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1. INTRODUCTION

1.1 Project Description

Arrow Energy Pty Ltd (Arrow) proposes to expand its coal seam gas operations in the Surat Basin of Queensland through the Surat Gas Project (the project). The project is expected to cater to the growing demand for gas in the Australian market and in the global liquefied natural gas (LNG) export market. The project development area covers approximately 8,600 km^2 and is located approximately 160 km west of Brisbane in Queensland's Surat Basin. It extends from the township of Wandoan in the north towards Goondiwindi in the south, in an arc through Dalby. The towns of Wandoan, Chinchilla, Kogan, Dalby, Cecil Plains, Millmerran, Miles and Goondiwindi are located in or adjacent to the project development area (Figure 1.1). The project envisages producing coal seam gas from approximately 7,500 production wells spread over five development regions across a 35-year project life. The gas from the production wells will be transported to approximately 18 production facilities (field compression facilities, central gas processing facilities and integrated processing facilities). Field compression facilities and central gas processing facilities will compress the gas. Integrated processing facilities will compress gas as well as storing and treating coal seam water.

This environmental management plan forms part of an environmental impact statement (EIS), which will be submitted to Commonwealth and State governments for project approval.

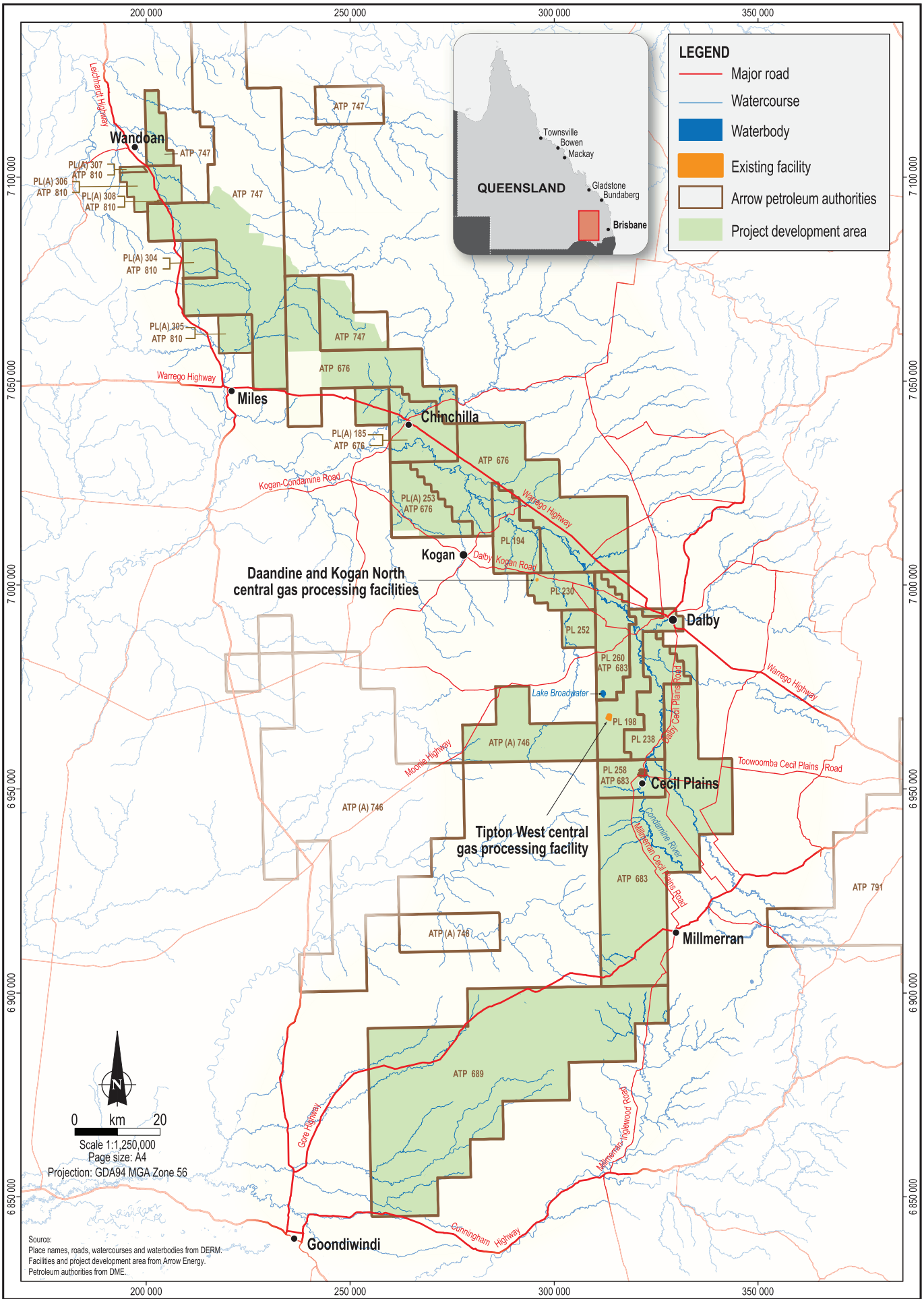
1.2 Project Proponent

Arrow is an integrated energy company with interests in coal seam gas field developments, pipeline infrastructure, electricity generation and a proposed LNG project.

Arrow is a Queensland-based wholly owned subsidiary of Arrow Energy Holdings Pty Ltd, a 50:50 joint venture between a subsidiary of Royal Dutch Shell plc and a subsidiary of PetroChina Company Limited (PetroChina). The joint venture took ownership of Arrow on 23 August 2010.

Royal Dutch Shell plc has had a presence in Australia since 1901. Current operations include petroleum refining, sale of petroleum products and retail businesses. The company maintains equity in the exploration and development of large gas resources off the coasts of Western Australia and the Northern Territory. Royal Dutch Shell is an internationally recognised leader in LNG production and has delivered some of the world's largest and most complex LNG projects in the last 40 years, including facilities in Qatar, Nigeria, Russia and Southeast Asia. Through its subsidiary, Shell International Trading and Shipping Company Limited, Royal Dutch Shell operates one of the largest LNG carrier fleets in the world.

PetroChina is a subsidiary of China's largest state-owned oil and gas producer and distributor, China National Petroleum Corporation, and is one of the world's largest oil companies. PetroChina was incorporated as a joint stock company in 1999 and has extensive experience in exploration, refining and marketing of oil and natural gas in China and other countries.



coffey environments	Date: 11.11.2011 MXD: 7040AC_04_GIS005_v1_4 File Name: 7040_04_ATT5_F01.01_GIS_GL	Arrow Energy Surat Gas Project	arrowenergy go further	Surat Gas Project development area (including petroleum authorities)	Figure No: 1.1

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 account for around 20% of Queensland's overall domestic gas production.

Arrow supplies gas to the Daandine, Braemar 1, Braemar 2, Townsville and Swanbank E power stations, which participate in the National Electricity Market. With Arrow's full ownership of Braemar 2 and the commercial arrangements in place for Daandine and Townsville power stations, Arrow has access to supply 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 Pipeline between Moranbah and Gladstone.

1.3 Purpose of the Environmental Management Plan

This environmental management plan forms part of the EIS and, as such, has been developed in accordance with the Surat Gas Project Final Terms of Reference but can also be read as a stand-alone document. The Queensland Department of Environment and Resource Management's (DERM's) 2010 Guideline for Preparing an Environmental Management Plan for Coal Seam Gas Activities (DERM, 2010c) was also used to inform the content and structure of this plan.

The purpose of this environmental management plan is to detail environmental values; potential impacts to these values from project activities; and environmental protection commitments for the project to implement during planning and design, construction, operation and decommissioning to protect the environmental values identified.

The environmental management plan will inform the environmental management plan (EM Plan) that will be prepared to support the application for Arrow's environmental authority for the Surat Gas Project.

The key objectives of this environmental management plan are to:

- Document acceptable environmental protection commitments to manage potential impacts on the environmental values as a result of proposed activities and, in doing so, to help the administrating authority decide on the approval conditions for the EIS.
- Provide the community with evidence that the environmental management of the project is appropriate.

1.4 Environmental Management Plan Scope

This environmental management plan describes Arrow's approach to the management of environmental impacts associated with project activities, from planning and design through to decommissioning and rehabilitation. Broadly, the document describes the following:

- Arrow's health, safety and environmental management system (HSEMS).
- Existing and proposed activities associated with the Surat Gas Project.

- Existing environment of the project development area and surrounds, including the identification of relevant environmental values.
- Potential impacts of the project's activities on identified environmental values.
- Environmental protection commitments for each of the following environmental elements to minimise the identified potential impacts:
  - Air quality.
  - Geology, landform and soils.
  - Landscape and visual amenity.
  - Terrestrial ecology.
  - Groundwater.
  - Surface water.
  - Aquatic ecology.
  - Coal seam gas water.
  - Dams.
  - Noise and vibration.
  - Waste.
  - Preliminary hazard and risk.
  - Indigenous cultural heritage.
  - Non-Indigenous cultural heritage.
  - Roads and transport.
  - Agriculture.
- Decommissioning and rehabilitation.

As a separate document, Arrow has also developed a draft social impact management plan. The plan was prepared based on the Guideline to Preparing a Social Impact Management Plan (DIP, 2010) and provides avoidance, mitigation and management measures to address the potential impacts identified in the social impact assessment conducted as part of the Arrow Surat Gas Project EIS.

1.5 Environmental Framework

Uncertainty about the location and timing of development of coal seam gas infrastructure has been addressed through the development of a framework comprising constraints mapping and environmental management controls.

Constraints mapping identifies those areas (called constrained areas) where development should not occur or should only occur if carried out in accordance with appropriate environmental management controls. Constraints to development have been identified through the analysis of geographic information system (GIS) data informed by the findings of technical studies. The sensitivity of an environmental value is a key determinant in defining constraints to development, and these sensitivities are expressed as no-go, high, moderate and low.

The types of activities permitted in constrained areas are based on the capacity of the environment to cope with disturbance and of environmental management controls to effectively mitigate the potential impacts. The level of constraint informs the environmental management requirements, which increase from standard or procedural environmental management controls for areas of low constraint through to site-specific management plans for highly constrained areas.

Constraints mapping informs site and route selection with the aim of reducing potential impacts on environmental values. Environmental management controls appropriate to each identified level of constraint aim to ensure effective management of project activities.

1.6 Project Stakeholders

The project's social and cultural area of influence is located within the Darling Downs Statistical Division, which includes the Regional Council areas of Toowoomba, Goondiwindi and Western Downs. The towns of Cecil Plains, Chinchilla, Dalby, Goondiwindi, Miles, Millmerran and Wandoan were considered to represent the major service centres within the project development area and served as consultation focal points for both rural and town-based stakeholders.

In addition to members of the residential communities mentioned, project stakeholders include but are not limited to:

- State government departments.
- Federal government agencies.
- Local governments.
- Local non-government organisations (NGOs).
- Indigenous groups.
- The agricultural sector.
- The business sector.
- Emergency and health services.
- TAFE and training providers.
- Landcare and catchment groups.
- Service clubs (such as the Rotary Club and Lions Club).
- Chambers of commerce.
- Tourist information centres.

1.7 Environmentally Relevant Activities

Under the *Environmental Protection Act 1994* (Qld) (the EP Act), some activities associated with the project are considered to be environmentally relevant activities. Detailed planning of the final project design will allow the environmentally relevant activities to be identified. Based on the preliminary field development concept, environmentally relevant activities that are expected to be relevant to the Surat Gas Project include, but are not limited to, those described in Table 1.1.

A number of activities associated with the project are deemed to be level 1 Chapter 5A activities that, under s. 23(1) of the Environmental Protection Regulation 2008, are prescribed as level 1 ERAs. The EP Act defines level 1 Chapter 5A activities as having a 'medium to high risk of causing serious environmental harm'.

Table 1.1 Environmentally relevant activities that may be applicable to the project

Environmentally Relevant Activities (ERAs)	Description	Applicable Project Activities
Level 1 Chapter 5A activity	Chapter 5A activities include all authorised activities under the *Petroleum and Gas (Production and Safety) Act 2004* (Qld) (P&G Act), including incidental activities.	All petroleum activities.
ERA 8 – chemical storage	10 m^3 or more of chemicals of class C1 or C2 combustible liquids under AS 1940 (Standards Australia, 2004a) or dangerous goods class 3.	Storage of chemicals.
ERA 14 – electricity generation	Electricity generation (the relevant activity) consists of generating electricity by using gas at a rated capacity of 10 megawatt (MW) electrical or more.	Power generation to supply gas compression and water treatment facilities.
ERA 15 – fuel burning	Fuel burning (the relevant activity) consists of using fuel-burning equipment that is capable of burning at least 500 kg of fuel in an hour.	Compressor units, generators, water treatment facilities, etc.
ERA 56 – regulated waste storage	Regulated waste storage (the relevant activity) consists of operating a facility for receiving and storing regulated waste for more than 24 hours.	Storage of regulated waste prior to treatment (including coal seam gas water and solid waste).
ERA 58 – regulated waste treatment	Regulated waste treatment (the relevant activity) consists of operating a facility for receiving and treating regulated waste or contaminated soil to render the waste or soil non-hazardous or less hazardous.	Coal seam gas water treatment, solid waste treatment.
ERA 43 – concrete batching	Concrete batching (the relevant activity) consists of producing 200 t or more of concrete or concrete products in a year by mixing cement with sand, rock, aggregate or other similar materials.	May be required if concrete for facility construction is produced at a batching plant.
ERA 60 – waste disposal	Operating a facility for disposing of more than 200,000 t of regulated waste.	Temporary storage of waste; both solid and liquid.
ERA 63 – sewage treatment	Operating one or more sewage treatment works at a site that has a total daily peak design capacity of more than 21 equivalent persons.	Sewerage facilities at construction camp sites or at production facility sites.
ERA 64 – water treatment	Water treatment (the relevant activity) consists of carrying out any of the following activities in a way that allows waste, whether treated or untreated, to be released into the environment: a. Desalinating 0.5 ML or more of water in a day. b. Treating 10 ML or more of raw water in a day. c. Carrying out advanced treatment of 5 ML or more of water in a day.	Coal seam gas water treatment process.

A level 1 environmental authority is required before a level 1 Chapter 5A ERA can be undertaken. As part of the application procedure for a level 1 environmental authority, DERM determines whether an EIS is required before deciding the application. An EM Plan is required to be submitted with the application to DERM in accordance with s. 310D of the EP Act.

The purpose of the environmental management plan is to propose environmental protection commitments to assist the administering authority (DERM) to assess and condition the Surat Gas Project EIS. This environmental management plan will be further refined to meet the obligations for preparing an EM Plan under the EP Act to support the application for the environmental authority. The environmental management plan identifies the environmental avoidance, mitigation and management measures that will be implemented to protect the environmental values identified in the EIS.

For projects of significant scale, an EIS process is generally required to identify the potential environmental impacts and propose appropriate assessment methods and mitigation measures to determine if an environmental authority should be granted. Arrow has elected to prepare a voluntary EIS under Chapter 3, Part 2, of the EP Act as the first step toward preparing the environmental authority applications for the project.

1.8 Petroleum Tenures and Authorities

All petroleum or gas projects require both a tenure from the Department of Employment, Economic Development and Innovation that gives Arrow rights in relation to petroleum and an environmental authority from DERM that regulates the environmental management of the project.

There are two main types of petroleum tenures for coal seam gas extraction: an authority to prospect and a petroleum lease. An authority to prospect is granted to facilitate the exploration and testing of coal seam gas resources for a maximum of 12 years. A petroleum lease is given to facilitate exploration, testing and production of coal seam gas resources for a maximum of 30 years. A petroleum tenure requires a four- to five-year plan to be approved by the Queensland Government that details the extent and nature of activities to be carried out during that period. If the plan is significantly changed within the period, another plan must be lodged.

Arrow and its subsidiaries currently hold petroleum leases for operations within parts of the Surat Gas Project development area. These are regulated under the environmental authority for the Dalby Expansion Project and include petroleum leases PL194, PL198, PL230, PL238, PL252, PL258 and PL260. These are mapped in Figure 1.1.

1.9 Project's Financial Assurance

Provision of financial assurance is required for all level 1 environmental authorities under s. 310D of the EP Act. This is to be calculated in accordance with DERM's guideline Financial Assurance for Petroleum Activities (DERM, 2011a) and must include the cost of rehabilitation of any disturbed land that has been the subject of whole or partial surrender due to the grant of a new petroleum authority over the land.

The calculation of financial assurance for the construction and operations phases will be part of the application stage of the environmental authority for the project. This calculation will be in accordance with the DERM guideline.

1.10 Project Life

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 occur between 2014 to approximately 2019. 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.

2. ENVIRONMENTAL MANAGEMENT SYSTEM

Arrow is committed to the sound management of health, safety and the environment throughout all of its business activities. The company maintains a comprehensive and integrated health, safety and environmental management system (HSEMS) based on the principles of ISO 14001, Environmental Management Systems - Requirements with Guidance for Use (Standards Australia, 2004b) and AS/NZS 4801:2001, Occupational Health and Safety Management Systems - Specification with Guidance for Use (Standards Australia, 2001).

2.1 Policy

Arrow's environmental policy (Figure 2.1) governs the development and implementation of Arrow's HSEMS. Together, these documents are the key tools used by Arrow to engage in activities and to supply services in an environmentally sustainable manner. By implementing the Arrow HSEMS and site-based environmental management plans, Arrow aims to:

- Conduct operations in compliance with all relevant environmental legislation, regulations, licences, permits, standards, approvals and authorities.
- Clearly allocate responsibilities for environmental performance at all levels within Arrow and its business associates and build environmental competency through provision of structured environmental training to its employees, contractors and other service providers.
- Seek continuous improvement in environmental performance through setting objectives and targets for improved environmental performance, provide sufficient financial and human resources to meet these objectives and targets, apply research and development and cleaner production principles and, where applicable, use environmentally sustainable products and resources.
- Apply best industry practice in the management, supply and delivery of coal seam gas.
- Communicate with customers and the community about commitments to this vision, its application and their view of Arrow's performance.
- Report annually on environmental performance.

2.2 Roles and Responsibilities

Arrow is ultimately responsible for the ongoing environmental management of project activities. However, all Arrow employees and contractors are responsible for the environmental performance of their activities and must demonstrate compliance with Arrow procedures and policies and with any commitments made as part of the HSEMS and this environmental management plan.

Key Arrow personnel have specific environmental responsibilities when managing environmental management issues. These personnel and their responsibilities are presented in Table 2.1.

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Corporate Environmental Policy

Policy Statement

Arrow Energy promotes sustainable environmental practices as part of our commitments, beliefs and values.

Scope and Responsibility

This Policy applies to all personnel involved in Arrow operations and it is a cornerstone to the Arrow Management System.

The Chief Executive Officer and the leadership team are responsible for the implementation, review, update and enforcement of this Policy and each employee, consultant, contractor and service provider is responsible for actively participating in and implementing this Policy.

Practice, Implementation and Supporting Documents

Arrow Energy ensures all elements of the Environmental Policy are implemented by:

- Seeking continuous improvement in managing significant environmental impacts by clearly defining objectives and targets and evaluating them through transparent review and implementation processes.
- Establishing programs to reduce environmental impacts, conserve and recycle resources, reduce waste and pollution, and improve processes to help protect the natural environment as well as monitoring and measuring performance.
- Ensuring all of our activities comply with all applicable environmental laws and regulations.
- Promoting a culture where employees andservice providers are aware of environmental impacts affecting their work and promptly report any environmental impacts or incidents while encouraging improvements.
- Monitoring Policy implementation at all relevant Arrow controlled workplaces, and periodically reviewing and updating.

Expectations

- Maintaining open and transparent communications with employees, government and other stakeholders. transparent community,
- Communicating expectations to all employees and service providers and holding them accountable for their performance.
- Operating within compliance with all applicable environmental laws and regulations.
- Collaborating with stakeholders and participating in research and development, aimed at enhancing knowledge and improving our environmental performance.
- Employing new and improved technologies and developing industry partnerships that are aimed at reducing the carbon emission per unit of production and improving cost/benefit balance.
- Our Environmental Policy plays a vital role in Arrow's Sustainable Development Policy.

Andrew Faulkner, Chief Executive Officer
18th Day April 2011, Review Date:2014

Doc No: 9&-V-POL-0002

coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Arrow's Corporate Environmental Policy	Figure No: 2.1
	File Name: 7040_04_ATT5_F02.01_FT	Surat Gas Project			

Table 2.1 HSEMS roles and responsibilities

Role	Responsibility
Chief Executive Officer	• Performance of Arrow. • Corporate environmental policy. • Fostering a partnership that promotes 'ownership' of Arrow's environmental responsibilities.
Chief Operating Officer	• Implementation of corporate and environmental policy. • Systems and resources to ensure compliance with environmental policy.
Vice President Health, Safety, Sustainability and Environment	• Performance measurement and reporting, including recommendations for improvement and corrective actions.
General Manager: Environment and Water	• Authorised officer for signing environmental documentation. • Ensuring management and monitoring practices and procedures are documented and clearly communicated within the organisation.
General Manager: Assets	• Implementation of management and monitoring practices and procedures in all operation areas. • Resourcing. • Accountable for compliance.
Environment managers	• Environmental approvals management. • Development of operational procedures and practices relevant to the environment. • Coordinating incident response. • Reporting and compliance related issues.
All site and field personnel	• Environmental approvals management. • Development of operational procedures and practices relevant to the environment. • Coordinating incident response. • Reporting and compliance-related issues. • Training in and implementing procedures, including those that address environmental management, at a site or operational level. • Overseeing day to day activities. • Carrying out specific activities that ensure compliance with environmental authority conditions, including monitoring and data collection.

2.3 Inductions and Training

Environmental awareness inductions and training appropriate to the level of risk and type of work being performed will be provided to all employees, contractors, subcontractors and visitors. Training plans will be developed to attain, improve and maintain personnel competencies and the overall environmental performance of Arrow. Additionally, plans will be reviewed following change, incident investigations and hazard studies. Training will:

- Cover all emergency response procedures.
- Review hazards and control measures.
- Review environmental standard operating procedures.
- Present consequences and impacts of departure from hazard and control measures.
- Reinforce the role of hazard and control measures in achieving company and business unit objectives and targets.

- Be regularly evaluated to ensure the required learning outcomes are being achieved.

Training, competency and awareness of site personnel are tracked via a database that addresses the needs stipulated by an individual's work area. This database is reviewed through the course of internal and external compliance audits and will be maintained on site and available on request.

2.4 Monitoring and Reporting

Monitoring and reporting provide a direct measure of the project's impacts and the consequences of its operations, together with an indication of the effectiveness of Arrow's HSEMS. Planned monitoring and reporting include the following:

- Monitoring implementation of specific environmental management plans and procedures.
- Regular inspection of construction and operational activities.
- Environmental monitoring of impacts over time (e.g., photo-monitoring and audits).
- Reporting and analysis of regulated discharges, emissions and waste disposal.
- Any other prescribed monitoring in accordance with the conditions of the relevant environmental authority.

2.5 Incidents and Emergencies

Incident reporting and management within Arrow are reinforced through environmental management plans, procedures and incident reporting guidelines and are included and emphasised during training of personnel.

Environmental incidents are reported through Arrow's management line and are investigated to establish immediate and system (root) causes. Corrective actions are applied to prevent recurrence. Arrow's Environment and Approvals managers ensure that external environmental reporting requirements in the event of any incident are fulfilled.

Arrow has plans and procedures for preparedness and response to emergencies. These are applied to both environmental and safety events.

2.6 Inspections, Reviews and Audits

Internal inspections, reviews and audits are undertaken as both scheduled and unscheduled activities. Monthly audits are conducted for aspects of operations and maintenance activities in conjunction with site environmental improvement plans and review meetings. In addition, spot audits are undertaken during ad hoc site visits. External audits will be undertaken at least once every two years and when required to evaluate compliance with environment authority conditions and Arrow's HSEMS.

2.7 Continuous Improvement and Corrective Action

The components of the Arrow HSEMS (including relevant management plans, procedures and guidelines) will be reviewed and updated as a result of audit outcomes, subsequent corrective actions, changes in activities, procedures or improved technology. Updates will also reflect legislative amendments together with relevant project changes or issues that arise during petroleum project activities.

2.8 Community Concerns and Complaints

Arrow is committed to managing all community concerns in an accountable, transparent, timely and meaningful way. Arrow has in place a complaints management system that outlines how staff must handle, report and address complaints. The system is consistent with the AS ISO 10002-2006, Customer Satisfaction – Guidelines for Complaints Handling in Organizations (Standards Australia, 2006).

Complaints will be recorded in the complaints management system database. All complainants will be treated courteously and kept informed of the progress of their complaint throughout the complaint management process.

By monitoring complaints and recording their outcomes, Arrow will ensure continued improvement in its operations and activities through meaningful feedback provided about potential improvements identified as a result of complaints.

2.9 Document Control and Records Management

As required by ISO 14001, Arrow will maintain a database for storage and retrieval of environmental data, records and other relevant information for the project.

3. DESCRIPTION OF PETROLEUM ACTIVITIES

3.1 Overview

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 and excluded from town centres. Facilities supporting the petroleum development activities, such as depots, offices, and construction and operation support facilities, may be located in or adjacent to towns.

The conceptual project design presented in the EIS is premised upon sustained production from Arrow's Surat Basin gas fields of approximately 1,050 TJ/d of which 970 TJ/d (which includes a 10% fuel gas requirement for facility operation) will be exported and 80 TJ/d will be used for domestic consumption.

3.2 Resource Description

In geological terms, the project development area covers the eastern margin of the Surat Basin and the western margin of the Clarence-Moreton Basin, as shown on Figure 3.1. The geological formations of these basins are relatively continuous at their adjoining margins; however, given that the majority of Arrow's tenements and of the project development area are located within the Surat Basin, the project is referred to as the 'Surat Gas Project'. For simplicity, geological descriptions in this section apply to both basins but are only referred to as the Surat Basin.

The gas resource for the Surat Gas Project lies within the coal seams of the Walloon Coal Measures of the Surat Basin. The Walloon Coal Measures lie beneath the Kumbarilla Beds and above the Eurombah Formation, Marburg Formation and Hutton Sandstone (Figure 3.2). The Walloon Coal Measures are complex; are characterised by carbonaceous mudstone, siltstone, minor sandstone and coal; and contain the following formations:

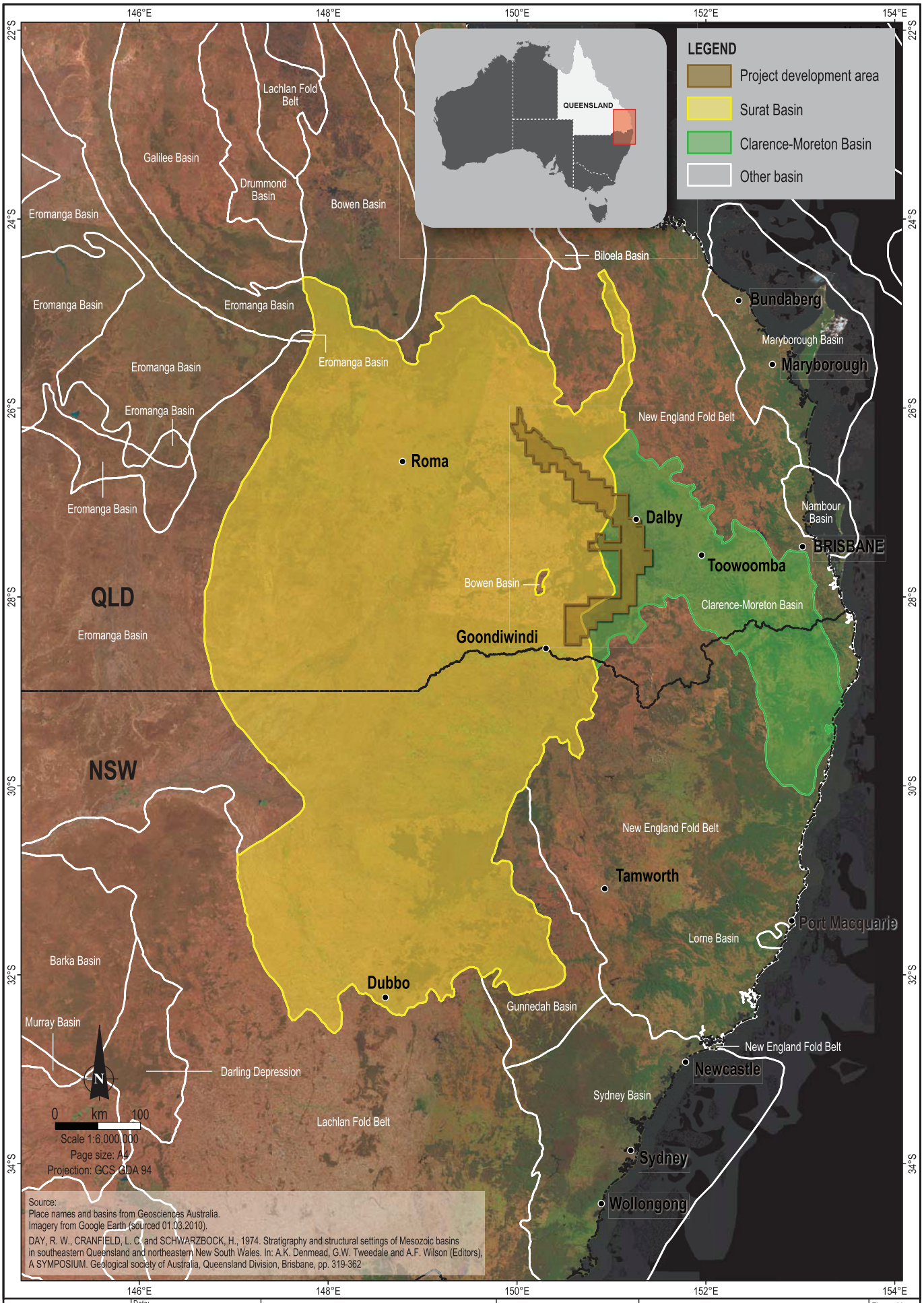
- Juandah Coal Measures.
- Tangalooma Sandstone.
- Taroom Coal Measures.
- Durabilla Formation.

Of these four formations, the Juandah and the Taroom Coal Measures are targeted for exploration and production, which will generally range in depth from 150 to 750 m below ground level across the project development area.

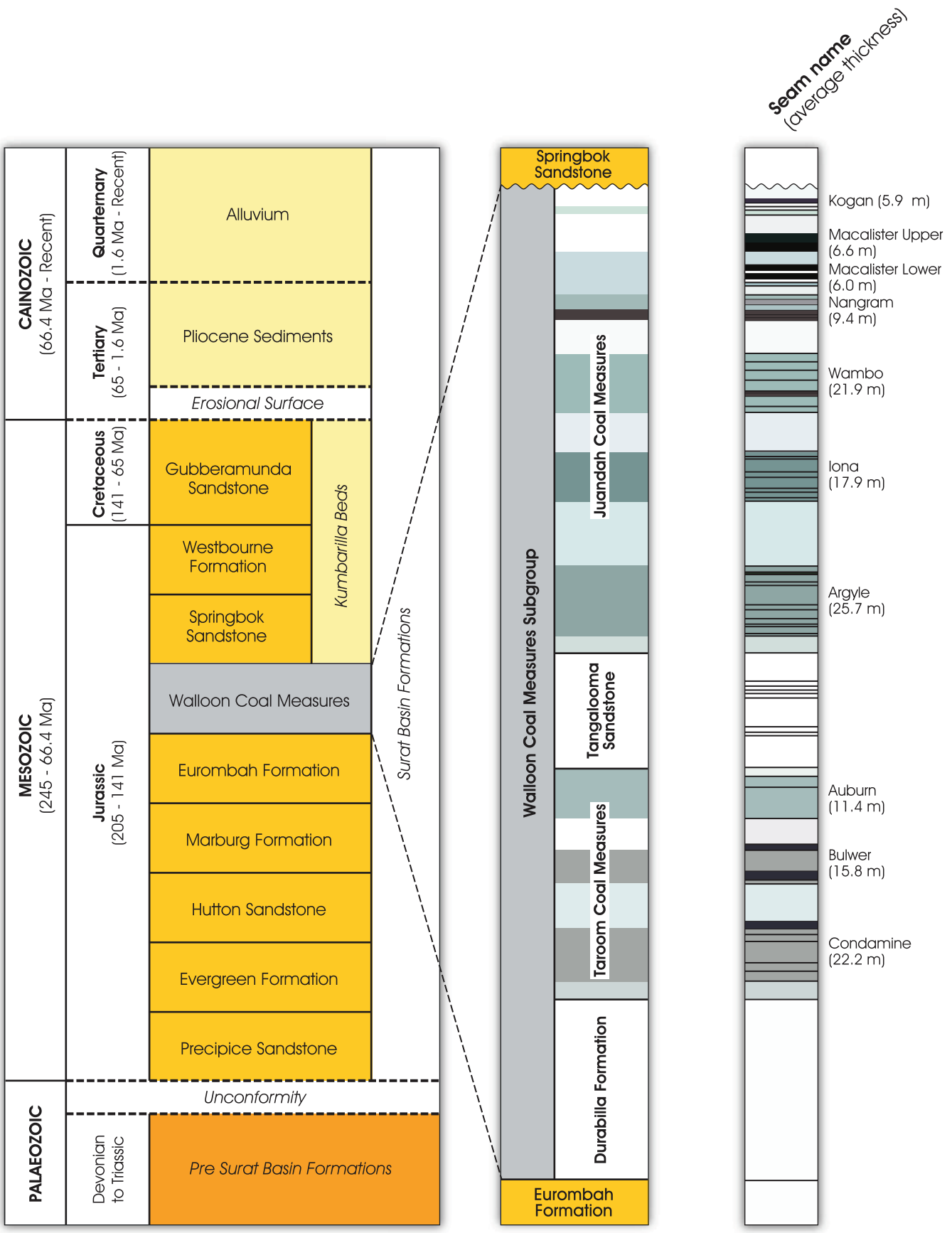
The coal seam gas composition within the project development area has been characterised from Arrow's existing testing and production. Typical coal seam gas components are shown in Table 3.1.

Table 3.1 Typical coal seam gas composition

Component	Typical Quantity (%)
Methane	98.75
Ethane	0.01
Carbon Dioxide	0.19
Nitrogen	1.05



coffey environments	Date: 25.11.2011 MXD: 7040_04_GIS006_v1_3 File Name: 7040_04_ATT5_F03.01_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Location of the Surat and Clarence-Moreton basins	Figure No: 3.1



Source: Data form Arrow Energy
Scott et al (2004)

coffey environments	Job No: 7040 File Name: 7040_04_ATT5_F03.02_GL	Arrow Energy Surat Gas Project	arrow energy go further	Project development area stratigraphic profile	Figure No: 3.2

3.3 Major Infrastructure Components

Development of the coal seam gas reserves in the Surat Basin will require significant infrastructure to extract and transport the gas for production and sale. Arrow proposes that numerous production wells be installed, first to remove the coal seam water and then to extract the coal seam gas for production at a number of production facilities. Production facilities will dehydrate and compress the gas for transport to market, as well as treat and store the coal seam gas water in dams. Power generation facilities will be required, as will various supporting infrastructure.

The main infrastructure components of the Surat Gas Project are:

- Production wells.
- Gas and water gathering systems.
- Production facilities.
- Water and brine treatment and storage facilities.
- Power generation facilities.
- High-pressure gas pipelines.
- Supporting infrastructure and logistics.

3.3.1 Production Wells

In total, approximately 7,500 production wells will be required across the project development area over the life of the project, with a development rate of approximately 400 wells per year. Arrow proposes to install production wells on an approximately 800-m-grid spacing. This equates to an indicative density of one well per 65 to 130 ha (approximately 160 to 320 acres). The precise locations of the wells have yet to be determined.

Wells do not need to be placed on a precise grid and may be spaced as far apart as 1,500 m depending on such constraints as environmental and social values, economics, reservoir characteristics and existing land use.

3.3.2 Gas and Water Gathering Systems

Following construction of a production well, coal seam gas and water are produced at low pressures of approximately 100 kPa. Gas and water gathering systems are required to collect and transport the gas and water to production facilities.

Gas and water gathering systems may include:

- Wellhead facilities, such as a water and gas separator vessel, water pump, electrical generator, electrical control panel, instrumentation, piping and valving at the wellhead to control the flow of the gas and coal seam water from the well to the gathering system.
- Low-pressure gas and water gathering pipelines to transport gas and water from the wellhead to production facilities. Low-pressure pipelines will be 100- to 630-mm-diameter, high-density polyethylene buried pipelines.
- Medium-pressure pipelines to transport gas between field production facilities. Medium-pressure pipelines will be buried and constructed of lightweight, plastic-composite, glass-reinforced epoxy or steel.

3.3.3 Production Facilities

Gas and water collected in the gathering systems will be transported to production facilities located at approximately 25-km intervals. Production facilities primarily:

- Receive gas from wells located within reasonable proximity of the facility.
- Remove any bulk water remaining in the gas through a slug catcher.
- Compress gas through multiple stages to achieve sales gas pipeline pressure.
- Dehydrate gas to sales gas pipeline quality.
- Meter and control gas flow from the wells and to the sales gas pipeline.
- Provide a control centre for activities in the facility and the associated gas fields.
- Flare gas in the event of plant upset conditions or control failure.
- Vent process gas in emergency situations.

A combination of three types of production facilities will be required – field compression facilities, central gas processing facilities and integrated processing facilities – each of which has specific functions as shown in Figure 3.3. Field compression facilities compress the gas and send it on to a central gas processing facility or an integrated processing facility. Central gas processing facilities compress and dehydrate the gas and include a water transfer dam and pumping station to transfer the coal seam gas water to a water treatment and storage facility at an integrated processing facility. Integrated processing facilities compress and dehydrate gas and also treat coal seam gas water and store the treated water and the related brine. This type of facility also includes infrastructure to transport treated water and brine.

3.3.4 Water Storage Dams

Central gas processing facilities will each require a water transfer dam in the order of 600 ML capacity. Integrated processing facilities will each require feedwater dams in the order of 840 ML capacity and treated water dams in the order of 960 ML capacity.

Coal seam gas water storage dams are assessed using the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011b). If a dam is assessed as being in the significant or high-hazard category, it will be considered a regulated dam and will need to be registered with DERM. Detailed dam design reports for regulated dams will be submitted to DERM following grant of the environmental authority that provides in-principle approvals to construct dams.

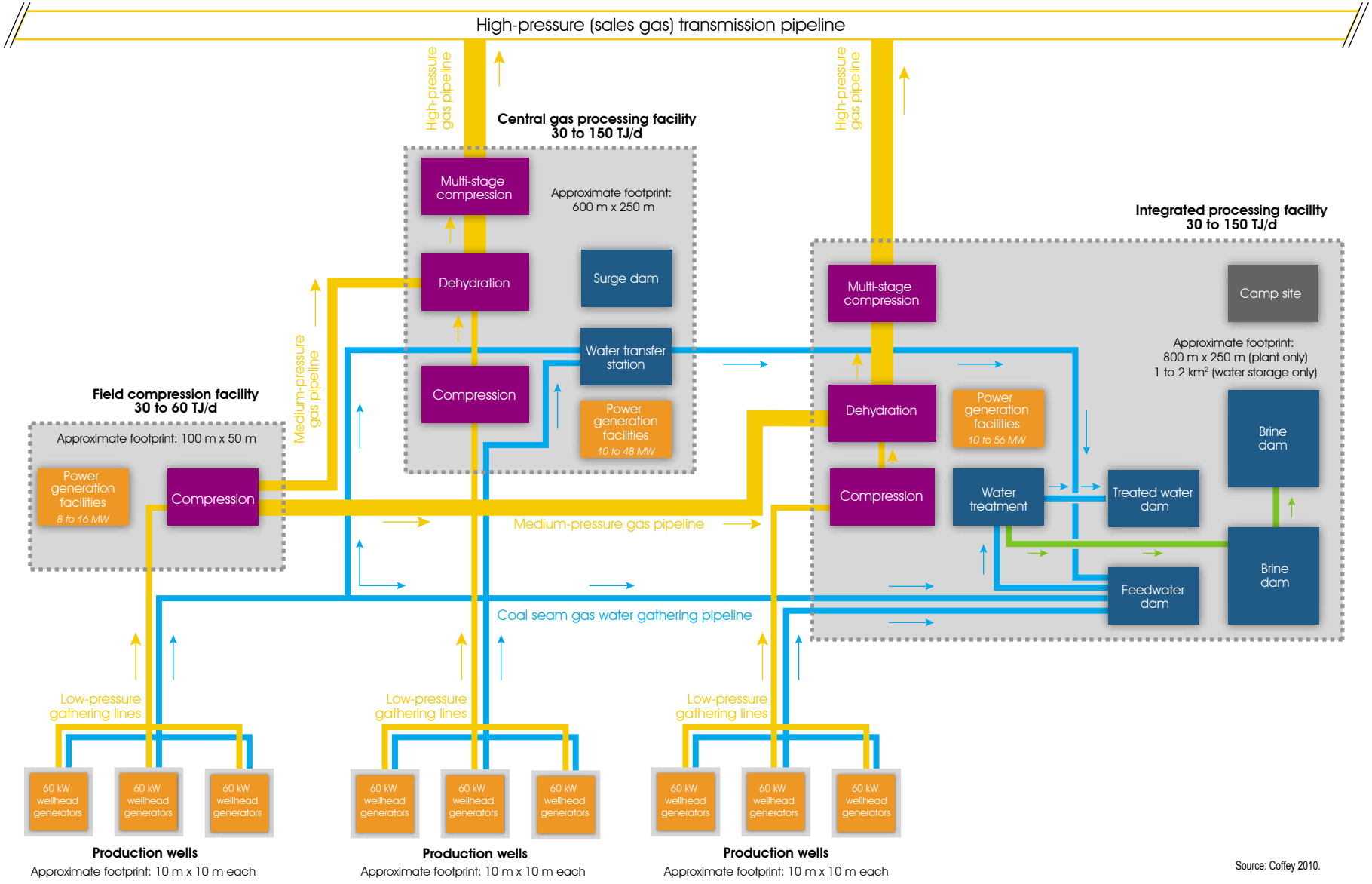
3.3.5 Water Treatment Facilities

Reverse osmosis has been selected as the treatment technology for the coal seam gas water, although Arrow will continue to investigate new and emerging technologies to evaluate their applicability to operations based on economics, energy consumption and brine recovery, as well as the operational and environmental footprint of the associated technology.

Each integrated processing facility will contain a reverse osmosis water treatment plant with 30 to 60 ML/d of water treatment capacity.

3.3.6 Brine Storage Dams

The reverse osmosis treatment of water will produce concentrated brine. Each integrated processing facility will contain two 1,440-ML brine dams (see Figure 3.3). Brine dams are considered regulated dams and will be constructed similarly to coal seam gas water storage dams.



Source: Coffey 2010.	coffey environments	Job No: 7040 File Name: 7040_04_ATT5_F03.03_GL	Arrow Energy Surat Gas Project	arrow energy go further	Gas and water production and treatment Figure No: 3.3

3.4 Other Infrastructure for the Beneficial Use of Coal Seam Gas Water and Brine

Other infrastructure associated with the water treatment and storage facilities may comprise:

- Interconnection between the water treatment facilities. The linking of facilities will provide additional flexibility to cope with variations or spikes in water production across the development regions.
- A network of distribution pipelines to transport treated water to end users through direct supply, through substitution of existing allocations or for 'make good measures' to ensure ongoing water supply to landowners with impaired bore capacity. The network location and its extent will be dependent on the location or locations of the end user market.
- A selective salt precipitation plant. Arrow is consulting commercial enterprises to investigate viable opportunities for the beneficial use of brine. Infrastructure required to convert brine to salt for beneficial use would include a salt storage area with a concrete apron, process building, bunding and roof. This area is expected to be in the order of 150 m by 150 m for each facility, keeping in mind that the facility would require heavy articulated vehicle access and loading facilities.

Management of coal seam gas water and brine is further discussed in Section 4.8, Coal Seam Gas Water.

3.5 Power Generation Facilities

Power is required for the extraction, transport and production of coal seam gas and water and incidental activities. Power generation facilities are assumed to be required at both the production wells and the production facilities. These facilities are expected to generate electricity continuously 24 hours a day, 365 days a year, except for scheduled and unscheduled maintenance.

A power generation facility will likely comprise a series of high-efficiency coal-seam-gas-fired reciprocating engines with lean-burn technology to achieve high-efficiency generation (greater than 40%) with reduced emissions (low nitrogen oxide combustion technology). Each engine will be coupled to alternators generating directly at 11 kV. Power generation facilities will be located within or in close proximity to production facilities. An estimated 80 m by 150 m footprint will be required to accommodate a power generation facility. These facilities will supply power for gas compression, dehydration and water treatment.

3.6 High-pressure Gas Pipelines

High-pressure gas pipelines will transport gas at high pressure (10,200 kPa) from the outlet of central gas processing facilities and integrated processing facilities to the main Arrow Surat Pipeline, Surat Header Pipeline or Daandine hub. These high-pressure pipelines will be constructed of steel and will be buried within a generally 30-m right of way (ROW).

Pipeline route selection will be informed by environmental, native title, stakeholder and social constraints as well as constructability, technical and cost constraints.

3.7 Supporting Infrastructure and Logistics

The development of the Surat Gas Project will occur over a large and diverse area, which will require supporting infrastructure to construct and operate the various extraction, gathering and production facilities. Where existing infrastructure is not in place, additional supporting infrastructure will be constructed to facilitate project development requirements. The main supporting infrastructure for the project is expected to include tracks and roads, depots, borrow pits, temporary workforce accommodation facilities, telecommunications facilities and potable water supplies.

3.7.1 Workforce

A significant workforce will be required for the development of the Surat Gas Project. A peak workforce of approximately 1,000 personnel is predicted in years 2021 and 2032. Workforce predictions will be influenced by the contractual volumes of sales gas and may increase or decrease with the rate of development.

Arrow prefers to recruit its workforce from the local area. This includes candidates without the necessary industry-specific skills, who show a strong willingness to be trained.

3.7.2 Accommodation Facilities

Accommodation for the construction and operation of the Surat Gas Project will include a combination of construction camps and permanent housing.

The construction workforce will primarily be accommodated in self-contained temporary accommodation facilities that contain a canteen, fitness facility, laundry, vehicle parking, fuel handling and storage area, and a camp waste management and storage area including ablution facilities. These accommodation facilities would typically occupy an area located in the vicinity of a central gas processing facility or integrated processing facility.

Small mobile camps to house well drilling staff may also be required in a location central to the drilling activities. These camps would contain a small canteen, vehicle parking areas and waste management and storage areas including ablution facilities.

Operations staff are expected to be accommodated in permanent housing in or near towns within the project development area.

3.7.3 Borrow Pits

The project construction and operations activities will require foundation aggregate for construction of camps, roads and production facilities. Where approved by the relevant government agency, existing quarries and borrow pits will be used for rock, gravel, sand and soil. If unavailable, alternative sources of quarry and borrow pit materials will be sought from more remote sources or through the identification and development of new borrow pits. Proximity to production facilities will be a key factor in investigating alternative borrow pit sites. Borrow pit site selection will primarily be informed by quality of material, access to resource, environmental and social constraints and consultation with landowners and relevant government agencies.

3.7.4 Potable Water

Potable water is required during construction and operational activities. Water will be sourced and trucked from existing town water supplies, groundwater bores or treated coal seam gas water depending on the location of the activities and production facilities.

The expected volume of potable water consumed during construction and operations will be approximately 7 ML per annum and 12 ML per annum, respectively.

3.7.5 Depots

Depots are likely to be located in:

- The township of Dalby servicing the Dalby and Kogan regions.
- The township of Miles servicing the Wandoan and Chinchilla regions.
- The township of Millmerran servicing the Millmerran region and possibly the northern portion of the Goondiwindi region.

The depots will accommodate administration, engineering and production, supervisory support, occupational health and safety management, stores, workshops, laboratories and associated personnel.

4. ENVIRONMENTAL VALUES, IMPACTS AND MANAGEMENT ACTIONS

This chapter identifies the existing environment and environmental values in the project development area and describes Arrow's approach to managing potential environmental impacts that are associated with project activities.

Unique commitment numbers have been assigned to each of the environmental protection commitments identified in the below sections. These commitment numbers are also referenced in the Surat Gas Project EIS.

4.1 Air Quality

This section describes Arrow's approach to managing potential environmental impacts on air quality associated with project activities.

4.1.1 Existing Environment and Environmental Values

The existing air quality environment is characterised by a climate typical of subtropical regions. Land use consists primarily of bushland and agricultural land along with industry that includes coal-fired power stations, coal mines and industrial manufacturing. Rural road networks connect a number of sparsely occurring small, regional towns. Sensitive places within the project development area, including schools and dwellings, are shown in Figures 4.1a, 4.1b and 4.1c.

Table 4.1 provides the existing maximum ground-level concentrations of key pollutants within the project development area along with health-based Environmental Protection (Air) Policy 2008 (EPP (Air)) objectives.

Table 4.1 Existing maximum ground-level concentrations of key pollutants

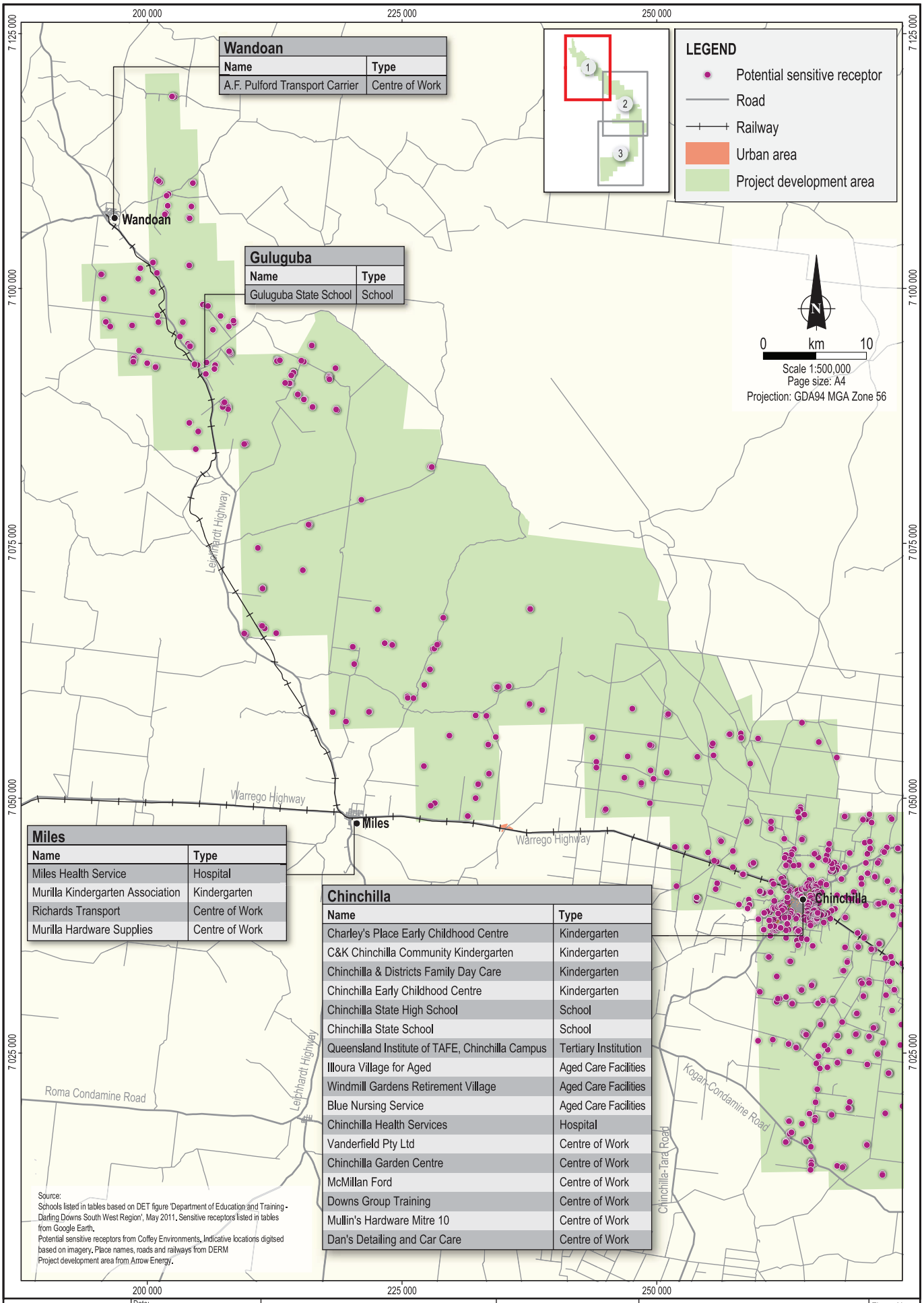
Pollutant	EPP (Air) Objective ($\mu g/m^3$)[a]	Averaging Period	Existing Concentration ($\mu g/m^3$)
Nitrogen dioxide (NO_2)	250[b]	1 hr	22[c]
	62	Annual	2.2
Ground level ozone (O_3)	210[b]	1 hr	136[c]
	160[b]	4 hr	123[c]
Sulfur dioxide (SO_2)	570	1 hr	40.0[d]
	230	24 hr	5.7[d]
	57	Annual	2.9[d]
Carbon monoxide (CO)	11,000	8 hr	750.1[d]
Particulate matter (PM_{10})	50	24 hr	25.7 [d]
Particulate matter ($PM_{2.5}$)	25	24 hr	6.8[d]
	8	Annual	3.6[d]

[a] Health-based objectives at standard temperature and pressure (0 ˚C, 1 atm).

[b] Allowed one-day exceedence per annum.

[c] Second highest day per annum.

[d] Average of DERM monitoring station results for Toowoomba with the exception of SO_2, which is taken from Flinders View (DERM, 2007, DERM, 2008, DERM, 2009a, DERM, 2010a). The ninetieth percentile of the data was taken for subannual averaging periods.



Wandoan

Name	Type
A.F. Pulford Transport Carrier	Centre of Work

Guluguba

Name	Type
Guluguba State School	School

Miles

Name	Type
Miles Health Service	Hospital
Murilla Kindergarten Association	Kindergarten
Richards Transport	Centre of Work
Murilla Hardware Supplies	Centre of Work

Chinchilla

Name	Type
Charley's Place Early Childhood Centre	Kindergarten
C&K Chinchilla Community Kindergarten	Kindergarten
Chinchilla & Districts Family Day Care	Kindergarten
Chinchilla Early Childhood Centre	Kindergarten
Chinchilla State High School	School
Chinchilla State School	School
Queensland Institute of TAFE, Chinchilla Campus	Tertiary Institution
Illoura Village for Aged	Aged Care Facilities
Windmill Gardens Retirement Village	Aged Care Facilities
Blue Nursing Service	Aged Care Facilities
Chinchilla Health Services	Hospital
Vanderfield Pty Ltd	Centre of Work
Chinchilla Garden Centre	Centre of Work
McMillan Ford	Centre of Work
Downs Group Training	Centre of Work
Mullin's Hardware Mitre 10	Centre of Work
Dan's Detailing and Car Care	Centre of Work

Source:
Schools listed in tables based on DET figure 'Department of Education and Training - Darling Downs South West Region', May 2011. Sensitive receptors listed in tables from Google Earth.
Potential sensitive receptors from Coffey Environments. Indicative locations digitsed based on imagery. Place names, roads and railways from DERM
Project development area from Arrow Energy.

coffey environments

Date: 01.12.2011
MXD: 7040AC_04_GIS201a_v1_2
File Name: 7040_04_ATT5_F04.01a_GIS_FT

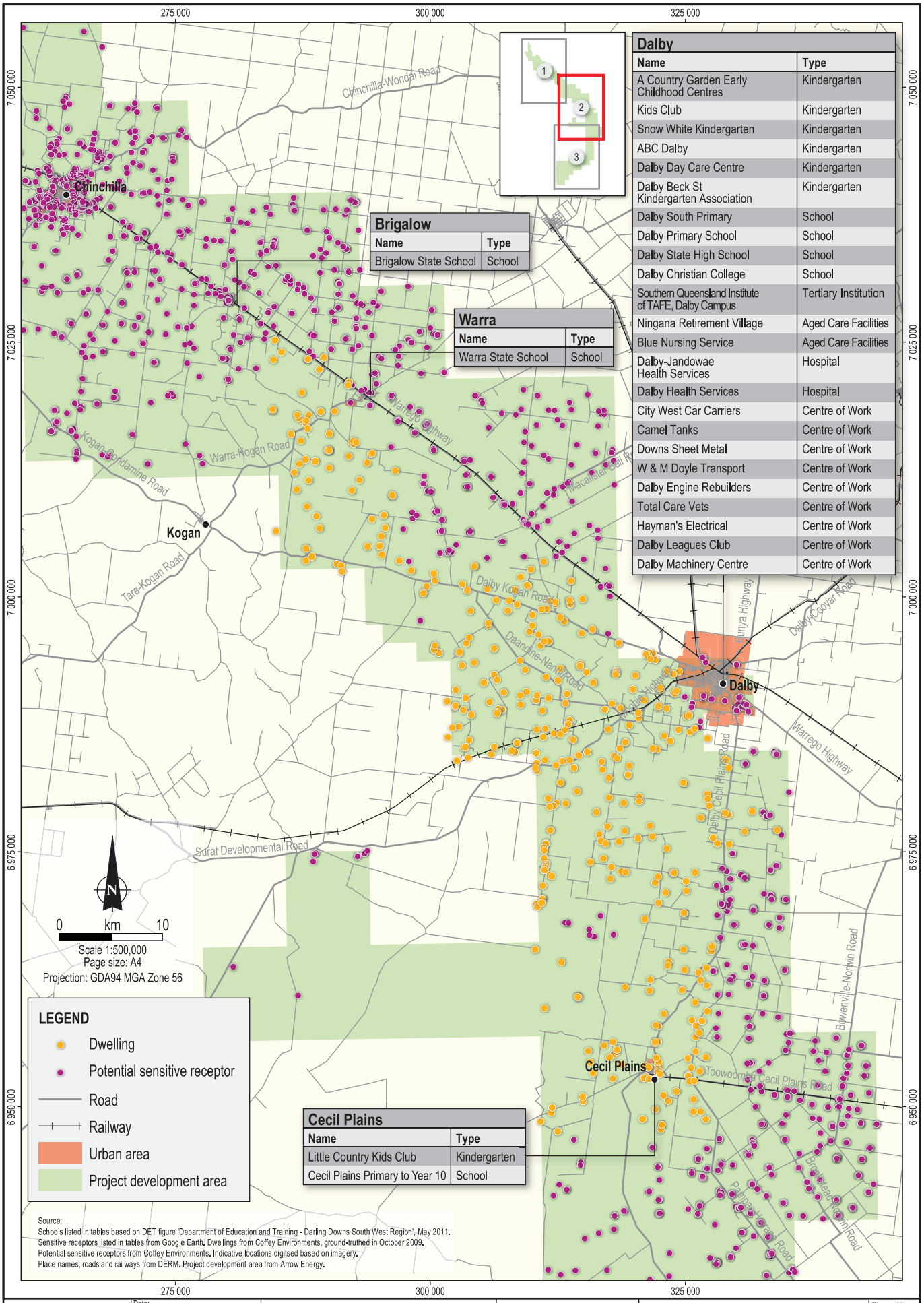
Arrow Energy

Surat Gas Project

arrow energy go further

Sensitive receptors (northern project development area), Map 1 of 3

Figure No: 4.1a



Brigalow

Name	Type
Brigalow State School	School

Warra

Name	Type
Warra State School	School

Dalby

Name	Type
A Country Garden Early Childhood Centres	Kindergarten
Kids Club	Kindergarten
Snow White Kindergarten	Kindergarten
ABC Dalby	Kindergarten
Dalby Day Care Centre	Kindergarten
Dalby Beck St Kindergarten Association	Kindergarten
Dalby South Primary	School
Dalby Primary School	School
Dalby State High School	School
Dalby Christian College	School
Southern Queensland Institute of TAFE, Dalby Campus	Tertiary Institution
Ningana Retirement Village	Aged Care Facilities
Blue Nursing Service	Aged Care Facilities
Dalby-Jandowae Health Services	Hospital
Dalby Health Services	Hospital
City West Car Carriers	Centre of Work
Camel Tanks	Centre of Work
Downs Sheet Metal	Centre of Work
W & M Doyle Transport	Centre of Work
Dalby Engine Rebuilders	Centre of Work
Total Care Vets	Centre of Work
Hayman's Electrical	Centre of Work
Dalby Leagues Club	Centre of Work
Dalby Machinery Centre	Centre of Work

Cecil Plains

Name	Type
Little Country Kids Club	Kindergarten
Cecil Plains Primary to Year 10	School

Source:
Schools listed in tables based on DET figure 'Department of Education and Training - Darling Downs South West Region', May 2011.
Sensitive receptors listed in tables from Google Earth. Dwellings from Coffey Environments, ground-truthed in October 2009.
Potential sensitive receptors from Coffey Environments. Indicative locations digitsed based on imagery.
Place names, roads and railways from DERM. Project development area from Arrow Energy.

coffey environments

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File Name: 7040_04_ATT5_F04.01b_GIS_FT

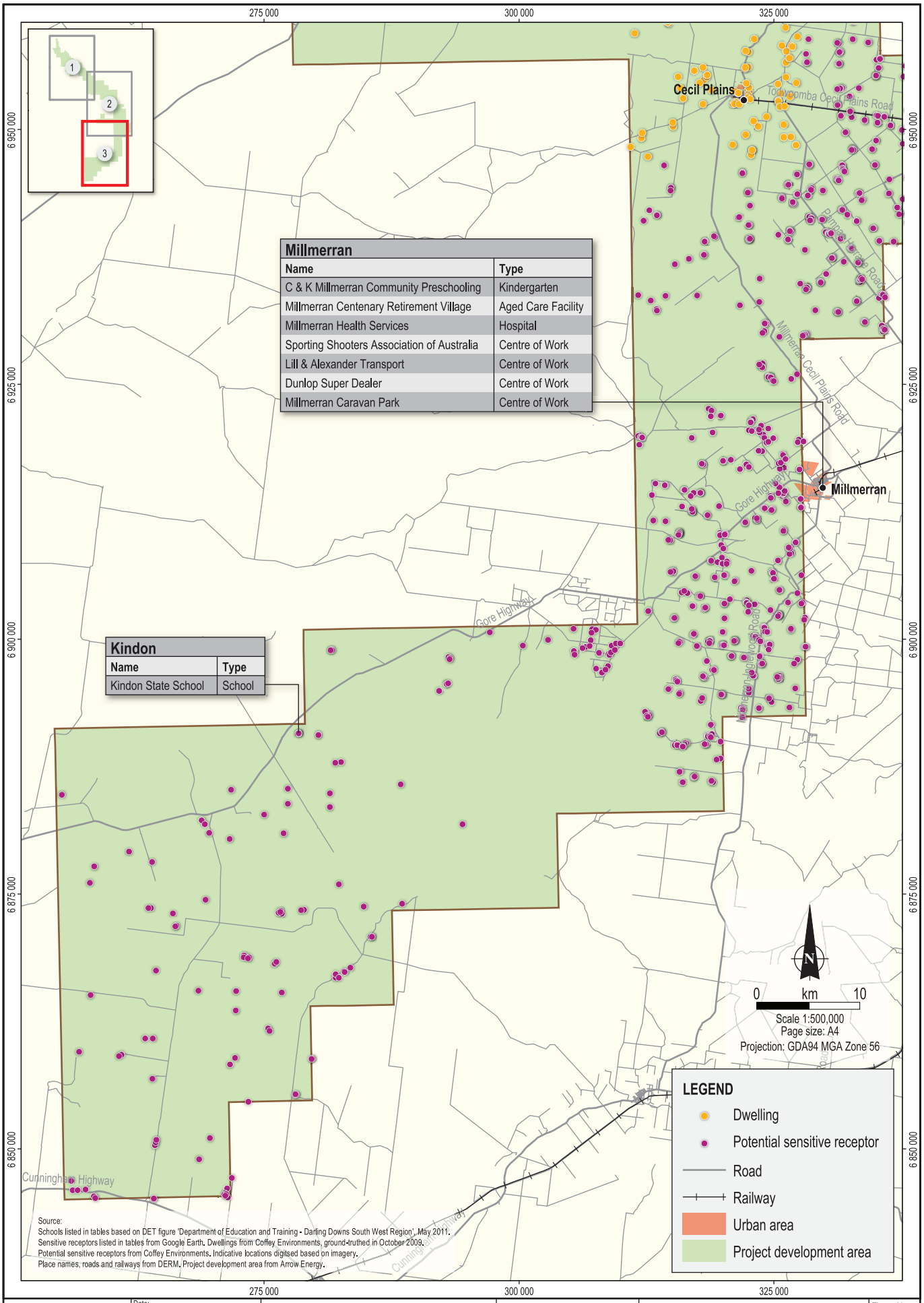
Arrow Energy

Surat Gas Project

arrow energy go further

Sensitive receptors (central project development area), Map 2 of 3

Figure No: 4.1b



coffey environments

Date: 01.12.2011
MXD: 7040AC_04_GIS201c_v1_2
File Name: 7040_04_ATT5_F04.01c_GIS_FT

Arrow Energy

Surat Gas Project

arrow energy go further

Sensitive receptors (southern project development area), Map 3 of 3

Figure No: 4.1c

As can be seen, the existing ground-level concentrations of key pollutants within the project development area are below the EPP (Air) objectives.

The environmental values to be enhanced or protected in and around the project development area in accordance with the EPP (Air) include:

- The qualities of the air environment that are conducive to protecting the health and biodiversity of ecosystems.
- The qualities of the air environment that are conducive to human health and wellbeing.
- The qualities of the air environment that are conducive to protecting the aesthetics of the environment, including the appearance of buildings, structures and other property.
- The qualities of the air environment that are conducive to protecting agricultural use of the environment.

4.1.2 Potential Impacts

Potential impacts to air quality from the project include fossil fuel combustion emissions (such as nitrogen dioxide), release of unburnt gas and generation of dust.

Key pollutants include those outlined in Table 4.1, as well as the following:

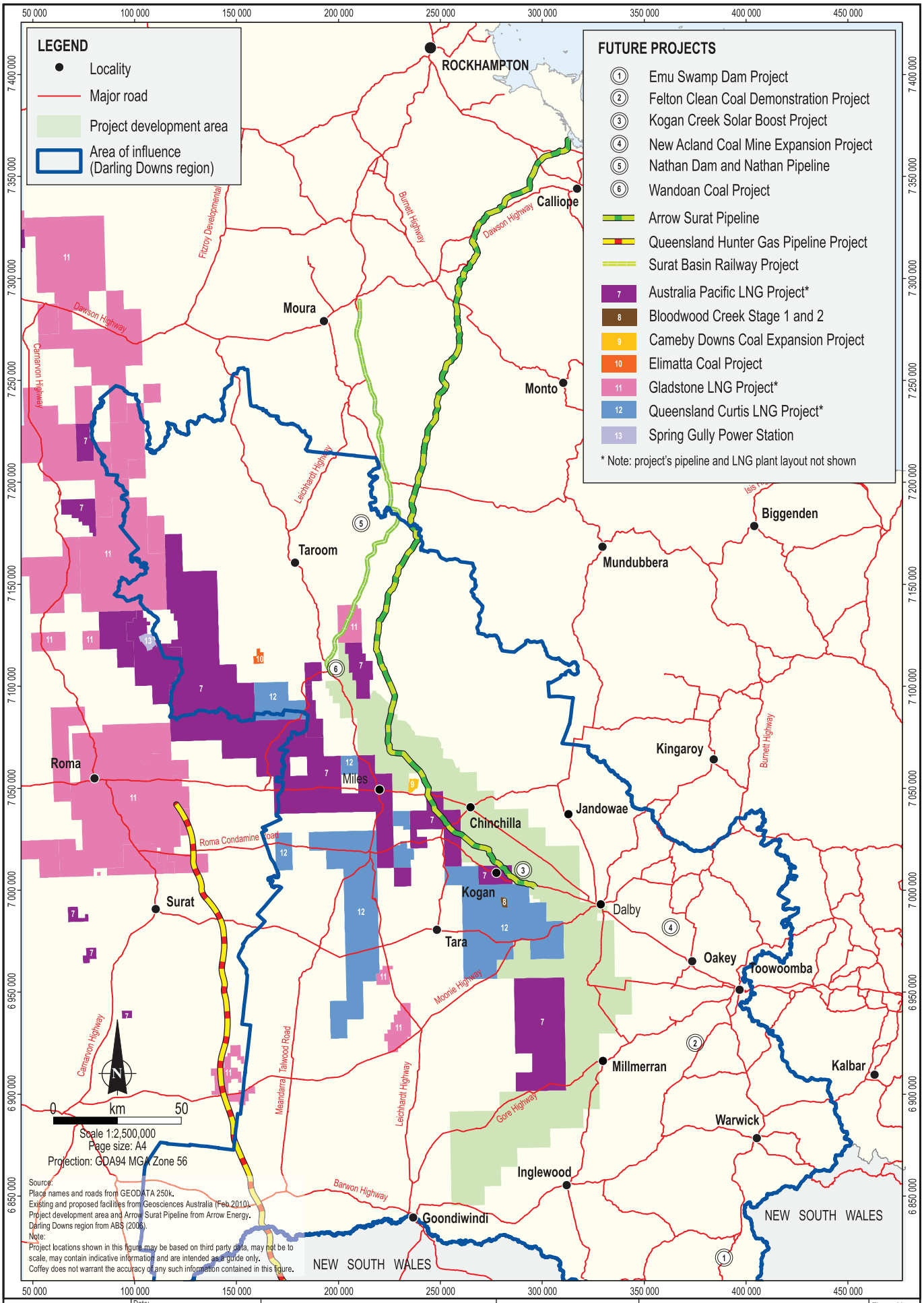
- Volatile organic compounds (VOCs) (however, note that coal seam gas contains negligible VOCs).
- Carbon dioxide (CO_2) and its role as a greenhouse gas.
- Hydrogen sulfide (H_2S) as a pollutant and odourant. Hydrogen sulfide is likely to only be present in trace amounts in the project's coal seam gas stream; and flaring and unplanned releases (venting) are expected to be infrequent, resulting in negligible hydrogen sulfide emissions from project activities.

The majority of emission sources associated with construction are transient and limited in duration, with the exception of ramp-up flaring prior to production facility commissioning. Operational emissions are ongoing sources, which have the greatest potential to cause impacts.

Potential Regional Impacts

Potential regional impacts on air quality were estimated using photochemical modelling. Pollutant levels were determined by consideration of existing and planned sources of contaminant emissions. Existing projects included in assessment of potential regional impacts on air quality are shown in Figure 4.2. Major projects underway or under construction included in assessment of potential regional impacts are shown in Figure 4.3.

The main substances of concern regionally are NO_2 and O_3, commonly used as indicators of photochemical smog. Other key air pollutants expected to contribute to the regional airshed are currently below relevant guidelines in the existing environment, and project activities are not expected to generate emissions that will lead to exceedences of relevant guidelines.



coffey environments	Date: 23.11.2011 MXD: 7040AC_04_GIS039_v1_2 File Name: 7040_04_ATT5_F04.02_GIS_GL	Arrow Energy Surat Gas Project	arrowenergy go further	Projects considered relevant for regional cumulative impact assessment Figure No: 4.2

coffey environments	Date: 04.11.2011 MXD: 7040AC_04_GIS074_v1_2 File Name: 7040_04_ATT5_F04.03_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Major projects underway or under construction in the Darling Downs Figure No: 4.3

A worst-case emission scenario was modelled including emissions from all 18 production facilities operating at once across the entire project development area. Modelled emissions contributed to a regional airshed scenario of existing and proposed emission sources. This scenario provides a worst-case scenario as it does not take into consideration the staging of development and it assumed that the number of wellhead engines operational was equal to the year of maximum operation (2020) with a total of 2,307 engines. Estimations were based on the assumption that facilities were operating at peak power capacity.

Estimation of emissions and modelling of air quality was carried out assuming the following stack parameters:

- Flaring stacks were assumed to have a 9.1-m height of release, 0.56-m stack diameter and exit temperature of 753 K.
- Production facility gas engine stacks were assumed to have a 7.0-m height of release, 0.64-m stack diameter, exit velocity of 28.4 m/s, gas volume flow rate of 0.207 Nm^3/s, exhaust volume flow rate of 9.0 m^3/s and exit temperature of 658 K.
- Wellhead gas engine stacks were assumed to have a 2.5-m height of release, 0.08-m stack diameter, exit velocity of 29 m/s, gas volume flow rate of 0.005 Nm^3/s, exhaust volume flow rate of 0.2 m^3/s and exit temperature of 922 K.

The maximum predicted concentrations of NO_2 and O_3 from the regional model are shown in Table 4.2, along with existing air quality concentrations and health-based EPP (Air) objectives.

Table 4.2 NO_2 and O_3 maximum concentrations and health-based objectives

Pollutant	EPP (Air) (µg/m³)	Averaging Time	Existing Value (µg/m³)	Worst-case Regional Modelled Scenario (µg/m³)
NO_2	250[a]	1 hr	22[b]	85[b]
	62	Annual	2.2	9
O_3	210[a]	1 hr	136[b]	160[b]
	160[a]	4 hr	123[b]	154[b]

[a] Value considers one-day exceedence allowable per annum as per EPP (Air).

[b] Second highest day modelled value.

The modelling demonstrates that the cumulative, worst-case scenario, whereby the Surat Gas Project exhibits peak air emissions and a number of proposed projects have commenced and also contribute to the regional airshed, is not predicted to cause exceedences of the ground-level EPP (Air) objectives for NO_2 and O_3 in the region.

Potential Localised Impacts

Localised impacts are those experienced relatively close to emission sources. Localised emissions of NO_2, VOCs and particulate matter were modelled using a dispersion model, assuming typical maximum emission rates and continuous power generation or flaring to provide a worst-case scenario.

Modelling of VOCs and particulate matter indicated that there were no significant impacts associated with these air pollutants and no concentrations in excess of the EPP (Air) objectives.

Modelling predicted that the maximum NO_2 concentrations associated with flaring would be well below the EPP (Air) objective of 250 $\mu g/m^3$.

Maximum predicted one-hour NO_2 concentrations close to field compression facilities and wellhead generators were below the EPP (Air) objective. With appropriate separation distances between sensitive receptors and the integrated processing and central gas processing facilities, maximum predicted one-hour NO_2 concentrations were also below the EPP (Air) objective.

Greenhouse Gas

Greenhouse gases included in the emissions inventory developed for the project are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2). Greenhouse gas emissions are categorised as follows:

- **Scope 1 Emissions.** Direct emissions (e.g., combustion of fuels in stationary sources, transport-related emissions, releases of gas from venting or flaring, fugitive emissions from equipment).
- **Scope 2 Emissions.** Indirect emissions (e.g., the procurement of electricity).
- **Scope 3 Emissions.** Emissions associated with fuel cycles (diesel and electricity consumption from the grid), the end-use of produced gas and third-party infrastructure required to export the gas.

Greenhouse gas emissions as CO_2 equivalents (CO_2-e) were estimated for each phase of the project, as shown in Table 4.3. The year shown for each project phase is the worst-case year, in other words, the year expected to generate the highest greenhouse gas emissions.

Table 4.3 Project greenhouse gas emissions by project phase and scope

Project Phase	Worst-case Year	Scope 1 (t CO_2-e/annum)	Scope 2 (t CO_2-e/annum)	Scope 3 (t CO_2-e/annum)	Total (t CO_2-e/annum)
Ramp-up period (2014 to 2019)	2019	2,361,663	216,467	18,413,406	20,991,536
Operational period (2020 to 2039)	2030	2,807,044	678,053	23,095,897	26,580,994
Ramp-down period (2040 to 2047)	2040	2,619,118	305,229	20,316,199	23,240,546

Project greenhouse gas emissions as CO_2 equivalents have been expressed as a percentage of global, Australian and Queensland greenhouse gas emissions. Emissions from the project associated with the worst-case scenario for each project phase were calculated as 0.012% of global, 0.85% of Australian and 1.92% of Queensland's 2007 emissions.

4.1.3 Air Quality Management

A management hierarchy of avoid, minimise and manage impacts was applied when assessing air quality management options.

The primary mitigation measure to avoid impacts to air quality will be the exploration of opportunities to maximise the distance of project development sites from the nearest sensitive receptors. Large separation distances are made possible due to the typically low population density within the project development area. Once locations are finalised, equipment selection and design during detailed engineering will include consideration of air quality objectives.

Table 4.4 outlines air quality mitigation and management measures for the project from planning and design through to decommissioning.

Table 4.4 Management measures for air quality across all project-related activities

Element or issue	• Decline in air quality through fuel combustion, fugitive emissions and dust generation from project activities. • Contribution to greenhouse gas emissions.
Environmental objectives	• To construct and operate in a manner that minimises impacts on ambient air quality. Ensure relevant air quality guidelines are met at sensitive receptors to maintain human and environmental health. • To minimise greenhouse gas emissions generated by project activities throughout the life of the project.
Performance criteria	• Compliance with project air quality objectives at sensitive receptors. • Compliance with relevant greenhouse gas programs. • Complaints are recorded, managed and responded to.
Implementation strategy for planning and design	• Conduct site-specific air quality modelling once site locations are known to ensure project-related air emissions meet EPP (Air) objectives at the nearest sensitive receptor. [C001] • Select equipment with consideration for low emissions to air (NOx, SOx), high energy efficiency and fuel efficiency. [C002] • Design facilities to meet relevant EPP (Air) objectives at sensitive receptors. [C003] • Minimise fuel consumption of vehicles by optimising transport logistics. [C004] • Select gaskets, seals and vehicle exhaust systems that are suitable for the task. [C005] • Arrow will develop a greenhouse gas management plan that will take into account both biodiversity and economic values of carbon. [C006] • Consider energy efficiency programs both locally and across the company that contribute to greenhouse gas emission reductions. [C007] • Arrow will participate actively in any government-approved emissions trading scheme. [C008] • Consider supporting gas industry initiatives that seek to improve technology or processes, such as contributions to or sponsorship of research and development. [C022] • Consider supporting through corporate community involvement programs the development of energy efficiency initiatives in the areas where Arrow operates. [C010]
Implementation strategy for construction, operations and decommissioning	• Ensure all engines, machinery equipment and pollution control mechanisms are operated and maintained in accordance with manufacturer's recommendations. [C011] • Implement dust suppression measures for roads and construction sites to ensure that dust does not cause a nuisance. [C012] • Cover dust-generating materials prior to transportation. [C013] • Consult with potentially affected landowners prior to undertaking activities. [C014] • Minimise the disturbance footprint and vegetation clearing. [C020]
Implementation strategy for construction	• Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Prevent venting and flaring of gas as far as practicable and where safe to do so. [C016] • Manage odours so that they do not cause a nuisance or harm to sensitive receptors. [C017]

Table 4.4 Management measures for air quality across all project-related activities (cont'd)

Implementation strategy for operations	• Prevent venting and flaring of gas as far as practicable and where safe to do so. [C016] • Manage odours so that they do not cause a nuisance or harm to sensitive receptors. [C017] • Optimise gas-engine operation to minimise duration of operation at low-efficiency levels that may result in increased emissions. [C018] • During the construction phase, minimise greenhouse gas emissions through selection of equipment and the commitment to clear areas progressively. Implement rehabilitation as soon as practicable following construction activities. [C021]
Implementation strategy for decommissioning	• Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • During the decommissioning phase, minimise greenhouse gas emissions by optimising transport logistics and minimising the footprint of disturbance. [C023]
Inspection and monitoring	• Monitoring and inspection of mitigation and management measures will be implemented to ensure that the calculated ground-level concentrations of relevant pollutants do not exceed EPP (Air) objectives throughout the lifetime of the project. [C511] • Assess the energy-efficiency opportunities and estimate greenhouse gas emissions associated with the project in accordance with regulatory requirements. Calculate annual greenhouse gas emission as required under the *National Greenhouse and Energy Reporting Act 2007* (Cwlth) (NGER Act) and Energy Efficiency Opportunities program, as well as future carbon price mechanisms. [C512]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	• Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan. • The method of measurement and reporting of air emissions will comply with the DERM Air Quality Sampling Manual. • Annual greenhouse gas emissions and energy consumption/production from the project will be reported as required under the NGER Act and Energy Efficiency Opportunities program, as well as future carbon price mechanisms.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

More detailed mitigation measures relating to dust control are included in Section 4.2, Geology, Landform and Soils, and Section 4.15, Roads and Transport.

4.2 Geology, Landform and Soils

This section describes Arrow's approach to managing potential environmental impacts on geology, landform and soils that are associated with project activities.

4.2.1 Existing Environment and Environmental Values

The geology of the project development area is relatively simple, with basement rocks overlain by deep sediments with volcanic intrusions. The project development area straddles the common boundary of the Surat and Clarence-Moreton basins, with the majority of the tenements in the

Surat Basin (see Figure 3.1). The geological formations of these basins are relatively continuous at their adjoining margins; however, given that the majority of Arrow's tenements and project development area are located within the Surat Basin, the project is referred to as the 'Surat Gas Project'. For simplicity, geological descriptions in this section apply to both basins but are only referred to as the Surat Basin. The Surat Basin is separated from the Clarence-Moreton Basin, which lies to the east, by the Kumbarilla Ridge anticline.

A deep blanket of clay-rich colluvium and alluvium covers a large portion of the project development area. Therefore, much of the stratigraphic sequence does not outcrop. However, some outcropping rock of the older sequences of the Kumbarilla Beds, comprising variably textured sedimentary formations, occurs along the Kumbarilla Ridge in the western and southwestern portions of the project development area.

The landscape of the project development area is strongly linked to the underlying geology and geomorphological evolution of the area and is characterised by three physiographic regions: the Great Dividing Range highlands, the Kumbarilla Ridge uplands and four drainage basins, Condamine-Culgoa Basin (Condamine River and Balonne River), Fitzroy Basin (Dawson River), Border Rivers Basin (Weir and Macintyre Rivers and Macintyre Brook) and Moonie Basin (Moonie River). The following landforms and geomorphological processes were identified within the project development area and contribute to the general features of the landscape:

- Upland features.
- Steep slopes.
- Gilgai.
- Gully erosion.
- Watercourses.

Seven broad soil types were identified in the project development area and are listed below in the order of most to least clay content:

- Gilgai clays.
- Cracking clays.
- Uniform non-cracking clays.
- Texture contrast soils.
- Uniform loams and clays.
- Sands and sandy loams.
- Skeletal, rocky or gravelly soils.

The project development area lies within the Darling Downs, an area of national agricultural importance. Clay soils, which have higher water-holding capacity and fertility, are considered to have a higher cropping potential than sands or shallow soils. Approximately 59% (501,000 ha) of the project development area has been identified as good-quality agricultural land (GQAL), class A or B. The areas of potential strategic cropping land are similar in extent to GQAL, covering 49% of the project development area.

Within the project development area, the following features are considered to be of national environmental significance:

- Lake Broadwater Conservation Park.
- Chinchilla Sands Local Fossil Fauna Site.
- Barakula State Forest Area and Scientific Areas.

The project development area was divided into six broad terrain units. Table 4.5 summarises the geological, landform and soils values relating to each existing terrain unit.

Table 4.5 Value of the existing environment: geology, landform and soils

Existing Environment	Characteristics Contributing to the Value
Terrain Unit I – Clay Alluvial Plains	• No geoheritage features. • GQAL and strategic cropping land. • Sodic, saline subsoils susceptible to water erosion. • Soft soils prone to waterlogging; susceptible to flooding near the Condamine River and its tributaries. • Soils generally high in fertility, well-structured, deep cracking clays, with areas of texture contrast soils. • Will be difficult to rehabilitate to predisturbance condition. Particular areas will be more challenging due to lower fertility and distinct soil profiles.
Terrain Unit II – Sandy Alluvial Plains	• Contains the Chinchilla Sands Local Fossil Fauna Site (subunit IIb). • GQAL and strategic cropping land close to rivers and creeks. • Sodic, saline subsoils susceptible to water erosion, except along some watercourses. Sandy soils susceptible to wind erosion. • Loose sandy soils or soft clays prone to waterlogging. • Low-fertility sandy soils with poor rehabilitation potential, or high-fertility, well-structured soils difficult to rehabilitate.
Terrain Unit III – Brigalow Plains and Uplands	• Contains the Barakula State Forest Area and Scientific Areas. • GQAL and strategic cropping land. • Sodic, saline subsoils susceptible to water erosion. Texture contrast soils moderately susceptible to wind erosion. • Soft soils prone to waterlogging. • Well-structured clay soils and gilgai deep cracking clays will be difficult to rehabilitate. Areas of lower fertility with distinct soil profiles will be difficult to rehabilitate.
Terrain Unit IV – Sandstone Ridge	• Contains Lake Broadwater and the Barakula State Forest. • Low-relief areas classified as Class C (pasture land). All other areas classified as Class D (non-agricultural land). • Sodic, saline soils susceptible or highly susceptible to water erosion, moderately susceptible to wind erosion and prone to waterlogging. • Steep slopes associated with jumpups, plateaux or mesa edges, and cuesta escarpments locally increase sensitivity. • Soil profile and moderate to low fertility reduces rehabilitation potential.
Terrain Unit V – Basaltic Uplands	• Aquifer recharge zone (potential for contamination). • Steep slopes. • Lower slopes can be suitable for building and can be classified as GQAL and strategic cropping land. • Shallow, gravelly, erodible soils with rocky outcrops. Some deeper soils on lower slopes that are susceptible to water and wind erosion. • Steep slopes associated with mesa edges. • Poor rehabilitation potential due to shallow, low-fertility soils. Some areas are fertile, with well-structured soils, which will be difficult to rehabilitate to predisturbance condition.
Terrain Unit VI – Granite Uplands	• Shallow soils with a high quartz-gravel or quartz-rock content and hardpan. • Rock outcrops. • Steep slopes associated with isolated steep hills. • Prone to waterlogging. • Poor rehabilitation potential due to shallow, low-fertility soils.

Land can become contaminated through a range of activities and land uses. The Queensland Government defines such activities as notifiable activities under the EP Act. Although many of the listed notifiable activities are 'industrial' in nature, a significant number may be reasonably expected in an environment where agricultural activities predominate. Accordingly, many notifiable activities will have been carried out somewhere within the project development area. Some affected land parcels may be listed on the Environmental Management Register and Contaminated Land Register administered by DERM, but others will not have been identified or reported. In addition to the specified notifiable activities, uncontrolled and otherwise unidentified activities may also have contributed to contamination of land within the project development area. Figures 4.4 and 4.5 present the contaminated land strategy for production facilities, dams and pipelines and for wells, gathering infrastructure and utilities respectively.

In the absence of detailed information on the actual extent of contaminated land, the precautionary principle is applied, whereby the overarching assumption that land on which Arrow may propose to conduct development activities could potentially be contaminated. The existing environment and values relating to contaminated land are summarised in Table 4.6.

Table 4.6 Values of the existing environment: contaminated land

Existing Environment (Areas Likely to be Associated with Value)	Values
National parks, conservation areas, etc.	Greenfield areas where there is a statutory limitation to development.
Areas with no or low levels of modification	Land that is free from notifiable activities, uncontrolled activities or other contaminating land practices (i.e., greenfield sites).
Existing slightly to moderately modified areas	Developed land that has potentially supported notifiable activities.
Existing highly modified or industrial areas	Sites already recorded on the Contaminated Land Register or the Environmental Management Register or where known notifiable activities have occurred.

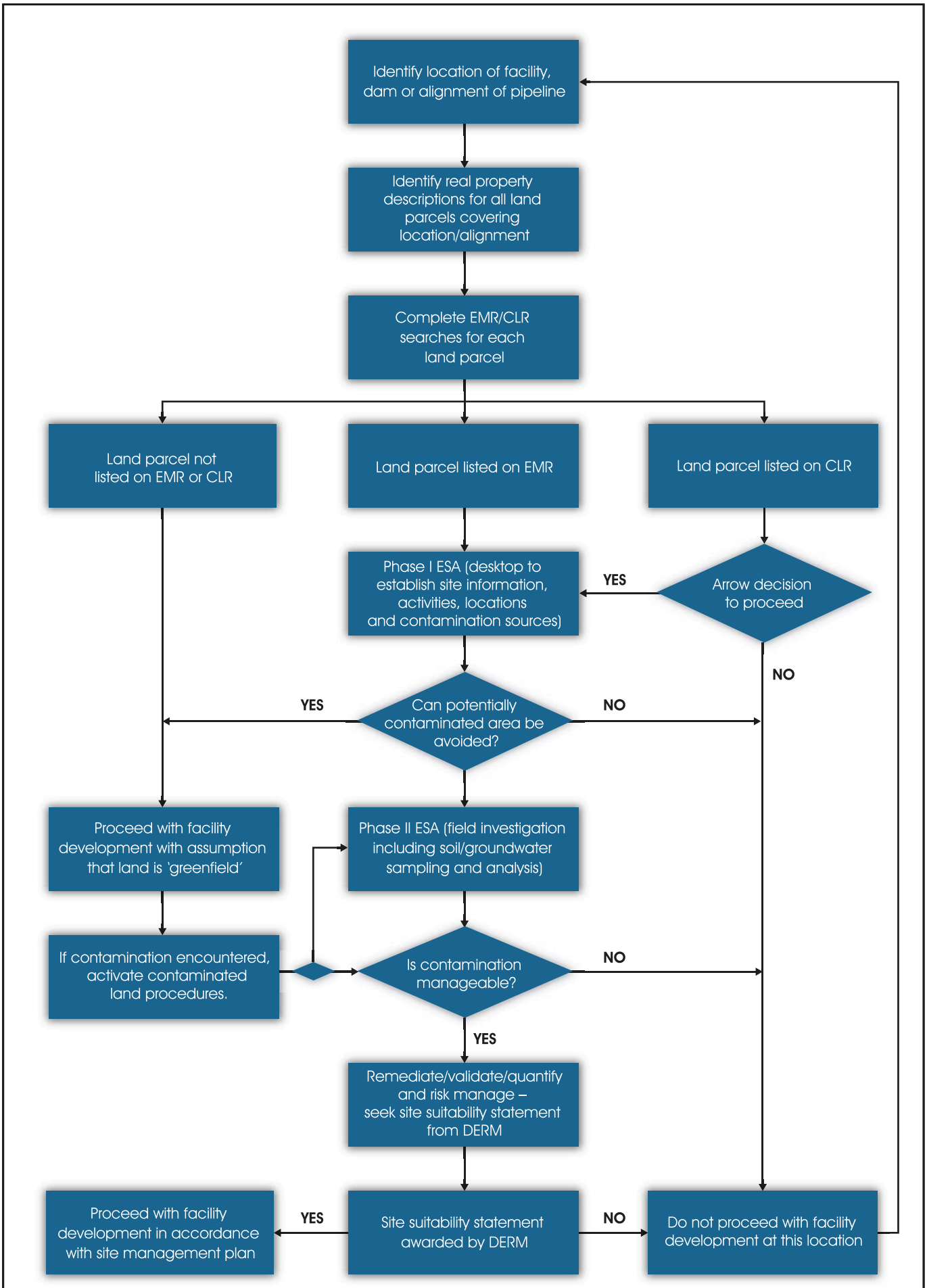
4.2.2 Potential Impacts

Potential impacts to geology, landform and soils values from project activities include:

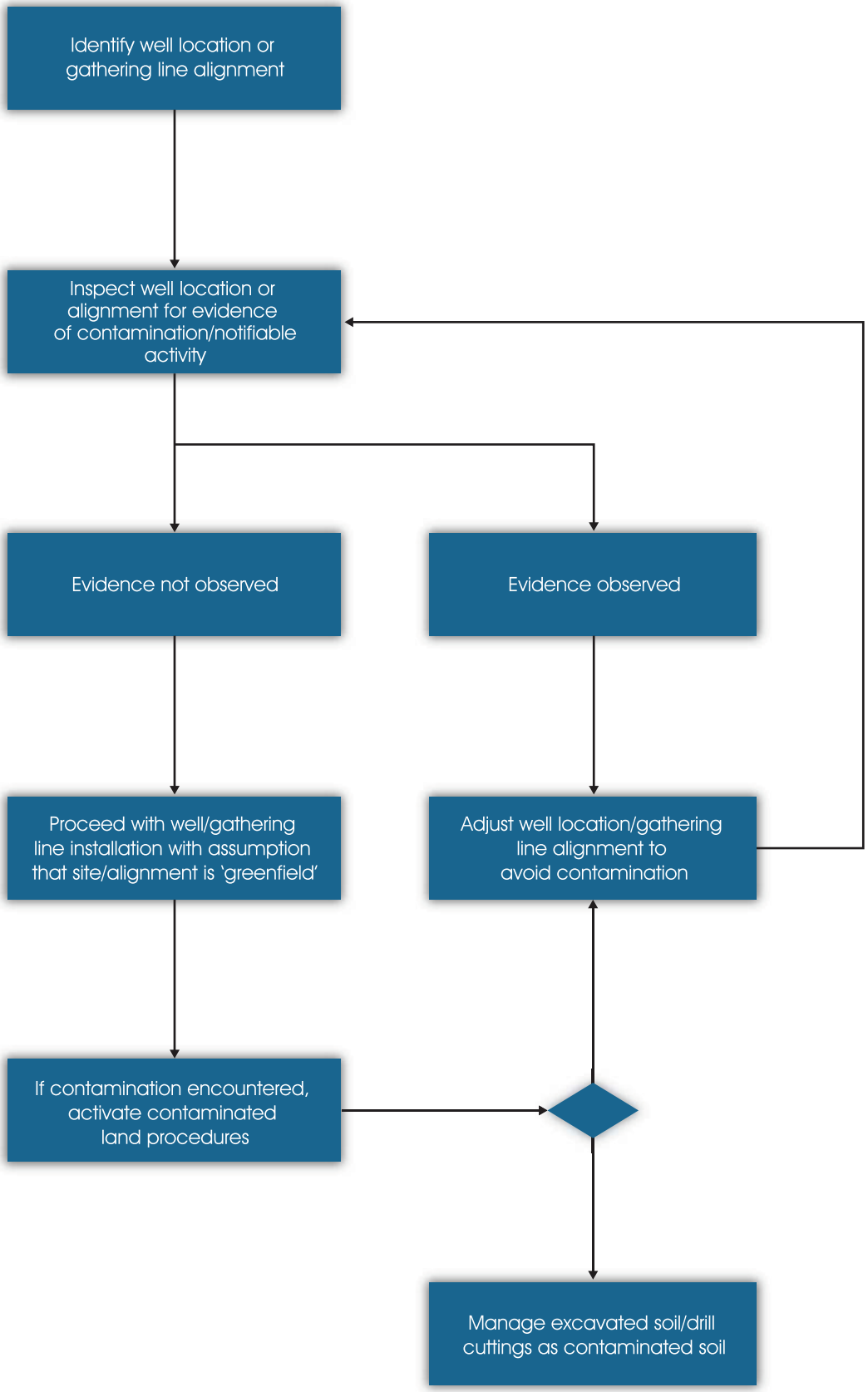
- Land degradation; erosion and associated sedimentation, dust generation and reduction in soil quality.
- Land contamination:
  - Disturbance of existing contaminated land.
  - Potential to cause land contamination through project activities.
- Disturbance or accidental damage of fossils.

Activities with the potential to cause these impacts during the construction phase of the project include:

- Increased erosion resulting from ground disturbance, vegetation clearance, alteration of natural drainage and flow concentration due to construction activities (i.e., excavation, trenching, drilling, earthmoving) during any activity which disturbs the ground (e.g., the construction of production wells, gathering lines, production facilities and associated infrastructure).



coffey environments	Job No: 7040 File Name: 7040_04_ATT5_F04.04_GL	Arrow Energy Surat Gas Project	arrow energy go further	Contaminated land strategy: production facilities, dams and pipelines	Figure No: 4.4



coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Contaminated land strategy: wells, gathering infrastructure and utilities	Figure No: 4.5
	File Name: 7040_04_ATT5_F04.05_GL	Surat Gas Project			

- Deposition downslope or downstream of eroded sediment as flow velocities decrease as an indirect result of project activities that cause erosion (e.g., construction of production wells, gathering lines, production facilities and associated infrastructure).
- Soil compaction potentially affecting long-term crop productivity from spoil placement or vehicular trafficking of access tracks and laydown areas.
- Topographic alteration from the construction of borrow pits for the use of rock in construction activities.
- Leaks or spills from fuel storage and handling leading to soil contamination.
- Outside the registered Chinchilla Sands Local Fossil Fauna Site, fossils being uncovered during site clearance activities or pipeline trenching in excavations that intersect the Chinchilla Sands formation (i.e., within terrain subunits Ia, Ic, IIIa and IVb).
- The siting of project infrastructure over contaminated land.
- Disturbance of contaminated soil during the drilling of coal seam gas wells.
- Disturbance of contaminated soil during excavation of trenches for the installation of gathering infrastructure, gas pipelines and other utilities associated with the development.
- Disturbance of contaminated soil during civil works associated with the construction of production facilities and dams.
- Uncontrolled movement of contaminated soil after disturbance by project activities.
- Transport to the surface of groundwater that has become contaminated through notifiable or uncontrolled activities (creating an exposure pathway that would otherwise not exist).
- Leaks and spills from or of:
  - Onsite fuel storage tanks.
  - Onsite chemical storage facilities.
  - Fuels and lubricants from the operation of earthmoving, drilling, and associated equipment.
  - Waste generated through the drilling of coal seam gas wells (e.g., waste drilling muds).

Activities with the potential to cause these impacts during the operations phase of the project include:

- Increased surface or subsurface erosion and waterlogging resulting from flow concentration due to differential settlement of pipeline backfill and padding.
- Leaks or spills from fuel storage and handling or overflow from brine dams leading to soil contamination.
- Transport to the surface of groundwater that has become contaminated through notifiable or uncontrolled activities (creating an exposure pathway that would otherwise not exist).
- Leaks and spills from or of:
  - Onsite fuel storage tanks.
  - Onsite chemical storage facilities.
  - Lubricants and chemicals from the operation of gas compression and associated equipment.

  - Chemicals from the operation of coal seam gas water treatment facilities.
  - Brine generated as a by-product of the treatment of coal seam gas water.

Activities with the potential to cause these impacts during the decommissioning phase of the project include:

- Reprofiling of microrelief leading to patchy exposure of sodic and saline subsoils from inversion of the soil profile during backfill of materials during rehabilitation.
- Imported materials for rehabilitation purposes, particularly in areas of GQAL, affecting agriculture production.

4.2.3 Geology, Landform and Soils Management

Arrow will generally avoid development in contaminated areas (i.e., areas of known existing soil contamination) to avoid environmental impacts and to minimise health and safety risks to workers. Management measures for geology, landform and soils across all project-related activities from planning and design through to decommissioning are found in Table 4.7.

Table 4.7 Management measures for geology, landform and soils across all project-related activities

Element or issue	• Land degradation – erosion and associated sedimentation, dust generation and reduction in soil quality. • Land contamination: – Disturbance of existing contaminated land. – Potential to cause land contamination through project activities. • Disturbance or accidental damage of recognised fossil sites.
Environmental objectives	• To maintain or restore soils and stabilise landforms to support the intended land use. • To minimise alteration of drainage systems (natural and man-made). • To protect the Chinchilla Sands Local Fossil Fauna Site. • To implement erosion and sediment control techniques to minimise project impacts.
	• To protect the Barakula State Forest Area and Scientific Areas and the Lake Broadwater Conservation Park. • To avoid or minimise the disturbance of contaminated land. • To avoid the contamination of land or watercourses as a result of project activities (from construction to decommissioning).
Performance criteria	• Soil structure and landform conducive to natural revegetation and intended land use. • No damage to the Chinchilla Sands Local Fossil Fauna Site. • No long-term adverse impacts to the Barakula State Forest Area and Scientific Areas and the Lake Broadwater Conservation Park. • Recovery or rehabilitation of all spilled contaminants. • Recovery or rehabilitation of existing contaminated land where land is required for the project.

Table 4.7 Management measures for geology, landform and soils across all project-related activities (cont'd)

Common implementation strategy for all phases	**Land Degradation** • Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. [C031] • Use existing roads and tracks, where practicable. [C032] • Confine project traffic to designated roads and access tracks, where practicable. [C033] • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034] **Land Contamination** • Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035] • Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. [C036] • Ensure appropriate spill response equipment, including containment and recovery equipment, is available on site. [C037] • Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities. [C038] • Assess contamination that may have occurred as a result of project activities in accordance with documented operating procedures. Appoint one or more suitably qualified and experienced contaminated land specialists. [C039] • Undertake an environmental site assessment in response to the identification of contamination that may have occurred as a result of project activities. [C040] • Complete excavation, remediation, characterisation and validation activities in response to the identification of contamination that may have occurred as a result of project activities. [C043] **Disturbance or Accidental Damage of Fossils** • Avoid the Chinchilla Sands Local Fossil Fauna Site and educate project personnel on the importance of the site. [C041]
Implementation strategy for planning and design	**Land Degradation** • Minimise the disturbance footprint and vegetation clearing. [C020] • Design infrastructure located in cracking clays to withstand the differential shrink-swell ground movement. [C042] • Incorporate construction methods and treatments to deal with reactive gilgai and cracking clays in infrastructure design. [C044] • Time construction works and access to sites to avoid wetter periods, where practicable. [C045] • Design and plan the project to avoid steep slopes and areas dissected by gully networks, where practicable. Where these are unavoidable, ensure the required infrastructure (e.g., roads) is appropriately designed for erosion control purposes. [C046] • Locate pipelines to avoid or minimise impact on irrigation flow or current farming practices. If the ROW must cross actively farmed arable land, ensure soil cover above the pipeline is deep enough to allow normal cultivation practices to resume. [C047]

Table 4.7 Management measures for geology, landform and soils across all project-related activities (cont'd)

Implementation strategy for planning and design (cont'd)	**Land Contamination** • Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities. [C019] • Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations (i.e., avoid land or the contaminated portion of a parcel of land that is listed on the Contaminated Land Register or the Environmental Management Register, where practicable). [C049] • Conduct physical investigations on selected parcels of land to influence facility siting decisions on a localised scale (i.e., target the portion of land that is not contaminated by understanding the extent of contamination). [C050]
Implementation strategy for construction	**Land Degradation** • Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034] • Reduce flow concentration and gully creation by minimising disruption to natural overland flow paths through the re-establishment of natural surface drainage lines. [C052] • Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses. [C053] • Do not disturb or remove flood banks and artificial levees except in consultation with parties benefitting from the structures and the relevant authorities. [C054] • Avoid disturbance of contour banks and irrigation bays. [C055] • Avoid mounding of soil along pipelines in irrigated paddocks, to the greatest extent practicable, allowing for settlement of backfill. [C056] • Conduct pipeline construction to minimise the duration of exposure of soils. [C057] • Avoid excessive watering of saline soils to reduce leaching of salts and rising groundwater. [C059] • Avoid excessive watering of surface-crusting soils to reduce crust formation. [C060] • Provide regular access points to pipeline construction ROWs to limit rutting and compaction of soils from vehicles travelling along the ROW. [C061] • Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles have a maximum height of 2 m, where the future use is intended for rehabilitation, and are protected from erosion. [C062] • Carry out ground investigations in soils prone to salinity prior to major earthworks to establish the depth at which saline conditions occur. [C063] • Stockpile cleared or mulched vegetation along the inside edge of the work sites (separate from soil stockpiles), to aid the control of runoff and ensure stockpiled vegetation does not pose a bushfire hazard. [C106] • Prevent subsurface water flows and erosion along the backfilled trench by appropriate means such as, trench blocks and compaction of backfilled soils. [C503]

Table 4.7 Management measures for geology, landform and soils across all project-related activities (cont'd)

Implementation strategy for construction (cont'd)	**Land Contamination** • Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works. [C064] • Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998). [C065]
Implementation strategy for operations	**Land Degradation** • Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. [C066] • Ensure coal seam gas water used on highly productive soils is of comparable water quality to that used for irrigation in the specific area. [C067] • Ensure the use of coal seam gas water meets beneficial-use licence conditions where it is to be used on GQAL or strategic cropping land or within heritage-listed or indicative sites. [C068] • Develop rehabilitation plans based on environmental sensitivities that address ground preparation requirements, natural and constructed drainage patterns, soil erodibility, contamination, slope steepness and length, rainfall frequency and intensity, potential flow magnitudes, vegetation cover, land use and landowner requirements. [C070] • Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled paddocks, this may not be practicable, and backfilling should be carried out in consultation with the landowner. [C071] • Remedy areas of differential settlement associated with buried infrastructure that interrupt the pre-existing surface water flow within intensively cultivated areas. [C072] • Excavate any saline material during rehabilitation of coal seam water dams or brine dams and select an appropriate option for management for the material (e.g., treat for reuse, or dispose of in a registered landfill). [C073] **Land Contamination** • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. [C069]
Inspection and Monitoring	• Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505] • Inspect pipeline ROWs routinely until ground stabilisation and natural revegetation or pasture grasses or crops are established. [C506] • Routinely monitor buffer zones and project footprint using satellite imagery. [C509] • Monitor soil salinity in salinity prone areas prior to major earthworks. [C514] • Provide chemical monitoring of contaminated soils and groundwater in relevant monitoring bores. [C515] • Routinely inspect spill containment controls and spill response kits.. [C516]

Table 4.7 Management measures for geology, landform and soils across all project-related activities (cont'd)

Inspection and Monitoring (cont'd)	• Visually inspect physical form downstream of watercourse discharge locations. [C517]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.3 Landscape and Visual Amenity

This section describes Arrow's approach to managing potential environmental impacts to landscape and visual amenity that are associated with project activities.

4.3.1 Existing Environment and Environmental Values

The existing environment contains a variety of landscapes, including broad, open, arable plains; elevated native forest; and wooded river valleys. The landscapes have been shaped by variations in geology, soils, landform, vegetation and the settlement and use by people.

Topography within the project development area varies subtly, with variations often linked to changes in the underlying geology and soils. This is most apparent where the soils change from Vertosols (largely flat topography) to Sodosols (smoothly undulating topography) or where the landscape is influenced by volcanic geology associated with the Bunya Mountains, becoming more undulating and hilly.

Ten landscape character types have been identified within the project development area on the basis of common landscape elements, attributes and values:

- Landscape Type A: Wooded River Valley.
- Landscape Type B: Settled Arable Plains.
- Landscape Type C: Sodic Transitional Pastures.
- Landscape Type D: Lowland Native Forest.
- Landscape Type E: Elevated Native Forest.
- Landscape Type F: Foothill Plains and Valleys.
- Landscape Type G: Lowland Brigalow Plains.
- Landscape Type H: Terraced Brigalow Farmland.
- Landscape Type I: Forested Steep Hills.
- Landscape Type J: Chromosol Undulating Lowlands.

The visual baseline is described in terms of views from selected representative viewpoints, which correspond to the location of residences, settlements, work places, recreational features, recognised vantage points, tourist trails and roads.

4.3.2 Potential Impacts

The primary construction activity that could impact landscape and visual amenity values is the construction of production wells, gathering lines, production facilities and associated infrastructure (e.g., construction camps, power lines). This activity will involve:

- Excavation, trenching, drilling, earthmoving, vegetation clearance or trimming, and temporary lighting that will disrupt landscape character, views and visual amenity.
- The presence of a workforce, construction camps and associated transport (e.g., large trucks, four-wheel-drive vehicles, graders, excavators and tractors).

The impact of the activity will vary depending on the nature of the construction activity (e.g., construction of a production well versus construction of a production facility), type of landscape and location of visual receptors.

During operations, the following project activities could impact upon landscape and visual amenity values:

- The presence and operation of production wells, gathering lines, power reticulation, production facilities and associated infrastructure that will disrupt landscape character, views and visual amenity.
- The presence of operation and maintenance crews, and associated transport.

The nature of the impact will largely be determined by the size of the infrastructure and the type of landscape.

Impacts upon landscape and visual amenity values during decommissioning include:

- Decommissioning, disassembly and removal of production wells, gathering lines, power reticulation, production facilities and associated infrastructure that will disrupt landscape character, views and visual amenity.
- The presence of a workforce and associated accommodation and transport (e.g., large trucks, four-wheel-drive vehicles, graders, excavators and tractors).

Waste generated in each project phase could also potentially impact landscape and visual amenity if not appropriately managed.

4.3.3 Landscape and Visual Amenity Management

The primary mitigation measure for landscape and visual amenity will be the exploration of opportunities to avoid visually sensitive locations and landscapes when siting facilities and to hide or screen the facilities using natural landscape features or planted native vegetation barriers where avoidance is not practicable.

Management measures for all project-related activities from planning and design through to decommissioning are listed in Table 4.8.

Table 4.8 Management measures for landscape and visual amenity across all project-related activities

Element or issue	• Changes in landscape character. • Diminished visual amenity.
Environmental and social objective	To reduce short-term and long-term visual impacts on sensitive receptors.
Performance criteria	Compliance with design specifications (which will aim to integrate facilities and associated infrastructure into the landscape setting).

Table 4.8 Management measures for landscape and visual amenity across all project-related activities (cont'd)

Implementation strategy for planning and design	• Adhere to the following mitigations specific to Landscape Type I: forested steep hills, Captains Mountain (comprising Captains Mountain, Commodore Peak and Mt Domville): – Avoid locating production facilities adjacent to and on Captains Mountain. – Avoid locating production wells and gathering systems on the forested steep slopes and ridges of Captains Mountain. – Avoid ROWs perpendicular to the slope when locating production wells and gathering systems adjacent to the forested steep hills of Captains Mountain. [C200] • Use shrouded, downcast lighting to minimise spill and restrict it to the minimum required for safety and security. Design lighting in accordance with AS 4282-1997, Control of the Obtrusive Effects of Outdoor Lighting (Standards Australia, 1997).[C262] • Co-locate facilities where practicable and design infrastructure layouts to minimise the footprint (taking into consideration the elements that contribute to landscape character) to reduce visibility of the facilities. [C263] • Site each production facility in the landscape of lowest sensitivity, where practicable, such as next to existing industrial developments or existing coal seam gas facilities. [C264] • Avoid visually sensitive locations and landscapes when siting facilities, where practicable. Seek backdrops when siting facilities to protect the skyline in distant views. Avoid siting facilities within view of sensitive viewpoints, particularly the bird hide and camping area at Lake Broadwater, Captains Mountain, the view from Jimbour House, expansive views from the Cunningham Highway, towns, schools and private residences. [C265] • When siting production facilities, maintain the maximum distance practicable from, and minimise visual disturbance to, the most sensitive visual receptors. Seek to maintain at least 500 m separation from sensitive viewpoints, particularly tourist trails, roads, residences and built-up areas. [C266] • Hide or screen production facilities using natural landscape features or planted native vegetation barriers, where appropriate. Avoid removal of mature trees and other woodland features that screen views to facilities. Establish screening barriers using endemic species in advance of construction of the facilities. [C267] • Integrate facilities into the landscape setting where screening is not practical, considering building and structure colour, texture and lines. Use matt and low-glare finishes two shades darker than the prevalent shading of the site, having regard to sun angles throughout the day and year and to the harvesting of crops, where practicable. Consider camouflage paints or finishes in highly sensitive landscapes. [C268] • Consult with potentially impacted visual receptors (landowners and neighbours) in locating facilities. Seek to reduce the form and shape of facilities visible by landowners and residents. [C269] • Conduct planned maintenance flaring during daylight hours to minimise light spill, where practicable. [C270] • Where it is not practicable to screen or integrate a facility into the landscape, consider designing the facility to be a feature in the landscape, taking into consideration the form, texture and arrangement of buildings and structures. [C271]

Table 4.8 Management measures for landscape and visual amenity across all project-related activities (cont'd)

Implementation strategy for planning and design (cont'd)	• When clearing vegetation, seek to avoid creating gaps in stands or patches and to avoid isolating parcels of remnant vegetation from more continuous tracts. [C272] • Minimise the disturbance footprint and vegetation clearing. [C020]
Implementation strategy for construction	• Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. [C031] • Use existing roads and tracks, where practicable [C032] • Where practicable, plan the movement of equipment and materials during times of least visual impact (i.e., work day start and end). [C273] • Where feasible, target dry weather periods when undertaking construction in sensitive landscape areas (e.g., waterway crossings) to minimise visual impacts due to sedimentation and erosion. [C274] • Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Locate topsoil and spoil mounds in visually unobtrusive locations, where practicable. [C275] • Incorporate excess spoil from site excavations into bunding at the base of a planted vegetation screening barrier to increase the overall height of the barrier. [C276] • Utilise landscape features and contours, where practicable, to integrate linear infrastructure (access tracks, gathering lines) into the landscape. [C277] • Minimise the length and width of roads and tracks. [C278] • Avoid roads traversing highly visible hills. [C279] • Minimise construction time near sensitive visual receptors. [C280] • Develop and implement waste management procedures in accordance with the Queensland Environmental Protection (Waste Management) Policy 2000. [C281]
Implementation strategy for operations	• Implement dust suppression measures for roads and construction sites to ensure that dust does not cause a nuisance. [C012] • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034] • Maintain visual amenity controls used to reduce landscape and visual impacts. Replace lost trees or shrubs in screening barriers to ensure they establish and maintain an effective barrier. [C282]
Implementation strategy for decommissioning	Remove surface infrastructure and reinstate disturbed areas as soon as practicable to predisturbance landscape characteristics or consult with landowners regarding reinstatement objectives. [C283]
Inspection and monitoring	Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.4 Terrestrial Ecology

This section describes Arrow's approach to managing potential environmental impacts to terrestrial ecology that are associated with project activities.

4.4.1 Existing Environment and Environmental Values

Queensland is divided into 13 bioregions based on broad landscape patterns that reflect the major underlying geology, climate patterns and ecology. The project development area lies within the Brigalow Belt South bioregion.

The Brigalow Belt South bioregion is a major pastoral and agricultural area with much of the natural vegetation heavily cleared as a result of land development. The resulting landscape is one of isolated patches of remnant, disturbed and regrowth vegetation, which varies in size, shape and isolation. This is evident in the network of linear vegetation (both remnant and regrowth) along road verges and fence lines and by the few larger stands of vegetation containing unbroken habitat preserved in areas that are either unsuitable for agriculture or that have been preserved through alternative uses.

Vegetation communities in Queensland are categorised into regional ecosystems (REs) to enable consistent mapping for ecosystem assessment, biodiversity planning and conservation management at regional scales. There are 35 regional ecosystems mapped within the project development area. Using the vegetation management class under the *Vegetation Management Act 1999* (QLD), there are 9 'endangered', 7 'of concern' and 19 'least concern' regional ecosystems (Figures 4.6a, 4.6b and 4.6c). Using the biodiversity status, there are 11 regional ecosystems listed as 'endangered and 7 listed as 'of concern', while 17 are identified as being of 'no concern at present'.

Flora Threatened Communities

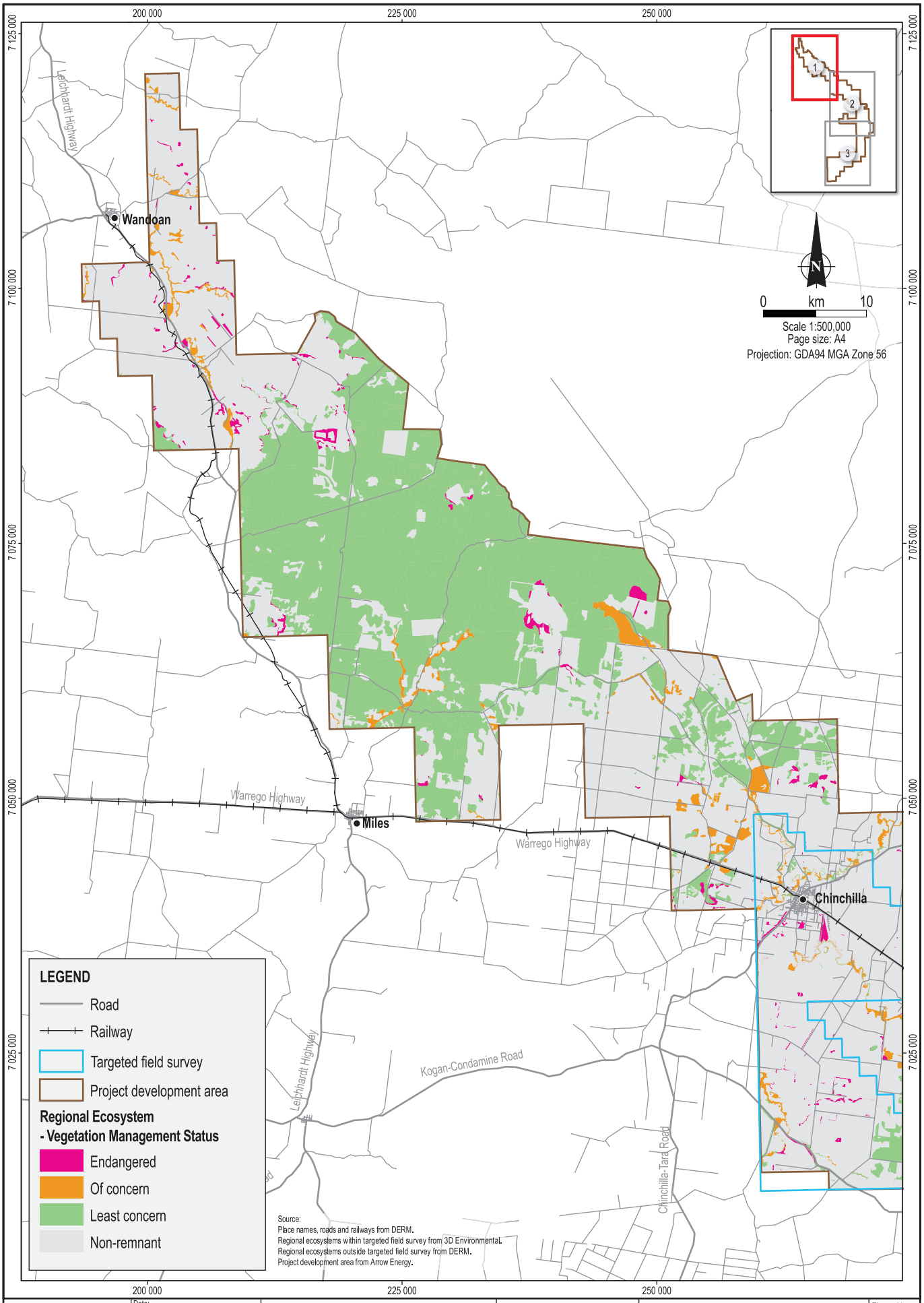
Nationally threatened vegetation communities are identified under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) as 'critically endangered', 'endangered' and 'vulnerable' relative to their risk of extinction in the immediate future, as determined in accordance with the prescribed criteria.

Two nationally significant, threatened ecological communities were identified within the project development area during the field surveys and an additional four communities are considered as 'possible' or 'likely' occurrences:

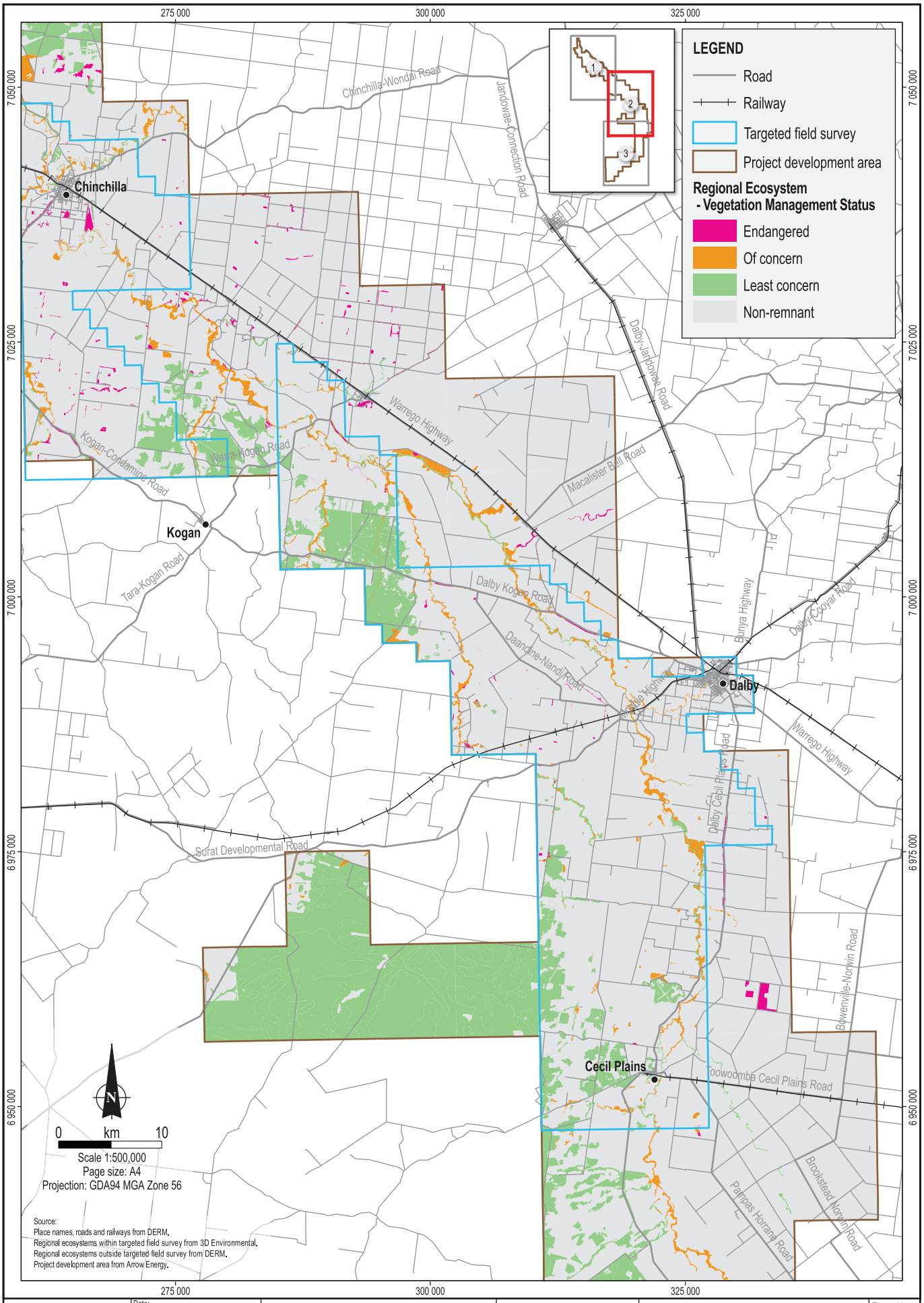
- Brigalow (*Acacia harpophylla* dominant and co-dominant) ('endangered'): field observations and regional ecosystem mapping suggest that *A. harpophylla* dominant and co-dominant communities are a common, although highly fragmented, ecosystem. These communities were recorded throughout the project development area as REs 11.3.1, 11.4.3, 11.4.10, 11.9.5 and 11.9.6 and also as advanced brigalow regrowth communities.
- Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland ('critically endangered'): these communities were identified during field surveys as narrow strips in road verges and stock routes. Represented as REs 11.3.21 and 11.3.24, this community occupies 990 ha within the project development area.
- Semi-evergreen vine thickets of the Brigalow Belt (North and South) and Nandewar bioregions ('endangered'): field surveys did not identify this community; however, vegetation mapping shows this community as occurring over 31 ha of the project development area. Occurrences

within the project development area were limited to severely degraded, small (less than 1.7 ha), isolated remnants within REs 11.9.4a and 11.8.3.

- Weeping Myall Woodlands ('endangered'): this community is often associated with RE11.3.2 which occurs extensively through the project development area. Field surveys did not locate any examples of this community, although scattered weeping myall trees were observed to be associated with RE 11.4.12 and is therefore considered possible.
- White Box – Yellow Box – Blakely's Red Gum grassy woodland and derived native grassland ('critically endangered'): this community was not identified during field surveys, however, it possibly exists within the project development area within RE 11.8.2a, in the Captains Mountain area approximately 9 to 10 km southwest of Millmerran.
- Coolibah – Black Box Woodlands of the Darling Riverine Plains and Brigalow Belt South Bioregions ('endangered'): this community is represented as RE 11.3.3 and is likely to be found in areas north of Chinchilla around the Charleys Creek floodplain and other tributaries of the Condamine River. Although not identified in field surveys, this community is likely to occur as a subdominant community in association with RE 11.3.25 and RE 11.3.4.



coffey environments	Date: 07.12.2011 MXD: 7040AC_04_GIS205a_v1_3 File Name: 7040_04_ATT5_F04.06a_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Regional ecosystems (northern project development area), Map 1 of 3	Figure No: 4.6a



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Surat Gas Project

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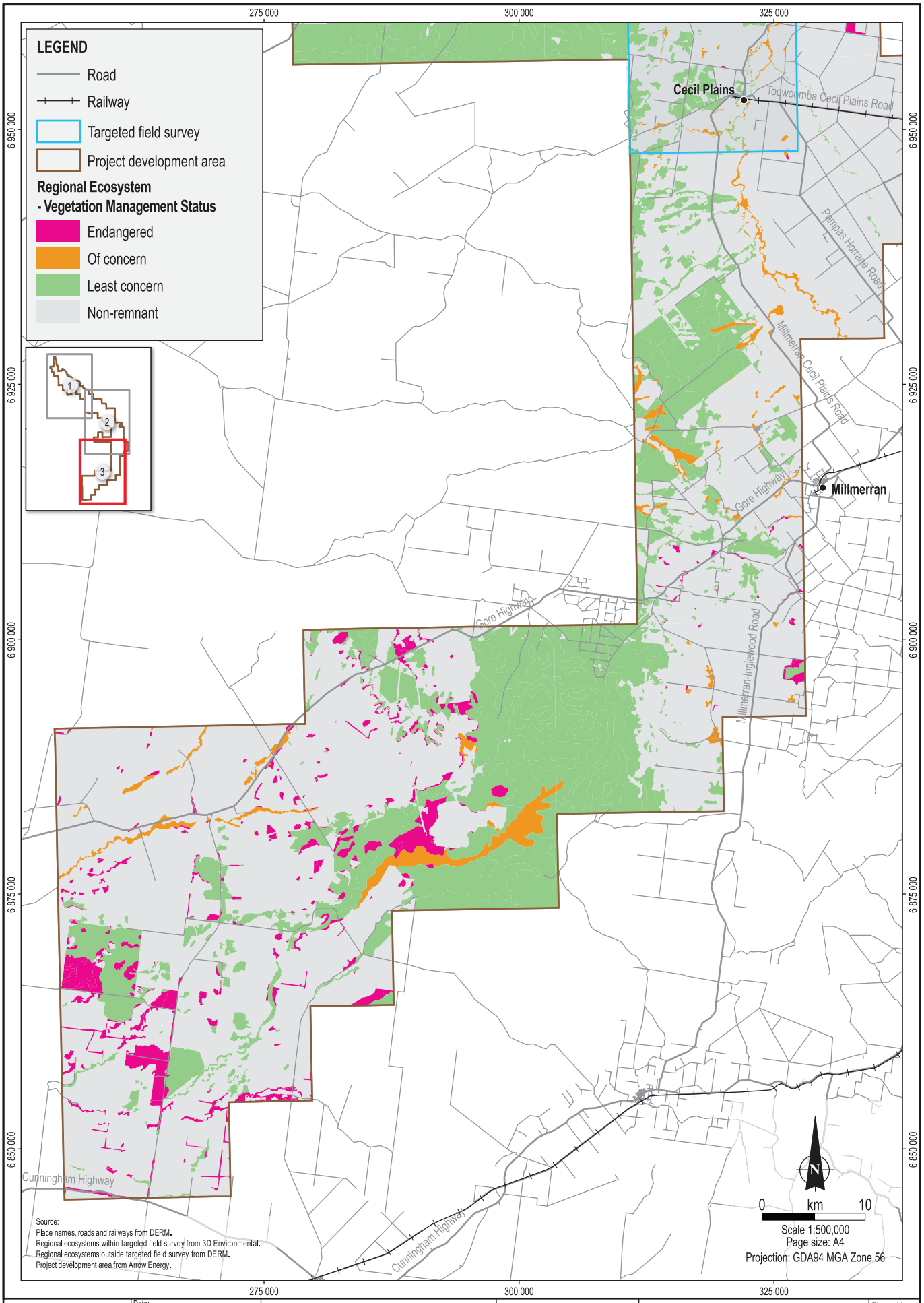
Regional ecosystems (central project development area), Map 2 of 3

Figure No: 4.6b



coffey environments	Date: 07.12.2011 MXD: 7040AC_04_GIS205c_v1_3 File Name: 7040_04_ATT5_F04.06c_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Regional ecosystems (southern project development area), Map 3 of 3	Figure No: 4.6c

Flora Species

Nationally significant species are listed under the EPBC Act as 'extinct', 'extinct in the wild', 'critically endangered', 'endangered', 'vulnerable' or 'conservation dependent'. State significant flora species are listed under the *Nature Conservation Act 1992* (Qld) as 'extinct in the wild', 'endangered', 'vulnerable', or 'near-threatened'.

The flora of the project development area is highly diverse with a total of 1,390 flora species. The flora identified represents approximately 14% of Queensland's known flora species. Flora species of particular importance include:

- State and nationally listed species (37 in total) that are either known to occur (six species verified) or are likely to occur within the project development area (Table 4.9). Species for which spatial records are available are shown in Figure 4.7.
- Regionally significant (non-listed) species (eight in total).
- Pest flora species (218 species, or 16% of total flora identified within the project development area), with most of lower pervasiveness and minimal concern.

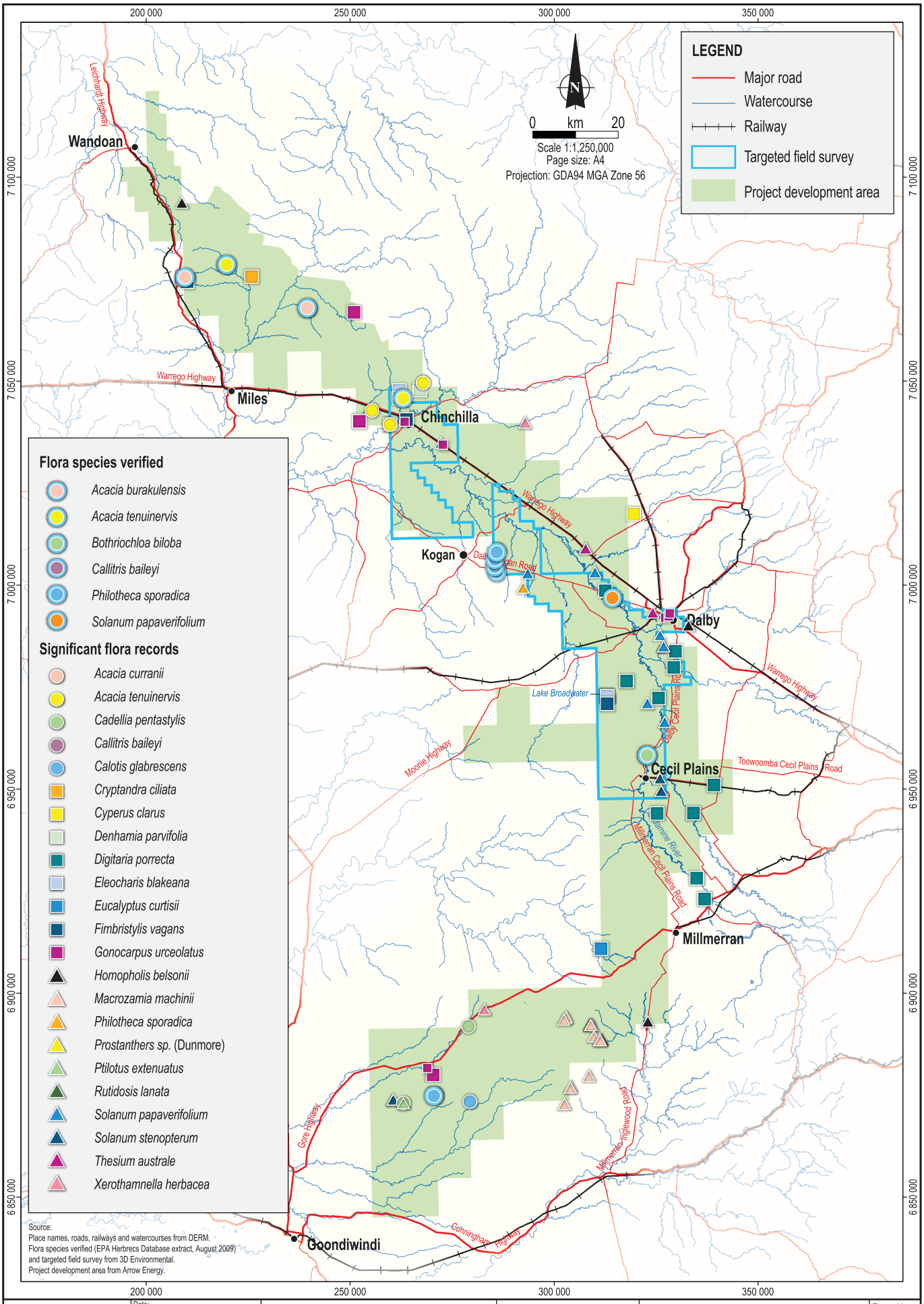
The occurrence and distribution of exotic (non-native) flora species varies throughout the bioregion. Twenty declared pest weed species under the *Land Protection (Pest and Stock Route Management) Act 2002* (Qld) are known to occur within the project development area. An additional three species not previously recorded were identified as posing a high risk of proliferation.

Specifies identified as being of primary concern within the project development area include:

- Lippia (*Phyla canescens*).
- African lovegrass (*Eragrostis curvula*).
- Parthenium (*Parthenium hysterophorus*).
- Mesquite (*Prosopis glandulosa* var. *glandulos, Propospis velutina*).

Table 4.9 Listed flora species identified in the project development area

Status	Known	Likely
EPBC Act (Cwlth)		
Endangered	• *Digitaria porrecta*	• *Microcarpaea agonis*
Vulnerable	• *Acacia curranii* • *Bothriochloa biloba* • *Macrozamia machinii* • *Denhamia parviflora* • *Homophilis belsonii* • *Philotheca sporadica* • *Prostanthera* sp.(*Dunmore)* • *Pterostylis cobarensis* • *Thesium australe* • *Xerothamnella herbacea*	• *Picris evae* • *Acacia handonis* • *Acacia wardellii* • *Cadellia pentastylis* • *Calytrix gurulmundensis* • *Rhaponticum australe*
Nature Conservation Act (QLD)		
Endangered	• *Aristida forsteri* • *Homopholis belsonii* • *Pomaderris coomingalensis* • *Rutidosus lanata* • *Solanum papervifolium* • *Xerothamnella herbacea*	• *Ptilotus extenuatus* • *Microcarpaea agonis* • *Micromyrtus carinata*
Vulnerable	• *Acacia barakulensis* • *Acacia curranii* • *Cyperus clarus* • *Denhamia parviflora* • *Gonocarpus urceolatus* • *Macrozamia machinii* • *Philotheca sporadica* • *Picris barabrorum* • *Prostanthera* sp.(*Dunmore)* • *Solanum stenopterum* • *Thesium australe*	• *Picris evae* • *Acacia handonis* • *Acacia wardellii* • *Apatophyllum teretifolium* • *Calytrix gurulmundensis* • *Rhaponticum australe*
Near threatened	• *Acacia tenuinervis* • *Callitris baileyi* • *Cryptandra ciliata* • *Digitaria porrecta* • *Eleocharis blakeana* • *Eucalyptus curtisii* • *Fimbristylis vagans*	• *Calotis glabrescens*



coffey environments	Date: 12.12.2011 MXD: 7040AC_04_GIS176_v1_7 File Name: 7040_04_ATT5_F04.07_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Listed flora species identified in the project development area	Figure No: 4.7

Terrestrial Fauna

Fauna identified within the project development area comprised 497 terrestrial vertebrate species (29 frogs, 97 reptiles, 308 birds and 63 mammals) and 63 terrestrial invertebrate species (49 butterfly and 14 dragonfly species).

The desktop study identified 27 state and nationally listed fauna species as known or likely to occur within the project development area, comprising 2 butterflies, 1 amphibian, 9 reptiles, 12 birds and 3 mammals (Table 4.10). Species for which spatial records are available are shown in Figure 4.8.

Table 4.10 Listed fauna species identified in the project development area

Group	Scientific Name	Common Name	EPBC Status	NC Act Status
Insects	*Hypochrysops piceatus*	Bulloak jewel butterfly	-	E
	Jalmenus eubulus	Pale imperial hairstreak	-	V
Amphibians	*Cyclorana verrucosa*	Rough collared frog	-	NT
Reptiles	*Strophurus taenicauda*	Golden-tailed gecko	-	NT
	Delma torquata	Collared delma	V	V
	Paradelma orientalis	Brigalow scaly-foot	V	V
	Anomalopus mackayi	Five-clawed worm-skink	V	E
	Egernia rugosa	Yakka skink	V	V
	*Tympanocryptis cf. tetraporophora**	Grassland earless dragon	E	E
	Acanthophis antarcticus	Common death adder	-	NT
	Furina dunmalli	Dunmall's snake	V	V
	Hemiaspis damelii	Grey snake	-	E
Birds	*Accipiter novaehollandiae*	Grey goshawk	-	NT
	Lophoictinia isura	Square-tailed kite	-	NT
	Nettapus coromandelianus	Cotton pygmy-goose	-	NT
	Stictonetta naevosa	Freckled duck	-	NT
	Calyptorhynchus lathami	Glossy black-cockatoo	-	V

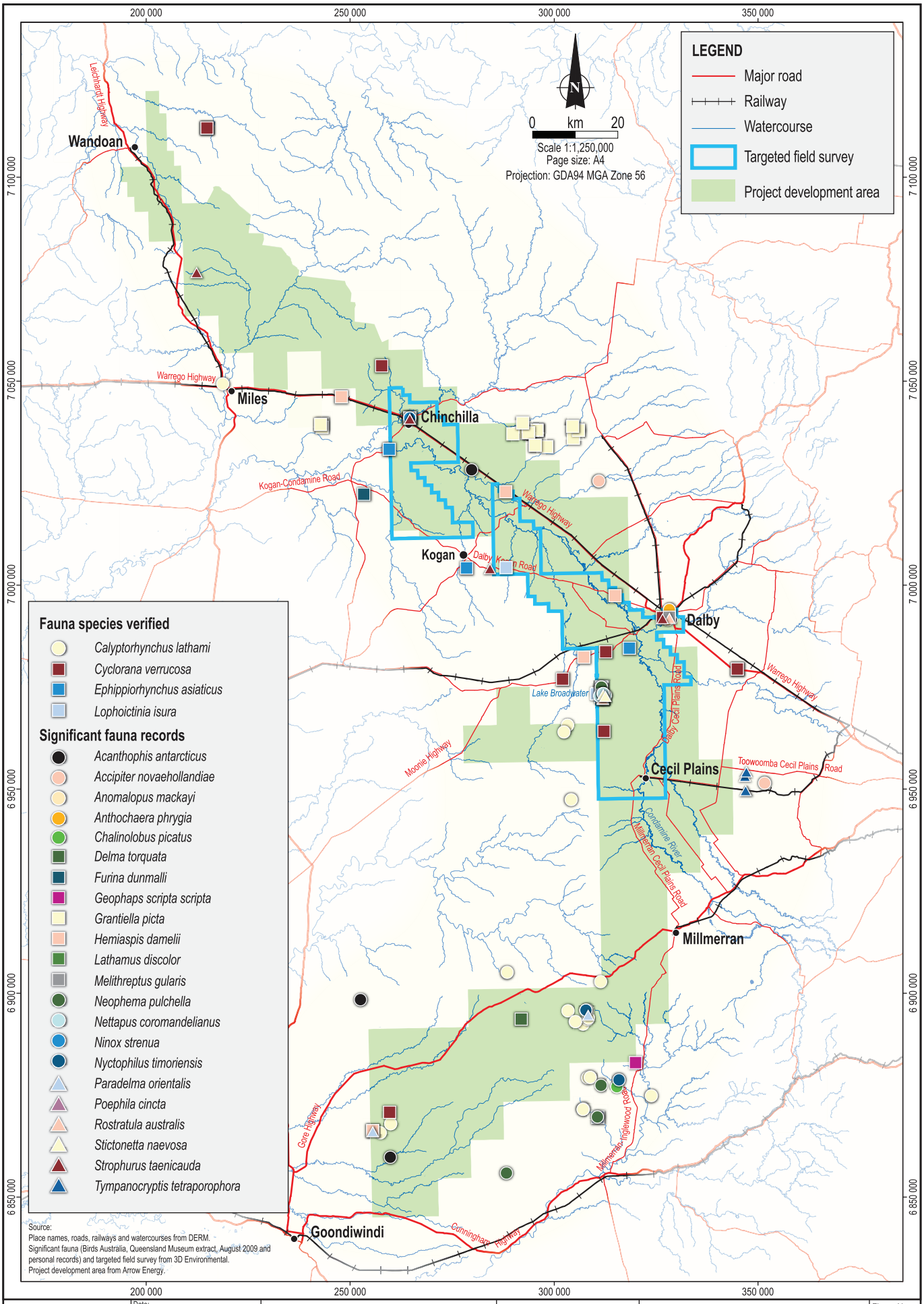
Table 4.10 Listed fauna species identified in the project development area (cont'd)

Group	Scientific Name	Common Name	EPBC Status	NC Act Status
Birds (cont'd)	*Ephippiorhynchus asiaticus*	Black-necked stork	-	NT
	Geophaps scripta scripta	Squatter pigeon (southern)	V	V
	Anthochaera phrygia	Regent honeyeater	E	E
	Grantiella picta	Painted honeyeater	-	NT
	Melithreptus gularis	Black-chinned honeyeater	-	NT
	Neophema pulchella	Turquoise parrot	-	NT
	Rostratula australis	Australian painted snipe	V	V
Mammals	*Dasyurus maculatus maculatus*	Spotted-tailed quoll	V	V
	Chalinolobus picatus	Little pied bat	-	NT
	Nyctophilus corbeni§	South-eastern long-eared bat	V	V

Notes: E = 'Endangered', V = 'Vulnerable', NT = 'Near-threatened', - = none.

* Based on genetic studies the grassland earless dragon (*Tympanocryptis pinguicolla)* (EPBC listed, no Vegetation Management Act listing) does not occur in Queensland and the earless dragon species located within the project development area is more closely related to the Darling Downs earless dragon (*Tympanocryptis* cf. *tetraporophora)*. *Tympanocryptis* cf. *tetraporophora* is recognised as endangered under Queensland legislation as a new species, however this change has not been formally recognised for *Tympanocryptis* cf. *tetraporophora* and is currently not identified under the EPBC Act. The possibility of occurrence of either variant (to be referred to as the grassland earless dragon (*Tympanocryptis* cf. *tetraporophora*)) has been retained for assessment purposes.

§ Other names = *Nyctophilus timoriensis.*



Source:
Place names, roads, railways and watercourses from DERM.
Significant fauna (Birds Australia, Queensland Museum extract, August 2009 and personal records) and targeted field survey from 3D Environmental.
Project development area from Arrow Energy.

coffey environments	Date: 13.12.2011 MXD: 7040AC_04_GIS177_v1_8 File Name: 7040_04_ATT5_F04.08_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Listed fauna species identified in the project development area	Figure No: 4.8

A total of 29 EPBC Act–listed migratory fauna species were identified as potentially occurring in the project development area and six of these were verified during field surveys. Of the species verified, one migratory marine, one migratory wetland and four migratory terrestrial species were recorded. Nearly half of the migratory species with potential to occur within the project development area are wader species, typical of estuarine habitats. These species may occur at Lake Broadwater and other permanent and semi-permanent watercourses, which are likely to provide suitable habitat for threatened migratory species.

A number of species identified in database searches were removed from the assessment as they were considered highly mobile (transient visitation) species with little relevance in the project development area or were identified as being unlikely to occur in the project development area due to low-precision records and lack of suitable habitats.

In addition to species listed under state and national legislations, 47 non-listed species of bioregional significance (e.g., scientific value or of cultural significance) were identified (e.g., koala).

Pest fauna species are listed in the Land Protection (Pest and Stock Route Management) Act. Class 2 species are species which have or may have a substantial negative economic, environmental or social impact. Seven Class 2 declared pest species were identified within the project development area, namely wild dog (*Canis familiaris*), European red fox (*Vulpes vulpes*), feral cat (*Felis catus*), feral deer (*Cevus* spp.), feral goat (*Capra hircus*), European rabbit (*Oryctolagus cuniculus*) and feral pig (*Sus scrofa*). The European rabbit does not pose a threat (as described by its Class 2 classification) within the area due to unfavourable ecological conditions. These other six species have increased potential to proliferate and affect native fauna values within the project development area. The cane toad (*Rhinella marina*- no classification given) is also considered to have a substantial risk of proliferation and impact.

Environmentally Sensitive Areas

Queensland's Environmental Protection Regulation 2008 provides a mechanism to enforce the EP Act and allows for an assessment of the risk that an environmentally relevant activity poses to environmentally sensitive areas (ESAs). The classification of Category A, B and C ESAs is based on a ranking of environmental sensitivity.

Category A, B and C ESAs identified within the project development area are shown in Figure 4.9.

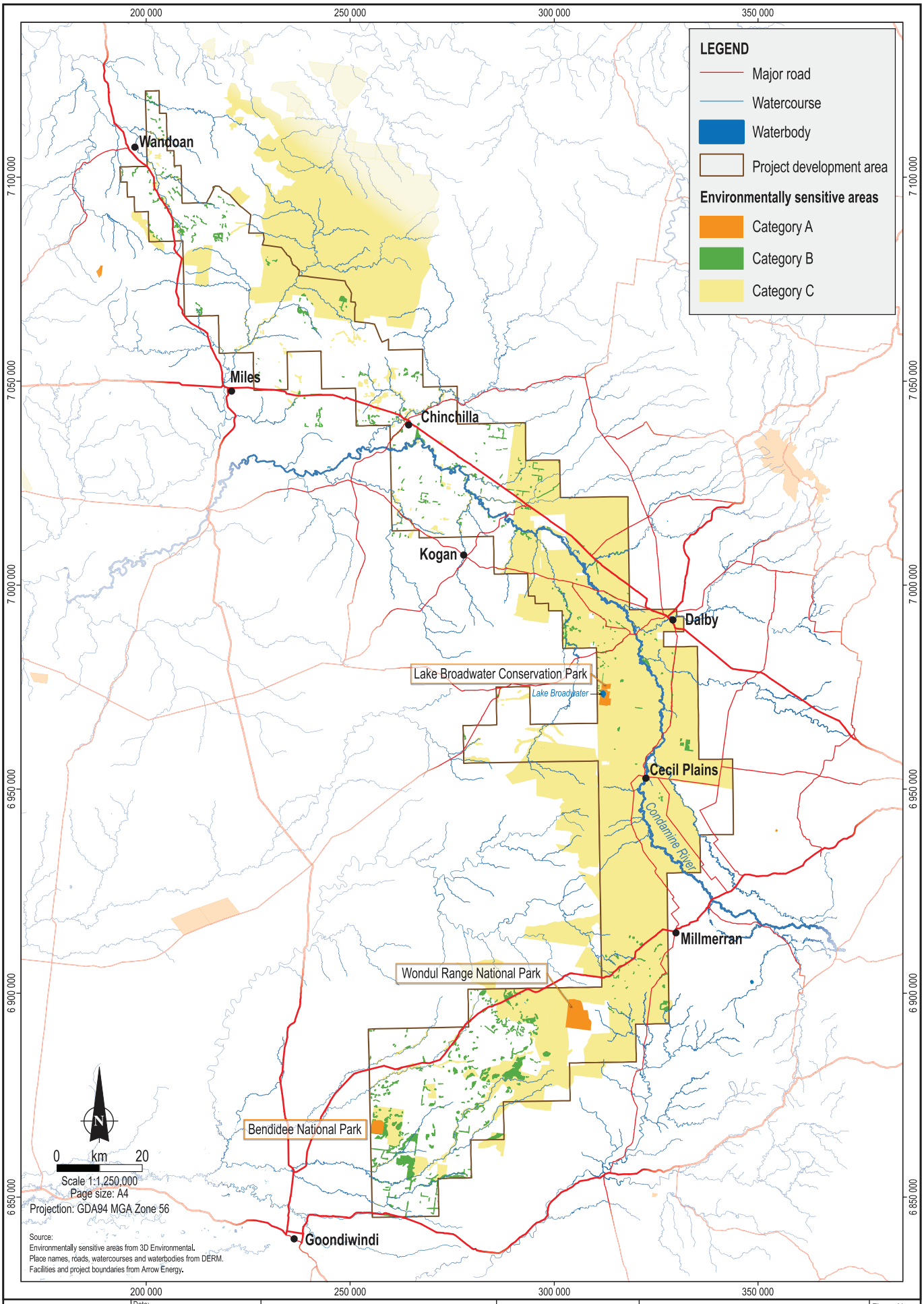
4.4.2 Potential Impacts

Habitat Fragmentation and Isolation of Populations

Vegetation clearance has the potential to impact upon corridors that connect the landscape. These corridors facilitate movement of terrestrial fauna species and help to ensure genetic diversity among populations.

Discounting habitat degradation and loss of individuals of flora and fauna that occur due to edge effects, fragmentation resulting from project activities may lead to:

- An altered landscape (and hence habitat) mosaic.
- Modification of large core unmodified habitats that may be structurally varied, contain source populations and have high habitat heterogeneity.



coffey environments	Date: 08.12.2011 MXD: 7040AC_04_GIS057_v1_5 File Name: 7040_04_ATT5_F04.09_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Environmentally sensitive areas within the project development area	Figure No: 4.9

- Increased barriers to movement, isolating populations or reducing movement rates.
- Impacts to significant wildlife corridors, including riparian areas along Wilkie Creek, Charleys Creek and the Condamine River.

Habitat Loss or Degradation and Fauna Mortality

Impacts resulting in habitat loss or degradation and fauna mortality could result from project activities.

Habitat Loss and Degradation

Habitat will be lost through clearing of vegetation for the coal seam gas and water gathering systems, access roads, temporary camps, production wells, production facilities and borrow pits.

Habitat degradation could result from dust generated by vehicle movement, noise, light spill or the spread and invasion of pest flora and fauna species and exposure to contaminants.

Pest Flora Invasion

Unmanaged, the project has the potential to increase the number of pest plant species, which may have serious economic and social impacts, as well as impacts on native vegetation and general biodiversity. Mechanisms of weed dispersal from project activities are generally associated with movement of equipment and machinery, particularly machinery sourced from adjacent regions, and with ground disturbance, such as grading, removal and relocation of topsoil.

Four exotic flora species, all of which are classified as weeds, are considered to have a high potential for impact within the project development area due to the favourable climatic conditions and habitats available:

- African lovegrass (*Eragrostis curvula*) is an aggressive and difficult-to-control, grassy weed that is widely established on road verges. The species has the long-term potential to displace native pasture grasses and decrease grazing productivity. African lovegrass provides a potential threat to the integrity of native grassland and associated listed species.
- Parthenium (*Parthenium hysterophorus*) colonises weak pastures with disturbed ground cover. A few widely scattered occurrences have been recorded on roadsides within and in the vicinity of the project development area; however, no major infestations are known.
- Mesquite (*Prosopis glandulosa* var. *glandulos, Prosopis velutina*), which forms dense impenetrable thickets in riparian areas that can outcompete native vegetation, is known from a few scattered records around Brookstead and Millmerran on heavy soils.
- Lippia (*Phyla canescens*) is widespread on the floodplains in the project development area and is a prominent weed on the floodplain of the Condamine River, displacing native ground covers. The species spreads both vegetatively and by seed and severely threatens grazing productivity. Its deep-rooting nature may be associated with stream bank erosion and is considered a major threat to floodplains and native pasture grasses.

Pest Fauna Invasion

Project-related activities have the potential to increase pest fauna abundance, which could lead to increased competition with and predation of native fauna and habitat degradation (e.g., through wallowing and foraging by feral pigs). In particular, pest fauna abundance and distribution may increase due to:

- The construction of linear infrastructure, which may create pathways and increase dispersal capability.
- The construction of dams, which can provide a permanent water source for feral animals, thereby increasing their abundance and distribution. In addition, dams may attract cane toads, increasing the risk of toxic ingestion in predatory species, such as grey snake, common death adder and black-necked stork.
- Putrescible waste, which can become a food resource for a variety of pest fauna species, thereby leading to an increase in their abundance.

Fauna species considered to have a moderate potential for increased distribution as a result of project activities include:

- Cane toad (*Rhinella marina*).
- European red fox (*Vulpes vulpes*).
- Feral cat (*Felis catus*).
- Wild dog *(Canis familiaris).*
- Feral pig (*Sus scrofa).*

Fauna Mortality

Fauna mortality can potentially result from entrapment in the pipe trench and dams, vehicle strikes, increased predation, or displacement and starvation as a result of vegetation clearance. Mortality of small mammals and reptiles residing within piled logs and debris may occur during movement of these materials during rehabilitation works.

Edge Effects

Edge effects occur where project activities encroach on a vegetation community. The structural type of the community and the extent and type of disturbance at the perimeter of the community determine the degree to which ecosystem function is affected, particularly the extent to which the community can continue to provide viable habitat. Changes resulting from edge effects include modified composition and structure of the community (as perimeter plants are exposed to different light conditions and the drying affects of wind) and refuge loss as fauna species withdraw deeper into the community.

Alteration of Ecological Processes

There is potential for the alteration of ecological processes, including fire frequency and fire extent and surface water flow conditions, to occur as a result of project activities.

Specifically, the project will be conducting construction activities (i.e., welding) and operations activities (i.e., flaring) that have the potential to increase the risk of ignition and fire if not conducted in accordance with appropriate procedures. Furthermore, the clearing of forests will alter the natural burning patterns through artificially created fire breaks along access roads and pipeline right of way (ROW).

Increased erosion and surface water flow disturbance may result from ground clearance, physical obstructions and increased runoff due to ground compaction. This flow disturbance could impact on vegetation communities and fauna, particularly migratory species around natural wetlands.

Project Activities with Potential to Impact Ecological Values

Project activities that may cause potential adverse impacts on terrestrial ecological values during the construction, operations and decommissioning phases of the project are described below.

Construction

The project activities most likely to adversely impact on terrestrial ecological values are the construction of production wells and associated low- and medium-pressure gas and water gathering pipelines and the high-pressure gas pipelines through:

- Site clearance.
- Ground disturbance and soil movements.
- Potential spills of hazardous materials.
- Vehicle movement (that potentially leads to fauna strikes and the spread of weeds and pathogens).
- Construction activities that create barriers for fauna movement or pathways for pest species.
- Trenching (which, when left open, may entrap animals and interfere with fauna movement pathways).
- Light and noise emissions.
- Storage of putrescible waste.

Construction of the production facilities will also involve these activities; however, they will be localised to the site, which will be selected to reduce impacts on terrestrial flora and fauna.

Operations

During operations, the following project activities could impact upon terrestrial ecological values:

- Potential release or spill of waste water or hazardous materials.
- Vehicle movements.
- Light and noise emissions.
- Storage of putrescible waste.

Decommissioning

During the decommissioning phase, impacts on terrestrial ecological values are similar to the construction and operations activities. These will occur in addition to the removal of infrastructure (e.g., pipelines and foundations) involving ground disturbance. These activities will predominantly occur in previously disturbed areas.

Cumulative Impacts

Multiple projects within the same bioregion (Brigalow Belt South bioregion) with similar impacts have the potential to cause compounding effects to terrestrial ecology. These compounded impacts have the potential to adversely alter a community to the extent that population recovery is not possible (i.e., the point at which the threshold is exceeded).

There are three ecological communities (including component regional ecosystems), 14 flora species and 11 fauna species with high potential for experiencing cumulative impacts due to their threshold levels. The ecological communities are:

- Natural grasslands on basalt and fine-textured alluvial plains of northern New South Wales and southern Queensland (‘critically endangered’). This comprises REs 11.3.21 and 11.3.24.
- Brigalow (*Acacia harpophylla* dominant and co-dominant) (‘endangered’). This is an EPBC Act–listed community and is located within REs 11.3.1, 11.4.3, 11.4.10, 11.9.5 and 11.9.6.

- Semi-evergreen vine thickets of the Brigalow Belt (north and south) and Nandewar Bioregions ('endangered'). It comprises REs 11.9.4a and 11.8.3.

The 14 flora species are curly-bark wattle (*Acacia curranii), Acacia wardellii, ooline (Cadellia pentastylis), Calytrix gurulmundensis, Cryptandra ciliate, Gonocarpus urceolatus,* Belson's panic (*Homopholis belsonii), Microcarpaea agonis, Micromyrtus carinata,* small-leaved wax flower (*Philotheca sporadic), Prostanthera sp. (Dunmore), Rutidosus lanata, Solanum papaverifolium, Solanum stenophorum* and *Xerothamnella herbacea.*

The 11 fauna species are pale imperial hairstreak *(Jalmenus eubulus),* collared delma (*Delma torquate),* brigalow scaly-foot *(Paradelma orientalis),* five-clawed worm-skink *(Anomalopus mackayi),* grassland earless dragon *(Tympanocryptis cf. tetraporophora),* common death adder *(Acanthophis antarcticus),* Dunmall's snake (*Furina dunmalli),* grey snake *(Hemiaspis damelii),* Australian painted snipe (*Rostratula australis),* painted honeyeater (*Grantiella picta)* and regent honeyeater *(Anthochaera Phrygia).*

These communities and species typically have a restricted distribution and are often endemic to the Brigalow Belt South bioregion.

There are also a number of highly restricted endemic species that may be susceptible to cumulative impact. These include the flora species Forster's wiregrass (*Aristida forsteri*) and *Macrozamia machinii* (no common name) and the bulloak jewel butterfly (*Hypochrysops piceatus*). Species endemicity in these cases is centred on the Surat Gas Project development area, highlighting the necessity for effective long-term management.

Cumulative impacts to ecological communities, regional ecosystems and threatened flora and fauna species can best be managed at the individual project scale. The successful management of cumulative impacts will be greatly assisted by a collaborative approach between the proponents of interacting projects, particularly with regard to ecological research and effective habitat offsetting.

4.4.3 Terrestrial Ecology Management

Management measures relating to terrestrial ecology for all project-related activities from planning and design through to decommissioning are listed in Table 4.11. Where residual impacts occur after the application of the management measures, Arrow will comply with relevant guidelines and legislation relating to planned impacts upon native flora and fauna. Where required, Arrow will obtain permits from the Queensland Parks and Wildlife Service for relocation or removal of species under the protection of the Nature Conservation Act. Where it is deemed by the relevant authority that offsets are required, the Environmental Offsets Policy 2008 (Qld) will be implemented.

As a matter of standard procedure, Arrow undertakes a desktop site selection process followed by a detailed field-based ecological assessment to identify and avoid sensitive locations. Key construction activities (such as clearing) will be routinely supervised by ecologists to ensure that the activity is being conducted in a responsible manner and within the approved area.

Table 4.11 Management measures for terrestrial ecology across all project-related activities

Element or issue	• Habitat fragmentation and isolation of populations. • Habitat loss and degradation and fauna mortality. • Edge effects. • Alteration of ecological processes.
Environmental protection objectives	• To minimise habitat loss and fauna mortality. • To avoid or minimise adverse effects on and to protect terrestrial ecosystems and associated biodiversity and habitat of state and national conservation significance. • To avoid or minimise adverse impacts to and to protect ESAs. • To control the introduction or spread of new or existing exotic terrestrial flora or fauna.
Performance criteria	• No unauthorised clearing outside marked clearing boundaries. • Minimal fauna mortality associated with project-related activities. • No reported instances of infestations of new or existing exotic terrestrial flora or fauna species resulting from project activities. • Biodiversity offset policy is implemented.
Implementation strategy for planning and design	• Minimise the disturbance footprint and vegetation clearing. [C020] • Design washdown facilities to ensure that runoff is contained on site and does not transfer weed seeds, spores or infected soils to adjacent areas. Treat or dispose of washdown solids in a registered landfill. [C187] • Develop a declared weed and pest management plan in accordance with the Petroleum Industry – Pest Spread Minimisation Advisory Guide (Biosecurity Queensland, 2008). Undertake species-specific management for identified key weed species at risk of spread through project activities (mesquite, parthenium, African lovegrass and lippia). Increase weed control efforts in areas particularly sensitive to invasion. The pest management plan should include, as a minimum, training, management of pest spread, management of pest infestations and monitoring effectiveness of control measures. [C188] • Design gathering lines and tracks to avoid watercourses, drainage lines and riparian area (particularly permanent watercourses or perennial aquatic habitat), where practicable. [C191] • Design dams to have an egress (escape point) for wildlife. [C214] • Avoid the following areas: – Wondul Range National Park, Bendidee National Park and Lake Broadwater Conservation Park (Category A ESAs). – Chinchilla Sands Local Fossil Fauna Site. – 'Critically endangered' EPBC Act communities within the project development area (REs 11.3.21, 11.3.24, 11.8.2a) including three natural grassland road reserves (Dalby Kogan, Dalby St George and Dalby Cecil Plains). [C217] • Aim to avoid: – Additional national- and state-listed communities: Brigalow (REs 11.3.1, 11.4.3, 11.4.10, 11.9.5, 11.9.6), Semi-evergreen vine thickets (REs 11.9.4a, 11.8.3), Weeping Myall Woodlands, and Coolibah-Blackbox woodlands (RE 11.3.3). – Category B ESAs. – Category C ESAs, including Gurulmundi State Forest, Bendidee State Forest, Binkey State Forest and Barakula State Forest. – Wyaga-Kindon Ooline populations. – Stock routes and state or bioregional wildlife corridors. – Essential and core habitat (supporting listed wildlife species).

Table 4.11 Management measures for terrestrial ecology across all project-related activities (cont'd)

Implementation strategy for planning and design (cont'd)	– State forests and resources reserves. – State-listed 'of concern' regional ecosystems. [C218] • Where avoidance is not possible, implement an offset strategy approved by a relevant government agency and comply with reporting conditions of an offset plan. [C219] • Conduct preconstruction clearance surveys to identify any additional areas that may need to be avoided. [C220] • Design facilities to ensure natural surface water flows are not impounded, e.g., by installing culverts on roads and stormwater diversion ditches around production facilities. [C221] • Develop fire plans for production facilities. [C223] • Develop threatened species management procedures as and when project activities are identified as likely to impact upon individuals. [C224] • Avoid construction activities in waterbodies frequented by migratory species. [C225] • Where not possible to avoid Bendidee State Forest (which provides habitat for the 'endangered' bull oak jewel butterfly), conduct activities in predisturbed areas following the development and implementation of a bull oak jewel butterfly management plan with regard to the existing recovery plan (Lundie-Jenkins & Payne, 2000). [C249]
Implementation strategy for construction	• Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Implement a 100-m buffer zone from the high bank of all watercourses to ensure that no development or clearance occurs within these buffers (other than construction of watercourse crossings for roads, pipelines and discharge infrastructure and associated stream monitoring equipment). [C157] • Identify declared weeds during the preconstruction clearance survey. [C193] • Manage potential impacts on Category A, B and C ESAs through implementation of the buffers proposed in Table 4.12. [C227] • Ensure boundaries are clearly marked for site-specific sensitive areas that require avoidance. [C228] • Ensure relevant workers, including contract plant and machinery operators, are made aware of the location of significant remnant vegetation and buffers and are guided by qualified personnel when clearing is undertaken. [C229] • Demarcate buffers and inform workers and machinery operators of buffer locations when working within the vicinity of national- and state-listed communities and areas identified for potential avoidance. [C230] • Minimise the width of construction ROWs within areas of sensitivity to the greatest extent practicable without compromising the safety of workers. [C231] • Conduct preconstruction clearance surveys and include as a minimum: – Vegetation mapping at a scale suitable for site-specific planning. – Identification of core habitats and listed species – Identification of site-specific sensitive areas that require avoidance or buffer areas. [C232] • Minimise the time a trench is left open. Construct exit points when construction is within 1 km of native vegetation, using appropriate material. Provide fauna refuges, such as sawdust-filled bags, regularly through areas of high fauna activity. [C233]

Table 4.11 Management measures for terrestrial ecology across all project-related activities (cont'd)

Implementation strategy for construction (cont'd)	• Retain habitat trees, where practicable. [C234] • Assess trees prior to felling for potential nesting hollows. If identified, fell trees in the presence of a qualified fauna spotter and roll them so that the hollows are facing upwards, allowing fauna to escape. [C235] • Identify key koala trees (*Eucalyptus tereticornis* and *E. populnea*), and visually inspect prior to clearing to ensure that they are free of koalas. If koalas are located, the tree should be retained until the animals have moved on, typically overnight. [C236] • Use appropriately trained personnel or a wildlife handler to capture injured wildlife, where possible. If further action is required, consult with a qualified vet to determine appropriate action. [C237] • Retain woody debris, logs and rocks for use in rehabilitation. These should be spread over part or all of the corridor or, as a minimum, piles along the edge of the cleared corridor to provide refuge for crossing fauna. [C238] • Translocate or propagate significant species where it is deemed necessary for use during rehabilitation or in offsets in accordance with relevant legislation. [C239] • Construct production wells, gathering lines and access tracks within cleared areas, where practicable, with the aim of avoiding remnant vegetation and high-value regrowth. [C240] • Fell trees away from existing stands where practicable. Where trees unavoidably fall into a stand, leave trees in situ to emulate natural tree fall and provide habitat for ground-dwelling species, where practicable. [C241] • Avoid damaging standing trees not identified for removal. Limit the scraping of standing tree trunks and breaking of limbs by equipment as far as practicable. [C242] • Erect fauna-exclusion fences around project dams. [C243] • During rehabilitation works, care will be taken when moving stockpiled logs and vegetation to avoid fauna mortality. [C473] • Should Arrow seek to work within disturbed areas within the Bendidee State Forest, a preconstruction clearance survey of the forest will also be conducted with input from a butterfly specialist to inform the critical habitat and food resource of the bull oak jewel butterfly (*Hypochrysops piceata*). [C523]
Implementation strategy for construction and operations	• Use coal seam gas water for dust suppression on roads or for construction and operation and maintenance activities authorised in the environmental authority in accordance with the water quality parameters described in the environmental authority. [C176] • Install and maintain appropriate sediment and erosion control structures at work sites. [C261]
Implementation strategy for decommissioning	• Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Consider the preconstruction clearance survey baseline characterisation when rehabilitating project sites. [C244] • Implement site planning, preparation and management requirements in accordance with a developed and approved decommissioning and rehabilitation plan. [C245] • Decommission the pipeline corridors in a manner that minimises potential impacts on the environment. [C246] • Identify areas for rehabilitation. [C247] • Prioritise areas for rehabilitation based on the preconstruction clearance survey baseline characteristics. [C248]

Table 4.11 Management measures for terrestrial ecology across all project-related activities (cont'd)

Implementation strategy for decommissioning (cont'd)	• Advise, through procedures and plans, on requirements for rehabilitation in identified areas that are no longer in use. [C250] • Reinstate self-supporting drainage lines. [C251] • Inspect rehabilitation areas after decommissioning for regrowth similar to the surrounding environment. [C252] • Select plant species for the purposes of rehabilitation that are specific to the original ecosystem and of local provenance, wherever practicable. [C253] • During rehabilitation works, care will be taken when moving stockpiled logs and vegetation to avoid fauna mortality. [C473]
Implementation strategy for construction, operations and decommissioning	• Confine project traffic to designated roads and access tracks, where practicable. [C033] • Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035] • Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities. [C038] • Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Wash down vehicles and equipment that have potentially been in contact with weeds before entering new work sites [C099] • Ensure all relevant personnel are made aware of the location and extent of weed infestations in the vicinity of the work area and the risks involved in moving from one site or property to another. [C179] • Do not wash down vehicles in watercourses. [C180] • When sourcing maintenance materials, ensure that such materials as bedding sand, topsoil, straw bales and sand bags are brought to site only after it is ascertained that the materials are not contaminated with weeds and plant or animal pathogens. Request a weed hygiene declaration form from the supplier where there is possible risk of contamination in products. [C190] • Implement noise control techniques in accordance with the noise and vibration commitments and standard industry noise suppression techniques. [C254] • Minimise light spill from project activities to reduce disturbance to nocturnal fauna. [C255] • Prohibit disturbance or harassment of wildlife and the unauthorised collection of flora and forest products. [C256] • Dispose of food scraps in large skips or bins that prevent animal access. Empty these storage devices regularly in a manner that does not involve disposal to onsite trenches or waste dumps. [C258]

Table 4.11 Management measures for terrestrial ecology across all project-related activities (cont'd)

Implementation strategy for construction, operations and decommissioning (cont'd)	• Train field personnel to identify key pest species and to maintain constant vigilance for weeds and pest fauna species throughout the project life to ensure early detection and intervention. [C259] • Implement speed limits on project-controlled roads to reduce the potential for vehicle collisions with wildlife. [C260] • Install and maintain appropriate sediment and erosion control structures at work sites. [C261]
Inspection and Monitoring	• Inspect food scrap bins and exclusion fences to ensure they are properly operated and maintained. [C212] • Develop monitoring programs that are site specific and based on the identified risk to the conservation or maintenance of a viable population. [C303] • Carry out routine monitoring of rehabilitation success. [C478] • Inspect and monitor the success of newly propagated or translocated listed species, in accordance with the approved translocation or management plan. [C482] • Inspect and manage open trenches in accordance with the following: – Inspect trenches for the presence of fauna daily (preferably in the morning), as well as immediately prior to closing a trench. – Have appropriately trained personnel remove any fauna from a trench to minimise stress to the animal and to avoid personal injury. – Record details of trapped fauna for inclusion in the DERM Wildnet database. [C500] • Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505] • Routinely inspect for pest flora and evidence of pest fauna species within project disturbed areas. [C508] • Inspect areas of avoidance to ensure that boundaries are clearly marked prior to clearing activities. [C533] • Monitor clearing activities to ensure marked boundaries are adhered to. [534] • Inspect marked areas after clearing activities to ensure areas of avoidance remain and that no unauthorised encroachment has occurred. [C535] • Supervise construction activities in sensitive areas to ensure appropriate methods (e.g., narrowing of ROW) are being implemented, where required. [C536]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

The following definitions relating to project activities apply:

- **Low Impact Activities**. These activities include the limited prescribed activities that do not result in the clearing of native vegetation, cause disruption to soil profiles through earthworks or excavation or result in significant disturbance to land. Examples of such activities include, but are not limited to, soil surveys, topographic, cadastral and ecological surveys and traversing land by car or foot via existing access tracks or routes.
- **Limited Petroleum Activities.** Such activities include well sites not exceeding 1 ha of disturbance and multi-well sites not exceeding 1.5 ha of disturbance, geophysical surveys, ecological and geological surveys, gathering pipelines from a wellhead to the initial production facility, supporting access tracks, and roads and communication and powerlines necessary for the undertaking of petroleum activities. The definition excludes construction of dams, borrow pits, production facilities and construction camps.

Table 4.12 Proposed buffer distances from the ESA boundary

ESA Category	Proposed Activities within the ESA	Proposed Activities within 200 m of the ESA Boundary	Proposed Activities within a Secondary Protection Zone*
Category A	None	Low impact activities	Limited petroleum activities within 800 m of the primary protection zone.†
Category B: excluding regional ecosystems with 'endangered' status	Low impact activities	Low impact activities	Limited petroleum activities within 300 m of the primary protection zone.†
Category B: regional ecosystems with an 'endangered' status	Limited petroleum activities	Limited petroleum activities	Only limited petroleum activities within 300 m of the primary protection zone.†
Category C: excluding regional ecosystems with an 'of concern' status, state forests and timber reserves	Low impact activities	Low impact activities	Limited petroleum activities within 300 m of the primary protection zone.†
Category C: regional ecosystems with an 'of concern' status, state forests and timber reserves	Limited petroleum activities	Limited petroleum activities	Limited petroleum activities within 300 m of the primary protection zone.†

* ESA buffers (derived from the guidelines under the EP Act 1994; Model Conditions for level 1 Environmental Authorities for Coal Seam Gas Activities) will be applied unless the activity occurs in pre-existing cleared areas or significantly disturbed land within the buffer and no reasonable or practicable alternatives exist.

† The primary protection zone is considered to be within 200 m of the ESA boundary.

4.5 Groundwater

This section describes Arrow's approach to managing potential environmental impacts to groundwater that are associated with project activities.

4.5.1 Existing Environment and Environmental Values

The properties and distribution of groundwater systems within the project development area and broader groundwater study area are a reflection of the geological evolution of the region and hydrogeological processes. Groundwater use across the project development area is a function of existing groundwater quality characteristics and general land use practices.

Regional Geology

The groundwater study area includes the project development area as well as portions of the surrounding Surat Basin and Clarence-Moreton Basin that were included in the extent of the numerical groundwater model (Figure 4.10). Arrow's tenements straddle the common boundary of the Surat and Clarence-Moreton basins, with the majority of the tenements in the Surat Basin. The majority of the formations across these basins are sedimentary, with some limited volcanic outcrops towards the eastern boundary of the study area.

Sedimentation into the Surat Basin commenced approximately 200 million years ago, resulting in a sedimentary sequence up to a maximum thickness of around 2,500 m. The geological sequence contains a series of interbedded groundwater-bearing formations (aquifers) and low-permeability, generally fine-grained formations (aquitards).

Each aquifer is characterised by a set of intrinsic hydraulic parameters, such as porosity, hydraulic conductivity and specific storage. These parameters control how the aquifers behave in the subsurface environment. Major aquifer formations present within the project development area can be grouped into groundwater systems with similar characteristics, as presented in Figure 4.11.

Regional Hydrogeology

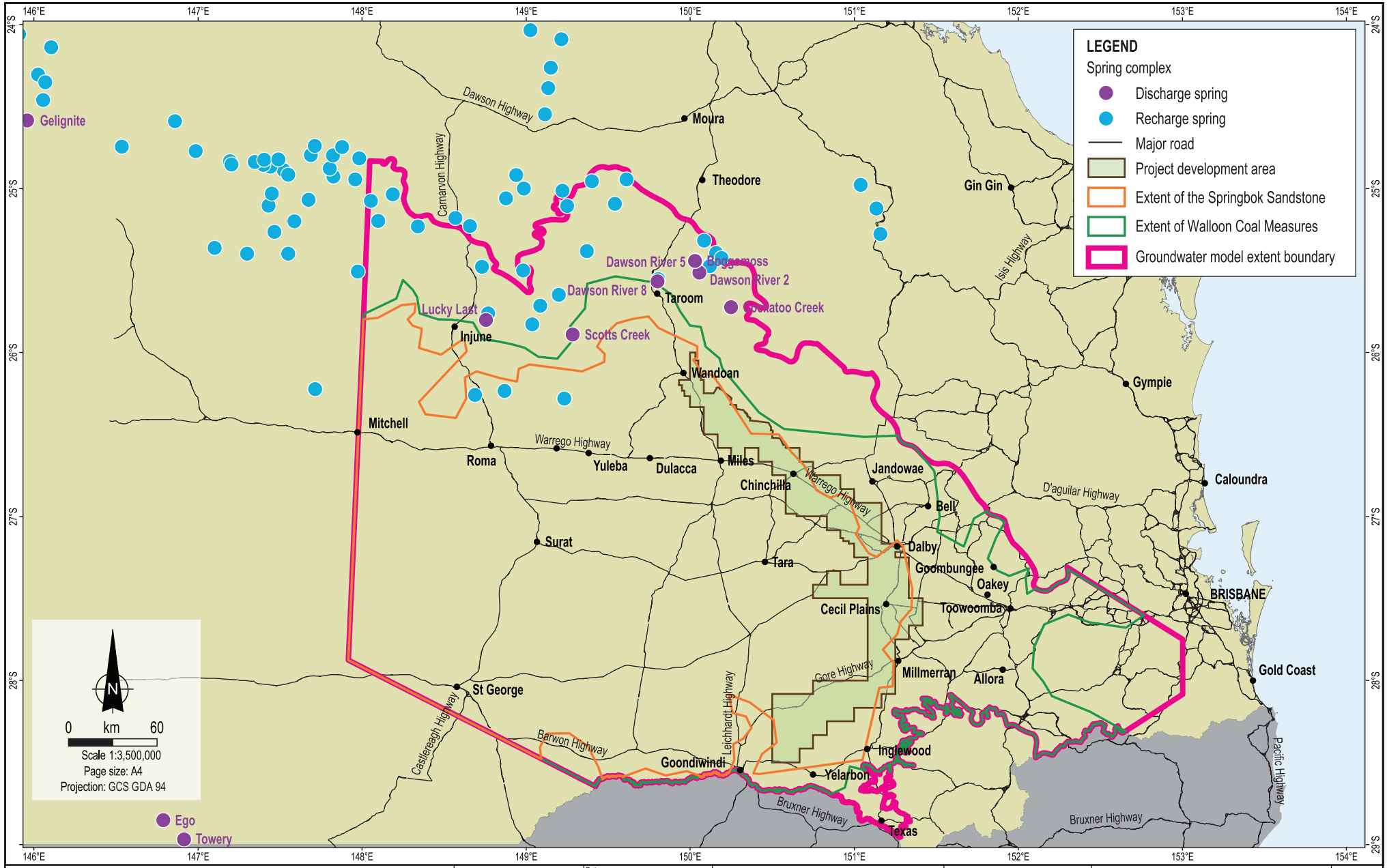
The project development area is located on the eastern margin of the Great Artesian Basin, which is made up of a multi-layered, confined aquifer system and is up to 3,000 m thick. According to the Water Resources (Great Artesian Basin) Plan 2006, the Great Artesian Basin aquifers that are present within the project development area include:

- Kumbarilla Beds (average depth ranges from 150 to 530 m below ground surface:
  - Mooga Sandstone.
  - Gubberamunda Sandstone.
  - Springbok Sandstone.
- Walloon Coal Measures (average depth ranges from 530 to 830 m below ground surface).
- Hutton Sandstone/Marburg Subgroup (average depth ranges from 905 to 1,045 m below ground surface).
- Precipice Sandstone (average depth ranges from 1,205 to 1,280 m below ground surface).

Sandstone aquifers that make up the Great Artesian Basin are exposed at the surface along its eastern margin in areas of relatively high rainfall, forming a recharge area that extends in a continuous arc from east of Goondiwindi to the top of Cape York Peninsula (Figure 4.12). Studies show that average basin-wide recharge across the basin is estimated to range between 5 and 10 mm/a. From the recharge zone, subsurface groundwater flow within the Great Artesian Basin is generally towards the southern, southwestern, western and northern margins of the basin.

A typical range of recharge for the Surat Basin is reported to be between 0 and 3 mm/a, and higher rates of up to 10 mm/a are reported in localised areas.

A shallow, unconfined aquifer that does not form part of the Great Artesian Basin is the Condamine Alluvium. Water balances for the Condamine Alluvium aquifer indicate that significant aquifer recharge occurs via rainfall, irrigation runoff and leakage from river beds, with little flow from aquifers to watercourses. Studies of the Condamine Alluvium indicate that is recharged at a rate estimated to range significantly from 0 to 25 mm/a.



Source:
Place names and roads from GEODATA250k.
Groundwater model extent, Walloon Coal Measures and Springbok Sandstone extents boundaries from Schlumberger.
Project development area from Arrow Energy.
Location, physical and biological attributes of Great Artesian Basin spring complexes, R.J. Fensham, R.J. Fairfax, T. Gotch, D. Niejalke, November 2005, Queensland Herbarium, Environmental Protection Agency

coffey environments

Date: 09.12.2011
MXD: 7040AC_04_GIS108_v1_4
File Name: 7040_04_ATT5_F04.10_GIS_GL

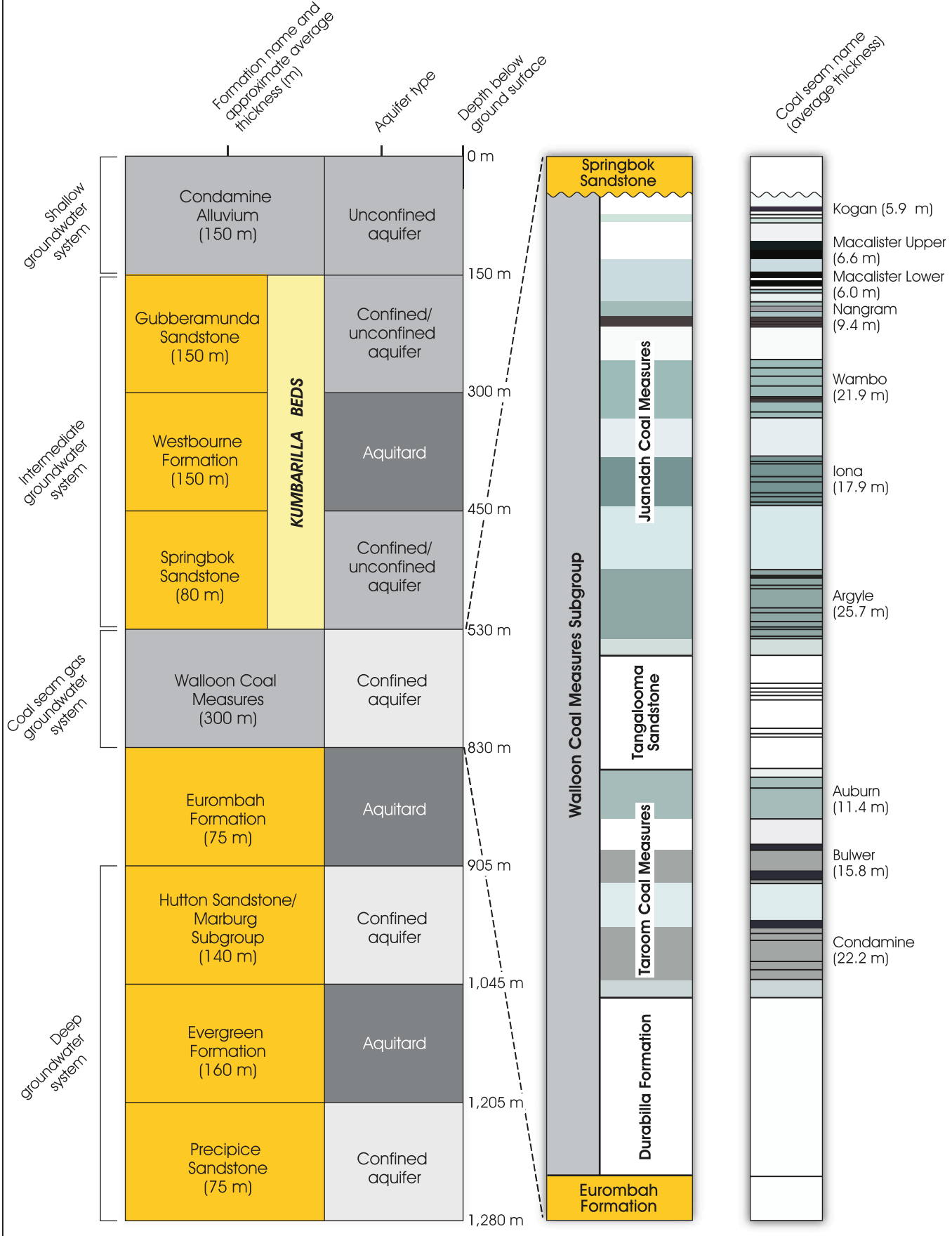
Arrow Energy

Surat Gas Project

arrow energy go further

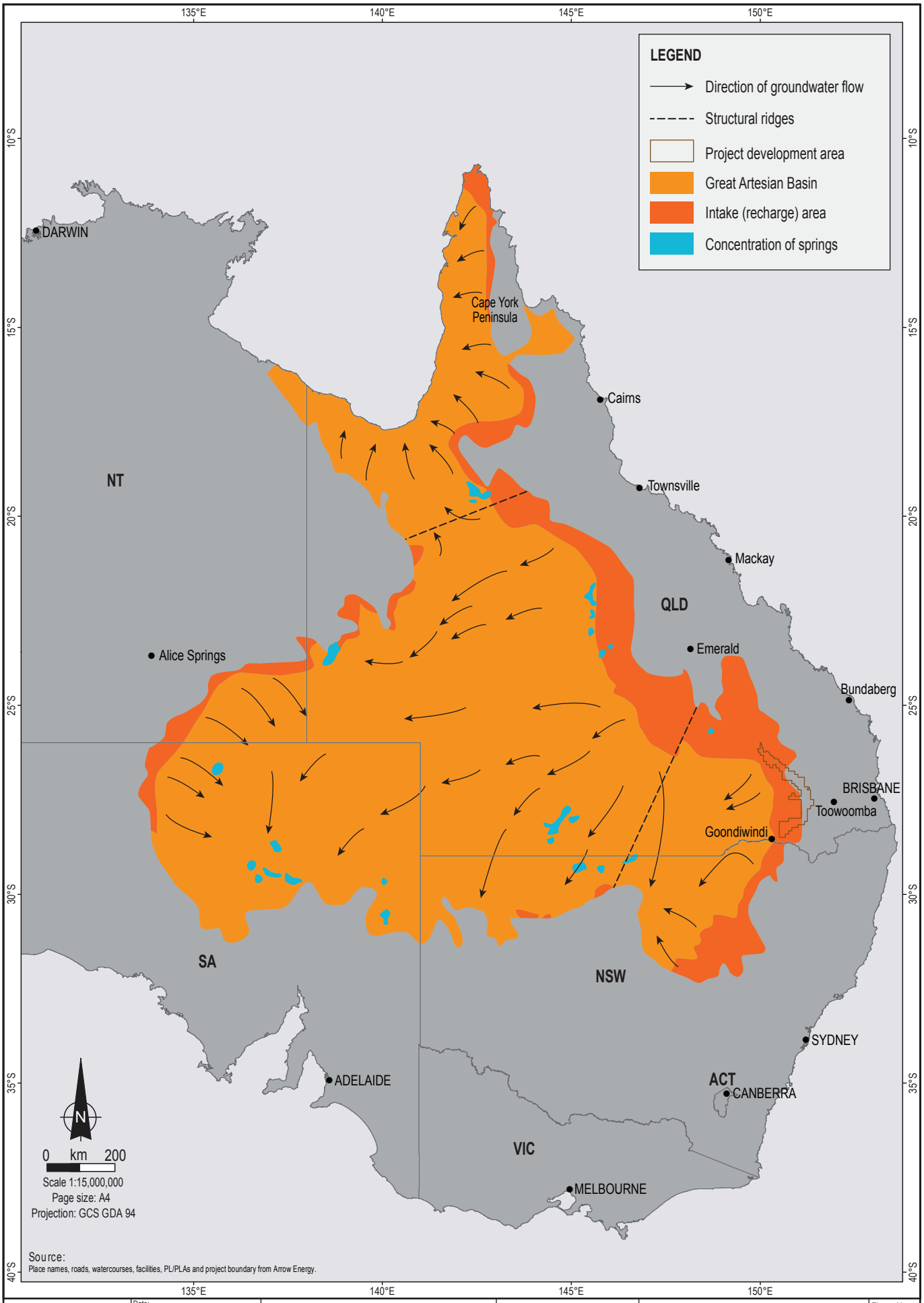
Approximate location of known groundwater springs within the groundwater model extent

Figure No: 4.10



Source: Data form Arrow Energy
Scott et al (2004)

coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Stratigraphy and groundwater systems present within the project development area	Figure No: 4.11
	File Name: 7040_04_ATT5_F04.11_GL	Surat Gas Project			



coffey environments	Date: 09.12.2011 MXD: 7040AC_04_GIS106_v1_2 File Name: 7040_04_ATT5_F04.12_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Great Artesian Basin hydrology Figure No: 4.12

Groundwater Use

Extraction of groundwater in the Surat Basin commenced prior to the 1900s, resulting in a large-scale decline in groundwater levels within key aquifer units. The DERM database shows that the majority of registered bores within the project development area access groundwater within the Condamine Alluvium. The Queensland water entitlements registration database shows that the majority of bores within the project development area are licensed for use as irrigation water supplies. The documented 'nominal entitlement' of the licensed groundwater bores within the project development area is 331,545 ML/a and may be a significant underestimate. Only 51% of licenses had a nominal entitlement referenced. One hundred ninety-one bores either are not metered or have not had any groundwater usage data incorporated into the Queensland water entitlements registration database.

Each groundwater system identified within the project development area has a variety of characteristics. The combination of characteristics that define a groundwater system allow the groundwater to be relied upon in a number of ways, as defined in the Environmental Protection (Water) Policy 2009 (EPP (Water)), including:

- **Support to Biological Areas.** The ability of groundwater systems to maintain the biological integrity of groundwater-dependent ecosystems is related to the ecological value of the groundwater. Within the groundwater study area, recharge and discharge springs are known to occur (see Figure 4.10). There are also areas of interaction between the Condamine River and underlying groundwater systems.
- **Consumptive or Productive Uses.** Groundwater systems can support a variety of consumptive and productive uses. As defined in the EPP (Water), groundwater systems can be used to provide suitable drinking water supplies, water for agricultural purposes or use in aquaculture and production of aquatic food for human consumption, or water for a wide variety of industrial uses.
- **Support to Areas of Cultural and Spiritual Importance.** Groundwater can support areas of cultural and spiritual importance, such as wells and springs with Indigenous and non-Indigenous anthropological, archaeological, historic, sacred or scientific significance. No specific sites of cultural or spiritual importance have been identified within the project development area; however, where groundwater discharges to the Condamine River, the Condamine Alluvium aquifer may indirectly support cultural values associated with the Condamine River. In addition, aquifers in the deep groundwater system have historical cultural significance as artesian supply.

Four groundwater systems have been identified within the project development area on the basis of common aquifer characteristics and values (Table 4.13).

Table 4.13 Summary of groundwater values

Groundwater System	Ecological Value	Biological Integrity Able to be Maintained	Potential Consumptive and Productive uses	Cultural and Spiritual Values
Shallow: Condamine Alluvium	The system is more prone to modification due to the infiltration of pollutants, nutrients, and agricultural chemicals, such as fertilisers, herbicides and pesticides, into the shallow subsurface due to land development, settlement, and urbanisation. There are physical connections between this groundwater system and such surface features as the Condamine River.	Where physical connection between this groundwater system and surface features occurs, the groundwater quality is predominantly able to maintain slightly to moderately disturbed ecological systems.	Groundwater from this system has generally low to moderate total dissolved solids concentrations (average of approximately 1,300 mg/L), allowing a wide range of beneficial uses; however, it is predominantly suitable for agricultural use within the project development area.	No specific sites are identified within the project development area; however, where baseflow discharge to the Condamine River occurs, the Condamine Alluvium aquifer may indirectly support cultural values associated with the Condamine River.
Intermediate: Mooga Sandstone Gubberamunda Sandstone Springbok Sandstone	The ecological value of the intermediate groundwater system increases with depth, as this generally reflects increased isolation from potentially impacting human processes. There are no known areas of physical connection between this groundwater system and surface features within the project development area; however, they may exist within the groundwater model extent.	If a physical connection between this groundwater system and surface features exists, the groundwater quality is predominantly able to maintain effectively undisturbed ecological systems and some slightly to moderately disturbed ecological systems.	Based on variable total dissolved solids concentrations (average of approximately 1,400 mg/L), groundwater from this system has a range of uses; however, it is predominantly suitable for agricultural use within the project development area.	No specific sites are identified within the project development area.
Coal Seam Gas: Walloon Coal Measures	Groundwater from this system is generally considered to be of lower ecological value due to higher salinity, high sodium absorption ratio, and coal formation chemistry. There are no known areas of physical connection between this groundwater system and surface features within the project development area; however, they may exist within the groundwater model extent.	If a physical connection between this groundwater system and surface features exists, the generally poor groundwater chemistry and salinity would likely fail to support ecological systems.	The aquifers within the coal seam groundwater system are generally considered to be of lower quality due to higher salinity (average total dissolved solids values of approximately 4,600 mg/L) and high sodium absorption ratios. The groundwater is generally suitable for stock watering and production of aquatic food for human consumption.	No specific sites are identified within the project development area.

Table 4.13 Summary of groundwater values (cont'd)

Groundwater System	Ecological Value	Biological Integrity Able to be Maintained	Potential Consumptive and Productive uses	Cultural and Spiritual Values
Deep: Hutton Sandstone/ Marburg Subgroup Precipice Sandstone	The deep groundwater system is generally considered to be of high ecological value due to lower salinity, isolation from potentially impacting human processes and the identified natural connection between the deep groundwater system and mound spring complexes in more regional Great Artesian Basin groundwater discharge areas. There no known areas of physical connection between this groundwater system and surface features within the project development area, however, they may exist within the groundwater model extent.	If a physical connection between this groundwater system and surface features exists, groundwater quality from this system is predominantly able to maintain effectively undisturbed ecological systems and some slightly to moderately disturbed ecological systems.	Lower total dissolved solids concentrations (average of approximately 1,900 mg/L for the Hutton Sandstone) allow a wide range of uses; however, groundwater from this system is predominantly suitable for agricultural uses within the project development area.	No specific sites are identified within the project development area; however, aquifers in the deep groundwater system have historical cultural significance as artesian supply.

4.5.2 Potential Impacts

Potential impacts to the groundwater values from associated project activities are described for each project phase.

Potential impacts to groundwater that are related to land contamination as a result of disturbance of existing contaminated land or the potential to cause land contamination through project activities are discussed in Section 4.2, Geology, Landform and Soils.

Construction

The primary activities that could impact groundwater values are the construction of production wells and monitoring bores, gathering lines, production facilities and associated infrastructure (e.g., construction camps). These activities have the potential to impact on groundwater values in the following ways:

- Reduced rainwater infiltration and subsequent reductions in aquifer recharge from the surface due to the following:
  - Construction of impervious surface coverings associated with integrated production facilities.
  - Land disturbance activities resulting in reduced porosity and permeability of surface profiles.
- Incomplete or incorrect well installation resulting in interconnection of aquifers and consequential cross-contamination.
- Use of lubricants and drilling fluids during the drilling process resulting in localised contamination of aquifers.
- Leaks and spills at the wellhead during drilling draining and infiltrating into the boreholes leading to contamination of the intersected aquifers.

Operation

Coal seam gas water will be extracted from the Walloon Coal Measures, so direct impacts to the groundwater levels in this aquifer cannot be avoided. There also are potential indirect impacts to surrounding groundwater systems as a result of coal seam gas water extraction.

In addition to coal seam gas water extraction, other operations activities to be conducted by Arrow have the potential to affect groundwater, such as drilling wells and storing saline water, chemicals and fuels.

Coal Seam Gas Water Extraction

The extraction of coal seam gas will result in depressurisation of the Walloon Coal Measures. Coal seam gas water production across the project development area will be variable but is estimated to average 22 GL/a and peak at about 43 GL/a. Depressurisation of the Walloon Coal Measures will lower aquifer pressures, potentially resulting in the following direct impacts:

- Reduced groundwater flow to groundwater-dependent ecosystems or areas of cultural and spiritual importance fed by the Walloon Coal Measures.

- Reduced groundwater supply to existing or future groundwater users accessing groundwater from the Walloon Coal Measures.

The extraction of coal seam gas water from the Walloon Coal Measures has the potential to indirectly impact upon other groundwater systems present within the project development area. Subsequent depressurisation of adjacent aquifers has the potential to cause indirect aquifer interflow and groundwater drawdown, resulting in the following indirect impacts:

- Diminished groundwater quality in aquifers above and below the Walloon Coal Measures. This relates to groundwater mixing as drawdown in the Walloon Coal Measures induces flow across deeper and shallower aquifers, especially the Springbok and Hutton sandstones.
- Reduced groundwater flow to discharge features or areas of cultural and spiritual importance fed by the adjacent aquifers.
- Reduced groundwater supply to existing or future groundwater users accessing groundwater from the adjacent aquifers.
- Land subsidence and changes to surface water flow regimes and landforms.

The results of a numerical groundwater model predicted the unmitigated direct groundwater drawdown in the Walloon Coal Measures together with the unmitigated indirect groundwater drawdown in the aquifers above and below the Walloon Coal Measures as a result of coal seam gas extraction by Arrow. The results of the predictive modelling from Arrow's Surat Gas Project activities are summarised in Table 4.14 below.

Table 4.14 Summary of predicted groundwater drawdown

Groundwater System, Aquifer and Average Depth	Predicted Maximum Groundwater Drawdown	Comments
Shallow groundwater system Condamine Alluvium (0 to 150 m)	Greater than 0.1 to less than 1 m	Greatest drawdown is predicted within the Dalby development region, along the western extent of the Condamine Alluvium. Average drawdown across the project development area is less than 1 m. Peak drawdown is predicted in 2059, indicating a lag between gas extraction activities across the entire project development area and corresponding drawdown in the shallow Condamine Alluvium. Recovery is predicted to be slower than drawdown, with groundwater levels not returning to initial levels by 2071, which was the maximum temporal extent of the model.
Intermediate groundwater system Kumbarilla Beds (150 to 530 m)	30 m	Maximum drawdown is predicted in 2029. Greater drawdown, up to 20 to 30 m, is predicted along the eastern boundary of the Kumbarilla Beds. Average drawdown in the majority of the project development area is predicted to range from 2.5 to 5 m. By 2061, drawdown along the eastern extent of the Kumbarilla Beds has recovered to approximately 5 m; however, drawdown contours extend across the southern portion of the project development area. This is primarily due to the late onset of coal seam gas water extraction from the Goondiwindi development region.

Table 4.14 Summary of predicted groundwater drawdown (cont'd)

Groundwater System, Aquifer and Average Depth	Predicted Maximum Groundwater Drawdown	Comments
Coal seam gas groundwater system Walloon Coal Measures (530 to 830 m)	More than 75 m	Drawdown is predicted to be greatest in the Juandah Coal Measures, peaking in 2024 in excess of 75 m. In 2024, drawdown is predominantly limited to within the project development area, and predicted drawdown reduces to less than 5 m approximately 10 km from the project development area. Maximum predicted drawdown in the Taroom Coal Measures and the Tangalooma Sandstone is estimated to range from 50 to 75 m in 2024. By 2061, significant groundwater recovery is predicted due to recharge areas along the east boundary of the model extent, with residual drawdown predicted to be less than 10 m across the Juandah and Taroom Coal Measures and the Tangalooma Sandstone. Maximum predicted groundwater drawdown can vary across the five development regions as a function of the modelled thickness of the formations within the Walloon Coal Measures, and the predicted coal seam gas extraction rates.
Deep groundwater system Hutton Sandstone/ Marburg Subgroup (905 to 1,045 m)	20 to 30 m	Maximum drawdown is predicted in the Goondiwindi development region in 2035.[1] In all other development regions, peak drawdown is predicted in 2027, with the greatest drawdown observed in the Wandoan development region. Across the majority of the project development area, an average drawdown of 10 to 20 m is predicted. During 2027, drawdown up to 0.5 m extends approximately 25 km west and 5 km east of the project development area. By 2061, predicted drawdown has reduced to an average of 5 m across the project development area, and drawdown up to 0.5 m expands to the west, approximately 60 km from the project development area.
Deep groundwater system Precipice Sandstone (1,205 to 1,280 m)	10 to 15 m	Maximum predicted drawdown of 10 to 15 m is modelled in 2042 within the Dalby development region. At this time, the average drawdown across the majority of the project development area is predicted to range from 1 to 5 m. By 2061, predicted drawdown has reduced in the vicinity of the Dalby development region; however, the contours across the remainder of the project development area indicate slow recovery rates.

1. The Goondiwindi development region begins extraction of coal seam gas water later than all other development regions, creating a peak in the production curve that is reflected in the outcomes of the predictive modelling.

Other Operations Activities

Surface activities during the operations phase of the project that can impact groundwater values are as follows:

- Leaks and spills of chemicals, fuels and oils stored at the surface in association with integrated production facilities may result in contamination of the intersected aquifers.
- Discharges of liquid domestic wastes and effluent to land have the potential to contaminate groundwater systems.

Activities related to the storage, treatment and transfer of coal seam gas water and its by-products during the operations phase of the project have the potential to impact on groundwater values as listed below:

- Seepage or leaks of untreated coal seam gas water and brine from storage facilities have the potential to contaminate the shallow groundwater system.
- Coal seam gas water discharged to streams has the potential to infiltrate the subsurface profile and contaminate the shallow groundwater system.
- Leaks and spills from subsurface infrastructure, e.g., gathering lines, could result in contamination of intersected aquifers.
- Seepage or leaks of coal seam gas water and its by-products from storage facilities (e.g., dam failure) have the potential to alter the shallow groundwater flow direction and associated recharge or discharge patterns.

Decommissioning

Potential impacts to groundwater values during decommissioning include incomplete or incorrect well decommissioning that results in interconnection of aquifers and consequential cross-contamination.

Cumulative Impacts

Numerical groundwater modelling was used to considered scenarios that accounted for the cumulative effects of several significant groundwater users, including coal seam gas developments by Arrow, Santos, QGC and Origin. Table 4.15 summarises the maximum drawdowns predicted for the cumulative modelling scenario in comparison to the Arrow-only modelling scenario.

Table 4.15 Summary of cumulative groundwater drawdown impacts

Groundwater System and Aquifer	Predicted Maximum Groundwater Drawdown – Arrow Only	Predicted Maximum Groundwater Drawdown – Cumulative Model
Shallow groundwater system	Greater than 0.1 to less than 1 m	2.5 m
Intermediate groundwater system	30 m	60 m
Walloon Coal Measures	Greater than 75 m	150 m
Deep groundwater system	10 to 30 m	75 m

The Queensland Government has established a ‘cumulative management area’ for the Surat and Southern Bowen Basin areas, including the alluvium of the Condamine River (the Surat Cumulative Management Area). Recent changes to the *Water Act 2000* (Qld) enable a cumulative management area to be declared if an area contains two or more petroleum tenures, including tenures on which coal seam gas activities operate and where there may be cumulative impacts on groundwater resulting from water extraction by the tenure holders. Within the Surat Cumulative Management Area, the Queensland Water Commission (QWC) is responsible for relevant activities like groundwater impact monitoring, modelling, and preparation of cumulative underground water impact reports. The QWC also has the responsibility for management of cumulative impacts from coal seam gas operations on springs. The QWC has prepared terms of reference for assessment of identified priority

springs and will prepare a Springs Impact Management Strategy. The outcomes of this strategy will enable Arrow to refine their monitoring, mitigation and management strategies to minimise impacts to groundwater-dependent ecosystems associated with springs.

4.5.3 Groundwater Management

The primary mitigation measure for groundwater will involve the application of a hierarchy of management options that form the basis for an adaptive management framework. The adaptive management framework is structured to allow management decisions to be made based on an increased knowledge base developed over time.

Management measures for groundwater across all project-related activities from planning and design through to decommissioning are listed in Table 4.16.

The management of potential impacts to groundwater that are related to land contamination as a result of disturbance of existing contaminated land or the potential to cause land contamination through project activities are discussed in Section 4.2, Geology, Landform and Soils.

Table 4.16 Management measures for groundwater across all project-related activities

Element or issue	• Reduced flows to groundwater-dependent ecosystems and areas of cultural and spiritual importance. • Reduced groundwater supply to existing or future groundwater users. • Diminished groundwater quality. • Altered groundwater flow patterns impacting supply to third-party users, groundwater-dependent ecosystems and areas of cultural and spiritual importance. • Diminished rainwater infiltration and reduced aquifer recharge. • Land subsidence affecting surface water systems and landforms.
Environmental protection objectives	• To minimise impacts due to altered groundwater levels. • To minimise impacts to groundwater quality.
Performance criteria	• Groundwater-dependent ecosystems and areas of cultural and spiritual importance are not adversely affected. • Existing groundwater users are not adversely affected. • Groundwater quality in aquifers above and below the Walloon Coal Measures is not adversely affected. • Natural groundwater flow patterns are maintained through use of smallest practicable project footprints. • Respond to potential impacts related to land subsidence based on the results of any measured surface deformation and subsidence resulting from coal seam gas extraction activities.

Table 4.16 Management measures for groundwater across all project-related activities (cont'd)

Implementation strategy for planning and design	• Inspect and observe site locations for the presence of contamination prior to commencement of intrusive activities. [C019] • Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035] • Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Avoid development on contaminated land through the completion of appropriate register searches and desktop investigations (i.e., avoid land or the contaminated portion of a parcel of land that is listed on the Contaminated Land Register or the Environmental Management Register, where practicable). [C049] • Conduct physical investigations on selected parcels of land to influence facility siting decisions on a localised scale (i.e., target the portion of land that is not contaminated by understanding the extent of contamination). [C050] • Arrow will enforce a no hydraulic fracturing (fraccing) policy in the project development area. [C079] • Prepare a baseline assessment plan to establish benchmark data in registered third-party bores (where possible) prior to the commencement of Arrow extraction activities in accordance with the Water Act, including the preparation and implementation of a groundwater monitoring and investigation strategy. [C120] • Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water dams and brine dams. [C124] • Consider local groundwater conditions when identifying sites for the installation of buried infrastructure (e.g., gathering lines). [C125] • Avoid unnecessary impervious surface coverings and minimise land footprint and vegetation clearing when designing facilities. [C126] • Undertake bore assessments of third-party bores (where possible) in accordance with the Water Act, including: – Having the Queensland Water Commission for the Surat Cumulative Management Area identify bores requiring assessment. – Developing make-good agreements that include the outcome of bore assessments and implementation of make-good measures in the event that impaired capacity occurs. [C127] • Continue an investigative program that will help quantify the connectivity between the Condamine Alluvium and the Walloon Coal Measures. The program will involve: – Monitoring the effects of groundwater extraction in the Walloon Coal Measures on the Condamine Alluvium to estimate horizontal and vertical hydraulic conductivity between the alluvium and the Walloon Coal Measures. – An investigative drilling program that will provide greater definition of the interface between the two units and will evaluate the geological and hydrogeological properties of the material at the interface of the units. – Groundwater chemistry studies to characterise mixing and migration between the units. – Groundwater modelling, utilising the connectivity data obtained through investigative components of the program, to understand important processes in the system and predict potential impacts. [C128]

Table 4.16 Management measures for groundwater across all project-related activities (cont'd)

Implementation strategy for planning and design (cont'd)	• Continue a program of aquifer testing in dedicated groundwater monitoring bores to increase the predictability of aquifer properties and groundwater movement. [C129] • Collect relevant geological and hydrogeological data from existing and future production wells, monitoring bores and registered third-party bores (where possible) together with information collated collaboratively with other proponents and regulatory authorities. [C130] • Update and calibrate the geological model and the numerical groundwater model with relevant data on an ongoing basis, including: – Aquifer thicknesses and interfaces between formations. – Aquifer properties, e.g., porosity, permeability. – The location of sensitive areas, e.g., groundwater discharge springs. – Observed responses in monitoring bores that reflect aquifer behaviour during coal seam gas extraction. [C131] • Utilise the updated geological and numerical groundwater models to: – Make ongoing predictions regarding changes to groundwater levels and groundwater quality as the project develops. – Improve confidence in the understanding of the sensitivity and resilience of the aquifers within the identified groundwater systems. [C132] • Perform groundwater modelling simulations to predict impacts on groundwater resources in overlying and underlying aquifers. This information will subsequently be used to evaluate the suitability of these resources for use in make-good measures. [C133] • Verify the preferred water management strategy by modelling the effectiveness of substitution and injection (where conducted) in offsetting depressurisation impacts in aquifers. [C134] • Address the potential for surface deformation through participation by Arrow in a collaborative study with other proponents using historical and baseline data from the Advanced Land Observation Satellite covering a time-lapse period from January 2007 until January 2011. This will allow a detailed analysis of the region and will enable the analysis of the evolution of measured surface deformation in space and time. The assessment will correlate and calibrate data deliverables (calibrated global map and vector files for measurement points) from the Advanced Land Observation Satellite to show the mean deformation rate, identify areas of large-scale deformation and compare patterns with other information (e.g., geology, basin structure, extraction wells and injection data). [C136]

Table 4.16 Management measures for groundwater across all project-related activities (cont'd)

Implementation strategy for construction	• Avoid disturbance of contaminated soil and groundwater when it is identified or observed during intrusive works. [C064] • Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998). [C065] • Construct all coal seam gas production infrastructure in accordance with the standards described in the P&G Act and regulations to that act. [C137] • Construct all monitoring bores in accordance with the minimum construction requirements for water bores in Australia (LWBC & NMBSC, 2003) and the minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland (DERM, 2004). [C138] • Select drilling fluids to minimise potential groundwater impacts. Do not use oil-based drilling fluids. [C139] • Ensure well drilling is monitored by a suitably qualified geologist to ensure aquifers are accurately identified for correct well construction. [C140] • Develop the construction, design and monitoring requirements for new dams (either raw water, treated water or brine dams) and determine the hazard category of the dam, in accordance with the requirements of the most recent version of the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011b). Construct the dams under the supervision of a suitably qualified and experienced person in accordance with the relevant DERM schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements. [C141] • Install groundwater monitoring bores near dams as a leak detection measure: – The number of monitoring wells and their location will take into account site-specific hydrogeology, preferential pathways and potential receptors of impacts. – Monitor bores installed near dams will have groundwater levels and relevant water quality parameters monitored on a routine basis. – The number of monitoring bores or associated monitoring frequencies will be increased and further investigation will be triggered where impacts are identified. [C504]

Table 4.16 Management measures for groundwater across all project-related activities (cont'd)

Implementation strategy for operations	• Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. [C036] • Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities. [C038] • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. [C069] • Store onsite materials in suitable containment systems constructed to industry standards and Australian standards (AS 1940-2004, The Storage and Handling of Flammable and Combustible Liquids (Standards Australia, 2004a), and AS 3780, The Storage and Handling of Corrosive Substances (Standards Australia, 2008), at a minimum). Maintain quality control and quality assurance procedures to monitor volumes and quantities. Bund aboveground storage areas to contain spills. [C102] • Consider injection of coal seam gas water or brine of a suitable quality (if proven technically feasible) into shallow or deep aquifers to offset depressurisation impacts in aquifers. [C135] • Manage potential impacts on identified spring complexes by: – Supporting the identification of specific aquifers that serve as a groundwater source for discharge springs. – Assessing springs that are predicted to be subject to unacceptable impacts through the source aquifer. – Developing monitoring and mitigation strategies to avoid or minimise unacceptable impacts. [C142] • Implement a well integrity management system during commissioning and operation of production wells. [C143] • Minimise impacts of groundwater depressurisation on sensitive areas (e.g., groundwater-dependent ecosystems). [C144] • Develop a procedure for investigating the impaired capacity of third-party bores. The investigation will be comprised (but not limited to) the following phased investigation response: – Verify groundwater levels in the nominated bores and investigate groundwater levels and groundwater quality in compliance monitoring bores against established trigger thresholds. – Request bore information and groundwater data from affected parties. – Review and assess data. – Advise bore owners in writing of findings. [C145] • If impaired capacity is confirmed (bore can no longer produce quality or quantity of groundwater for the authorised purpose, and the impact is due to coal seam gas activities), implement make-good measures in accordance with the Water Act. [C146] • Include where possible make-good measures such as substitution of groundwater allocations of equal or better quality to maintain user supply, deepening of bores, modification of pumps, or supply of groundwater from an alternative source. [C147]

Table 4.16 Management measures for groundwater across all project-related activities (cont'd)

Implementation strategy for operations (cont'd)	• Connect wastewater and sewerage systems to sewers where locally present. Alternatively, install wastewater treatment or reuse systems in accordance with AS/NZS 1547:2000, On-site Domestic Wastewater Management (Standards Australia, 2000); DERM guideline for managing sewerage infrastructure to reduce overflows and environmental impacts (DERM, 2010b); and Queensland water recycling guidelines (DERM, 2005). [C148] • Store and manage all waste materials (domestic and industrial) in accordance with industry regulations and DERM conditions. Use licensed waste management contractors. Conduct audits of disposal facilities, disposal permits and onsite operations to ensure adherence to regulations. [C149]
Implementation strategy for decommissioning	• Excavate any saline material during rehabilitation of coal seam water dams or brine dams and select an appropriate option for management for the material (e.g., treat for reuse, or dispose of in a registered landfill.) [C073] • Implement a decommissioning and rehabilitation plan in accordance with the dam design plan. [C074] • Decommission or repair all production wells and monitoring bores, either at the end of their operating life span or in the event of a failed integrity test in accordance with the minimum construction requirements for water bores in Australia (LWBC & NMBSC, 2003) and the P&G Act and regulations to that act. Should production wells be converted into monitoring bores, do so in accordance with relevant regulations. [C150]
Inspection and monitoring	The groundwater monitoring and inspection program is an intrinsic part of the adaptive management framework and requires several aspects, associated with site-specific controls around project infrastructure and more regional monitoring of groundwater levels and groundwater quality associated with Arrow's activities, as listed below: • Install groundwater monitoring bores near dams as a leak detection measure: – The number of monitoring wells and their location will take into account site-specific hydrogeology, preferential pathways and potential receptors of impacts. – Monitor bores installed near dams will have groundwater levels and relevant water quality parameters monitored on a routine basis. – The number of monitoring bores or associated monitoring frequencies will be increased and further investigation will be triggered where impacts are identified. [C504] • Prepare groundwater monitoring reports in accordance with the P&G Act, EP Act and Water Act. [C510] • Provide chemical monitoring of contaminated soils and groundwater in relevant monitoring bores. [C515] • Ensure methods used to monitor groundwater levels and quality, together with monitoring frequencies and parameters, are in accordance with approved regulatory standards. [C521] • Develop a structured database to host groundwater data from the project (i.e., groundwater levels and groundwater quality). [C522]

Table 4.16 Management measures for groundwater across all project-related activities (cont'd)

Inspection and monitoring (cont'd)	• Install an appropriate regional groundwater monitoring network (that satisfies Arrow's obligations as described in the underground water impact reports) to: – Establish baseline groundwater level and groundwater quality conditions. – Assess natural variation (i.e., seasonal variations) in groundwater levels. – Monitor groundwater levels during the operations phase. – Monitor groundwater quality during the operations phase. – Establish suitable datum levels for each aquifer system. – Target sensitive areas where more frequent monitoring and investigation is required (e.g., groundwater-dependent ecosystems). – Monitor groundwater drawdown as a result of coal seam gas extraction. – Monitor impacts in accordance with the Water Act and regulations. – Provide an 'early warning system' that identifies areas potentially impacted by project activities to allow early intervention. [C524] • Comply with inspection and monitoring requirements developed by the Queensland Water Commission in relation to groundwater drawdown and springs. [C525]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.6 Surface Water

This section describes Arrow's approach to managing potential environmental impacts on surface water that are associated with project activities.

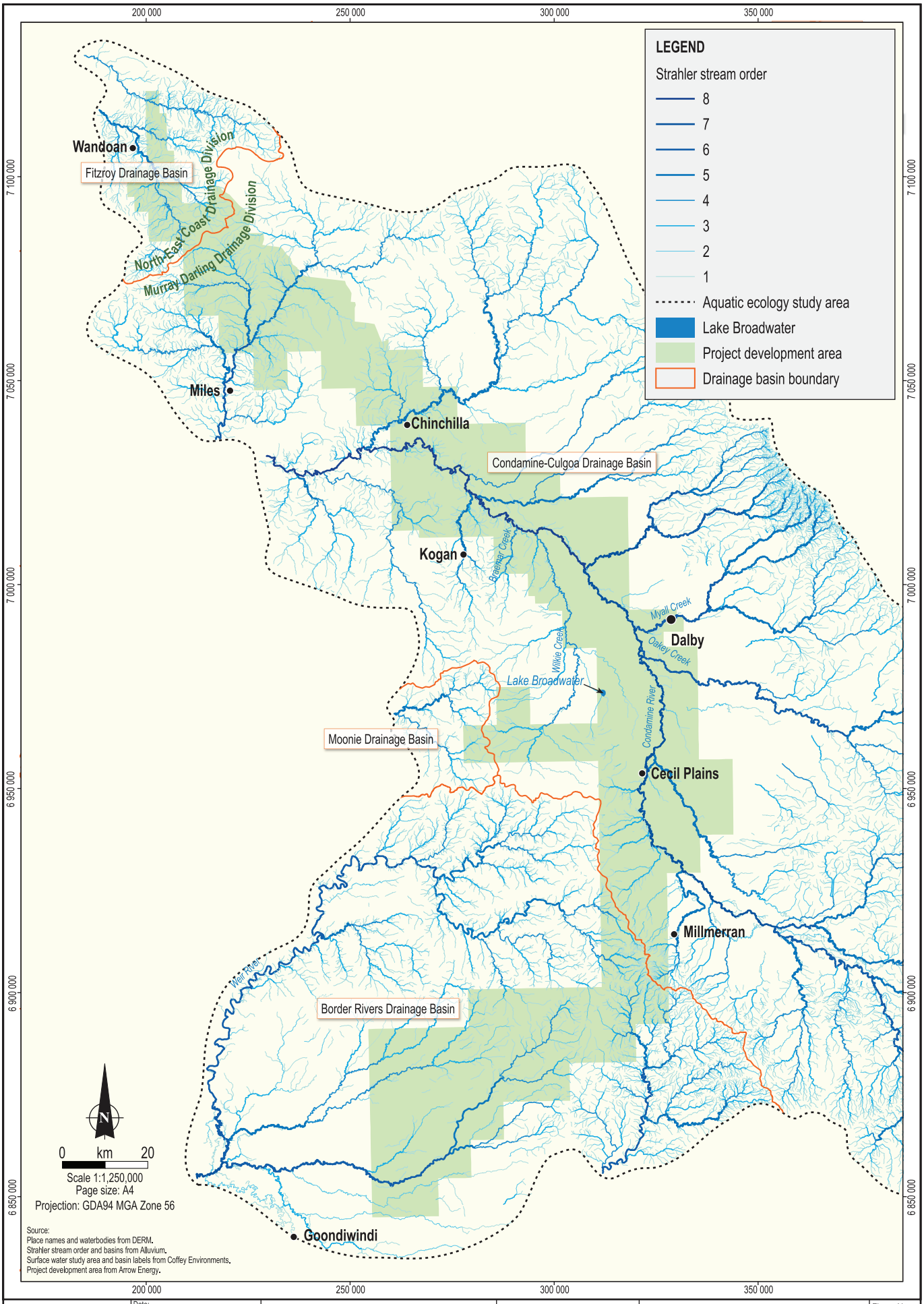
4.6.1 Existing Environment and Environmental Values

The regional surface water environment is represented by four drainage basins, all of which intersect the project development area: Condamine-Culgoa, Fitzroy, Border Rivers and Moonie.

The Condamine-Culgoa, Border Rivers and Moonie basins form part of the Murray-Darling drainage division, while the Fitzroy Basin is part of the North-East Coast drainage division (Figure 4.13). The size of each watercourse based on the Strahler stream order classification (which is an indication of the relative size of a watercourse within a climatic and geomorphic setting) is also shown on Figure 4.13.

The project development area is characterised by an extensive network of watercourses that are largely ephemeral with varying geomorphic stream reach types that provide geomorphic diversity and contribute to habitat diversity. Rivers and creeks within the project development area are generally intermittent, with many watercourses receding to disconnected pools and dry beds during the dry season.

Watercourses and other waterbodies can be classified into groups of similar geomorphic characters using the River Styles® framework (Brierley & Fryirs, 2005). The majority of the watercourse lengths within the project development area are geomorphically categorised as valley fill (i.e., alluvial and colluvial sediments across a valley floor with no channel). Valley fill and chain of ponds are the most sensitive River Styles® occurring within the project development area, 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 that they provide, the role they play in attenuating flows (reducing flood peaks and extending base flows in major downstream watercourses) and the role they play as long-term sediment stores. Floodout (another geomorphology classified River Style®) is likely to be less susceptible to erosion than valley fill and chain of ponds but still vulnerable if disturbed.



coffey environments	Date: 13.12.2011 MXD: 7040AC_04_GIS139_v1_4 File Name: 7040_04_ATT5_F04.13_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Location of project development area in relation to drainage basins	Figure No: 4.13

The hydrology of the watercourses flowing through the project development area has been extensively modified by dams, weirs and pumping infrastructure and land clearance to facilitate agricultural and grazing activities. The extent of these modifications varies between the basins.

Overland flow characteristics also vary, with vast areas of low-gradient floodplains or terrace surfaces generating little runoff except when saturated or under intense rainfall. When runoff is generated, expansive areas may be inundated.

Regional climate can be described as subtropical to semi-arid characterised by a wet summer and lower winter rainfall. Typically, rainfall and runoff occur in late spring, summer and autumn, with flooding most likely to occur in January and February.

Present and potential water uses for the catchments in the project development area include agricultural (crop production and stock watering), pastoral, urban, mining and recreational use. Water is also drawn for drinking water supply from a number of watercourses within the project development area, including the Condamine River, Balonne River, Macintyre Brook and Weir River and adjoining streams, such as Charleys Creek, Dogwood Creek and Cattle Creek.

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

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. The most common land use within the Border Rivers Basin is grazing on cleared land or in thinned native vegetation. Water consumption is dominated by irrigation, with major crops including cotton, grapes, salad vegetables and orchard fruits.

Other water uses include recreation (e.g., swimming, fishing) and aesthetics. While no specific sites of cultural and spiritual importance were identified within the project development area in relation to surface water, it is likely that cultural and spiritual values associated with the Condamine River exist.

Watercourses mapped in the project development area exhibit a range of conditions from near pristine to highly disturbed. Disturbance of watercourses has resulted in bed and bank erosion to varying levels throughout the project development area. The changes to water flows throughout the year are likely to result in shifts in water quality across the seasons, with water quality during storm events differing from that of drying pools (e.g., reductions in dissolved oxygen in drying pools (DERM, 2009b)).

Water quality results collected during the three baseline surveys in the project development area were variable and generally not consistent with guideline values developed for the protection of slightly to moderately disturbed ecosystems (ANZECC, 2000). Baseline water quality results were generally comparable to reference data provided by DERM for relevant catchments in the vicinity of the project development area. Overall, water quality characteristics vary throughout the project development area and across the four drainage basins.

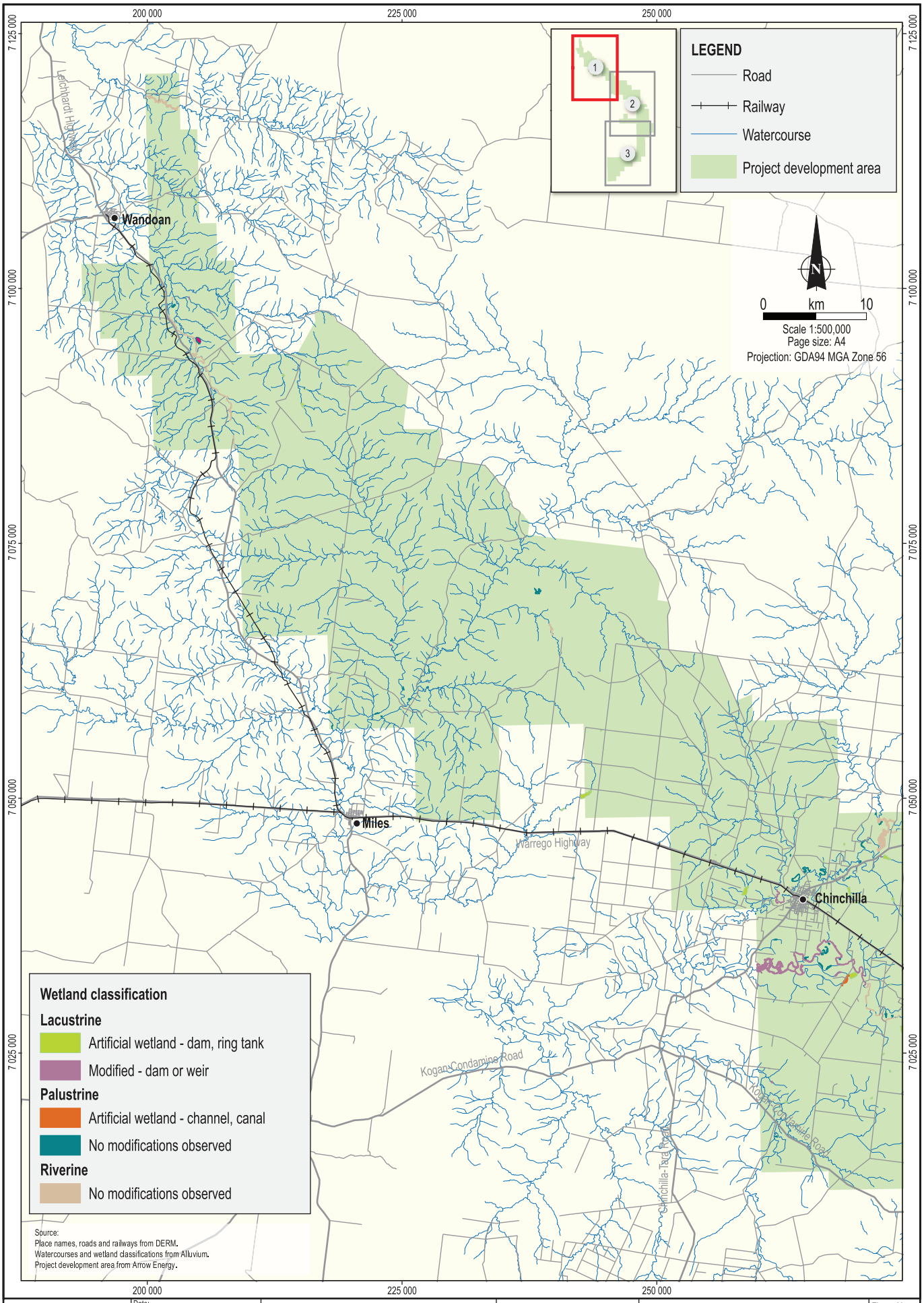
A review of historical flood information, including extent, levels and frequency, was undertaken for major waterways within the project development area using information available from BOM (2011). Floods are defined as follows:

- **Major Flooding.** This causes major inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuations 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 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 a river necessary.

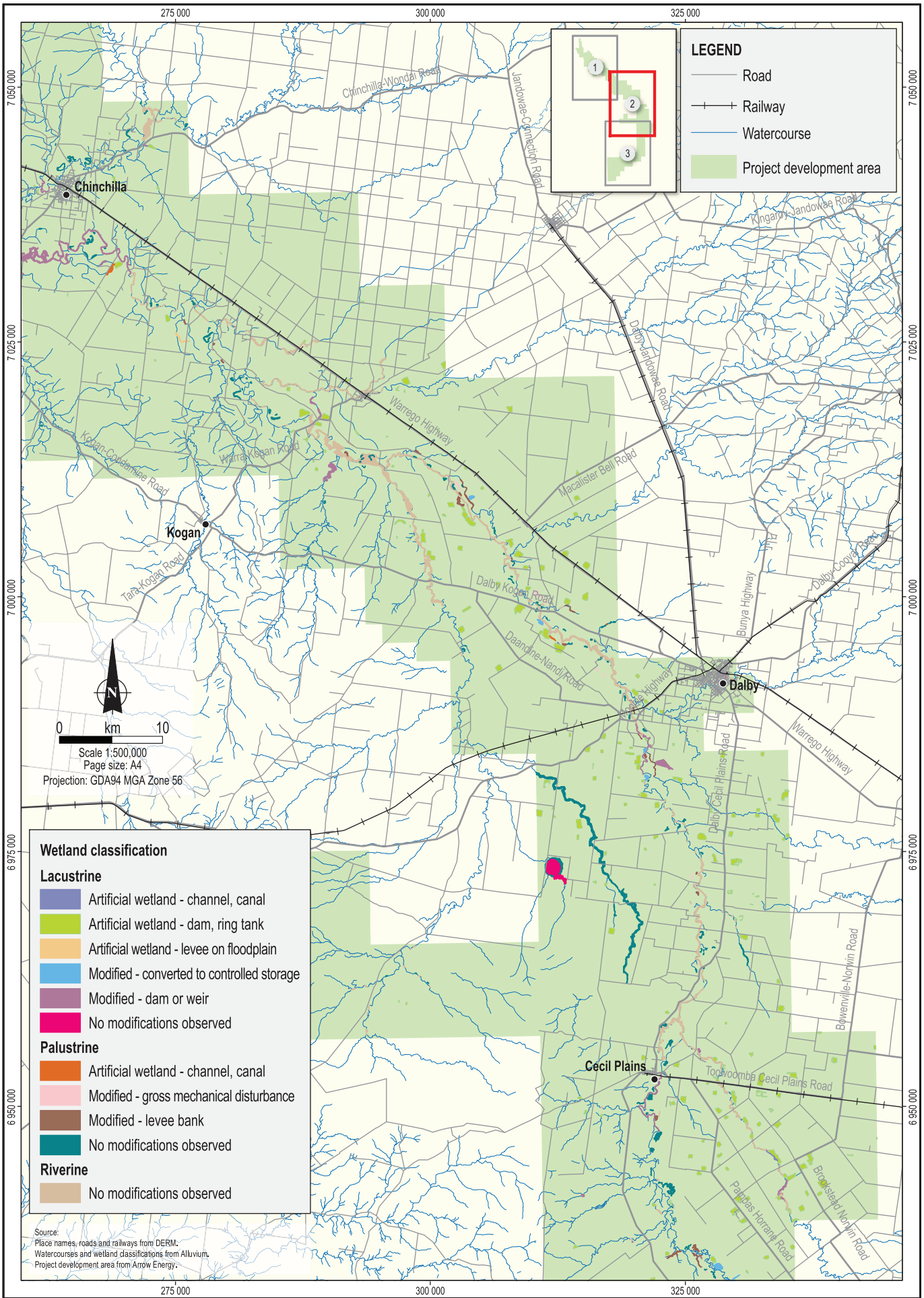
Major flooding of watercourses within the project development area has occurred 6 times over the last 10 years, generally in the months of late spring, summer and autumn. Peak water levels of 15.35 m were recorded at Chinchilla Weir in the Condamine River catchment in December 2010.

Three types of wetlands – riverine, lacustrine and palustrine – contribute to habitat diversity in the project development area. The location of wetlands and their classifications as identified by the Queensland Wetlands Program are shown in a series of figures, Figures 4.14a, 4.14b and 4.14c. The wetlands are classified by type and whether any modifications have been made or if the wetlands are artificial.

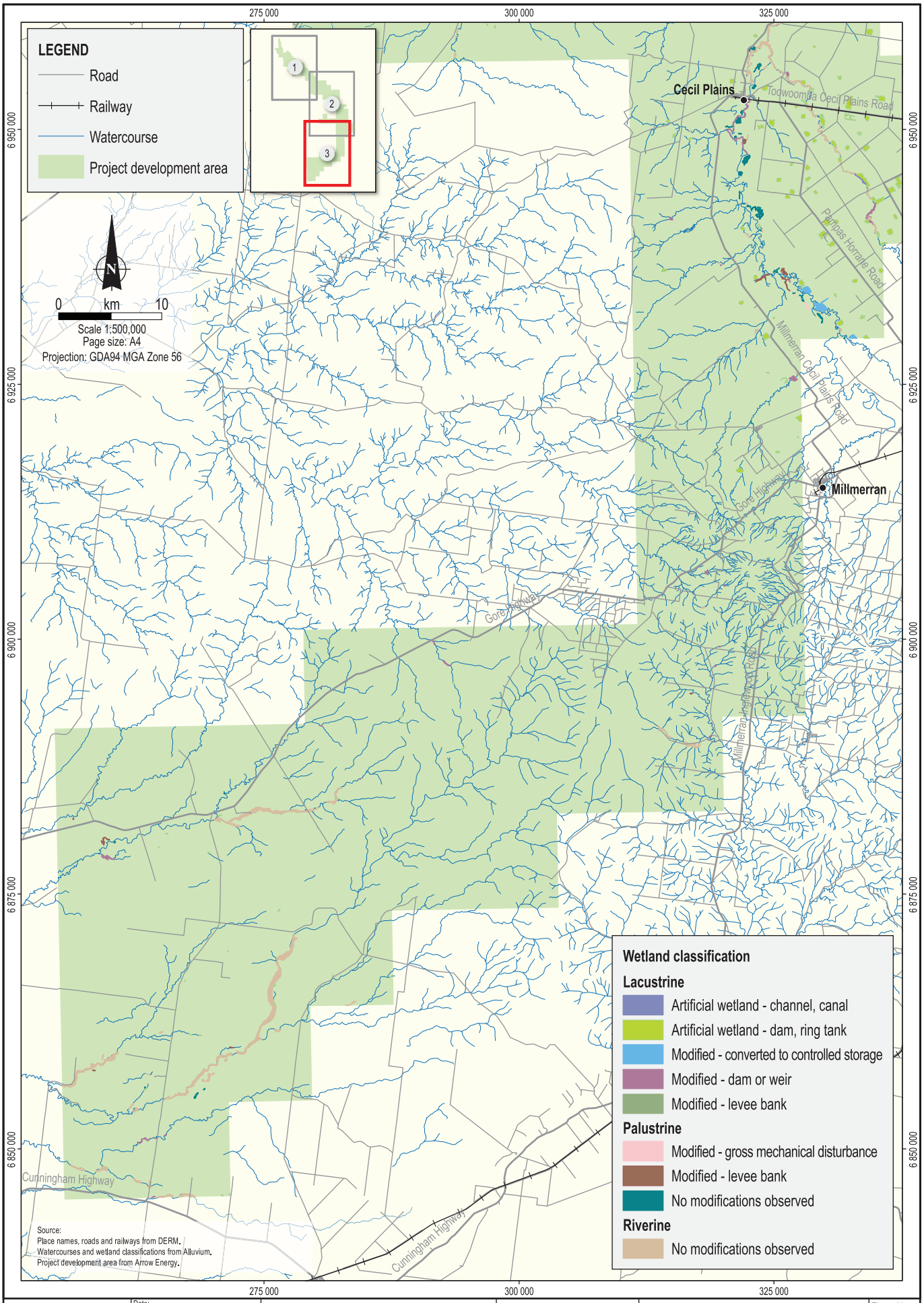
There is one wetland of national significance in the project development area; Lake Broadwater, west of Dalby, is a semi-permanent freshwater lake used for recreational purposes (e.g., skiing, swimming, boating) and is classified as a conservation park.



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS184a_v1_3 File Name: 7040_04_ATT5_F04.14a_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Queensland Wetlands Program identified wetlands (northern project development area), Map 1 of 3	Figure No: 4.14a



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS184b_v1_3 File Name: 7040_04_ATT5_F04.14b_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Queensland Wetlands Program identified wetlands (central project development area), Map 2 of 3	Figure No: 4.14b



coffey environments	Date: 06.12.2011 MXD: 7040AC_04_GIS184_v1_3 File Name: 7040_04_ATT5_F04.14c_GIS_FT	Arrow Energy Surat Gas Project	arrow energy go further	Queensland Wetlands Program identified wetlands (southern project development area), Map 3 of 3	Figure No: 4.14c

Table 4.17 summarises the characteristics contributing to surface water values relating to each existing environment.

Table 4.17 Values of the existing environment: surface water

Existing Environment	Characteristics Contributing to the Value
Wetlands (Lake Broadwater)	• High degree of ecological intactness. • Valuable aquatic habitat, in particular for: – National and state listed aquatic fauna species of significance, including the Murray cod. – Locally significant species. • Provides important ecological processes for maintaining water quality and filtering sediment and other pollutants.
Wetlands (other)	• Generally high degree of ecological intactness; however, site-specific variation occurs. • Support terrestrial and aquatic species. • Contribute to habitat diversity. • Provide aquatic habitat. • Provide ecological processes for maintaining water quality and filtering sediment and other pollutants.
High-order streams (permanent and semi-permanent watercourses)	• Moderate degree of ecological intactness with clear evidence of disturbance. • Continuous flow that supports benefits of downstream use. • Contribution to habitat diversity. • Sensitivity to disturbance. • Support of recreational activities. • Reduction of flood peaks and extending base flows.
Low-order streams (ephemeral watercourses)	• Provide marginal habitat. • Provide marginal ecological processes.

4.6.2 Potential Impacts

Potential impacts to surface water values from associated project activities are described for each project phase.

Construction

During construction of wells, gathering lines and production facilities, the following impacts could occur:

- Changes to physical form and diminished water quality from the removal of riparian vegetation and subsequent reduced bank stability and increased erosion and sediment mobilisation.
- Diminished water quality from the removal of terrestrial vegetation leading to increased runoff and sedimentation in the watercourses.
- Changes to hydrology, diminished water quality and changes to physical form from controlled and uncontrolled releases of hydrotest fluids.

- Diminished water quality from spills of hazardous materials or drilling muds.
- Damage to property from placement of infrastructure in floodplains.
- Diminished water quality from earthmoving and soil stockpiling leading to increased sedimentation in watercourses.
- Flooding, changes to physical form and changes to hydrology by placing infrastructure in surface water flow paths.
- Changes in physical form and water quality from pipeline or vehicle watercourse crossings causing bed and bank erosion and subsequent mobilisation of sediment.
- Changes in hydrology due to blockages in streams from pipeline watercourse crossings (open-cut crossings).
- Surface water quality degradation due to contaminated runoff from activities.

Operation

During operation of the wells and production facilities, the following impacts could occur:

- Changes to hydrology, diminished water quality and changes to physical form from controlled and uncontrolled releases of coal seam gas water and hydrotest fluids.
- Diminished water quality from increased runoff from compacted areas leading to sedimentation in the watercourses.
- Surface water degradation and injury to people or property from a catastrophic release of a water storage dam.
- Diminished water quality from spills of hazardous materials.
- Damage to property from placement of infrastructure in floodplains.
- Flooding, changes to physical form and changes to hydrology by placing infrastructure in surface water flow paths.
- Changes to hydrology caused by changed surface flow paths.
- Changes to physical form due to scour and generation of sediment at watercourse crossings caused by use and maintenance of access tracks.
- Surface water quality degradation due to contaminated runoff from activities.

Decommissioning

During decommissioning of wells, gathering lines and production facilities, the following impacts could occur:

- Diminished water quality from spills of hazardous materials.
- Diminished water quality from earthmoving and soil stockpiling leading to increased sedimentation in watercourses.

- Diminished water quality from increased runoff in cleared areas leading to sedimentation in the watercourses.
- Changes to physical form from activities causing sediment movement into watercourses due to the proximity of works to watercourses and wetlands.

4.6.3 Surface Water Management

Avoidance, mitigation and management measures have been proposed to achieve the identified environmental and social protection objectives. The primary means by which avoidance is achieved is through design and site selection. Management measures for all project-related activities from planning and design through to decommissioning are listed in Table 4.18.

Table 4.18 Management measures for surface water across all project-related activities

Element or issue	• Changes to physical form. • Changes to hydrology. • Surface water quality degradation.
Environmental and social objectives	• To protect Lake Broadwater Conservation Park. • To avoid or minimise degradation in water quality, impedance of flow and changes to the physical characteristics of watercourses and wetlands.
Performance criteria	• Avoid permanent impact to the physical form or hydrology of watercourses as a result of project activities. • Avoid unauthorised release of contaminants directly or indirectly into watercourses.
Implementation strategy for planning and design	• When siting facilities, avoid wetlands and consider the following: – Stream processes that may result in channel migration (either over time or as a result of project activities) and areas that are highly susceptible to erosion (i.e., dispersive soils). – Downstream values of nearby watercourses or wetlands. – Minimising changes to natural drainage lines and flow paths. – Flooding regimes and areas subject to inundation. [C151] • Minimise watercourse crossings, where practicable, during route selection. Where required, select crossing locations to avoid or minimise disturbance to aquatic flora, waterholes, watercourse junctions and watercourses with steep banks. [C152] • Avoid permanent pools, chains of ponds, and alluvial islands, where practicable, when selecting watercourse crossing points. [C153] • Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. [C154] • Where practicable, site facilities above the 1 in 100 year average flood recurrence interval. [C155] • Manage potential impacts on Lake Broadwater Conservation Park (Category A ESA) through implementation of the relevant buffer proposed (see Table 4.12). [C156] • Implement a 100-m buffer zone from the high bank of all watercourses to ensure that no development or clearance occurs within these buffers (other than construction of watercourse crossings for roads, pipelines and discharge infrastructure and associated stream monitoring equipment. [C157]

Table 4.18 Management measures for surface water across all project-related activities (cont'd)

Implementation strategy for planning and design (cont'd)	• Develop site-specific management plans for permanent and semi-permanent watercourse crossings detailing construction and environmental management requirements, including consideration of the scour potential of the watercourse. [C158] • Design culverts and drains to maintain flow and prevent headward erosion. [C159] • Consider the bank and stream bed stability when siting watercourse crossings and, where practicable, utilise existing stable crossings or locations where bedrock control exists to minimise the risk of erosion and generation of sediment. [C160] • Plan construction of watercourse crossings to occur during periods of low rainfall and low flow, when practicable. [C161] • Identify strategies to minimise coal seam gas water surface storage and to promote increased efficiency. [C205] • Develop a protocol for the discharge of coal seam gas water to watercourses in a controlled manner under emergency situations, taking the sensitivity of the receiving watercourse into consideration. Conduct discharge events in accordance with specific parameters, including discharge volumes, flows and duration, and water quality. [C498]
Implementation strategy for construction	• Minimise potential impacts on surface waters through implementation of the following measures during construction of watercourse crossings: – Avoid disrupting overland natural flow paths and, where avoidance is not practicable, maintain connectivity of flow in watercourses. [C053] – Delay clearance of stream banks until the watercourse crossing is due to be constructed, to the greatest extent practicable. Implement appropriate erosion and sediment control measures (e.g., silt fences, sediment basins and erosion berms) on watercourse approaches and banks and ensure prompt completion of construction. [C162] – Check for flood warnings or subscribe to flood warning services where relevant during construction of watercourse crossings. [C163] – Construct watercourse crossings in a manner that minimises sediment release to watercourses, stream bed scouring (e.g., the crossing location will be at low-velocity, straight sections, with the pipeline or road orientated as near to perpendicular to water flow as practicable), obstruction of water flows and disturbance of stream banks and riparian vegetation (i.e., the crossing location will be at a point of low velocity, and straight sections will be targeted, with the pipeline or road orientated as near to perpendicular to water flow as practicable). Avoid, where practicable, the use of rock gabions, as they are unsuited to watercourses of the region. [C164] – Stockpile watercourse bed material in the watercourse channel adjacent to the construction ROW only when the watercourse is dry, and site the stockpile to avoid impacts on riparian vegetation and in-stream features. [C165] – Retain coarse alluvial material from watercourse crossings for backfill armouring over the finer unconsolidated material. [C166] – Stabilise and maintain stream banks following watercourse crossings. [C167]

Table 4.18 Management measures for surface water across all project-related activities (cont'd)

Implementation strategy for construction (cont'd)	• Develop and implement a hydrostatic testing procedure prior to commencement of hydrotest activities that includes but is not limited to the following measures: – Conduct consultation with landowners and relevant regulatory authorities prior to sourcing and disposing of hydrotest water. – Avoid or minimise harmful chemical additives and reuse hydrotest water on adjacent pipeline sections where practicable. – Ensure hydrotest water that is discharged or recycled for secondary uses meets relevant statutory water quality guidelines. [C168] • Minimise potential impacts to surface waters caused by erosion and sedimentation through implementation of the following measures: – Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] – Minimise the disturbance footprint and vegetation clearing. [C020] – Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034] – Control sediment runoff from stockpiles. [C107] – Grade soil away from watercourses. [C169] – Locate soil stockpiles away from watercourses and wetlands to minimise potential for sediment runoff to enter the watercourse or wetland. [C170] • Install and maintain diversion drains to divert clean surface runoff water around production facilities and away from construction areas. [C024] • Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned. [C171]
Implementation strategy for operations	• Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035] • Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. [C066] • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. [C069] • Segregate stormwater discharge from potential contaminant process areas. [C172] • Inspect rehabilitated watercourse channels and banks following significant flow events and undertake remedial works as required. [C173] • Maximise beneficial use of coal seam gas water. [C174]

Table 4.18 Management measures for surface water across all project-related activities (cont'd)

Implementation strategy for operations (cont'd)	• Establish water quality monitoring stations upstream and downstream of discharge points to watercourses as part of a monitoring program to ensure compliance with environmental authority conditions and relevant standards. [C175] • Use coal seam gas water for dust suppression on roads or for construction and operation activities authorised in the environmental authority in accordance with the water quality parameters described in the environmental authority. [C176] • Minimise the inventory of hazardous materials stored on site. [C177]
Implementation strategy for decommissioning	Decommission infrastructure in such a manner that it will not adversely affect overland or flood flows and in accordance with relevant legislation and regulations. [C178]
Inspection and monitoring	• Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505] • Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of crossings immediately prior to, during and after construction of watercourse crossings. [C507] • Routinely monitor buffer zones and project footprint using satellite imagery. [C509] • Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of central gas processing and integrated processing facility stormwater and coal seam gas water discharge points. [C526] • Routinely visually inspect physical form integrity and monitor hydrology, turbidity, total suspended solids, pH, dissolved metals and total petroleum hydrocarbons upstream and downstream of authorised locations where water is to be discharged directly to a watercourse. [C527] • Routinely inspect spill containment controls and spill response kits. [C516] • Measure the volume and quality of treated coal seam gas water released to surface waters on a routine basis in accordance with regulatory requirements and approved release limits. [C529] • Routinely measure the volume and quality of treated sewage effluent on a routine basis in accordance with regulatory requirements and approved release limits. [C530] • Routinely monitor water quality in dams. [C009]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.7 Aquatic Ecology

This section describes Arrow's approach to managing potential environmental impacts on aquatic ecology that are associated with project activities.

4.7.1 Existing Environment and Environmental Values

Aquatic environments within the aquatic ecology study area (which includes the project development area, as well as surrounding drainage basins) are diverse, with permanent, semi-permanent and highly seasonal flowing water and non-flowing water environments represented in four drainage basins. These are the Condamine-Culgoa Drainage Basin, Fitzroy Drainage Basin, Border Rivers Drainage Basin and Moonie Drainage Basin. There are a number of storages and weirs throughout the region, and flows in the major river systems are highly regulated.

In general, the aquatic environments within the project development area are moderate to highly disturbed as a result of many decades of modification to terrestrial environments and altered drainage basin processes.

Areas of Environmental Sensitivity

Lake Broadwater Conservation Park is located within the project development area and is classified under the EP Act as a Category A environmentally sensitive area (ESA). This site is likely to be seasonally inhabited by aquatic species, potentially including EPBC Act-listed species, for foraging or spawning. There are no other Category A ESAs in the project development area. Category B and C ESAs are not relevant to aquatic ecology and are discussed in Section 4.4 (Terrestrial Ecology).

There are no declared wild rivers areas within the project development area.

Watercourses

Ephemeral Watercourses

Ephemeral watercourses may experience short periods of high flow but also undergo long periods of low or zero flow during which the streams become a series of waterholes or dry out completely.

In general, the ephemeral watercourses within the project development area are not unique on a local or regional scale and represent a very small proportion of regional aquatic habitat. They are likely to be opportunistically utilised by aquatic fauna and flora that are tolerant of significant disturbance events and that are adapted to rapidly colonising and regenerating when conditions are suitable.

These ecosystems range from being moderately disturbed by existing land use activities to being highly disturbed agricultural drainages. They contain no formal conservation status; no species, habitat or aquatic communities of special conservation significance; no fisheries values; and no ecotourism potential.

Permanent and Semi-permanent Watercourses

Permanent and semi-permanent watercourses within the project development area contain water year around. Recreational fisheries in these watercourses are considered an asset that requires protection. There are no commercial fisheries or fishing assets within the project development area or other areas that might potentially be affected.

Development and agricultural land use has resulted in the disturbance, ranging from minimal to highly disturbed, of the permanent and semi-permanent watercourses and their ecosystems. In general, these ecosystems have uniform aquatic flora, fauna and macroinvertebrate communities across the project development area as described below.

Aquatic Flora and Fauna Species

Surveys of the permanent and semi-permanent watercourses within the project development area indicate that the aquatic flora is in very poor condition and that the fish and aquatic reptile species present are generally resilient species that tolerate a wide range of conditions.

Aquatic flora is dominated by emergent and floating taxa. There is an absence of submerged aquatic flora due to the relatively high turbidity, which prevents light penetration, thus reducing the potential for submerged species to grow. Field surveys identified 23 native aquatic flora species and three introduced (exotic) aquatic flora species within the study area, none of which are species of national or state conservation significance.

Desktop studies and field surveys identified 20 native fish species, three introduced (exotic) fish species and two native turtle species. Seven of these native fish species are considered to be potentially or locally threatened; and although they are not currently listed under state legislation, they are of conservation interest due to a lack of resilience to change. Two EPBC Act–listed species were identified as being potentially present. These are the Murray cod (*Maccullochella peelii peelii*) and the Fitzroy River turtle (*Rheodytes leukops*). The Murray cod is stocked as a recreational species, and the Fitzroy River turtle could only potentially be present within the northernmost section of the project development area within the Fitzroy River drainage basin.

There is a high degree of similarity in the composition of macroinvertebrate populations between sampling sites across the project development area, irrespective of drainage basin or catchment land use. Most macroinvertebrate communities are characteristic of significantly degraded watercourses experiencing impacts through anthropogenic processes, such as water extraction and agricultural land use.

4.7.2 Potential Impacts

Potential impacts to aquatic ecological values from project activities include:

- Erosion and sediment transport.
- Decline in water quality and increased algal blooms.
- Introduction and spread of exotic species.
- Reduced movement of aquatic biota.
- Habitat loss, modification or fragmentation.

Activities with the potential to cause these impacts during the construction phase of the project include:

- The construction of road and pipeline watercourse crossings, which will involve:
  - Removal of riparian vegetation, thereby exposing the ground surface and increasing its susceptibility to increased sedimentation in watercourses and erosion. Disturbance to watercourse banks can also destroy turtle and frog habitat.

  - Earthworks and vehicle movement within the watercourse leading to potential scouring of the bed and banks and subsequent sedimentation (with the potential for sedimentation to smother benthic fauna).
  - The installation of temporary watercourse diversions, which could create an instream barrier and disrupt the hydrology and the flow of the watercourse.
- Accidental spills or release of construction waste near or in watercourses causing contamination. Terrestrial earthworks during well, pipeline and production facility construction could also cause sedimentation and the spread of exotic species.

Activities with the potential to cause impacts during the operation of the project include:

- Use of herbicides during maintenance of wellheads, production facility sites and pipeline easements.
- Accidental spills or release of waste or sanitary wastewater near or in watercourses.
- Emergency discharge of treated coal seam gas water into watercourses during periods of prolonged rainfall when the dams have reached maximum capacity.
- Use of vehicles for maintenance activities on access tracks within or near watercourses causing sedimentation (from soil erosion and runoff) and the spread of exotic species.

Activities with the potential to cause impacts during the decommissioning of the project include:

- Accidental spills near or in watercourses.
- Use of vehicles for decommissioning activities on access tracks within or near watercourses causing sedimentation (from soil erosion and runoff) and the spread of exotic species.

4.7.3 Aquatic Ecology Management

Management measures for all aquatic ecology project-related activities from planning and design through to decommissioning are listed in Table 4.19.

Table 4.19 Management measures for aquatic ecology across all project-related activities

Element or issue	• Erosion and sediment transport. • Decline in water quality and increased algal blooms. • Introduction and spread of exotic species. • Reduced movement of aquatic biota. • Habitat loss, modification or fragmentation.
Environmental objectives	• To avoid or minimise adverse impacts to the aquatic ecology within ESAs, permanent and semi-permanent watercourses and ephemeral watercourses. • To control the introduction or spread of new or existing exotic aquatic flora or fauna species.
Performance criteria	• Compliance with water quality objectives, no widespread impact to macroinvertebrates and no permanent impact to watercourse geomorphology as a result of project activities. • Successful rehabilitation, including prolonged bank stability at watercourse crossings.

Table 4.19 Management measures for aquatic ecology across all project-related activities (cont'd)

Performance criteria (cont'd)	• No unauthorised release of contaminants directly or indirectly into watercourses. • No reported instances of infestations of new or existing exotic aquatic flora or fauna species resulting from project activities.
Common implementation strategy for all phases	• Install and maintain diversion drains to divert clean surface runoff water around production facilities and away from construction areas. [C024] • Confine project traffic to designated roads and access tracks, where practicable. [C033] • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034] • Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035] • Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. [C036] • Ensure appropriate spill response equipment, including containment and recovery equipment, is available on site. [C037] • Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. [C066] • Wash down vehicles and equipment that have potentially been in contact with weeds before entering new work sites. [C099] • Ensure all relevant personnel are made aware of the location and extent of weed infestations in the vicinity of the work area and the risks involved in moving from one site or property to another. [C179] • Do not wash down vehicles in watercourses. [C180] • Avoid the use of vehicles and machinery in the vicinity of or within watercourses and riparian zones, wherever practicable. [C181] • Locate self-contained portable toilet facilities at designated work sites at appropriate distances from watercourses, ensuring that they are accessible to all operations personnel and are regularly maintained. Dispose of sewage and greywater from toilet facilities via a chemical treatment system or transport to a municipal sewage plant using a licensed contractor. [C182]

Table 4.19 Management measures for aquatic ecology across all project-related activities (cont'd)

Implementation strategy for planning and design	• Minimise the disturbance footprint and vegetation clearing. [C020] • Minimise watercourse crossings, where practicable, during route selection. Where required, select crossing locations to avoid or minimise disturbance to aquatic flora, waterholes, watercourse junctions and watercourses with steep banks. [C152] • Manage potential impacts to Lake Broadwater Conservation Park (Category A ESA) through implementation of the relevant buffer proposed (see Table 4.12). [C156] • Implement a 100-m buffer zone from the high bank of all watercourses to ensure that no development or clearance occurs within these buffers (other than construction of watercourse crossings for roads, pipelines and discharge infrastructure and associated stream monitoring equipment). [C157] • Plan construction of watercourse crossings to occur during periods of low rainfall and low flow, when practicable. [C161] • Where appropriate, design ground disturbance works to minimise the need for cut-and-fill earthworks. [C183] • Design watercourse crossings to enable passage of flows resulting from a 1 in 100 year average recurrence interval flood event, as a minimum. [C184] • Design the width of the pipeline ROWs to be narrower at watercourse crossings, where practicable. [C185] • Co-locate pipelines into one watercourse crossing corridor, where practicable. [C186] • Design washdown facilities to ensure that runoff is contained on site and does not transfer weed seeds, spores or infected soils to adjacent areas. Treat or dispose of washdown solids in a registered landfill. [C187] • Develop a declared weed and pest management plan in accordance with the Petroleum Industry - Pest Spread Minimisation Advisory Guide (Biosecurity Queensland, 2008). Undertake species-specific management for identified key weed species at risk of spread through project activities (mesquite, parthenium, African lovegrass and lippia). Increase weed control efforts in areas particularly sensitive to invasion. The pest management plan should include, as a minimum, training, management of pest spread, management of pest infestations and monitoring effectiveness of control measures. [C188] • Plan construction and maintenance activities to minimise movement of plant and equipment between properties or areas with weed infestations. [C189] • When sourcing maintenance materials, ensure that such materials as bedding sand, topsoil, straw bales and sand bags are brought to site only after it is ascertained that the materials are not contaminated with weeds and plant or animal pathogens. Request a weed hygiene declaration form from the supplier where there is possible risk of contamination in products. [C190] • Design gathering lines and tracks to avoid watercourses, drainage lines and riparian areas (particularly permanent watercourses or perennial aquatic habitat), where practicable. [C191] • Obtain all relevant permits required under the *Fisheries Act 1994* (Qld), including permits for construction of waterway barriers or disturbance of fish habitat. [C192]
Implementation strategy for construction	• Minimise the disturbance footprint and vegetation clearing. [C020] • Identify declared weeds during the preconstruction clearance survey. [C193] • Avoid transport of equipment across watercourses unless an appropriate crossing that minimises disturbance to the watercourse bed and banks and to riparian vegetation is available. [C194]

Table 4.19 Management measures for aquatic ecology across all project-related activities (cont'd)

Implementation strategy for construction (cont'd)	• Construct watercourse crossings in a manner that minimises sediment release to watercourses, stream bed scouring, obstruction of water flows and disturbance of stream banks and riparian vegetation (i.e., the crossing location will be at a point of low velocity, and straight sections will be targeted, with the pipeline or road orientated as near to perpendicular to water flow as practicable). [C195] • Ensure flumes used to construct watercourse crossings are suitably sized to maintain flows and enable fish passage. Protect the bed of the watercourse from scouring at the site of the downstream discharge of any flumes or pipes. [C196] • Store stockpiled, cleared vegetation away from watercourses or drainage lines. [C197] • If diversion of watercourse flows using pumps is required, screen the pump intakes with mesh to protect aquatic life. [C198]
Implementation strategy for operations	• Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. [C069] • Limit the use of herbicides in the vicinity of watercourses or within riparian zones. Use non-toxic, non-persistent (i.e., biodegradable) herbicides to treat weeds, except on properties where organic or biodynamic farming is practiced, for which the method of weed treatment is to be agreed with the landowner. [C199]
Implementation strategy for decommissioning	• Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled paddocks, this may not be practicable, and backfilling should be carried out in consultation with the landowner. [C071]
Inspection and monitoring	• Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505] • Routinely monitor buffer zones and project footprint using satellite imagery. [C509] • Visually inspect physical form and monitor hydrology, turbidity and pH upstream and downstream of crossings immediately prior to, during and after construction of watercourse crossings. [C507] • Routinely inspect for pest flora and evidence of pest fauna species within project disturbed areas. [C508] • Routinely visually inspect physical form integrity, macroinvertebrates, flow, turbidity, total suspended solids, pH, dissolved metals and total petroleum hydrocarbons upstream and downstream of authorised locations where water is discharged directly to a watercourse [C531] • Routinely inspect spill containment controls and spill response kits. [C516]
Auditing	Compliance with the management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.

Table 4.19 Management measures for aquatic ecology across all project-related activities (cont'd)

Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.8 Coal Seam Gas Water

This section describes Arrow's approach to managing potential environmental impacts of coal seam gas water that are associated with project activities.

4.8.1 Existing Environment and Environmental Values

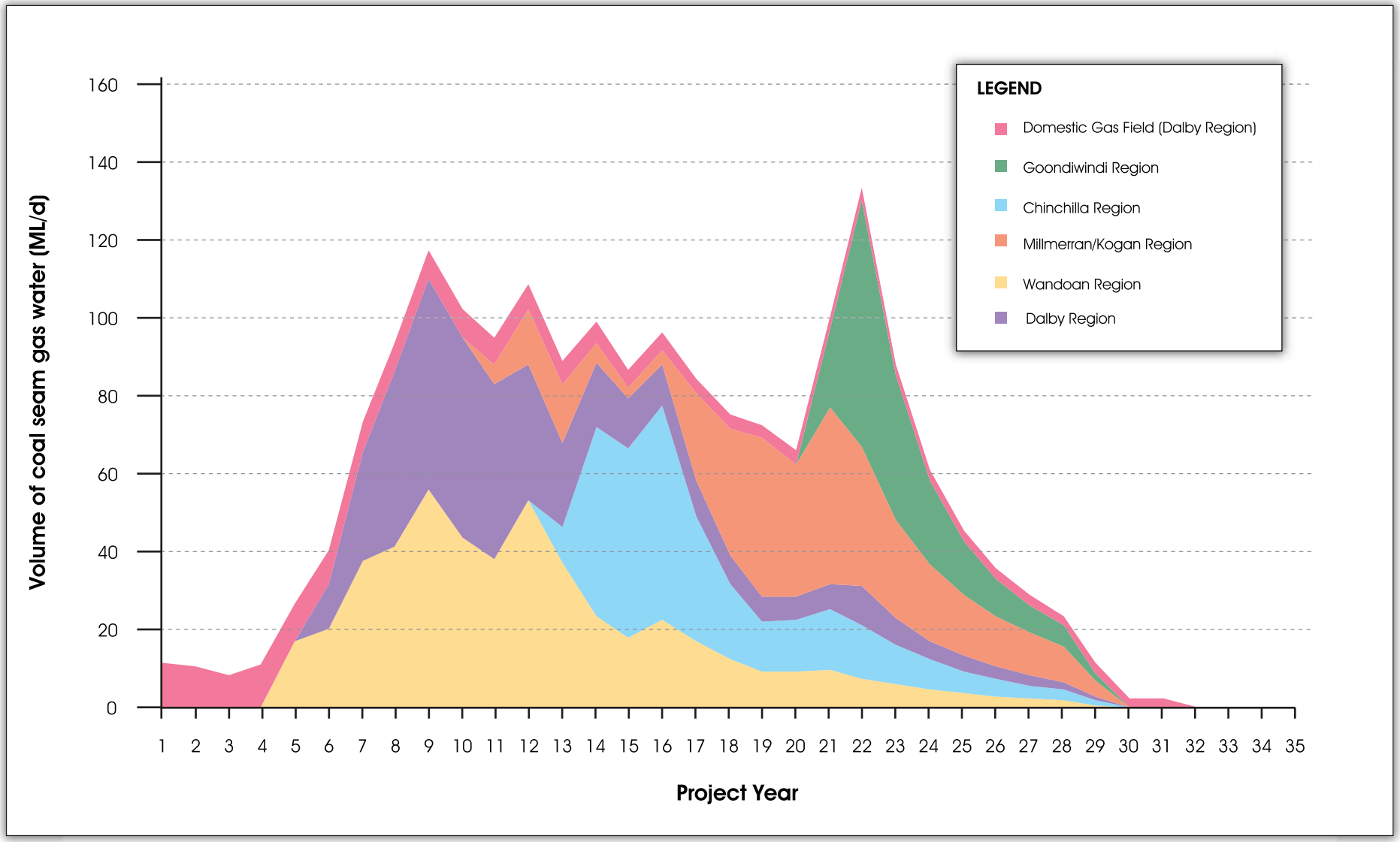
Coal seam gas is the name given to any naturally occurring gas trapped in underground coal seams by water and ground pressure. Coal seams store both gas and water. The coal seam gas is under pressure from the weight of water, holding the gas in place. When the water pressure is reduced, the gas is released. In the production process, the water pressure is reduced by drilling a well into a coal seam and then gradually pumping the water out of the seam. This allows the gas to flow to the surface in the well.

The Surat Gas Project will be producing coal seam gas from the Walloon Coal Measures, which form part of the geological sequence within the project development area. The geological sequence contains a series of interbedded groundwater-bearing formations (aquifers) and low-permeability, generally fine-grained formations (aquitards). Groundwater is commonly extracted from other aquifers (predominantly the Condamine Alluvium) within the project development area and used for a wide range of purposes (predominantly irrigation).

Coal seam gas water production across the project development area is variable but is estimated to average 22 gigalitres (GL) per annum and peak at about 43 GL per annum. The predicted cumulative annual average coal seam gas water production rates over the life of the project are presented in Figure 4.15.

The coal seam gas water quality from the Walloon Coal Measures can vary from fresh water to saline or highly turbid water. Coal seam gas water from the Surat Basin typically has the following characteristics:

- pH of approximately 7 to 11.
- Salinity generally ranging from 3,000 to 8,000 milligrams per litre (mg/L) (i.e., brackish) and total dissolved solids including sodium salts, bicarbonate salts, chlorides and others.
- Suspended solids from the well that will usually settle out over time.
- Ions including calcium, magnesium, potassium, fluoride, bromine, silicon and sulfate (as SO_4).
- Trace metals and low levels of nutrients.



	coffey environments	Job No: 7040 File Name: 7040_04_ATT5_F04.15_GL	Arrow Energy Surat Gas Project	arrow energy go further	Estimated cumulative annual average production of coal seam gas water for the Surat Gas Project	Figure No: 4.15

Table 4.20 presents concentrations for a range of coal seam gas water quality parameters reported for samples collected from 67 existing production wells currently drawing coal seam gas water from the Walloon Coal Measures.

Table 4.20 Coal seam gas water quality in the Walloon Coal Measures

Water Quality Parameter	Unit	Minimum	Maximum	Mean
pH		7.1	11.4	8.1
Conductivity (a measure of salinity)	µS/cm	830	31,000	7,223
Total dissolved solids	mg/L	534	20,150	4,694
Calcium (Ca)	mg/L	4	1,160	136
Magnesium (Mg)	mg/L	2	850	113
Sodium (Na)	mg/L	135	6,950	1,420
Chloride (Cl)	mg/L	65	12,770	2,280
Bicarbonate (HCO_3)	mg/L	5.2	1,980	561
Sulfate (SO_4)	mg/L	0	355	43

The design of water treatment and storage facilities will consider Queensland's Coal Seam Gas Water Management Policy (DERM, 2010) and the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams prepared by DERM (2011).

Infrastructure required for the treatment and storage of coal seam gas water includes:

- Water storage dams.
- Treatment facilities.
- Brine storage dams.
- Treated coal seam gas water and brine infrastructure.

Coal Seam Gas Water Management Strategy

Arrow's Coal Seam Gas Water Management Strategy (Attachment 9) seeks to manage coal seam gas water during the life of the project in a way that maximises beneficial use and minimises the environmental impacts associated with water use and disposal. The conceptual coal seam gas water management overview presented in Figure 4.16 identifies the preferred and potential management options for coal seam gas water and associated brine or salt, including treatment, storage, beneficial use and disposal. This conceptual coal seam gas water management overview is based on a 1,050-TJ/d gas production profile and presents both the average and peak expected volumes per annum. The distribution of coal seam gas water to the different management options will be continually reviewed as planning for field development evolves and opportunities for beneficial use present themselves.

Coal Seam Gas Water Management Options

Although coal seam gas water is considered a waste under the *Environmental Protection Act 1994* (Qld) (EP Act), the government may approve its use as a 'resource' on a case-by-case basis if the water has a beneficial use that would negate the need for its disposal. When used beneficially, coal seam gas water ceases to be defined as a waste.

The management options presented below apply to treated and untreated water. Untreated water may be suitable for any of the beneficial use options identified in Figure 4.16, depending upon the water quality requirements of the end user. However, investigations indicate that there is limited demand as yet for the beneficial use of untreated coal seam gas water in the project development area.

Substitution of Allocations

Arrow's preferred approach is to beneficially use coal seam gas water by substituting existing water allocations in the area; i.e., the volumes of groundwater and surface water currently extracted in accordance with existing allocations would be replaced with coal seam gas water provided by Arrow. The strategy proposes substitution of water allocations for the duration of the project until the production of coal seam gas water ceases. The other potential beneficial uses currently identified are discussed under 'Beneficial Uses of Coal Seam Gas Water' below.

New Uses

Over the course of the project, it is anticipated that new opportunities for the beneficial use of treated and untreated water will emerge and be investigated.

Injection

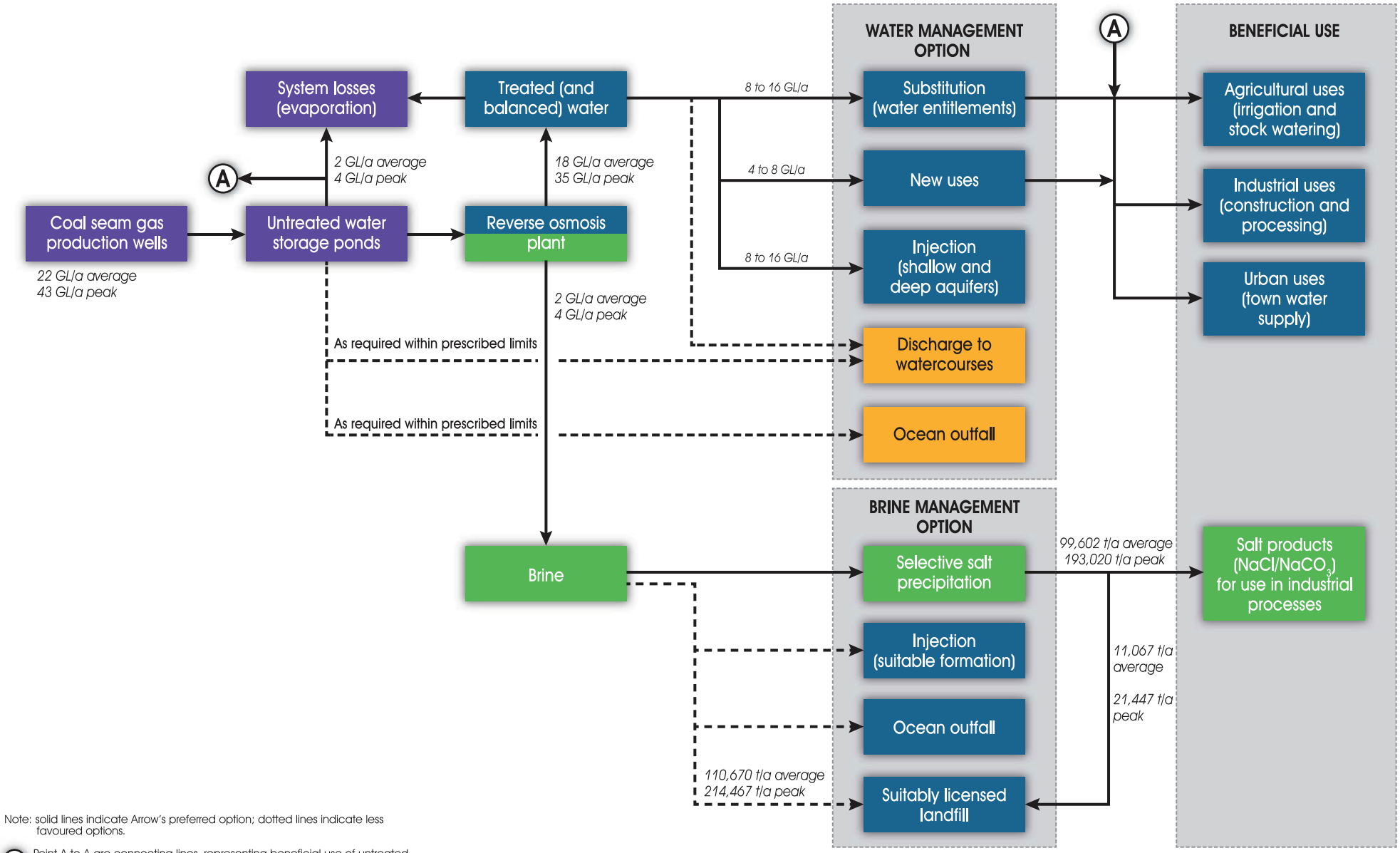
The benefits of injecting water are to offset the impacts of groundwater depressurisation and to provide a disposal option for any water that cannot be accommodated through another beneficial use.

Arrow conducted an injection feasibility study in 2010 and is preparing environmental authority applications to conduct shallow and deep aquifer injection trials. The purpose of the trials is to understand the suitability of the formations for injection and to determine the potential volumes and rates of water that could be injected. Further studies and trials will be required to define the extent and feasibility of injection over the project development area.

Disposal to Watercourses

Disposal to watercourses will be considered in the event that beneficial uses of coal seam gas water are temporarily unavailable or the demand for water decreases and alternative disposal options are required to maintain dam integrity and safety, e.g., due to adverse climatic conditions, such as prolonged rainfall or severe storms.

Coal seam gas water may be discharged, subject to obtaining or holding relevant approvals, to watercourses in a controlled manner, taking the sensitivity of the receiving watercourse into consideration. Discharge events will be conducted in accordance with specific parameters, including discharge volumes, flows and duration, and water quality. Appropriate monitoring will be required to ensure the released water adequately dilutes and does not cause any adverse effects on the receiving aquatic environment. At this stage, it is anticipated that disposal to watercourses will only be conducted under emergency conditions.



Note: solid lines indicate Arrow's preferred option; dotted lines indicate less favoured options.

(A) Point A to A are connecting lines, representing beneficial use of untreated coal seam gas water within prescribed limits.

coffey environments	Job No: 7040	Arrow Energy	arrow energy go further	Conceptual coal seam gas water management overview	Figure No: 4.16
	File Name: 7040_04_ATT5_F04.16_GL	Surat Gas Project			

Ocean Outfall

Disposal of coal seam gas water to the sea via an ocean outfall pipeline is recognised as a feasible option; however, it is not the preferred option. In the event that preferred coal seam gas water management options do not eventuate, the feasibility of an ocean outfall as an emergency or alternative disposal option for coal seam gas water will be evaluated. This evaluation will be conducted at the time of detailed design of the field and facilities.

Beneficial Uses of Coal Seam Gas Water

Implementation of the proposed coal seam gas water management options will result in the supply of coal seam gas water to the following beneficial uses.

Agriculture

Irrigation. Irrigation is the predominant water use within the project development area. Arrow is pursuing options to substitute existing allocations and supply water to new irrigation projects, both of which may include flood irrigation. Key considerations for providing coal seam gas water to third parties for irrigation include:

- The ability of the third party to take large volumes of water regularly and reliably (the third party will need to have buffer storage in the event that water cannot be used daily, such as during and following storm events or prolonged periods of rainfall).
- The location of the third party in relation to the water treatment facility (due to the cost of transporting water over large distances).
- The point of transfer of responsibility (Arrow is responsible and liable for water pipelines from a water treatment facility to a defined transfer point where responsibility for the water changes hands. Arrow intends that the water and the implications of its use will be the responsibility of the third party once the water is in their possession as Arrow retains no control over how the water is used beyond the transfer point).

Other Agricultural Uses. Other potential agricultural beneficial uses include provision of water for livestock watering purposes (including at feedlots).

Industrial Uses

Coal seam gas water may be used for industrial purposes in Arrow's operations, e.g., dust suppression, drilling and construction water supply, and power station cooling. Arrow will also continue to supply existing third-party users and look for further similar opportunities in the future.

Urban Uses

Arrow has undertaken a preliminary analysis of augmenting the Dalby town water supply with coal seam gas water. Augmenting town water supplies would decrease reliance on potable aquifers.

Brine Management Options

Brine is a significant by-product of the water treatment process and also requires specific measures to manage its storage, use or disposal.

Assuming an average salt concentration of 4,500 mg/L, Arrow expects that treatment of coal seam gas water will generate in the order of 4.5 t of salt per megalitre of coal seam gas water. Arrow will

continue to monitor coal seam gas water quality as the development progresses; however, planning for the development has assumed that similar water quality and salt concentrations will be observed across the entire project development area.

Figure 4.16 displays the brine management options and the expected average and peak annual volumes of salt production.

Although beneficial use is the preferred option for brine management, for the purposes of this impact assessment it is assumed that brine will be stored in dams and disposed of to a suitably licenced landfill.

Selective Salt Precipitation

The concentrated brine produced through water treatment is comprised of sodium chloride (salt), carbonate and bicarbonate salts (soda ash). Arrow is consulting commercial enterprises to investigate viable opportunities for the beneficial use of these potential products. As part of this process, Arrow will commission selective salt precipitation trials to:

- Understand the chemical composition of the brine.
- Identify methods to enhance precipitation of the brine.
- Identify viable chemical processes to transform the brine into commercial products.

Brine Injection

Should Arrow identify an appropriate formation during the exploration phase of the project, disposal of brine via injection will be considered. A criterion for injection is finding a target formation where the water quality is lower than that of the brine. To date, no such target formations have been identified.

Ocean Outfall

Disposal of brine to the sea via an ocean outfall pipeline is a feasible option that is being investigated by Arrow. As with coal seam gas water, the viability of an ocean outfall will be evaluated further at the time of detailed design of the field and facilities.

Suitably Licenced Landfill

An assessment of waste disposal facilities for brine indicates that suitably licenced facilities exist in the region. It is assumed that other commercial operations will be developed to capitalise on this waste stream. Arrow will develop appropriate storage capacity to manage brine until such time as permanent disposal solutions are operational. The closest currently available suitably licenced waste disposal facility is located at Swanbank, near Ipswich. This EIS has assumed that all brine concentrate will be trucked to Swanbank.

4.8.2 Potential Impacts

Potential impacts related to the management of coal seam gas water throughout all phases of the project include:

- Diminished surface water and groundwater quality and subsequent impacts on ecosystems and third-party users (including users downstream).
- Altered physical form and changes to hydrology within watercourses.

Other impacts related to the treatment, storage, beneficial use and disposal of coal seam gas water and its by-products are included in the following sections:

- Section 4.2, Geology, Landform and Soils.
- Section 4.4, Terrestrial Ecology.
- Section 4.5, Groundwater.
- Section 4.6, Surface Water.
- Section 4.7, Aquatic Ecology.
- Section 4.9, Dams.

4.8.3 Coal Seam Gas Water Management

The primary mitigation measure will involve the application of a hierarchy of beneficial use and disposal options that form the basis of the coal seam gas water management strategy as described above.

General management measures for coal seam gas water across all project-related activities from planning and design through to decommissioning are listed in Table 4.21. Specific management measures associated with other environmental values potentially impacted by the management of coal seam gas water (such as those related to groundwater and to surface water) are contained within the relevant component sections of the Environmental management plan.

Table 4.21 Management measures for coal seam gas water across all project-related activities

Element or issue	• Diminished surface water quality. • Diminished groundwater quality. • Diminished soil quality. • Altered physical form and changes to hydrology within watercourses due to discharge of coal seam gas water to watercourses. • Altered surface water supply and quality to downstream users due to discharge of coal seam gas water to watercourses. • Altered aquatic and terrestrial ecological processes.
Environmental and social objectives	• To maximise beneficial use of coal seam gas water and brine. • To minimise impacts to the receiving environment associated with coal seam gas water use and disposal.
Performance criteria	• Beneficially use the majority of coal seam gas water. • No releases of coal seam gas water or brine to watercourses or land except under authorised and controlled (emergency) situations. • Compliance with water quality objectives and no permanent impact to the physical form or hydrology of watercourses as a result of project activities.
Common implementation strategy for all phases	• Maintain water balance models for long-term planning and management of coal seam gas water. Review and update modelling in alignment with the production-forecasting schedule. [C204] • Identify strategies to minimise coal seam gas water surface storage and to promote increased efficiency. [C205] • Ensure coal seam gas water used for dust suppression on roads or for construction and operation activities is treated if required. [C497]

Table 4.21 Management measures for coal seam gas water across all project-related activities (cont'd)

Implementation strategy for planning and design	• Develop and continually maintain the coal seam gas water management strategy throughout the project life to optimise the investigation and implementation of the potential coal seam gas water management options in alignment with the overall project development. [C201] • Develop a protocol for the discharge of coal seam gas water to watercourses in a controlled manner under emergency situations, taking the sensitivity of the receiving watercourse into consideration. Conduct discharge events in accordance with specific parameters, including discharge volumes, flows and duration, and water quality. [C498]
Implementation strategy for operations	• Discharge water from project activities at a rate and location that will not result in erosion. Install additional erosion protection measures, including energy dissipation structures, at discharge outlets. [C066] • Incorporate into an emergency response plan or water management plan procedures for the controlled discharge of coal seam gas water under emergency conditions. Procedures will include water balance modelling, weather monitoring and forecasting, stream flow data, notification and reporting. [C069] • Demonstrate the requirement for disposal when beneficial uses are unavailable, including details of the control measures that will be implemented. [C203]
Inspection and monitoring	• Routinely visually inspect physical form integrity and monitor hydrology, turbidity, total suspended solids, pH, dissolved metals and total petroleum hydrocarbons upstream and downstream of authorised locations where water is to be discharged directly to a watercourse. [C527] • Measure the volume and quality of treated coal seam gas water released to surface waters on a routine basis in accordance with regulatory requirements and approved release limits. [C529] • Maintain and update a water balance model that includes but is not limited to: – Monitoring of volume and quality of coal seam gas water produced and treated. – Monitoring of disposition volumes of treated and untreated coal seam gas water. – Monitoring of the volume of brine and its by-products used beneficially or disposed to landfill. [C539] • Ensure that the quality of coal seam gas water used for dust suppression meets the prescribed limits. [C540]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.9 Dams

The following sections describe the requirements for regulated dams, including design, operation and safety.

4.9.1 Existing Environment and Environmental Values

Dams are necessary for the storage of coal seam gas water and brine that are produced as part of coal seam gas extraction and coal seam gas water treatment for the Surat Gas Project. In addition, water used for hydro-testing may be diverted to holding dams prior to release.

Water storage dams will be assessed using the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams prepared by DERM (2011). If a dam is assessed as being in the significant or high-hazard category, it will be considered a regulated dam and will be registered with DERM.

Each central gas processing facility will contain a water transfer station, which comprises a water transfer dam and a pumping station. The water transfer station is used to manage the water received from field compression facilities via pipelines and directly from local gathering systems. A surge dam will also be constructed at each facility as part of this system to store water in the event of an emergency (e.g., the reverse osmosis plant is unavailable to accept water). The collected water is eventually pumped to an integrated processing facility for storage, treatment and disposal.

The reverse osmosis treatment of water will produce concentrated brine, which will be stored in brine dams, which are considered to be regulated dams.

Water storage requirements for each of the production facility types are shown in Table 4.22.

Table 4.22 Water storage requirements for production facilities

Production Facility	Water Treatment and Storage
Field compression facility	No coal seam gas water treatment onsite, and no water storage.
Central gas processing facility	• No coal seam gas water treatment onsite. • Pumping station. • 600-ML water transfer dam.
Integrated processing facility	• Reverse osmosis water treatment capacity of 30 to 60 ML/d requiring two 1,440-ML brine dams. • Water storage facilities to include: – 840-ML feedwater dam. – 960-ML treated water dam.

Dam safety is controlled through dam safety guidelines, which will apply for all facilities forming part of the project development. Dams will accordingly be designed and sized to account for predicted flood conditions. Each dam will be subject to separate approvals by the regulating authority. Each approval will require the incorporation of general and specific controls to avoid, mitigate or manage threats associated with flooding.

Environmental values to be protected with regard to dams include:

- Land use capability, including maintaining the agricultural values of the land.

- The life, health and wellbeing of people.
- The diversity of ecological processes and associated ecosystems.
- The biological integrity of aquatic ecosystems and the suitability of waters for primary industry or recreational purposes.
- The suitability of coal seam gas water for use in agriculture.

4.9.2 Potential Impacts

Potential impacts of dams from associated project activities are described for each project phase.

Construction and Operation

- Dust and noise emissions from earthworks and vehicular activity.
- Loss of vegetation or habitat due to clearing requirements.
- Fauna mortality due to entrapment in dams.
- Salinisation of land surrounding dams due to spills, leaks and the inappropriate containment of coal seam water or brine.
- Salinisation of shallow groundwater in the vicinity of dams due to the long-term seepage and migration of coal seam water or brine.
- Disruption of overland flows.
- Surface water degradation and injury to people or property from a catastrophic release of a water storage dam.
- Loss of productive land through construction of dams.
- External events, such as flooding, extreme rainfall events, earthquake or land subsidence, causing dam overflow and subsequent surface water degradation.

4.9.3 Dams Management

The primary mitigation measure will be to design, construct and monitor dams in accordance with the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011b), Queensland standards and DERM guidelines.

Management measures related to dams for all project-related activities from planning and design through to decommissioning are listed in Table 4.23.

Table 4.23 Management measures for dams across all project-related activities

Element or issue	• Impacts on land use relative to the footprint of the dam. • Hazard to people if the dam overtops or fails. • Impacts from salinity through leakage of untreated coal seam gas water or of brine. • Loss of habitat relative to the footprint of the dam. • Diminished surface and groundwater quality if the dam overtops or fails.
Environmental and social objectives	• To ensure no uncontrolled release or leakage occurs and that coal seam gas water and brine in regulated dams is appropriately managed.
Performance criteria	• Operated and maintained in accordance with the certified design plan.
Implementation strategy for planning and design	• Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water dams and brine dams. [C124] • Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. [C154] • Subject each dam to separate approvals by the regulating authority. Each approval will require the incorporation of general and specific controls to avoid, mitigate or manage threats associated with flooding. [C206] • Use an independent, suitably qualified, third party to certify that dams meet the dam design plan. [C209] • Have in place a system for the collection and proper disposal of any contaminants that move beyond the bounds of the containment system of brine dams. [C210] • Design and size dams to account for predicted flood conditions. [C211]
Implementation strategy for construction	• Develop the construction, design and monitoring requirements for new dams (either raw water, treated water or brine dams) and determine the hazard category of the dam in accordance with the requirements of the most recent version of Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011b). Construct the dams under the supervision of a suitably qualified and experienced person in accordance with the relevant DERM schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements. [C141] • Line banks of dam with an impervious lining. [C213] • Design dams to have an egress (escape point) for wildlife. [C214]
Implementation strategy for operations	• Establish overflow and operational controls in accordance with the dam operating plan. [C215] • Inspect and maintain dam integrity. [C216]
Implementation strategy for decommissioning	• Implement a decommissioning and rehabilitation plan in accordance with the dam design plan. [C074]
Inspection and monitoring	• Implement the dam operating plan. [C207] • Routinely monitor water quality in dams. [C009] • Monitor dam levels. [C528] • Have a suitably qualified person routinely monitor the integrity and available storage of dams. [C532]

Table 4.23 Management measures for dams across all project-related activities (cont'd)

Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.10 Noise and Vibration

This section describes Arrow's approach to managing potential environmental impacts relating to noise that are associated with project activities.

4.10.1 Existing Environment and Environmental Values

The environmental values to be protected from noise and vibration are the qualities of the acoustic environment conducive to the following:

- Protecting the health and biodiversity of ecosystems.
- Protecting human health and wellbeing by ensuring a suitable acoustic environment for individuals to do any of the following:
  - Sleep.
  - Study or learn.
  - Be involved in recreation, including relaxation and conversation.
- Protecting the amenity of the community.
- In relation to vibration only, protecting the structural and cosmetic integrity of cultural heritage sites and dwellings.

The existing noise environment is dominated by natural sounds, such as birds and wind in the trees, resulting in a low noise environment typical of rural settings. There are, however, some areas where existing facilities associated with the coal seam gas, power generation or mining industries may have an influence on the existing acoustic environment.

Baseline noise monitoring at four representative locations in the project development area confirmed low ambient (L_{Aeq}) and background (L_{A90}) noise levels in the absence of existing coal seam gas industry activities. Elevated levels were recorded at sensitive receptors in proximity to existing production facilities. The location of potential sensitive receptors is illustrated in Figures 4.1a, 4.1b and 4.1c.

Using this baseline data, each monitoring location's rating background level was calculated and is summarised in Table 4.24. These background levels are considered to be representative of all seasons.

Table 4.24 Calculated rating background levels

Measurement Location	Industrial Noise Influence	Rating Background Level (dB(A))*		
		Day	Evening	Night
ML 1	Yes	26	29	26
ML 2	No	29	22	19
ML 3	No	25	22	19
ML 4	Yes	32	34	34

*The rating background level is the median of the daily lowest tenth percentile (lowest 10th percent) of background noise levels, giving an overall background noise level for an assessment period (day, evening or night) over a monitoring period of three to seven days.

No appreciable vibration sources could be detected during inspection of the four representative measurement locations.

4.10.2 Potential Impacts

Potential impacts to the acoustic environment from project activities include:

- Environmental noise disturbance. This includes nuisance noise and background noise creep, which is when noise levels progressively creep higher over time.
- Vibration-induced human discomfort and structural damage.

Activities with the potential to cause these adverse impacts on the values of the acoustic environment during the construction, operations and decommissioning phases of the project include the following:

- Construction of the production wells, which includes site preparation, drilling and well construction.
- Construction of the associated gas and water gathering pipelines.
- Construction of the medium- and high-pressure gas pipelines that connection production facilities to one another and with the sales gas pipeline.
- Construction of the production facilities, comprising the field compression facilities, central gas processing facilities and integrated processing facilities.
- Blasting during construction. Blasting is not anticipated during construction of the project, but it was considered in the assessment should the need arise.
- Operation of the production wells and the production facilities.
- Operation of the power generators.
- Decommissioning of the production wells.
- Decommissioning of powerlines in the event that mains power is used to eliminate the need for a wellhead generator.
- Decommissioning of the production facilities.

Predicted Construction Noise Levels

Given that construction equipment and techniques have also not been finalised, noise levels were modelled based upon known sound levels of typical construction equipment.

For construction of production facilities, modelling predictions indicate that, under worst-case meteorological conditions where noise propagation is pronounced, the daytime long-term noise criterion of 40 dB(A) will be met at sites located 3 km or more from the facility site. Noise criteria will be met within 3 km of a production facility with the application of appropriate acoustic treatments.

For construction of production wells and pipelines, modelling predictions indicate that acoustic treatment will be required for the noise at sensitive receptors to meet established criteria.

Predicted Operational Noise Levels

Production facility operational noise was modelled at each of the reference locations under the assumption of a worst-case noise scenario where all equipment is operating simultaneously and continuously, using a 150-TJ/d integrated processing facility, which is considered to be the facility that would generate the most noise. The noise levels, modelled without any acoustic treatment, are shown as noise contours around the integrated processing facility in Figure 4.17.

The modelling of sound propagation from a typical facility operating at full output, indicates that, without any acoustic treatment, the long-term night-time noise criterion of 28 dB(A) will be met at the reference locations at a distance of 5 km or more from the production facility. The application of acoustic treatment will ensure that the long-term night-time noise criterion of 28 dB(A) can be met at all reference locations located 1 km or more from the production facility (Figure 4.18).

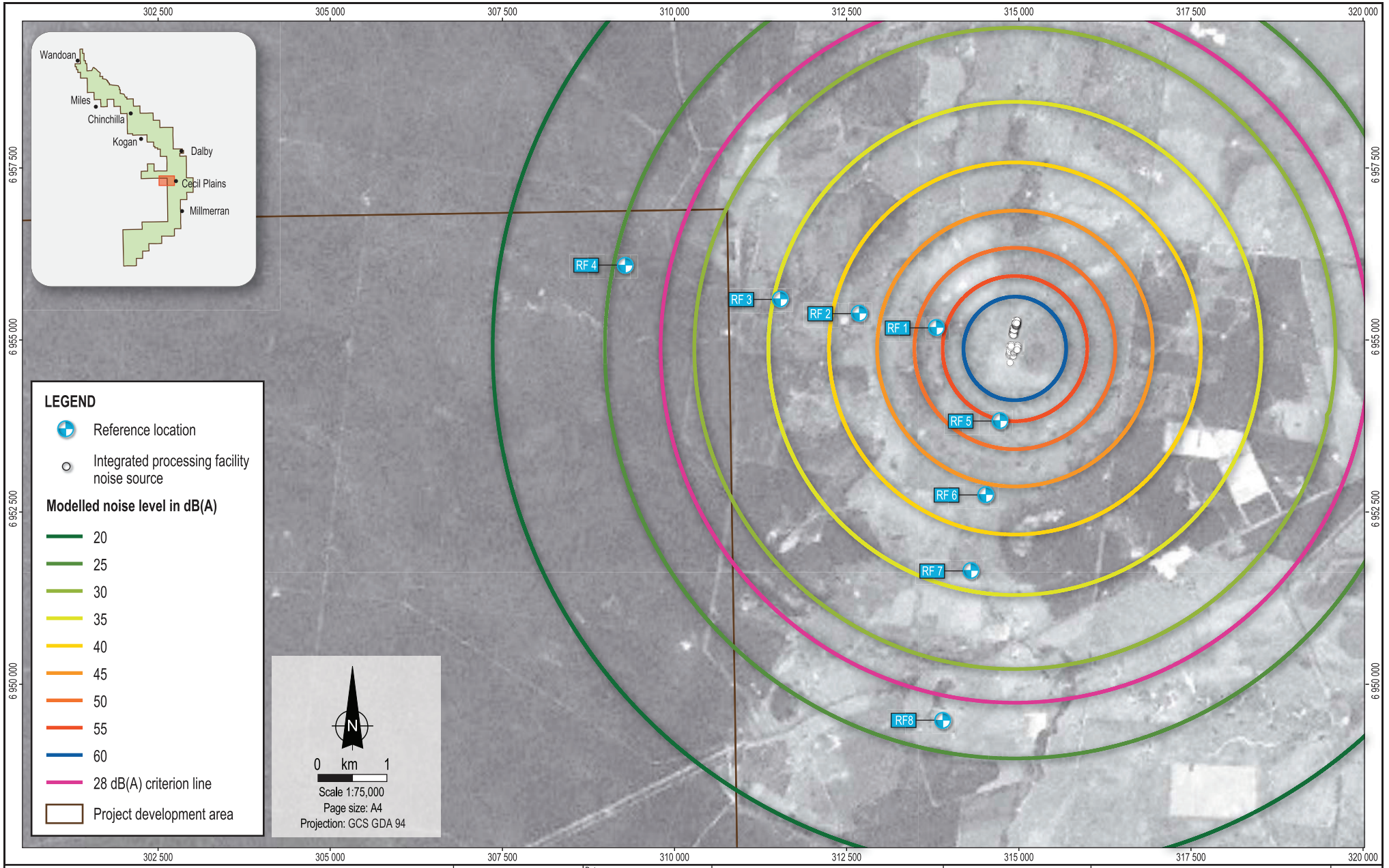
Production well operational noise modelling predicted that, without any acoustic treatment, the long-term night-time noise criterion of 28 dB(A) can be met at a distance of 300 m from a production well. This distance decreases to 200 m for the alternative scenario where the 5.7-L gas generator is replaced by the use of electricity from the power grid, and to 80 m with the incorporation of acoustic treatments (e.g., barriers and equipment housing) into facility design.

There will be no significant noise sources associated with the operation of water and gas pipelines as they will be located underground.

Modelling of short-term noise sources (for example, gas flaring) indicates that the short-term night-time criterion of 28 dB(A) will be met at locations 1 km or more from a typical integrated processing facility. Facilities will be sited to provide adequate separation from sensitive receptors, although short-term exceedences might occur under emergency conditions.

Modelling of low-frequency noise levels indicates that, with the application of acoustic treatment at the source, the criterion of 20 dB(A) during the evening or night and 25 dB(A) during the day will be met at locations 1 km or more from the source.

Vibration levels throughout the construction and operation of the project are expected to be below the threshold of human detection and to not cause structural damage at sensitive receptors that are located at distances greater than 100 m from the activity.



Source:
Place names from GEODATA250k.
Noise contours, receivers and IPF noise sources from Sonus.
Project development area from Arrow Energy.
Imagery from ArcOnline (currency unknown).

coffey environments

Date: 22.11.2011
MXD: 7040AC_04_GIS112_v0_3
File Name: 7040_04_ATT5_F04.17_GIS_GL

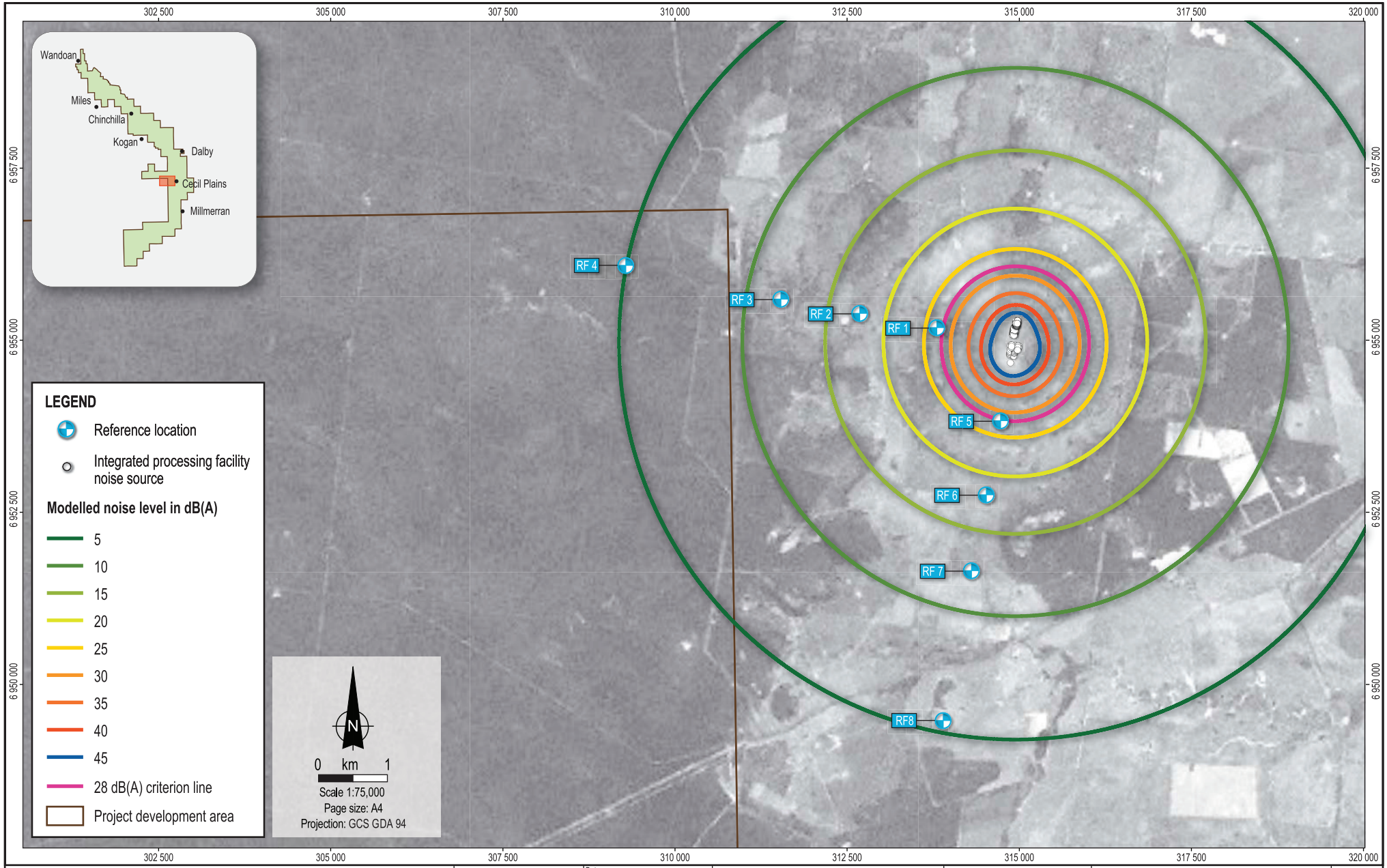
Arrow Energy

Surat Gas Project

arrow energy go further

Noise contours – without acoustic treatment

Figure No: 4.17



Source:
Place names from DERM.
Noise contours, receivers and IPF noise sources from Sonus.
Project development area from Arrow Energy.
Imagery from ArcOnline (currency unknown).

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Date: 22.11.2011
MXD: 7040AC_04_GIS141_v1_1
File Name: 7040_04_ATT5_F04.18_GIS_GL

Arrow Energy

Surat Gas Project

arrow energy go further

Noise contours – with the acoustic treatment required to achieve 28 dB(A) at 1 km

Figure No: 4.18

4.10.3 Noise and Vibration Management

A management hierarchy of avoid, minimise and manage impacts was applied when developing noise and vibration management measures.

Therefore, the primary mitigation measure will be the exploration of opportunities to maximise the distance of project development sites from the nearest sensitive receptors. The relatively sparse pattern of occupation throughout the project development area provides opportunities to site the infrastructure to provide adequate separation; i.e., the need for acoustic treatment is minimised.

Once locations are finalised, equipment selection and facility design will be undertaken during detailed engineering to ensure noise and vibration criteria are met at sensitive receptors. This process will consider best-practice noise attenuation technology to control and prevent background creep, contain and minimise variable noise, and avoid sleep disturbance.

Residual impacts are expected to be negligible as the impact assessment determined that relevant noise and vibration criteria can be achieved at sensitive receptors through the application of acoustic treatments.

Management measures for noise and vibration for all project-related activities from planning and design through to decommissioning are found in Table 4.25.

Table 4.25 Management measures for noise and vibration across all project-related activities

Element or issue	• Environmental noise disturbance. This includes nuisance noise and background noise creep, which is when noise levels progressively creep higher over time. • Vibration-induced human discomfort and structural damage.
Environmental and social objectives	• To ensure that noise emissions from project activities comply with applicable noise and vibration criteria. • To protect the amenity of sensitive receptors by reducing noise and vibration impacts from production facilities and associated workforce and infrastructure.
Performance criteria	• All complaints are registered, addressed and closed out. • Applicable noise and vibration levels are met at the sensitive receptor.
Common implementation strategy for all phases	• Ensure all engines, machinery equipment and pollution control mechanisms are operated and maintained in accordance with manufacturers' recommendations. [C011] • Where noise reduction devices are deemed necessary, ensure devices (such as mufflers, low-noise fans and possibly enclosures) are fitted and work correctly. [C301] • Operate equipment and handle materials in a manner that does not cause unnecessary noise (e.g., excessive revving or dropping materials). [C302] • Manage noise in accordance with the relevant environmental authority conditions. Where night-time activities are planned (10 p.m. to 6 a.m.) and are likely to exceed the prescribed noise criteria, conduct prior consultation with affected parties. [C304] • Consult with those who may be affected by increased noise levels due to construction activities with particular reference to the type and timing of works. [C305]

Table 4.25 Management measures for noise and vibration across all project-related activities (cont'd)

Common implementation strategy for all phases (cont'd)	• Conduct risk-based assessment or potential vibration monitoring during any construction activity that occurs within 100 m of a sensitive receptor that might be subject to vibration. [C306] • Implement a grievance management system that responds to noise complaints. If necessary, undertake noise monitoring of construction activities to facilitate a response to the grievance. [C307]
Implementation strategy for planning and design	• Preferential selection of sites in sparsely populated areas. [C309] • Site-specific detailed noise modelling of production facilities and the application of acoustic treatments where the modelled noise from facilities exceeds the established noise criteria at one or more sensitive receptors. Consideration of intrinsically quieter equipment or design of acoustic treatments such as hospital-grade exhaust systems and mufflers, or barriers and equipment housing will be given. [C310] • Locate equipment associated with production wells and associated wellhead infrastructure at a distance of 200 m or more from a sensitive receptor. [C311]
Implementation strategy for construction	• Consider the following factors prior to any blasting operations being conducted: – The type of rock and stratigraphy being blasted and any associated faulting. – The distance of the blast site from sensitive receptors. – The type, size and number of charges used. – The depth and manner in which the charge is installed. – The meteorological conditions. – Methods of controlling blast noise and vibration, such as mats or smaller blasts. [C312]
Implementation strategy for operations	• Where practicable, schedule planned flaring events (e.g., those preceding shut-down maintenance) for the period between 6 a.m. and 10 p.m. [C313]
Inspection and Monitoring	• Implement monitoring and inspection of avoidance, mitigation and management measures to ensure the residual impacts continue to be negligible throughout the lifetime of the project. [C317] • If directed by the administering authority in response to a valid noise complaint, undertake noise monitoring in accordance with the DERM (2000) Noise Measurement Manual. [C318]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	• Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan. • The method of measurement and reporting of noise levels will comply with the Noise Measurement Manual (DERM, 2000); AS 1055; or any legislation, standards or guidelines that supersede these documents.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.11 Waste Management

Waste types generated by the Surat Gas Project are likely to include regulated and non-regulated wastes of solid, liquid and gaseous forms.

4.11.1 Existing Environment and Environmental Values

The existing environment has been described in Sections 4.1 to 4.7. The key environmental values to be protected from waste streams are:

- **Soils and Land.** Land use capability, having regard to economic consideration, habitat for flora and fauna and quality of land, to guarantee environmental sustainability.
- **Air Quality.** Air quality that is suitable for sustaining human and environmental health and amenity.
- **Ecology.** The diversity of ecological process and associated ecosystems and suitability of flora and fauna habitats.
- **Water Resources.** Water quality that is suitable for sustaining human health, visual amenity and suitability of aquatic ecosystems.
- **Visual Amenity.** Features of the existing environment that are important for visual amenity.
- **Health and Safety.** The life, health and wellbeing of people, including the project workers.

4.11.2 Potential Impacts

Waste management issues associated with project activities include:

- **Uncontrolled Releases of Waste.** Failure to properly manage waste storage and containment systems could potentially result in soil and water contamination and impacts on visual amenity.
- **Controlled Releases of Waste or Emissions.** Discharge of waste water and air emissions could potentially lead to adverse health and ecological impacts, e.g., discharge of sewage and generation of air pollutants, such as nitrogen dioxide (NO_2).

4.11.3 Waste Management

Avoidance, mitigation and management of potential waste impacts will primarily be achieved through implementation of a waste hierarchy. Arrow will apply the following hierarchy of management options to all waste generated during the project activities: [C058]

- Source reduction: avoid, eliminate, change or reduce practices that result in the generation of wastes.
- Reuse: reuse waste materials that are in their original form.
- Recycling: where possible, send waste to appropriate facilities to convert waste into other usable materials.

- Treatment and disposal: render wastes safe by neutralisation or other treatment methods and dispose of waste products that can no longer be reused or recycled either through landfilling or incineration.

Management measures for waste across all project-related activities from planning and design through to decommissioning and rehabilitation are listed in Table 4.26. Management measures relating to gaseous waste are described in Section 4.1. Management measures relating to the treatment of coal seam gas water and brine are described in Section 4.8.

Table 4.26 Management measures for waste across all project-related activities

Element issue	Management of regulated and non-regulated wastes generated by project activities.
Environmental objective	In accordance with the Environmental Protection (Waste Management) Policy 2000: • To use a waste management hierarchy and principles based on waste avoidance, reuse, recycling and disposal. • To minimise resource utilisation by reuse and recycling of waste. • To minimise impacts to the environment from the management of waste. • To reduce the quantity of waste that is sent to landfills by recycling and reuse of waste.
Performance criteria	• Implementation of a waste management strategy. • Continuous improvement of the volume of waste generated per unit measure for each activity, with respect to proportion disposed of and proportion reused and recycled.
Implementation strategy for planning and design	• Develop and implement emergency response and spill response procedures to minimise any impacts that could occur as a result of releases of hazardous materials or any loss of containment of storage equipment. [C036] • Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Design water dams in accordance with relevant legislation and Queensland standards and DERM guidelines. [C154] • Develop onsite waste storage areas in accordance with industry practice and relevant waste management regulations. [C490] • Procure materials in bulk where practicable to minimise containers and movement of material. [C491] • Design the storage capacity of coal seam gas water and brine dams to be sufficient to manage waste liquids until such time that permanent disposal options are operational. [C492] • Provide training in the principles of the waste hierarchy to personnel handling wastes on a regular basis. [C502]

Table 4.26 Management measures for waste across all project-related activities (cont'd)

Implementation strategy for construction, operations and decommissioning	• Allocate bins for different waste streams to achieve solid waste segregation. Provide appropriate domestic waste disposal facilities at designated work sites to assist in segregation of waste. [C051] • Manage contaminated soil or groundwater that cannot be avoided through physical investigation; manage quantification of the type, severity and extent of contamination; and remediate or manage in accordance with the Queensland Government's Draft Guidelines for the Assessment and Management of Contaminated Land (DE, 1998). [C065] • Contain coal seam gas water in dams for treatment through reverse osmosis. [C202] • Arrow will carry out waste audits and reporting for waste generating activities to: – Provide waste data to enable continuous improvement of waste avoidance, reduction and management measures throughout the project life. – Assess whether action is required to fulfil set waste objectives and management. – Assess the adequacy of proposed mitigation measures and identify where mitigation measures need revision or additional measures. – Monitor potential environmental impacts to enable positive action to be implemented in case of incidents or accident related to waste activities. – Provide actual waste management results by comparing predicated impacts and mitigation measures. [C222] • Store liquid waste generated (other than coal seam gas water and sewage) and periodically remove it for disposal or recycling. [C226] • Dispose of waste that cannot be reused or recycled at appropriately licensed facilities. [C257] • Store putrescible solid waste in covered containers to prevent odours, public health hazards and access by fauna. [C330] • Contain all waste fluids and muds resulting from drilling activities in properly lined dams or storage tanks for in-situ treatment or disposal. [C411] • Determine the reuse of waste largely by the salvage value of the material. Reuse requires onsite segregation and storage and will include the following measures: – Reuse of cleared vegetation for mulch and soil erosion control. – Reuse of brine for production of potentially saleable salt products and implementing salt crystallisation (see Chapter 5, Project Description, of the EIS for options relating to beneficial use of brine and coal seam gas water). – Segregation of wastewater streams, i.e., contaminated stormwater, waste waters and coal seam gas water. – Reuse of treated waste water for dust suppression, construction activities or irrigation. – Reuse of treated coal seam gas water for town water supply, where of appropriate quality. – Reuse of hydrotest water. – Reuse of treated water for agricultural use, industrial use, potable water supply or injection into aquifers. – Treatment and reuse of solid wastes, such as drilling muds and cuttings, as soil conditioners, road base or construction material where practicable. [C454] • Use onsite waste treatment for such purposes as sewage, coal seam gas water and other specified wastes. Sewage will be treated in packaged sewage treatment plants. Sewage treatment plants will be located at production facilities and include settlement, digestion, aeration, clarification and disinfection equipment. [C469]

Table 4.26 Management measures for waste across all project-related activities (cont'd)

Implementation strategy for construction, operations and decommissioning (cont'd)	• Handle, store and dispose of regulated wastes in accordance with relevant standards and the Environmental Protection (Waste Management) Regulation 2000. [C494] • Comply with Queensland Government waste tracking requirements. [C495] • Segregate general waste, treat it if necessary and store it onsite prior to disposal. Segregation will include the separation of liquid from solid waste, separation of regulated from non-regulated waste, and separation of reusable and recyclable from non-reusable and non-recyclable waste. [C496]
Inspection and Monitoring	• Maintain a waste stream inventory identifying the type, classification, storage, transport and disposal requirements for the waste. [C375] • Inspect waste storage locations to ensure waste management measures are being adhered to. [C388] • Maintain a waste tracking system. [C493] • Maintain and update a water balance model that includes but is not limited to: – Monitoring of volume and quality of coal seam gas water produced and treated. – Monitoring of disposition volumes of treated and untreated coal seam gas water. [C539]
Auditing	• Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.12 Preliminary Hazard and Risk

This section describes Arrow's approach to managing potential hazards and risks associated with project activities.

4.12.1 Existing Environment and Environmental Values

The project development area is primarily composed of rural areas used for sheep, cattle grazing and cultivation, but includes isolated areas of bushland and state forests. Population is widely dispersed, except for townships, such as Dalby, Chinchilla, Cecil Plains, Wandoan and Goondiwindi.

The dispersed population, large amount of open land and widely distributed extent of the coal seam gas resource allow the Surat Gas Project to develop facilities in locations that maintain distance from centres of population and residential locations. This, and the inherent flexibility in the location of project infrastructure, contributes to the safety of people and property through adequate separation.

The existing environment contains areas of natural bushland and grassland. The hot summers and prolonged cycle of drought and drought-breaking rains mean that the project development area may be affected by bushfires as well as floods. The natural environment is also host to potentially hazardous wildlife, such as snakes, spiders, ticks, and disease vectors, such as mosquitoes.

The environmental values attributable to these aspects include:

- The health, safety and wellbeing of people, property and the wider community.
- The ecosystems in and surrounding the project development area that potentially could be affected by the development.

4.12.2 Potential Impacts

The potential issues associated with hazard and risk relate to the exposure of people (the public and the project workforce) and property to hazards that are inherent to coal seam gas development. Hazards and risks related to the construction, operation and decommissioning phases of the project include the following:

- Gas or pressure released or fire and explosion.
- External events, such as bushfire and flooding.
- Storage and handling of hazardous materials.
- Personal safety hazards of the project workforce.

The following types of personal safety hazards were identified as having the potential to injure persons, predominantly on work sites, but also including persons who may live or work in the immediate vicinity of work sites:

- Project-related vehicular travel and transportation.
- Light, heavy and rotating machinery.
- Fire ignited by vehicles accessing wells and facilities located in dry grassland.
- Electricity.
- Confined spaces.
- Working at heights.
- Waterbodies with engineered or unnatural banks (risk of drowning).
- Rigging up or down of drilling rig or during well tests and wellhead completion.
- Loss of containment of liquid hazardous materials under pressure.
- Bites from snakes, spiders, or ticks on or in the vicinity of facilities.
- Exposure to harmful materials and liquids (e.g., diesel, hydraulic oil, drilling fluids, very saline water and water treatment chemicals).
- Uneven terrain.

The following types of major accident hazards were identified as having the potential to injure multiple persons on or off of operating facilities:

- Pressure release or gas release due to physical damage to wellheads.
- Pressure release or gas release due to physical damage to pipelines and operational facilities.
- Pressure release or gas release due to failure of pipelines and operational facilities.
- Release of gas during a blowdown event.
- Ignition of combustible or flammable material.
- Dam failure.

4.12.3 Preliminary Hazard and Risk Management

A tiered management of safety hazards to avoid, minimise and manage risks through the application of site selection and engineering controls followed by procedural and behavioural controls was applied when developing risk management measures.

Management measures related to hazard and risk for all project-related activities from planning and design through to decommissioning are listed in Table 4.27.

Table 4.27 Management measures for hazard and risk across all project-related activities

Element or issue	• Gas or pressure released or fire and explosion. • External events, such as bushfire and flooding. • Storage and handling of hazardous materials. • Personal safety hazards of the project workforce.
Environmental objective	• To minimise the potential risk to people, the environment and property.
Performance criteria	• Successfully meeting Arrow's Target Zero Policy. • Compliance with applicable hazard and risk legislation, such as the P&G Act. • Compliance with relevant Australian standards.
Common implementation strategy for all phases	• Apply appropriate international, Australian and industry standards and codes of practice for the handling of hazardous materials (such as chemicals, fuels and lubricants). [C035] • The State Planning Policy 1/03 for mitigating the adverse impact of flood, bushfire and landslide will be taken into regard. [C538]
Implementation strategy for planning and design	• Arrow will enforce a no hydraulic fracturing (fraccing) policy in the project development area. [C079] • Subject each dam to separate approvals by the regulating authority. Each approval will require the incorporation of general and specific controls to avoid, mitigate or manage threats associated with flooding. [C206] • Use an independent, suitably qualified, third party to certify that dams meet the dam design plan. [C209] • Have in place a system for the collection and proper disposal of any contaminants that move beyond the bounds of the containment system of brine dams. [C210] • Design and size dams to account for predicted flood conditions. [C211] • Develop fire plans for production facilities. [C223] • Implement an in-vehicle monitoring system for project vehicles. [C288] • Prepare project safety management plans for the construction, operations and decommissioning of the infrastructure that form part of the present development. [C416] • Implement Arrow's health, safety and environmental management system for all activities and phases of development. [C417] • Conduct appropriate safety reviews during design of new and modified facilities, including the use of hazard and risk assessment processes. Base safety reviews on well-recognised methodologies, e.g., hazard and operability studies and AS 2885 (Standards Australia, 2007) risk assessment (safety management studies). [C418] • Select locations for project infrastructure with full consideration of and allowance for the minimum buffer zones indicated by the quantitative risk assessment. [C419] • Design and construct project infrastructure and facilities in accordance with applicable codes and standards. [C420]

Table 4.27 Management measures for hazard and risk across all project-related activities (cont'd)

Implementation strategy for planning and design (cont'd)	• Facilities will be designed with the ability to shut down and be isolated in preparation for impending bushfires. [C421] • Design and install combustion sources (such as generators and gas-fired compressors) on Arrow facilities in accordance with engineering codes and standards, thus ensuring they will have safety mechanisms built-in. [C422] • Develop protocols for the control of construction activities during extreme fire danger periods. [C423] • Arrow will develop emergency response plans in consultation with emergency services organisations that includes a list of required equipment, training and other resources, and foreseeable emergency and crisis situations (including escapes, blowouts, gas fire, bushfire, critical equipment failure, trapped or missing people, flooding, cyclones, power failure, security incidents and threats, and transport incidents). The plans should include safe evacuation procedures, communication protocols (internal and to emergency services, including the Petroleum and Gas Inspectorate), accounting for personnel and visitors, roles and responsibilities, and requirements for training. [C424] • Design all pipes and vessels to cope with maximum expected pressure. [C425] • Install pressure transmitters that remotely monitor high- and low-pressure alarms. [C426] • Consider remote-control isolation on gas and water lines. [C427] • Design equipment to withstand considerable heat load, e.g., through use of heat-resistant (fire-safe) isolation valves on production facilities. [C428] • Design radiation exclusion zones around flares according to API standard. [C429] • Register pipelines and below-ground electrical services with Dial Before You Dig. [C430] • Minimise enclosed spaces where flammable gas may accumulate. [C431] • Consider installing flow and pressure instrumentation to transmit upset conditions and plant shutdown valves status, where necessary. [C432] • Arrow will manage flooding risk through site location, drainage, etc., particularly for production facilities. [C433] • Design appropriate drainages for waste spills within buildings. [C434] • Apply dam safety guidelines, which will apply for all facilities forming part of the project development [C435] • Production wells will be designed and constructed so that the well is cased or concreted through aquifers other than the coal seam to prevent transmission of water and gas between strata. [C537]

Table 4.27 Management measures for hazard and risk across all project-related activities (cont'd)

Implementation strategy for construction	To reduce mosquito breeding in dams, dams and dam inner banks will be maintained so that they are as free of vegetation as practicable. [C208] • Develop the construction, design and monitoring requirements for new dams (either raw water, treated water or brine dams) and determine the hazard category of the dam in accordance with the requirements of the most recent version of Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2011a). Construct the dams under the supervision of a suitably qualified and experienced person in accordance with the relevant DERM schedule of conditions relating to dam design, construction, inspection and mandatory reporting requirements. [C141] • Line banks of dam with an impervious lining. [C213] • Design dams to have an egress (escape point) for wildlife. [C214] • Implement Arrow's health, safety and environment management system for all activities and phases of development. [C417] • Consider the Australian Pipeline Industry Association Construction Health and Safety Guidelines (APIA, 2008) for pipeline construction and development of Construction Health and Safety Plan. [C436] • Conduct pre-job safety meetings prior to the start of and during construction activities. [C437] • Perform blowout of pipes and equipment, to remove construction debris, using well-established procedures and under strict controls, including those detailed in risk assessments. [C438] • Develop an integrated risk management plan (in alignment with the relevant NSW Department of Primary Industries hazardous industry planning advisory paper). [C439] • Install, inspect and service fire-fighting equipment in accordance with risk assessments and relevant legislation and standards. [C440] • Implement transport-related safety programs, including driver training, journey management plans and preventative maintenance programs of vehicles. [C441] • Develop and implement safety training programs for personnel and contractors, including induction training of new starters. Include supervision requirements for drilling and construction activities. [C442] • Conduct pressure testing and inspection of equipment and pipelines in accordance with relevant legislative requirements and standards. [C443] • Bury gathering lines at a minimum depth of 600 mm. Where gathering lines are present above the ground (at wellheads and at vents or drains), maintain a clear area. The size of the cleared area will be determined on a site-by-site basis with consideration of the site-specific risk of bushfire. [C444] • Install isolation valves on pipelines in accordance with relevant standards and industry practices. [C445] • Commission fire-safety equipment in the early phase of the construction period. [C446] • Fit all buildings and production facilities with smoke or fire alarms. [C447] • Fit pumps with automatic pump shutdown or other safety devices to prevent leak in case of pumping against a blockage. [C448] • Install fire and gas detection systems to shutdown compressors. [C449] • Implement security controls e.g. fencing and locked gates. [C450]

Table 4.27 Management measures for hazard and risk across all project-related activities (cont'd)

Implementation strategy for construction (cont'd)	• Install lightning mast and earthing grid to minimise risk of lightning strike at production facilities. [C451] • Machine guard all rotating equipment in accordance with Australian standards. [C452] • Where necessary, automate emergency shutdown systems at production facilities and, if necessary, include remote monitoring and control. [C453] • Production wells will be designed and constructed so that the well is cased or concreted through aquifers other than the coal seam to prevent transmission of water and gas between strata. [C537]
Implementation strategy for operations	• Apply appropriate international, Australian and industry standards and codes of practice for the design and installation of infrastructure associated with the storage of hazardous materials (such as chemicals, fuels and lubricants). [C048] • Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned. [C171] • To reduce mosquito breeding in dams, dams and dam inner banks will be maintained so that they are as free of vegetation as practicable. [C208] • Establish overflow and operational controls in accordance with the dam operating plan. [C215] • Inspect and maintain dam integrity. [C216] • Develop fire plans for production facilities. [C223] • Arrow will develop emergency response plans in consultation with emergency services organisations that includes a list of required equipment, training and other resources, and foreseeable emergency and crisis situations (including escapes, blowouts, gas fire, bush fire, critical equipment failure, trapped or missing people, flooding, cyclones, power failure, security incidents and threats, and transport incidents). The plans should include safe evacuation procedures, communication protocols (internal and to emergency services including the Petroleum and Gas Inspectorate), accounting for personnel and visitors, roles and responsibilities and requirements for training. [C424] • Develop and implement safety training programs for personnel and contractors, including induction training of new starters. Include supervision requirements for drilling and construction activities. [C442] • Conduct pressure testing and inspection of equipment and pipelines in accordance with relevant legislative requirements and standards. [C443] • Implement security controls, e.g., fencing and locked gates. [C450] • Where necessary, automate emergency shutdown systems at production facilities and, if necessary, include remote monitoring and control. [C453] • Conduct systematic risk assessments (which include hazard identification, assessment, treatment and monitoring) in accordance with relevant legislation and standards during design, construction and operations. [C455] • Implement a permit to work system that includes a job safety analysis process. [C456] • Implement management of change processes, including protocols for communication of changes to appropriate levels of management. [C457] • Implement internal and external (independent) hazard audit programs. Communicate results from audit to management. [C458]

Table 4.27 Management measures for hazard and risk across all project-related activities (cont'd)

Implementation strategy for operations(cont'd)	• Barricade fall points and use personal fall-arrest equipment and wrist straps and lanyards to secure tools when working at heights. [C459] • Use whip check or safety chain and tie downs (or equivalent) on all high-pressure lines and pressurised air hoses. [C460] • Wear appropriate personal protective equipment on a site- and duty-specific basis. [C461] • Where applicable, establish blowout preventer and other well control measures. [C462] • Certify all equipment for drilling, where applicable. [C463] • Ensure equipment and vehicle operators are licensed. [C464] • Prepare a risk control action plan as part of the safety assessment process. [C465] • Purge equipment of oxygen prior to introducing flammable gas. [C466] • Purge equipment after shutdowns. [C467] • Develop protocols for the control of operational activities during extreme fire danger periods, e.g., flaring or shutdowns. [C468] • Consider non-static protective clothing for operations personnel. [C470] • Establish lone-worker protocols and communication. [C471] • Conduct regular patrols and inspections of pipeline easements, including status of signposting subsidence and of fire breaks. [C472] • Automate the chemical dosage system for water treatment at integrated processing facilities. [C474] • Consider the use of non-toxic gases for water treatment if gases are used. [C475] • Ensure operator supervision for unloading of hazardous materials at production facilities. [C476] • Provide escape ropes and ladders at strategic locations within a dam. [C477] • Use suitably trained and supervised staff or contractors to carry out depressurising and purging activities. [C479] • Ensure all personnel are familiar with Arrow's 12 Life Saving Rules, which embed safe practices in the day-to-day activities of the workforce. The rules encompass the following controls: – All staff to work with a valid permit where required. – Gas tests to be conducted where required. – Verification of isolation prior to work commencing and use of specified life-protecting equipment. – Authorisation to be obtained prior to entering a confined space. – Authorisation to be obtained prior to overriding or disabling any critical safety equipment. – All persons to protect themselves against a fall when working at a height. – No walking under a suspended load. – No smoking outside designated areas. – No alcohol or drugs while working or driving. – No phones to be used while driving and speed limits not to be exceeded. – Seat belts to be worn at all times. – Prescribed journey management plan to be followed. [C480]

Table 4.27 Management measures for hazard and risk across all project-related activities (cont'd)

Implementation strategy for operations (cont'd)	• Train relevant personnel in the identification and avoidance of potentially hazardous wildlife. Use qualified handlers to move wildlife from project areas when encountered. [C481] • Vegetation surrounding production facilities and wellheads will be maintained in a manner that limits the amount of combustible material in the area. The size of the cleared area will be determined on a site-by-site basis with consideration of the site-specific risk of bushfire. [C483] • Install manual isolation valves at the production well and skid edge. [C484] • Maintain facilities so that flammable and combustible material does not accumulate on site. [C485] • Keep access tracks to well sites clear of dry grass and combustible material wherever practicable and where there is a higher risk of bushfire (to minimise the risk of dry grass being ignited by hot components of vehicles accessing the sites). [C486] • Daily operations will be managed with consideration of the fire danger current at that time. [C487]
Implementation strategy for decommissioning	• Implement a decommissioning and rehabilitation plan in accordance with the dam design plan. [C074] • Develop rig move plans. [C488] • Depressurise and degas all plant and equipment in flammable-gas use prior to decommissioning. [C489]
Inspection and Monitoring	• Implement the dam operating plan. [C207] • Schedule inspections and develop a monitoring program to ensure that the safety management systems are functioning properly and that it is appropriate to the hazards identified. [C326] • Monitor dam levels. [C542] • Have a suitably qualified person routinely monitor the integrity and available storage of dams. [C543]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.13 Indigenous Cultural Heritage

This section describes Arrow's approach to managing potential impacts on Indigenous cultural heritage associated with project activities.

4.13.1 Existing Environment and Cultural Heritage Values

The existence of Indigenous cultural heritage within an area is generally dependent on the extent of previous Indigenous activity in the area and the extent to which development of the area has disturbed or destroyed Indigenous cultural heritage. Landscape features, combined with knowledge of existing land use and level of disturbance, help to identify areas most likely to contain Indigenous

cultural heritage. For example, there is strong potential for Indigenous cultural heritage to exist near watercourses and in forested areas that have not been cleared. It is, however, less likely that evidence of Indigenous cultural heritage remains in disturbed areas, such as cultivated areas, roads, residential communities and industrial developments.

Within the project development area, 372 sites are listed on the Queensland Indigenous Cultural Heritage database. Of these, approximately 60% are stone artefact scatters, with a further 25% being scarred trees. There are extensive ethnohistorical accounts of Indigenous activity in the project development area. Cultural heritage sites and places that are not yet known are likely to be found within the project development area.

Three known Indigenous cultural heritage sites listed on the Register of the National Estate are located wholly or partially within the project development area (Table 4.28).

Table 4.28 Register of the National Estate listed sites with Indigenous heritage values located within the project development area

Place Name	Description	Location	Within Project Development Area	Register of the National Estate Place ID (Listing Status)
Barakula State Forest	Known to contain a range of Indigenous cultural heritage values. A number of places listed on both the Queensland Indigenous Cultural Heritage database and Queensland Cultural Heritage Information Management System are found within the forest.	Northwest of Chinchilla	Yes (the project development area intersects the southwestern portion of Barakula State Forest)	18062 (indicative place)
Chinchilla Sands Local Fossil Fauna site	May have Indigenous cultural heritage values that are yet to be formally identified but which may be of National Estate significance. A single place (a scarred tree) recorded on the Queensland Indigenous Cultural Heritage Database falls within this area.	Warrego Highway, eastern outskirts of Chinchilla	Yes	14676 (registered)
Lake Broadwater Conservation Park	Known to be a particularly important place for Indigenous people, having been used for both residential and ceremonial purposes. Associations with an important creator being (i.e., the Rainbow Serpent) have also been identified.	10 km southwest of Dalby	Yes	18052 (indicative place)

The Bigambul People and the Iman People #2 have registered native title applications that cover part of the project development area.

The environmental values to be protected are associated with either archaeological significance (i.e., including physical evidence) or cultural significance (i.e., of significance to Indigenous peoples for

cultural, spiritual or historical reasons). Assets and artefacts in the existing environment include the following:

- Places with identified Indigenous values that are EPBC Act–listed and also included on the Register of the National Estate.
- Places that are included in the Queensland Indigenous Cultural Heritage Database. This database contains only broad information on each site, such as its type, date recorded, general location and Aboriginal party details. The details of many of these sites have been collected during cultural heritage assessments for other projects in the region.
- Places, objects and areas of cultural heritage value identified during previous investigations conducted by Aboriginal parties on behalf of Arrow. Where Aboriginal parties have allowed it, the details of these sites are retained in Arrow's GIS database.
- Places, objects and areas of cultural heritage value that are currently not identified, including those that become known through studies conducted prior to the commencement of construction activities. It is essential that these places, objects and areas of cultural heritage significance that are not yet known be recognised as an environmental value, as there is extensive evidence of the activity of Indigenous peoples across the project development area in terms of archaeological evidence and ethnohistorical accounts.

The value of the assets and artefacts in the environment are determined and attributed by the Indigenous people. It is the link between custom and folklore and spirituality that creates the value in places and in the inanimate objects that remain in the landscape. Table 4.29 summarises the landscape types and the likelihood that they contain cultural assets and values (as established by Bonhomme Craib & Associates (2009)).

Table 4.29 Sensitivity of the landscapes in which Indigenous cultural heritage may occur

Landscape Type	Cultural Assets and Values	Likelihood of Cultural Heritage Being Present
Defined waterways (including lagoons) and their immediate tributary areas on sandy or sandy loam soils	• Scarred trees. • Stone and shell scatters. • Axe-grinding grooves. • Burials.	High to very high
Black soil gilgais	• Stone artefacts (high frequencies of ‘tools’). • Hearths.	Moderate
Ridges and rocky uplands	• Stone arrangements. • Wells. • Stone artefacts.	Moderate to high

Table 4.29 Sensitivity of the landscapes in which Indigenous cultural heritage may occur (cont'd)

Landscape Type	Cultural Assets and Values	Likelihood of Cultural Heritage Being Present
High terraces below 300 m above sea level on duplex or sandy loam soils	• Scarred trees. • Stone artefact scatters.	Moderate
Ridges and escarpments	• Wells. • Quarries. • Bora grounds or stone arrangements.	Moderate to high
High plains above 300 m above sea level away from hydrological features	• Isolated stone artefact or artefacts. • Scarred trees.	Low
Black soil plains (including open floodplain)	• Scarred trees. • Isolated stone artefact or artefacts. • Stone sources and associated flaking.	Low

4.13.2 Potential Impacts

Potential impacts to Indigenous cultural heritage values from associated project activities during construction and operation include:

- Accidental destruction, damage or disturbance of cultural material in the landscape.
- Encroachment upon or disturbance of places of cultural significance to Indigenous persons.

4.13.3 Indigenous Cultural Heritage Management

Arrow will prepare cultural heritage management plans (CHMPs) or equivalent agreements in accordance with the provisions of the *Aboriginal Cultural Heritage Act 2003* (Qld). Cultural heritage will be managed in accordance with the CHMPs (or equivalent agreement), which will include avoidance (where practicable) as the primary mitigation measure. The management and mitigation measures for indigenous cultural heritage across the project through the construction and operation phases are outlined in Table 4.30.

Table 4.30 Management measures for indigenous cultural heritage across project-related activities

Element or issue	• Accidental destruction, damage or disturbance of objects of physical heritage in the landscape. • Encroachment upon or disturbance of places of cultural significance to Indigenous persons during the course of construction or routine operations.
Environmental and social objectives	• To avoid or minimise and manage adverse impacts from project activities on known and unknown Indigenous cultural heritage sites and objects. • To retain a documented record of the Indigenous cultural heritage that is found through the course of the project so that the history of the area is preserved for future generations.
Performance criteria	Compliance with the provisions of the CHMPs developed for the project.

Table 4.30 Management measures for indigenous cultural heritage across project-related activities (cont'd)

Implementation strategy for planning and design, construction, and operations	• Prepare CHMPs or equivalent agreements in accordance with the provisions of the Aboriginal Cultural Heritage Act. [C396] • Complete comprehensive initial cultural heritage assessments where disturbance is proposed (noting that this will be staged in line with proposed development schedules), with direct input from relevant Aboriginal parties. [C397] • Assess the results of the initial cultural heritage assessments in collaboration with the Aboriginal parties and develop a program for the management of all significant Aboriginal areas and objects to be affected by the project. Include management measures required prior to construction and those required throughout the life of the project. [C398] • Commission high-order constraints papers from Aboriginal parties to identify places of Aboriginal cultural heritage significance. Ensure avoidance of these places is considered during detailed design. Ensure that operations gives effect to the avoidance principle as enunciated in the Aboriginal Cultural Heritage Act. [C399] • Maintain a GIS database of sites of Indigenous cultural heritage that are known or found during the course of investigations and works (where Aboriginal parties allow the listing of the sites). [C400] • Obtain all necessary permits and approvals prior to the commencement of works. [C401] • Ensure site inductions provide cultural heritage awareness for places and objects (to avoid) and the appropriate procedures to follow should there be any new discoveries. [C402]
Inspection and Monitoring	Inspect known Indigenous sites identified as having the potential for being impacted by the project and subsequently acknowledged for avoidance, in accordance with the relevant approval and permit conditions including the cultural heritage management plan. [C324]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan and in accordance with the CHMPs.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan and the CHMPs.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority and in accordance with the CHMPs.

4.14 Non-Indigenous Cultural Heritage

This section describes Arrow's approach to managing potential impacts on non-Indigenous cultural heritage associated with project activities.

4.14.1 Existing Environment and Cultural Heritage Values

Non-Indigenous visitation in the region dates back to the mid-nineteenth century. Since this period, there has been a diverse range of settlement and land uses, resulting in scattered archaeological sites.

Many of the known heritage sites within the project development area are associated with early settlement and include early pastoral stations, towns, railway camps, schools and churches. Additional sites are associated with transport routes, such as railways, and their associated camps. Pastoralism left its mark in the area with fences, scattered pastoral stations and varied collections of farm machinery.

There is potential for other historic sites and places to exist that have not been found before. Areas most likely to contain previously unknown sites are those associated with major transport routes (particularly the railway lines), along stock routes and old stagecoach routes, as well as river corridors and vermin fences. Areas on disturbed land used for agricultural activities have a very low likelihood of containing intact non-Indigenous cultural heritage sites or artefacts. Non-Indigenous cultural heritage sites that are as yet to be discovered within the project development area are likely to include artefact sites from grazing and agricultural industries of local heritage value.

Within the project development area, there are no sites of national significance; however, the Dalby war memorial was formerly registered on the Register of National Estate (until being transferred to the Queensland Heritage Register) and the Boonaraga Cactoblastis Memorial Hall is believed to display national listing qualities.

Nine sites with state heritage significance have been identified in the project development area (Table 4.31; Figure 4.19), with three of these also registered with the National Trust of Queensland. Only one site is located outside the project's town exclusion areas (Wyaga Homestead).

Table 4.31 State listed heritage sites within the project development area

Heritage Site	Description	Register
Dalby War Memorial and Memorial Park	A memorial to commemorate the contribution made by local residents to World War I. The soldier statue on the memorial is one of only two in Queensland that are cast in bronze.	• Queensland Heritage Register (formerly entered on the Register of National Estate) • National Trust of Queensland
Boonaraga Cactoblastis Memorial Hall	A hall built to commemorate the role of the cactoblastis moth in controlling the prickly pear cactus during the 1920s and 1930s.	• Queensland Heritage Register • National Trust of Queensland
Dalby swimming pool complex	The earliest Olympic-sized pool in Queensland outside Brisbane. Built in 1936.	• Queensland Heritage Register
Dalby Town Council Chambers and offices (former)	The third council chambers to be built in the town. Built in 1936.	• Queensland Heritage Register
St Johns Anglican Church	A brick church built in 1922-1923.	• Queensland Heritage Register
Chinchilla War Memorial and digger statue	A memorial to commemorate the contribution made by local residents to World War I. Unveiled in 1919.	• Queensland Heritage Register
Dalby Fire Station	The central portion of the Dalby Fire Station dates from 1935 and includes extensions built in 1963 and 1957. It is the oldest and longest operating fire station in regional Queensland.	• Queensland Heritage Register

Table 4.31 State listed heritage sites within the project development area (cont'd)

Heritage Site	Description	Register
St Columba's Convent (former)	The convent is a substantial brick and timber building built in 1913 from donations made by parishioners. The convent was designed by local architect George Bernard Roskell. It illustrates the spread of the Catholic Church in regional Queensland and the contribution made by the Sisters of Mercy in its establishment of convents, schools and boarding accommodation. The order occupied St Columba's until 1990.	• Queensland Heritage Register
Wyaga Homestead	One of the oldest cattle runs in the district. Built around 1862.	• Queensland Heritage Register • National Trust of Queensland

Sites and site complexes were also identified through field surveys and consultation with local historians and the public (Table 4.32). These sites were assessed for significance against the criteria specified in the *Queensland Heritage Act 1992* (Qld) and The Burra Charter (Australia ICOMOS, 2000).

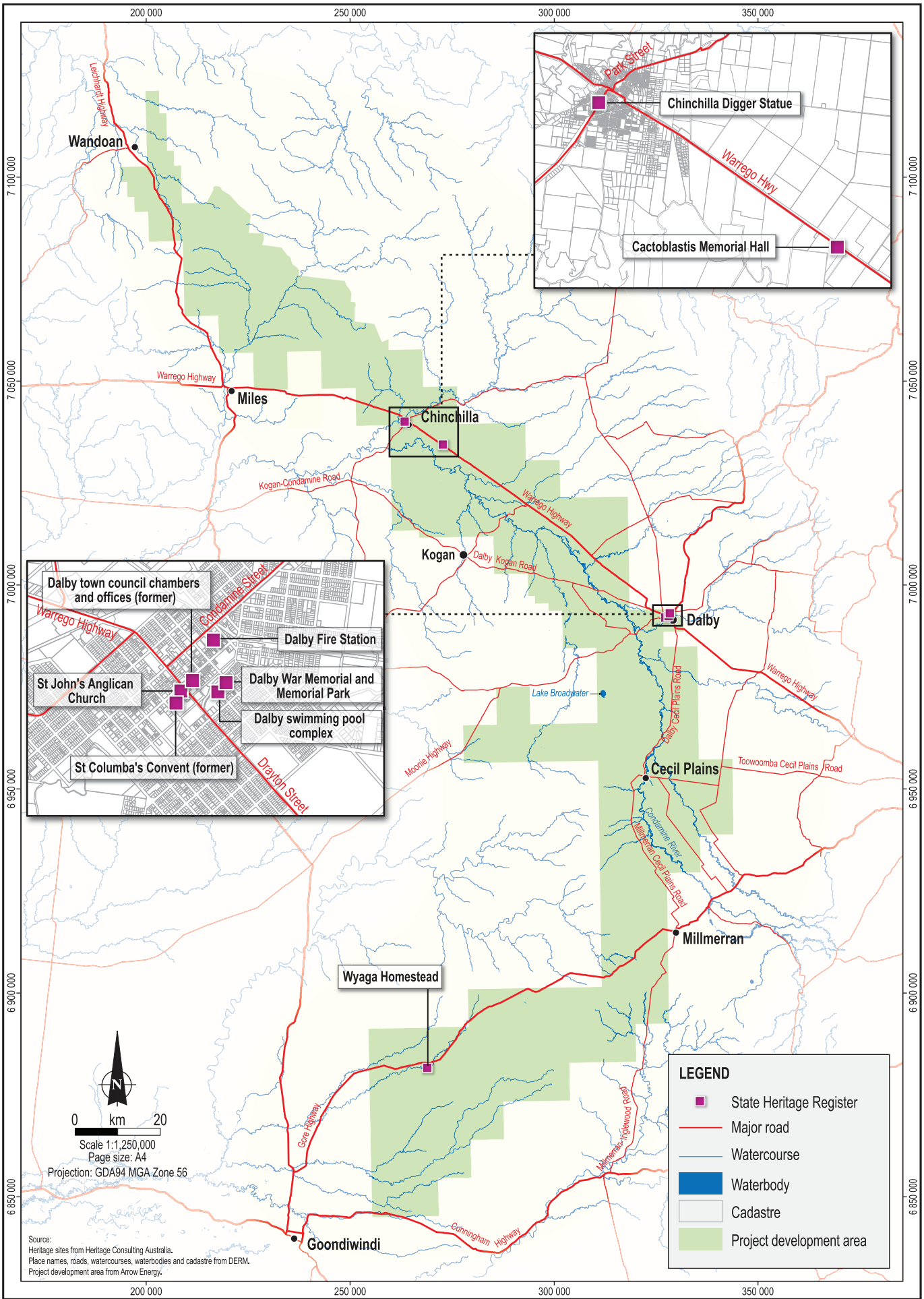
Table 4.32 Non-listed heritage sites identified within the project development area and surrounds

Heritage Site Type	Description	Number of Sites
Infrastructure (settlements and homesteads)	Campsites, monuments, homesteads, scarred trees, settler's huts and recreation grounds	50
Infrastructure (industry and places of worship)	General industry, railways, prickly-pear infrastructure, aquaculture, cheese and butter factories, hotels, churches, quarries and mines	50
Schools and former school sites	Schools and former school sites	26
Cemeteries	Cemeteries and isolated graves	9
War-related sites and memorials	War memorials and locations of deaths	7
	Total	**142**

4.14.2 Potential Impacts

Potential impacts to known non-Indigenous cultural heritage sites from project activities could occur by accidental destruction, damage or disturbance.

There is also the potential for unknown sites to be uncovered during the construction and operational phases of the project through 'chance find' discoveries.



Source:
Heritage sites from Heritage Consulting Australia.
Place names, roads, watercourses, waterbodies and cadastre from DERM.
Project development area from Arrow Energy.

coffey environments	Date: 07.12.2011 MXD: 7040AC_04_GIS061_v1_2 File Name: 7040_04_ATT5_F04.19_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Heritage sites of State Heritage significance in the project development area	Figure No: 4.19

4.14.3 Non-Indigenous Cultural Heritage Management

A management hierarchy of avoid, relocate, minimise and manage the adverse impacts from project-related activities was applied when assessing non-Indigenous cultural heritage options.

Following this, the primary mitigation measure during site selection will be to avoid locating project infrastructure near identified sites of significance and to incorporate buffer zones to minimise the impacts.

Management measures for non-Indigenous cultural heritage across all project-related activities from planning and design through to decommissioning and rehabilitation are listed in Table 4.33.

Table 4.33 Management measures for non-Indigenous cultural heritage across all project-related activities

Element or issue	• Accidental destruction, damage or disturbance to non-Indigenous cultural heritage sites and artefacts. • Encroachment on non-Indigenous cultural sites during the course of routine operations.
Environmental and social objectives	To avoid or minimise disturbance from project-related activities to non-Indigenous cultural heritage sites and artefacts.
Performance criteria	Compliance with the cultural heritage management plans developed for the project.
Implementation strategy for planning and design, construction, and operations	• Avoid known cultural heritage sites, where practicable, through site selection. [C403] • Develop a 'chance finds' procedure for the discovery of unknown sites during construction as part of the cultural heritage management plan. This should include a stop work requirement on initial discovery, appropriate reporting and recording, and such management measures as avoidance, salvage or destruction. [C404] • Develop a cultural heritage management plan in consultation with the Queensland Heritage Office prior to commencement of ground disturbance works that will mitigate and manage potential impacts on non-Indigenous cultural heritage sites. [C405] • Conduct preconstruction clearance surveys of sites to identify the presence of heritage sites. [C406] • Develop site-specific cultural heritage management plans in consultation with the Queensland Heritage Office should construction be planned within 100 m of listed heritage sites. [C407] • Consult with the local community regarding the management of threatened historic sites and places. [C408] • Incorporate cultural heritage awareness into site induction procedures, including information on heritage values of the region, legal obligations and implementation of the 'chance finds' procedure. [C409] • Record and report unknown sites identified during construction as chance finds. The cultural heritage management plan will include all measures for managing the discovery of chance finds. [C410] • Notify the Queensland Heritage Office if any cultural heritage sites or items of significance are uncovered during construction. [C412]

Table 4.33 Management measures for non-Indigenous cultural heritage across all project-related activities (cont'd)

Implementation strategy for planning and design, construction, and operations (cont'd)	• Undertake archaeological assessment by a qualified heritage practitioner if cultural heritage sites or artefacts are uncovered during construction. [C413] • Maintain a database of all sites where non-Indigenous cultural heritage is known or found during the course of investigations and works. [C414] • Take particular care when working in those areas where significant heritage places are located within 500 m of proposed wells, pipelines or other infrastructure. [C415]
Inspection and monitoring	Inspect known non-Indigenous sites identified as having the potential for being impacted by the project and subsequently acknowledged for avoidance, in accordance with the relevant approval and permit conditions including the cultural heritage management plan. [C325]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.15 Roads and Transport

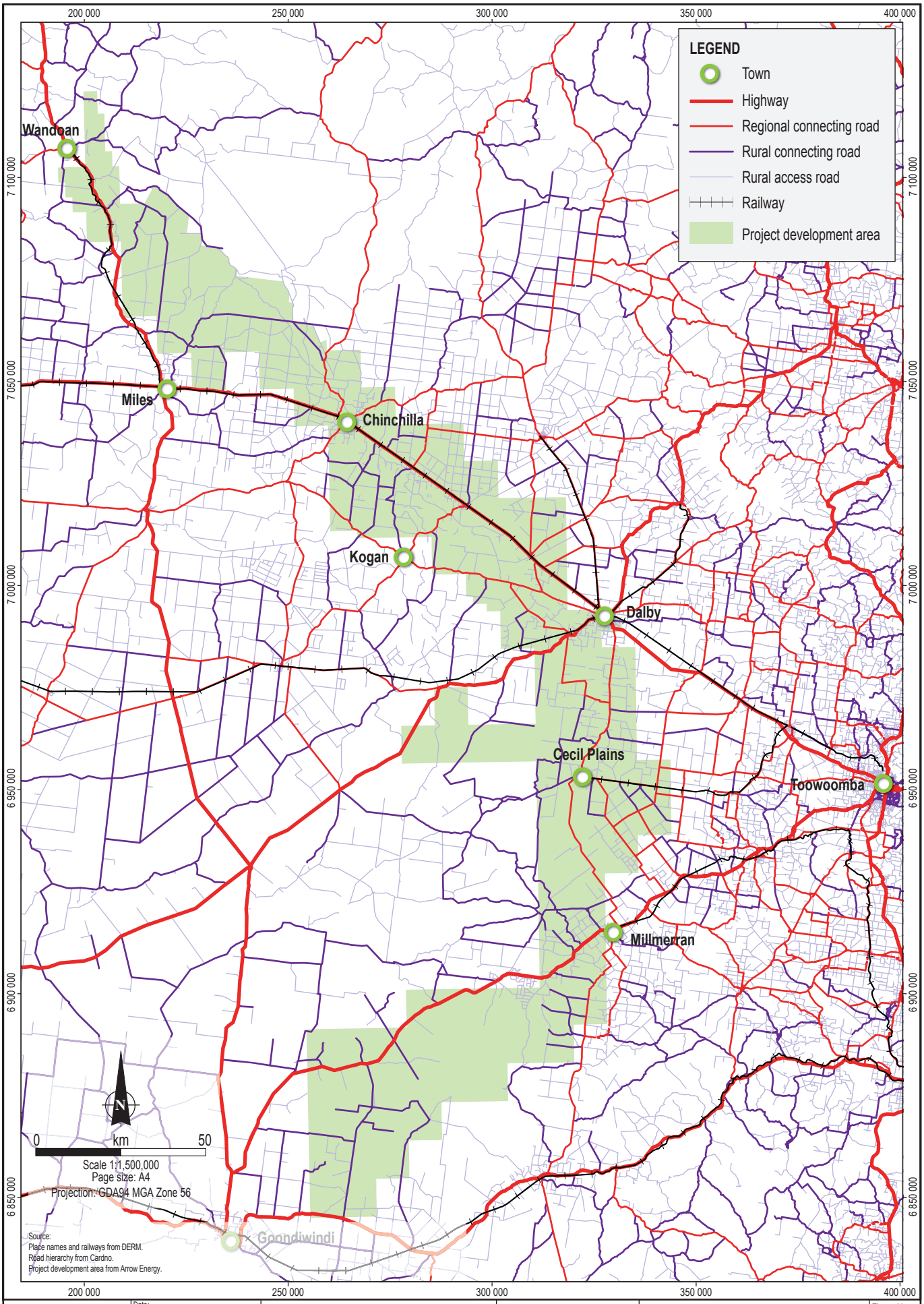
This section describes Arrow's approach to managing potential impacts on roads and transport associated with project activities.

4.15.1 Existing Environment and Environmental Values

Roads have been identified as the key mode of transport for the Surat Gas Project. Road traffic within the project development area varies widely depending on proximity to Dalby and other urban areas and on the period over which the observation is made. Higher population growth has generally been observed in recent years, and the volume of traffic on roads within the project development area has typically changed by between -1% per annum (decline) and 3% per annum (growth) over the past 10 years. However, higher annual traffic growth rates of between 4% and 8% have been observed at a few isolated locations.

The functional road types present within the project development area include highways, regional connecting roads, rural connecting roads and rural access roads (Figure 4.20):

- **Highway.** Highways are high-order roads of a high standard, facilitating connectivity between regional centres.
- **Regional Connecting Road.** Regional connecting roads are high-order roads of a high standard, facilitating connectivity between townships.
- **Rural Connecting Road**. Rural connecting roads are lower-order roads facilitating connectivity between higher-order roads.



coffey environments	Date: 12.12.2011 MXD: 7040AC_04_GIS113_v1_4 File Name: 7040_04_ATT5_F04.20_GIS_GL	Arrow Energy Surat Gas Project	arrow energy go further	Functional road type in the project development area	Figure No: 4.20

- **Rural Access Road**. Rural access roads are low-order roads predominately facilitating access to local uses.

Annual average daily traffic volumes (based on 2009 data) for state-controlled roads within the project development area vary, with highest volumes (1,000 to 2,999 vehicles per day) on roads servicing the main townships within the project development area (Chinchilla, Dalby, Cecil Plains and Millmerran.

Crash data sourced from the Department of Transport and Main Roads (DTMR) from April 2004 to March 2009 shows that the crash rate for key rural roads within the project development area varied from 9 crashes per 100 million vehicle kilometres travelled to 67 crashes per 100 million vehicle kilometres travelled. Millmerran Cecil Plains Road reported the highest crash rate and is the only key road in the project development area that displayed a crash rate above that typically observed in Queensland.

Such features as the standard of road construction, bridge construction (load ratings) and risk of flooding on individual sections of road also vary across the project development area.

The few rail lines that intersect the project development area are typically passively controlled (e.g., through use of signage) and tend to run parallel to highways and regional connecting roads, linking major centres. The most significant rail line in the project development area runs parallel to the Warrego Highway.

Stock routes, established to facilitate the movement of livestock on foot between grazing areas and markets, are abundant throughout the project development area. Stock routes appear to follow watercourses but generally traverse all levels of roads.

A number of school bus routes radiate from the townships within and near the project development area. School bus routes are typically found around the major towns and use highways and higher-order locals roads, such as regional connecting roads. Long-distance commercial bus services service the towns; however, no intra-city public transport facilities are provided.

Most towns have basic pedestrian and bicycle infrastructure. Roads outside of the townships typically do not include dedicated bicycle facilities, such as on-road bicycle lanes. A number of other road features exist within the project development area, including motorist rest areas.

The road environmental values are the functional road types present within the project development area. Three key aspects of each functional road type have been identified as important to various users, neighbours and road authorities of the road network:

- **Efficiency.** Efficiency relates to aspects of the road network that facilitate the efficient operation of the network, e.g., linkages between higher-order roads, overall volumes of traffic and types of intersection.
- **Safety.** Safety includes aspects of the physical road infrastructure that relate to safety, e.g., bridges, rail crossings, cattle grids, school bus infrastructure and standard of road construction.
- **Amenity.** Amenity relates to aspects of the experience afforded to the passive participants of the road network (users of adjacent land), e.g., light, dust and noise nuisance due to changes in traffic volumes or road function.

4.15.2 Potential Impacts

Increases in traffic volumes across the road network within the project development area can potentially impact the efficiency, safety and amenity of roads. The key traffic-generating activities that will occur during each phase of the project are as follows:

- **Construction.** Haulage of materials and equipment to depots and distribution from depots to works sites within the project development area, installation of production wells, gas and water gathering infrastructure, construction of production facilities, roads to production facilities, dams associated with production facilities and construction camps.
- **Operations.** Operation and maintenance of well sites, gathering infrastructure and production facilities.
- **Decommissioning.** Decommissioning and rehabilitation of well sites, gathering infrastructure and production facilities.

Due to the staged development approach, there will be points in time when the construction, operations and decommissioning phases will be occurring concurrently across the project development area.

Strategic modelling estimated that project-generated travel in the peak year (2035) is likely to be less than 1% of the total travel that occurred across the DTMR's Darling Downs district road network in 2009. At its peak, the project is anticipated to increase the extent of heavy-vehicle travel occurring on the district's road network by less than 2% of the existing (2009) levels and the extent of light vehicle travel by less than 1% of existing (2009) levels.

Highways in the project development area are built and operated at a standard that is likely to accommodate changed traffic conditions. Lower-order roads (rural connecting roads and rural access roads) are constructed for and operate with lower traffic volumes than higher-order roads, and they exhibit higher sensitivity to increases in traffic volumes.

Road-section specific features and specific impact of installation of infrastructure on such features as stock routes and bridges will be assessed in greater detail during preparation of road use management plans after the locations of production facilities and associated infrastructure are finalised.

4.15.3 Roads and Transport Management

A management hierarchy of avoid, minimise and manage impacts was applied when assessing road and transport management options.

Therefore, the primary mitigation measure will be the exploration of opportunities to avoid or reduce project traffic on the most sensitive routes through transport planning and logistics.

Management measures regarding roads and transport for all project-related activities from planning and design through to decommissioning and rehabilitation are listed in Table 4.34.

Table 4.34 Management measures for roads and transport across all project-related activities

Element or issue	Increases in traffic volumes across the road network within the project development area can potentially impact the efficiency, safety and amenity of roads.
Environmental and social objectives	To minimise potential impacts to road amenity, safety and efficiency from project-generated traffic and transport.
Performance criteria	• No permanent disruption to road efficiency. • No third-party traffic-related incidents associated with the project. • No net loss to road amenity.
Implementation strategy for planning and design	• Assess and identify works required to manage the increased traffic volumes and road safety issues associated with the project in road use management plans prepared and regularly reviewed in consultation with the relevant council or the Department of Transport and Main Roads. [C284] • Assess and identify the need to upgrade unsealed roads or widen sealed roads where project activities and traffic will create road safety issues. Such works will be done in consultation with the relevant council (if a local government road) or DTMR (if a state road). [C285] • Undertake threshold assessments to determine whether upgrading of rail crossings is warranted. [C286] • Implement driver training and fatigue awareness for employees and contractors. [C287] • Implement an in-vehicle monitoring system for project vehicles. [C288] • Schedule roster changes to avoid peak traffic times. [C289] • Develop project logistics plans to provide safe movement of people and materials, as well as to minimise traffic volumes. [C290] • Develop journey management plans in consideration of high-risk roads. [C291] • Use heavy-vehicle routes that avoid unsuitable bridges. [C292]
Implementation strategy for construction	• Where assessed necessary, provide protected turning lanes for entry to permanent facilities to address road safety issues. [C293] • Ensure access driveways to project facilities and infrastructure have appropriate sight distances. [C294] • Implement traffic controls, including signage (e.g., reduced speed limits, warning signs) and restrictions of movements (e.g., no travel during school bus pick-up and drop-off times). [C295]

Table 4.34 Management measures for roads and transport across all project-related activities (cont'd)

Implementation strategy for construction, operations and decommissioning	• Maintain the integrity of private roads and tracks and minimise dust generation, where appropriate, in consultation with relevant landowners and council. [C031] • Confine project traffic to designated roads and access tracks, where practicable. [C033] • Implement traffic controls, including signage (e.g., reduced speed limits, warning signs) and restrictions of movements (e.g., no travel during school bus pick-up and drop-off times). [C295] • Limit project traffic on school bus routes during pick-up and drop-off times on school days or install appropriate school bus infrastructure, e.g., signage or pull-over areas where necessary. [C296] • Make workers aware of school bus routes, as well as typical pick-up and drop-off times in the vicinity of the work sites. [C297] • Coordinate with local law enforcement for movement of heavy or oversized loads. [C298] • Implement journey management plans. [C299] • Manage project-related activities in the vicinity of existing stock routes in accordance with the Land Protection (Pest and Stock Route Management) Act. [C300]
Inspection and Monitoring	• Routinely monitor integrity and amenity on project-related roads. [C308] • Monitor compliance with the project's road safety requirements through regular review of reports generated by the in-vehicle monitoring system. [C314] • Conduct regular safety inspections of project vehicles. [C315]
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	• Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan. • The method of measurement and reporting of potential impacts to roads will comply with relevant DTMR guidelines.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

4.16 Agriculture

This section describes Arrow's approach to managing potential impacts on agriculture associated with project activities.

4.16.1 Existing Environment and Environmental Values

The landscape of the project development area is characterised by three physiographic regions: the Great Dividing Range highlands, the Kumbarilla Ridge uplands and four drainage basins, Condamine-Culgoa Basin (Condamine River and Balonne River), Fitzroy Basin (Dawson River), Border Rivers Basin (Weir River, Macintyre River and Macintyre Brook) and Moonie Basin (Moonie River). The river systems are characterised by relatively gentle gradient watercourses that comprise defined, poorly defined and indistinct channels. Consequently, seasonal and storm event flooding produces expansive overland flows that are important in replenishing soil water.

The main soil types used for agriculture in the project development area are the Vertosols and Dermosols (both black soils). Vertosols are light to heavy clays, fertile in a natural, undisturbed state with nutrient reserves, and have highly reactive shrink-swell properties. Dermosols are similar to Vertosols. Sandy alluvial plains with deeper, sandy Rudosols, Tenosols and Kandosols (i.e., sands, sandy loams, loams and clay loams) are also present in the project development area and are included in soils that define good-quality agricultural land (GQAL).

Summer and winter crops are both grown in the region. However, as there is generally higher summer rainfall in the project development area and greater economic returns are received for summer crops, summer crops are generally preferred. Stubble retention and strip cropping are carried out in flood-prone areas, and both irrigated and dryland cropping systems are used. Grain and cotton crops are grown, with raw cotton transported to Brisbane for export. Grain is used for human consumption, feedlots and in industrial plants. Crops such as cotton and wheat are grown across the Darling Downs region, as are speciality pulse crops such as Adzuki beans, which are used in high-value niche exports. Several certified organic farms operate in the region.

In 2006, livestock (cattle, pigs and sheep), cereal crops and non-cereal broadacre crops were the major agricultural enterprises in the region and the total gross value of agricultural production for the Darling Downs was approximately $1.7 billion. At this time, there were 958,082 beef cattle and 793,541 sheep and lambs, and cereals were grown over 733,595 ha.

Water availability is a major limitation to agricultural development, however the main soil and landscape-oriented limitations to development of GQAL include:

- **Gilgai.** The presence of gilgai can limit crop yield, as localised areas of waterlogging occur as a consequence of gilgai. Even if land is levelled, the gilgai make it difficult to surface irrigate as within a short period of time the filled gilgai reappear.
- **Dissected Landscape.** Features such as gullies, rills and watercourses dissect the landscape and limit the size of paddocks, consequently reducing the efficiency of farming operations.
- **Shallow Groundwater.** If groundwater is shallow (i.e., less than 2 m below natural surface level), there is an increased risk of salinity, which can lead to degradation of the soil and productivity of the land. This occurs when groundwater rises to the soil surface and then evaporates, leaving salt at the surface.
- **Salinity.** Saline soils are not suitable for irrigation, and can be caused by using poor quality irrigation water or from secondary salinisation from a rising watertable.
- **Sodic Soils.** These soils are not suitable for intensive agricultural development, as subsurface drainage is impeded, leading to perched watertables and tunnel erosion in sloping sites.
- **Impermeable Subsoils.** These soils have the same limitations as sodic soils, with the impeded drainage leading to perched watertables and short-term anaerobic conditions. Consequently, there is reduced plant growth and the soil is not suitable for irrigation.
- **Erosive Flooding.** During flood events, selective removal of the topsoil (approximately 100 mm) from cultivated soils can occur, reducing plant productivity.

- **Slope.** This affects the type of irrigation that can be carried out. For example, surface or flood irrigation can be used on slopes less than 2%, spray irrigation on slopes less than 15% and localised, or crop dependent irrigation when slopes are less than 25%.

Current agricultural activities include:

- **Dryland Broadacre Farming.** Includes cereal, pulse and cotton crops. Dryland farmers typically aim to maximise water infiltration. Consequently, paddocks are often laser levelled to remove undulations and fill natural drainage paths to create uniform slopes that optimise infiltration. Tillage is minimised to reduce soil compaction and assist with infiltration. Stubble is retained to assist with moisture retention and minimise soil and water erosion.
- **Irrigated Broadacre Farming.** Fields are usually engineered to increase the effectiveness of irrigation and drainage. In some instances, laser levelling of fields is conducted to target specific areas of concern. The majority of farms also have water storages to store water allocations and to collect overland flow. Surface, spray and localised irrigation techniques are used.
- **Horticulture.** For 2005/2006, the key vegetable crops grown in the Darling Downs were lettuce (8,037 t), onions (7,260 t), potato (5,092 t), cabbage (4,214 t) and broccoli (2,298 t). Watermelon, rockmelon and honeydew are grown near Chinchilla. Water availability for irrigation and the number of frosts during winter tend to be the main limiting factors to horticultural development.
- **Fruit.** Of the fruit crops grown in the Darling Downs for 2006/2007, strawberries were the largest crop at 33,319 t, and avocados the smallest at 6 t.
- **Vineyards.** For the 2006/2007 period, 1.9 t of grapes were grown in the Darling Downs region, with large wine grape producers near Jimbour and Maclagan, and table grape producers near Chinchilla. Approximately 721 ha of vineyards are in the Darling Downs area.
- **Livestock Industries.** Includes piggeries, poultry, beef feedlots and horse agistment and breeding. Laying chickens (3,183,158 birds), meat cattle (1,310,310 head), meat chickens (267,816 birds) and milk cattle (excluding house cows) (37,247 head) were the largest animal products of the Darling Downs region in 2006/2007.
- **Rangeland Grazing.** The main livestock enterprises in the Darling Downs are beef cattle (grazing) and sheep. They are usually farmed in conjunction with grain production.
- **Timber Production.** Cypress pine, spotted gum and ironbark are harvested from forests on freehold, leasehold and Crown land in the project development area. Specialty craftwood timbers such as brigalow, budgeroo, hairy oak and red ash are becoming more common as a boutique timber industry.

The environmental values are embodied in the soil profile (i.e., depth and composition of the soil horizons), soil properties (i.e., organic matter, biochemistry and soil water content), topography, flooding regime and climate. They influence the agricultural potential of the project development area and therefore the agricultural activities being, and able to be, conducted.

4.16.2 Potential Impacts

Potential impacts to the environmental or agricultural values of the project development area can be summarised as follows:

Reduced Productivity and Increased Costs. Caused by changes in farm configuration (e.g., creation of more headlands), disruption to farming practices (e.g., changes to irrigation infrastructure, interference with overland flow), unsuccessful rehabilitation and temporary loss of arable land.

Crop Losses or Disturbance to Stock. Caused by drilling or construction occurring during inopportune times disrupting cropping or breeding (depending on the proximity to breeding animals and the nature and intensity of the disturbance), and unsuccessful rehabilitation.

Soil Disturbance. Caused by compaction from traffic, mixing and inversion of soil horizons, settling of pipeline trenches or soil loss from erosion caused by construction activities.

Increased Costs of Farm Management. Caused by increased operating overheads from management of coal seam gas activities and coordination of activities (e.g., spraying and withholding periods) and integration with farm plans. Increased costs may also result from limitations on development of farms to incorporate new technologies and farming techniques.

Loss of Amenity. Caused by contractors and employees entering and working on properties, disruption to lifestyle, increased levels of noise and dust, and the visual impact of project infrastructure.

Project activities with the potential to cause these adverse impacts on agricultural enterprises during the construction, operation and maintenance, and decommissioning phases of the project are described below:

- Loss of productive land (temporary and potentially permanently) from development of production facilities.
- Temporary or permanent disturbance and potential diminished productivity as a result of the development of wells, gathering systems, pipelines and access tracks.
- Reduced crop yield from unsuccessful rehabilitation.
- Disruption to farm operations such as tillage, planting, irrigation, weed control and harvesting from inappropriate placement of wells, gathering systems, pipelines and access tracks.
- Disruption to intensive farming enterprises including piggeries, chicken production, feedlots or dairy farming from inappropriate placement of production facilities, wells, gathering systems, pipelines and access tracks.
- Soil degradation from disturbance of the soil structure, resulting in impacts to fertility and biologic function and crop yield from all project activities.
- Changes to surface irrigation infrastructure including head ditches, bays and tail drains from inappropriate placement of wells, gathering systems, pipelines and access tracks.
- Diversion of flows and changes to the hydrology of the landscape from poorly sited and constructed access tracks.

- Farm hygiene issues relating to weeds and disease management from construction and operation vehicles, plant and equipment.
- Site contamination from all project activities.

4.16.3 Agricultural Management

Each agricultural enterprise is unique and particular practices have been developed to maximise the productivity of the land. The planning, design and development of project infrastructure and undertaking of project activities will need to address the specific issues raised by each property i.e., coal seam gas development needs to be integrated with farm operation and development.

The primary mitigation for reducing potential impacts on agricultural land and agricultural enterprises is siting of infrastructure. The secondary mitigation is the design and development of construction, and operation and maintenance methods that enable project activities to integrate with farm activities. The tertiary mitigation is the application of environmental management controls i.e., proven methods and techniques for protecting the environment.

The effectiveness of the proposed environmental management controls in addressing the identified impacts is being investigated through trials and case studies that are currently focussed on rehabilitation of black soils (Vertosols and Dermosols) and construction methods for work on those soils. Trials and case studies currently in progress include:

- A trial on an Arrow-owned farm to demonstrate the effectiveness of the procedures developed for exploration chip and core drilling on black soils.
- Three separate case studies on different properties with different farming practices in intensively farmed land areas, involving working directly with landholders to design coal seam gas developments on their land in a manner that minimises the impact on their land and farming activities.
- Drilling and development trials of techniques to reduce impacts on intensively farmed land, including:
  - Implementing surface tanks to manage drilling muds during the drilling process to eliminate the need to excavate pits in intensively farmed land areas.
  - Constructing and restoring a pipeline in black soils to demonstrate how existing surface profiles can be maintained and rehabilitated, reducing impacts on farming enterprises.

Table 4.35 sets out the environmental management controls that would be applied in addition to any controls developed to achieve the performance objectives.

Table 4.35 Management measures for agriculture across all project-related activities

Element or issue	• Reduced productivity and increased costs. • Crop losses or disturbance to stock. • Soil disturbance. • Increased costs of farm management. • Loss of amenity.
Environmental objectives	• To avoid or reduce adverse impacts to agricultural infrastructure. • To reduce adverse impacts to agricultural production (cropping and breeding). • To reduce adverse impacts to farming practices (i.e., day-to-day agricultural activities). • Maintain and/or restore soils to support the intended land use.
Performance criteria	• Development activities (and infrastructure) integrated with farming operations. • Infrastructure and associated farm management areas of intensive farming operations avoided. • Production facilities, electricity substations and associated access tracks sited to avoid or reduce loss of cultivation areas and irrigation infrastructure. • Medium pressure pipelines routed to reduce impacts on cultivation areas and irrigation systems. • Introduction of additional headlands in cultivation paddocks minimised. • Loss of productive land in controlled traffic paddocks minimised. • Operation and effectiveness of soil conservation structures maintained. • Wells and access tracks located outside swept paths (effective coverage) of centre-pivot, and lateral and low pressure boom irrigators. • Integrity and efficiency of surface irrigation systems maintained. • Opportunities to schedule development and routine maintenance activities with the cropping cycle maximised. • Access tracks in cultivation paddocks designed to maintain the existing hydrologic and hydraulic regime of the site. • Disturbance and temporary loss of productive land associated with drilling wells minimised.
Common implementation strategy for all phases	• Comply with the provisions of the *Petroleum and Gas (Production and Safety) Act 2004* and the Land Access Code prior to accessing private land. All appropriate agreements (with accompanying maps of the area of interest and detail on infrastructure development) will be in place prior to entry onto the land. Arrow will ensure all appropriate landowners are notified prior to access being required to allow stock to be moved and access routes to be cleared of machinery or materials. [C075] • Avoid infrastructure and associated farm management areas of intensive farming operations, including piggeries, feedlots, vineyards, orchards, horticultural enterprises, poultry farms and small-lot plantations. [C076] • Maintain the grievance process (complaint management system) for the community to register complaints, issues, comments and suggestion. [C077] • Retain and regularly inspect erosion and sediment control structures until reinstated soils have been stabilised and sown. [C078] • Plan and integrate construction and operations activities with harvesting, spraying and withholding periods. [C080]

Table 4.35 Management measures for agriculture across all project-related activities (cont'd)

Common implementation strategy for all phases (cont'd)	Note: well workovers will take place every 3 to 5 years during a well life, which involves similar activities to those in construction. Therefore construction and operation implementation strategies have been combined. Decommissioning has also been combined as capping and sealing a well is a decommissioning specific activity. • Develop and implement a compensation framework to 'add value' rather than just compensating for impacts. [C081] • Develop coal seam gas development property plans to address key issues raised by landowners relating to potential impacts on intensively farmed land. [C082] • Investigate the opportunity to increase well spacing from 160 acres (65 ha) to 320 acres (129 ha) or greater to reduce the footprint on strategic cropping land. [C083] • Consult and agree with landowners on the appropriate location for infrastructure and access routes (to well sites and to and along pipelines). Clearly identify the outcome of the discussions on scaled plans of the property and clearly indicate agreed access routes using signs, temporary fencing, barricade tape or traffic control measures. [C084] • Study methods to reduce impacts and maintain the soil profile during gathering system pipeline construction by understanding the soil type, reducing pipe diameters, plowing (instead of trenching) and potentially burying deeper than the minimum standard. [C085] • Develop or facilitate the development of a method for assessing impacts on productivity (crop yields) that incorporates statistical analysis and appropriate control and sampling sites. [C086] • Investigate alternative drilling technologies such as using directional drilling to access coal measures, reducing gathering system pipe diameters and drilling multiple wells from one drill pad to potentially reduce the footprint on strategic cropping land. [C087] • Consult with landowners on the most appropriate method to minimise disruption to cultivation paddocks (including the introduction of additional headlands) and loss of productive land in controlled-traffic paddocks. The following measures will be considered in reaching agreement: – Locate infrastructure (in order of preference) outside of cultivation areas, in headlands or at the corners of cultivated areas, adjacent to boundary fences or in areas of a paddock with the lowest-quality soil. – Locate access tracks in headlands or adjacent to boundary fences. – Utilise existing access tracks and trafficked areas. – Align gathering lines and new access tracks parallel to the direction of cultivation, soil conservation structures and controlled traffic runs and avoid perpendicular or lateral connections. – Lay out drill pads in accordance with landowner requirements, subject to safety requirements, to reduce the overall impact on cultivation, where practicable. [C088] • Develop construction methods and design access tracks in cultivation paddocks to maintain the existing hydrologic and hydraulic regime of the site, and in a way that does not cause erosion. [C089] • Ensure coal seam gas water used for dust suppression on roads or for construction and operation activities is treated if required. [C497]

Table 4.35 Management measures for agriculture across all project-related activities (cont'd)

Implementation strategy for construction, operations and decommissioning	• Clear areas progressively and implement rehabilitation as soon as practicable following construction and decommissioning activities. [C015] • Develop an erosion and sediment control plan and install and maintain appropriate site-specific controls. [C034] • Strip, salvage and stockpile topsoil near the work site separately to subsoils (in consultation with landowners). Ensure topsoil stockpiles have a maximum height of 2 m, where the future use is intended for rehabilitation, and are protected from erosion. [C062] • Backfill soils in the reverse order of removal, and undertake backfilling progressively and regularly during pipeline construction. [C090] • Ensure construction activities do not extend beyond the work site boundaries. [C091] • Ensure dams for coal seam gas water and brine are not constructed on intensively farmed land. [C092] • Install gates in fences of an appropriate standard to restrict access to authorised personnel, vehicles, plant and equipment. [C093] • Ensure an Arrow representative is in attendance at the time of first entry to check contractors have the appropriate environmental management procedures and property-specific information. [C094] • Maintain the integrity and efficiency of surface irrigation systems by adopting the following measures: – Locate infrastructure at or adjacent to the end of head ditches or tail drains and in a manner that does not significantly interfere with swept paths of boom irrigators to avoid severance or fragmentation of water delivery systems. – Locate wells, gathering lines and access tracks adjacent to boundary fences, where practicable. – Align gathering lines and access tracks perpendicular to the direction of head ditches and tail drains (i.e., parallel to the direction of surface flows and cultivation). [C095] • Use surface tanks (not pits) to manage drilling muds on black soils when drilling production wells. [C096] • Fence the exclusion zone of production well sites (i.e., 10 m by 10 m) to exclude unauthorized personnel, stock and wildlife from that area. [C097] • Inspect work sites and access routes for notifiable weeds and pest plants and animals prior to accessing the site; and if detected, manage in accordance with the Petroleum Industry – Minimising Pest Spread Advisory Guidelines, Queensland Department of Primary Industries and Fisheries, June 2008 (Biosecurity Queensland, 2008). [C098] • Wash down vehicles and equipment that have potentially been in contact with weeds before entering new work sites. [C099] • When operating on black soils, collect, contain and store drilling fluids and waste (solid and liquid) on site in appropriate storage tanks until recycled, treated (if necessary) or disposed off site. [C100] • Stockpile drilling cuttings adjacent to the well or in containers and dispose of appropriately in consultation with the landowner. [C101] • Store onsite materials in suitable containment systems constructed to industry standards and Australian standards (AS 1940-2004, The Storage and Handling of Flammable and Combustible Liquids (Standards Australia, 2004a), and AS 3780, The Storage and Handling of Corrosive Substances (Standards Australia 2008) at a minimum). Maintain quality control and quality assurance procedures to monitor volumes and quantities. Bund aboveground storage areas to contain spills. [C102]

Table 4.35 Management measures for agriculture across all project-related activities (cont'd)

Implementation strategy for construction, operations and decommissioning (cont'd)	• Manage soil contaminated by oil, fuel and grease in accordance with the hydrocarbon management plan (prepared as part of the Arrow HSEMS), which includes procedures for the excavation and removal to a licensed landfill or remediation at site. Where contamination has occurred, investigate and remediate in accordance with Draft Guidelines for the Assessment and Management of Contaminated Land in Queensland, Department of Environment, 1998 (DE, 1998). [C103] • Maintain a minimum separation, as agreed with landowner, between animal enclosures and production wells and facilities. [C104] • Suspend works when rainfall or storm events produce onsite conditions that, if trafficked or worked, would compromise the effectiveness of erosion and sediment control structures, or would lead to rutting and compaction of soils or mixing or inversion of soil horizons. [C105] • Prevent subsurface water flows and erosion along the backfilled trench by appropriate means, such as trench blocks and compaction of backfilled soils. [C503] • Stockpile cleared or mulched vegetation along the inside edge of the work sites (separate from soil stockpiles), to aid the control of runoff and ensure stockpiled vegetation does not pose a bushfire hazard. [C106] • Construct batters and embankments of drill pads and production facility benches at appropriate slopes and protect from erosion. [C108] • Stockpile imported fill for bedding of pipes adjacent to the trench and away from vegetation, topsoil and subsoil stockpiles. [C109] • Remove excess imported fill and residual subsoil from the work site, and reuse or dispose in accordance with landowner requirements. [C110] • Maintain the operation and effectiveness of soil conservation structures by adopting the following measures: – Avoid breaching, diversion or disturbance of contour banks, waterways and dams. – Avoid earthworks that affect waterway function. – Locate wells, access tracks and gathering lines downhill and parallel to soil conservation structures and avoid perpendicular or lateral connections. – Utilise existing access tracks and trafficked areas. [C111] • Remove sediment fencing prior to cultivation and dispose in accordance with landowner requirements or in accordance with the waste management plan of the Arrow HSEMS. [C112] • Cap or fit wellhead equipment to wells at the completion of drilling to ensure no uncontrolled release of gas or water. [C113] • Remove salt from the landscape as part of decommissioning works and dispose in an approved and regulated landfill. [C114]
Implementation strategy for decommissioning	• Backfill and rehabilitate excavations, particularly pipeline trenches and drilling sumps. Conduct backfilling in a manner that will promote successful rehabilitation, including capping of exposed subsoil with topsoil and replacement of the land surface to preconstruction levels to reduce trench subsidence and concentration of flow. Mounding of soils to allow for settling may be required in some areas. However, in laser-levelled paddocks, this may not be practicable, and backfilling should be carried out in consultation with the landowner. [C071] • Replace or rehabilitate all disturbed infrastructure to predisturbance condition. [C115] • Regrade work sites to original surface contours following reinstatement. [C116] • Mulch vegetation and reuse in site rehabilitation. [C117]

Table 4.35 Management measures for agriculture across all project-related activities (cont'd)

Implementation strategy for decommissioning (cont'd)	• Deep rip and cross rip all construction areas and temporary access tracks to a depth of at least 0.4 m. Repeat following topsoil reinstatement to promote infiltration and assist the re-establishment of connections between soil horizons. [C118] • Compact padding material and subsoils used to backfill pipeline trenches to reduce settling. Limit compaction to no deeper than 0.5 m below natural surface level. [C119] • Rehabilitate clean water diversions, down-gradient soil erosion control works and temporary sediment dams to preconstruction site levels and rip prior to sowing with crops or pasture grasses. [C121] • Clean and reinstate (if necessary) erosion and sediment control structures prior to and following storm events and periodically during long periods of rain. [C122] • Visually inspect rehabilitated work sites for flow diversions and evidence of erosion associated with trench slumping or incomplete reinstatement of surface contours. [C123]
Inspection and monitoring	• Inspect erosion and sediment control measures following significant rainfall events to ensure effectiveness of measures is maintained. [C505] • Inspect pipeline ROWs routinely until ground stabilisation and natural revegetation or pasture grasses or crops are established. [C506] • Monitor crop productivity or pasture health periodically to measure productivity on disturbed areas. [C519] • Review landowner grievances regularly, including status of project actions and close-outs. [C520] • Ensure that the quality of coal seam gas water used for dust suppression meets the prescribed limits. [C540]
Auditing	The effectiveness of this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

5. DECOMMISSIONING AND REHABILITATION

Impacts on environmental values and corresponding management measures related to the decommissioning and rehabilitation phase of the project are presented in the following sections of the environmental management plan:

- Section 4.1, Air Quality.
- Section 4.2, Geology, Landform and Soils.
- Section 4.3, Landscape and Visual Amenity.
- Section 4.4, Terrestrial Ecology.
- Section 4.5, Groundwater.
- Section 4.6, Surface Water.
- Section 4.7, Aquatic Ecology.
- Section 4.8, Coal Seam Gas Water.
- Section 4.9, Dams.
- Section 4.10, Noise and Vibration.
- Section 4.11, Waste.
- Section 4.12, Preliminary Hazard and Risk.
- Section 4.13, Indigenous Cultural Heritage.
- Section 4.14, Non-Indigenous Cultural Heritage.
- Section 4.15, Roads and Transport.
- Section 4.16, Agriculture.

Given the proposed life span of the project and that details of final land uses following decommissioning and rehabilitation have not yet been determined, site-specific objectives, indicators and completion criteria cannot be developed at this time. However, options, general processes and objectives, indicators and completion criteria for the decommissioning and rehabilitation of areas disturbed by project-related infrastructure are discussed below.

A combination of underground and aboveground infrastructure will require removal during this phase of the project, and a variety of waste streams (solid, liquid and gaseous) will be generated.

5.1 Final Land Use Options

The project infrastructure has a design life ranging between 15 and 35 years, and decommissioning and rehabilitation will progressively occur throughout this period. Final decommissioning and rehabilitation will occur at the end of individual infrastructure life, taking into consideration a variety of final land use options. The final land use will be determined through consideration of a number of factors, including but not limited to the following:

- Relevant legislative and regulatory requirements of the day.
- Views of stakeholders, landowners and the local community.
- Surrounding land uses.
- Surrounding sensitive receptors and receiving environment.
- The environmental, social and cultural values of the area.

5.2 Decommissioning and Rehabilitation Goals

The goals of decommissioning and rehabilitation are to ensure that the project development area is:

- Safe for humans, wildlife and domestic animals.
- Non-polluting.
- Stable (landforms).
- Able to sustain an agreed land use.

Prior to decommissioning, detailed objectives, criteria and performance indicators will be developed for each of the above goals in consultation with the appropriate regulatory agency and landowners.

5.3 Phases of Decommissioning and Rehabilitation

Decommissioning and rehabilitation involves three key tasks:

1. **Progressive Rehabilitation.** This is undertaken after construction to stabilise the land and reduce the construction footprint for operations. The period of time between construction and the initial phase of progressive rehabilitation will be minimised to prevent degradation and loss of exposed soils. Surface structures, equipment and waste materials from the construction area will be removed prior to rehabilitation.

2. **Decommissioning.** At the end of the project infrastructure's life or when the infrastructure is no longer required, it will be decommissioned by removal of surface facilities and waste from the site. In some cases, subsurface infrastructure may remain in situ.

3. **Final Rehabilitation.** This involves the final reinstatement of topography, reprofiling and revegetation of the site (where required) to return the disturbed land to as near as practicable to the predisturbance state. Compacted areas will be ripped or scarified, and topsoil will be respread to encourage natural revegetation. In some cases, stabilisation measures will be used to ensure topsoil remains intact. Site-specific rehabilitation plans will be developed for areas where natural vegetation regeneration may be problematic. The final rehabilitation will be determined in conjunction with the landowner and DERM.

5.4 Summary of Rehabilitation Goals, Objectives, Indicators and Completion Criteria

Given that final land uses following decommissioning and rehabilitation have not yet been determined, site-specific objectives, indicators and completion criteria cannot be developed at this time. However, processes involved in decommissioning and rehabilitating project infrastructure types can be described.

5.4.1 Production and Monitoring Wells

Progressive rehabilitation after installation of wells will result in an operational footprint area of approximately 10 m by 10 m per well. When production and monitoring wells reach the end of their production life (approximately 15 to 20 years), they will be decommissioned in accordance with the P&G Act requirements.

These requirements include the removal of all surface equipment, including fencing; cutting off the well casing and the gathering line connections below the ground surface; and using a drilling rig to plug the well with concrete to isolate formations and prevent gas leakage to the surface. A statutory signpost will be erected on a nearby fence or other suitable location.

Well sites will then be rehabilitated to a standard consistent with the surrounding land use or as agreed with the landowner. Rehabilitation may involve recontouring, replacing topsoil, and re-establishing drainage lines and pasture species.

Rehabilitation goals, objectives, indicators and completion criteria for production and monitoring wells are shown in Table 5.1.

5.4.2 Gas and Water Gathering Systems and High-pressure Gas Pipelines

Australian Standard AS 2885 for gas and liquid petroleum pipelines provides guidance on the abandonment of pipelines.

Decommissioning of gas and water gathering lines will involve:

- Depressurising the pipeline.
- Isolating pipelines from wells or above ground facilities.
- Purging the gas pipelines, inerting or filling with water, then capping the ends.
- Leaving the gathering lines in situ (removing the pipes from the ground would result in additional and unnecessary environmental impacts).
- Where necessary, filling the pipe with a stabilising material, such as concrete, to prevent subsidence under roads, utilities or railway lines.
- Removing surface infrastructure and signage.

Rehabilitation of the gas and water gathering line easement would return it to the surrounding land use or the use negotiated with the landowner.

High-pressure gas pipelines will either be suspended for future use or decommissioned. Suspending a pipeline would involve filling it with inert gas (e.g., nitrogen) or water containing corrosion-inhibiting chemicals and capping the ends. Decommissioning of high-pressure pipelines would be consistent with the gas gathering pipelines methods described above.

In either case, a detailed rehabilitation plan would be developed in consultation with landowners.

Rehabilitation goals, objectives, indicators and completion criteria for production and monitoring wells are shown in Table 5.1.

5.4.3 Production and Power Generation Facilities

Arrow may undertake decommissioning of production facilities as a combined project or may progressively decommission and rehabilitate individual components. Given the life of production facilities is approximately 30 years, decommissioning and rehabilitation works may not occur for 15 to 30 years.

Table 5.1 Rehabilitation management of wells, gathering systems, pipelines, production facilities and power generation facilities

Petroleum Activity Feature	Relevant Resource Authority	Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
Production and monitoring wells. Gas and water gathering systems. High-pressure gas pipelines. Production facilities and power generation facilities.	Tenure number	Safe	Site is safe for humans and animals.	No injuries to humans or animals.	Infrastructure decommissioned in accordance with the relevant regulatory standards to prevent gas and water leakage. Petroleum-related infrastructure isolated, drained, purged and removed from site. Non-petroleum related infrastructure may remain on site with landowner approval. Statutory signposts installed to mark the location of decommissioned wells.
		Non-polluting	To prevent impact to soils, surface water and groundwater.	No soils, surface water or groundwater contamination above applicable objectives.	Wells decommissioned in accordance with the relevant regulatory standards to prevent groundwater mixing and future leakage to groundwater systems. Gathering lines decommissioned in accordance with the relevant regulatory standards to prevent gas and water leakage into the ground. Contents of gathering lines collected to prevent discharge to receiving environment. Solid or liquid wastes associated with facilities collected and removed to licensed waste facilities. Any contaminated land remediated to appropriate human health and environmental standards.
		Stable	To provide a stable landform.	No visual indications of erosion.	Former wellheads reduced to as small as practicable, with ground surface shaped to promote natural drainage patterns and limit pooling of surface water. Any underground infrastructure filled with an inert substance to prevent subsidence, where applicable. Soil ripped or scarified by another suitable technique in highly trafficked areas to promote free drainage.
		Self-sustaining	Final state can support an agreed land use and is compatible with surrounding land use.	Healthy and suitable vegetation growth.	A suitable vegetation cover to enable natural vegetation progression and minimal weed invasion. Ground conditions conducive to natural regeneration.

Major production facility equipment, such as compressors and gas engines, as well as ancillary equipment, such as flares, tanks, piping, electrical and other utility systems, will be isolated, drained, purged of gas and removed from site. Where practical, the major equipment will be reused elsewhere in Arrow's developments.

Any potentially contaminated soil will be remediated onsite or removed to an appropriate treatment or disposal facility.

Rehabilitation of production facilities may involve recontouring, topsoil replacement and revegetation. Rehabilitation will be done in consultation with the landowner.

Any infrastructure, such as roads, tracks or dams, that remains onsite for the landowner will have a written agreement in place that will be submitted to DERM with the final rehabilitation report.

Power generation facilities will be decommissioned and rehabilitated similarly to the production facilities. Overhead transmission lines would be isolated from the distribution system and will be either removed or left in situ, if agreed with landowners.

Rehabilitation goals, objectives, indicators and completion criteria for production and monitoring wells are shown in Table 5.1.

5.4.4 Water Treatment and Storage Facilities

Water treatment units will be drained and removed from site with a priority to reuse them elsewhere on Arrow developments. Dams may be left in situ if agreed with landowners. The water reticulation potential may be considered a beneficial end use for the land. However, if this is not practicable, dams will be removed. Any brine residue will be removed as waste and disposed of at an appropriately licensed facility.

Rehabilitation goals, objectives, indicators and completion criteria for water treatment and storage facilities are shown in Table 5.2.

5.4.5 Supporting Infrastructure

Accommodation camps will be constructed in modules and therefore can be easily removed from any site and reused elsewhere. Decommissioning and rehabilitation of borrow pits will involve ripping of the pit floors, slope stabilisation, contouring, respreading of topsoil and, if practicable, revegetation. Depots and offices blocks in regional centres will be left in place.

Rehabilitation goals, objectives, indicators and completion criteria for supporting infrastructure are shown in Table 5.3.

Table 5.2 Rehabilitation management of water treatment and storage facilities

Petroleum Activity Feature	Relevant Resource Authority	Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
Water treatment and storage facilities.	Tenure number	Safe	Site is safe for humans and animals.	No injuries to humans or animals.	Dams and associated reticulation system may be left in situ if agreed with landowners. Where dams are removed, their contents will be drained and disposed of to appropriate waste facilities.
		Non-polluting	To prevent impact to soils, surface water and groundwater.	No soils, surface water or groundwater contamination above applicable objectives.	Brine residue will be removed as waste and disposed of at an appropriately licensed facility. Any contaminated land will be remediated to appropriate human health and environmental standards.
		Stable	To provide a stable landform.	No visual indications of erosion.	Former dam backfilled and ground surface shaped to promote natural drainage patterns and limit pooling of surface water. Any underground infrastructure filled with an inert substance to prevent subsidence, where applicable.
		Self-sustaining	Final state can support an agreed land use and is compatible with surrounding land use.	Healthy and suitable vegetation growth.	A suitable vegetation cover to enable natural vegetation progression and minimal weed invasion. Ground conditions conducive to natural regeneration.

Table 5.3 Rehabilitation management of supporting infrastructure

Petroleum Activity Feature	Relevant Resource Authority	Rehabilitation Goal	Rehabilitation Objectives	Indicators	Completion Criteria
Supporting infrastructure	Tenure number	Safe	Site is safe for humans and animals.	No injuries to humans or animals.	Modular infrastructure removed from the site and reused elsewhere. Borrow pits contoured to establish a stable landform. Permanent office infrastructure left in place for continued operation or third-party use. Any contaminated land remediated to appropriate human health and environmental standards.
		Non-polluting	To prevent impact to soils, surface water and groundwater.	No soils, surface water or groundwater contamination above applicable objectives.	Solid or liquid wastes associated with accommodation camps collected and removed to licensed waste facilities. Any contaminated land remediated to appropriate human health and environmental standards.
		Stable	To provide a stable landform.	No visual indications of erosion.	Former disturbance area reduced to as small as practicable, with ground surface shaped.
		Self-sustaining	Final state can support an agreed land use and is compatible with surrounding land use.	Healthy and suitable vegetation growth.	A suitable vegetation cover to enable natural vegetation progression and minimal weed invasion. Ground conditions conducive to natural regeneration.

5.5 Monitoring, Auditing and Reporting Requirements

Monitoring, auditing and reporting requirements during the decommissioning and rehabilitation phase of the project are summarised in Table 5.4 below.

Table 5.4 Monitoring, auditing and reporting requirements

Inspection and Monitoring	At a minimum, undertake annual verification to ensure mitigation measures are working as planned and to intervene early, should the desired objectives not be achieved.
Auditing	Compliance with this management plan will be assessed during periodic HSEMS audits described in Chapter 2 of this environmental management plan.
Reporting	• Reporting will be undertaken in accordance with the requirements set out in Chapter 2 of this environmental management plan and will include the following information: – Total disturbance on the tenures for each annual reporting period. – Total area rehabilitated on the tenures for each annual return reporting period. – Total area remaining disturbed on the tenures for each annual return reporting period. – Details of any unsuccessful rehabilitation. • A final rehabilitation report and a decommissioning plan, including a contaminated land assessment, landowner commitments and agreements, and rehabilitation status, will be prepared and submitted to the appropriate authorities for approval.
Corrective action	Corrective actions will be undertaken in accordance with the outcomes of incident investigations, audits, monitoring results or advice given by the relevant regulatory authority.

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