: Moderate flooding occurred in the lower Macintyre River from 28th to 31st October.
1999	Nov		Borders/ Condamine-Balonne Rivers	Border Rivers: Flood warnings were issued for the Lower Macintyre River at the beginning of November following renewed rises in already flooded rivers. However river levels remained below the minor flood level and the warning was finalised on 4th November. Rainfall on 8th November caused further minor flooding in the Macintyre Brook and river rises in the Dumeresq River. The combined flows from these streams resulted in moderate flooding in the Macintyre River at Goondiwindi, where river levels peaked at 7.22 m on 11th November. Minor to moderate flooding continued downstream towards the NSW border during the following week. Condamine Balonne Rivers: Rapid stream rises occurred in the Upper Condamine River and tributaries following rainfall on 8th November. River levels peaked at Warwick the same day at 5.10 m, just above the minor flood level. Minor flooding continued downstream in the Condamine River to the Cecil Plains area over the next few days and the flood warnings were finalised on 12th November, as river levels were below the minor flood level.
2000	Jan	Brigalow	Condamine River	Minor to moderate flooding occurred in the Condamine River in the Tipton Bridge to Brigalow Bridge area at the start of the year. Downstream of Brigalow Bridge river levels remained below the minor flood level and the flood warning was finalised on 2nd January.
2000	Nov	Goondiwindi	Macintyre River	Widespread moderate rainfalls in the Macintyre River in NSW resulted in a minor flood at Goondiwindi late Friday 17th November. During the early hours of Monday 18th November, very heavy rainfall was recorded in the Macintyre River around Ashford. This resulted in major flooding in the Macintyre River to Goondiwindi where a flood peak of 10.0 m was recorded on Wednesday morning 13th November. Some rises were also recorded along the Dumaresq River during this period. Moderate flooding extended along the

Year	Month	Town	Major watercourse	BOM summary
				Macintyre River downstream of Goondiwindi to Mungindi to the end of November.
2001	Feb	Chinchilla	Condamine River	The event which caused the heavy rainfall in the south east corner of the State spilled over in the upper Condamine River and caused minor flooding along the upper Condamine and tributaries downstream to Chinchilla Weir to 11th February.
2001	Feb	Goondiwindi	Macintyre River	Minor flooding extended along the Dumaresq River and along the Macintyre River in NSW during the first few days of February. During this time there was no significant flooding in the Macintyre Brook. However the combined flows in the three systems resulted in a major flood peak of 9.2 m at Goondiwindi on Saturday 3rd February. Minor flooding extended downstream to Mungindi over the next two weeks.
2001	Feb		Moonie River	Moderate flooding developed in the upper to middle reaches of the Moonie River during the first few days of February and with minor flooding extending down to the NSW border by the middle of the month.
2001	Mar	Goondiwindi	Macintyre River	There were two instances of moderate flooding in the Border Rivers during March, both resulting from heavy rainfalls in the Macintyre River catchment in NSW. During the first period, the Macintyre River at Goondiwindi reached 7.4 m on 12th March and during the second, moderate flooding again occurred as the Macintyre River at Goondiwindi reached 7.3 m on 28th March.
2001	April	Goondiwindi	Macintyre River	Macintyre River flooding continued in early April.
2001	November	Goondiwindi	Macintyre River	On the 25th November, heavy rainfalls in the upper Macintyre River catchment in New South Wales subsequently caused moderate flooding downstream to Goondiwindi where a peak of 7.9 m was reached on Thursday 29th November.
2001	December	Goondiwindi	Macintyre River	The moderate flood which occurred in the Macintyre River in late November continued to ease at the beginning of December.
2003	Feb	Goondiwindi	Macintyre River	Rainfall in the upstream reaches of the Macintyre River, upstream of Goondiwindi caused river rises and minor flooding extending from Yetman to Riverview. A minor flood peak of 5.20 m was recorded at Goondiwindi on 25th February. The first warning as issued on 24th February was finalized on 1st March.
2003	Dec		Weir River	River rises and moderate flooding occurred along the Weir River during early December.
2003	Dec		Condamine River	Rises to below minor flood level were recorded along the Condamine-Balonne system to Surat in mid-December.
2004	Jan		Condamine River	A band of heavy rain with totals up to 100 mm was recorded in a band from Roma to Glenmorgan. This caused rapid river rises up to major flood levels in the Balonne River at Warkon and Surat within 2 days. During the following days, rainfall in the system was more widespread and resulted in minor to moderate flooding in the Condamine, Balonne and Maranoa systems, which continued until the end of the month. The initial flood peak reached St George on 22nd January causing major flooding but flooding continued until the end of the month.
2004	Jan		Weir River	Flooding in the Weir River system first developed on

Year	Month	Town	Major watercourse	BOM summary
				Saturday 17th January at O'Connor with moderate to major flood levels being recorded in the upper reaches down to Gunn Bridge on Monday 19th January. High river levels with moderate to major flooding continued downstream to Surrey for the next 5 days.
2004	Jan	Flinton	Moonie River	Moderate flooding developed in the middle reaches of the Moonie River around Flinton following a few days of heavy rain and extended down to Fenton, near the NSW border, by the 24th January.
2004	Dec	Upper Dawson / Taroom	Dawson River	Minor to moderate flooding occurred in the upper Dawson River around Taroom from 8th to 13th December.
2005	Dec	Upper Dawson / Taroom	Dawson River	Heavy rainfall in the Juandah Creek catchment during 2nd December led to major flooding in the Dawson River at Taroom on 4th December.
2006	Jan	Taroom	Dawson River	River rises were also recorded in the Dawson River at Taroom during the middle of January with moderate flooding.
2007	Mar	Upper Dawson	Dawson River	Local to minor flooding occurred in the upper Dawson River at Tarana Crossing on 15th and at Taroom on 16th and 17th March.

Flooding during the 2010-11 wet season is discussed in Section A4.4.