

COAL SEAM GAS WATER MANAGEMENT STRATEGY

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1 INTRODUCTION

1.1 Purpose

The purpose of this strategy is to define and communicate the management framework for coal seam gas water to be implemented by Arrow Energy Ltd (Arrow). This strategy and the associated coal seam gas water management plans for individual projects have been developed within the regulatory framework to ensure that Arrow’s operations are conducted at, or above, the legal requirements and standards expected by stakeholders and the broader community.

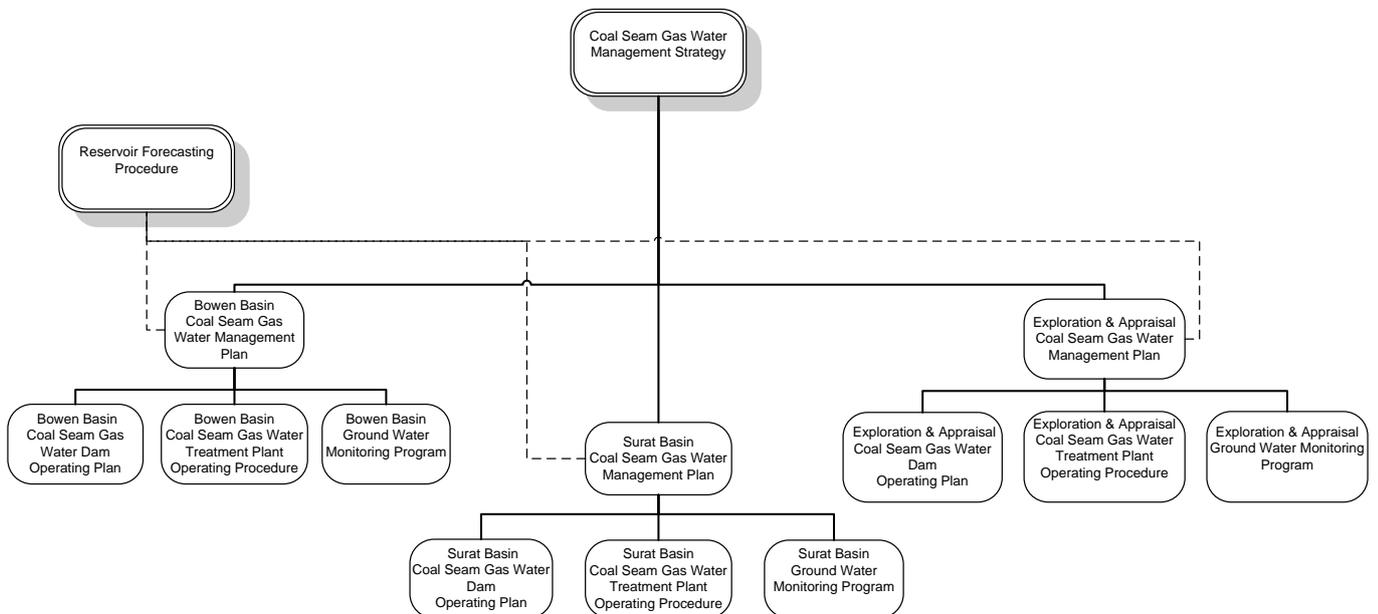
The strategy is intended to inform all Arrow personnel of the approach employed and principles adopted in managing coal seam gas water from the point of production through to beneficial use mitigation or in some cases disposal. It seeks to manage coal seam gas water produced as a result of Arrow operations in a way that maximises beneficial use and minimises the environmental impacts associated with water use and disposal. This strategy is to be implemented in conjunction with the coal seam gas water management plans and standard operating procedures (SOPs) developed for Arrow operations.

1.2 Objectives

The objectives of this strategy are to:

- Communicate corporate policy and principles for the management of coal seam gas water
- Identify the regulatory approvals required to enable gathering, treatment, storage, distribution, beneficial use mitigation and disposal of coal seam gas water
- Establish a framework for development of both aquifer and infrastructure groundwater monitoring programs

1.3 Document Hierarchy



2 COAL SEAM GAS WATER MANAGEMENT

2.1 Regulatory Framework

Coal seam gas water is regulated under the following legislation in conjunction with government policies, guidelines and procedures:

| Approvals | Approval & Legislation | Responsible |
|--|--|-------------------------------|
| Petroleum tenure required to produce gas and therefore coal seam gas water as a by-product | <ul style="list-style-type: none"> • Authority to Prospect (for production testing) • Petroleum Lease • Petroleum & Gas (Safety & Production) Act 2004 (P&G Act) • Petroleum Act 1923 | DEEDI |
| Environmental Authority (EA) required for each tenure or group of tenures comprising a single project to condition the activities authorised under the P&G Act | <ul style="list-style-type: none"> • Environmental Protection Act 1994 (EP Act) • Environmental Authority (EA) <ul style="list-style-type: none"> - Environmental management plan - Coal seam gas water management plan (including brine management plan) - Waste management plan - Dam design report and operating plan - Dam monitoring and auditing program (including infrastructure groundwater monitoring program) - Decommissioning management plan - Rehabilitation management plan | DERM |
| Regulated Waste Management – coal seam gas water is classified as regulated waste | <ul style="list-style-type: none"> • EP Act (EA) <ul style="list-style-type: none"> - Regulated waste management and tracking system | DERM |
| Dam design, construction, operation and monitoring | <ul style="list-style-type: none"> • EP Act (EA) <ul style="list-style-type: none"> - Dam design report and operating plan - Dam monitoring and auditing program (including infrastructure groundwater monitoring program) | DERM |
| Groundwater Monitoring Plans | <ul style="list-style-type: none"> • Water Act 2000 <ul style="list-style-type: none"> - Aquifer groundwater monitoring program - Groundwater model - Groundwater investigations, including landholder claims of impaired bore capacity - Baseline assessment plan for landholder bores - Bore assessment procedures • EP Act (EA) <ul style="list-style-type: none"> - Leakage detection for surface infrastructure (eg dams) – infrastructure groundwater monitoring program - Where springs exist, monitoring of groundwater levels • P&G Act <ul style="list-style-type: none"> - Water monitoring authority for off tenure - Land access | DERM DERM DEEDI |
| Underground Water Impact Reports | <ul style="list-style-type: none"> • Water Act <ul style="list-style-type: none"> - For Cumulative Management Areas (CMA) declared by DERM, published by the Queensland Water Commission - For areas outside of CMAs, submitted by the tenure holder | DERM QWC |
| Make Good Obligations | <ul style="list-style-type: none"> • Water Act <ul style="list-style-type: none"> - When CMA declared and ‘immediately affected area’ (IAA) identified, tenure holder must undertake assessment of all landholder bores in IAA - Where potential for impact on bore in the IAA (within 3 years) or where impaired capacity observed, tenure holder to negotiate a ‘make good’ agreement with the bore owner | DERM |

| Approvals | Approval & Legislation | Responsible |
|---|--|-------------|
| Supply untreated or treated water to a third party (on tenure) | <ul style="list-style-type: none"> Water Act <ul style="list-style-type: none"> - Water Supply Licence Environment Protection (Waste Management) Regulation 2000 <ul style="list-style-type: none"> - Beneficial Use Approval – general or specific Contract with third party | DERM |
| Supply untreated or treated water to a third party (off tenure) | <ul style="list-style-type: none"> Water Act <ul style="list-style-type: none"> - Water Supply Licence Environment Protection (Waste Management) Regulation <ul style="list-style-type: none"> - Beneficial Use Approval – general or specific Contract with third party Sustainable Planning Act 2009 <ul style="list-style-type: none"> - Development Approval | DERM |
| If charging for supply untreated or treated water to a third party (on or off tenure) | <ul style="list-style-type: none"> Water Act <ul style="list-style-type: none"> - Water Service Provider's Licence Environment Protection (Waste Management) Regulation <ul style="list-style-type: none"> - Beneficial Use Approval – general or specific Contract with third party | DERM |
| Supply of coal seam gas water to a drinking water service provider (direct or indirect augmentation) | <ul style="list-style-type: none"> Water Supply (Safety & Reliability) Act 2008 <ul style="list-style-type: none"> - Coal seam gas water defined as 'recycled water' - Recycled water management scheme, including appointment of scheme manager | DERM |
| Beneficial use of coal seam gas water: <i>General:</i> Dust suppression, some agricultural, aquaculture <i>Specific:</i> Potable water, other industrial, agricultural when parameters outside of general requirements e.g. irrigation or intensive feedlot | <ul style="list-style-type: none"> Environment Protection (Waste Management) Regulation <ul style="list-style-type: none"> - No application required for General Beneficial Use Approval, only provide notification to DERM - Application required for Specific Beneficial Use Approval, including extensive water and other analyses - For irrigation: a Resource Management Plan is required | DERM |
| Substitution of groundwater allocations with coal seam gas water | <ul style="list-style-type: none"> Water Act <ul style="list-style-type: none"> - Water Supply Licence Environment Protection (Waste Management) Regulation <ul style="list-style-type: none"> - Beneficial Use Approval for third party to use the water Contract with third party | DERM |
| Discharge into watercourse | <ul style="list-style-type: none"> EP Act (EA) <ul style="list-style-type: none"> - Environmental Impact Assessment to achieve EA approval - Receiving Environment Monitoring Program - Water Release Reduction Strategy Water Supply (Safety & Reliability) Act 2008 <ul style="list-style-type: none"> - Recycled water management scheme, including appointment of scheme manager - <i>Note: coal seam gas water is assumed to directly or indirectly augment a drinking supply and is therefore automatically captured under the Water Supply (Safety & Reliability) Act 2008 however application for exemption can be made to the Office of the Water Supply Regulator in DERM. Extensive monitoring, analyses, modelling and risk assessment are required for exemption</i> | DERM |

| | | |
|---|--|------------|
| Injection into an aquifer used or potentially used as a source of supply for drinking | <ul style="list-style-type: none"> • P&G Act <ul style="list-style-type: none"> - Authorised petroleum activity • EP Act (EA) <ul style="list-style-type: none"> - Application for approval to undertake injection trial - Application to include extensive monitoring, analyses, investigations and risk assessments - DERM specifications for injection well - Aquifer groundwater monitoring program - <i>Note: coal seam gas water is assumed to directly or indirectly augment a drinking supply and is therefore automatically captured under the Water Supply (Safety & Reliability) Act 2008 however application for exemption can be made to the Office of the Water Supply Regulator in DERM</i> | DEEDI/DERM |
| Salt or brine disposal | <ul style="list-style-type: none"> • Environment Protection (Waste Management) Regulation • EP Act (EA) <ul style="list-style-type: none"> - Coal seam gas water management plan (including brine management plan) - Regulated waste management and tracking system - No encapsulation of brine dams on site - Regulated waste management facility • Commercial agreement with regulated waste service provider | DERM |
| Beneficial use of salt or brine | <ul style="list-style-type: none"> • Environment Protection (Waste Management) Regulation <ul style="list-style-type: none"> - Beneficial Use Approval • EP Act (EA) • Contract with third party | DERM |
| Land access, including compensation for pipelines and Notice of Entry | <ul style="list-style-type: none"> • P&G Act • Land Access Procedure (99-V-PR-0025)) | DEEDI |
| Vegetation clearing | <ul style="list-style-type: none"> • EP Act (EA) • Environment Protection and Biodiversity Conservation Act 1999 (Federal) • Nature Conservation Act 1992 <ul style="list-style-type: none"> - Vegetation clearing permit | DERM/DEWHA |

| Policies, Procedures & Guidelines | Type | Responsible |
|--|-------------|--|
| Coal Seam Gas Water Management Policy | Policy | DERM |
| Regulated Dams in Environmentally Relevant Activities | Guideline | DERM |
| Manual for Assessing Hazard Categories and Hydraulic Performance of Dams | Guideline | DERM |
| Preparing an Environmental Management Plan for Coal Seam Gas Activities | Guideline | DERM |
| Monitoring and Sampling Manual - Environmental Protection (Water) Policy | Policy | DERM |
| Minimum Construction Requirements for Water Bores in Australia | Guideline | National Minimum Bore Specifications Committee |
| Minimum Standards for the Construction and Reconditioning of Water Bores that intersect the Sediments of Artesian Basins in Queensland | Guideline | DERM |

2.2 Source of Coal Seam Gas Water

Coal seam gas is the name given to any naturally occurring gas trapped in underground coal seams by water and ground pressure. The gas lines the open fractures between the coal (called cleaves) and the inside of the pores within the coal (the matrix).

Coal seams store both gas and water. The water, which is under pressure from the weight of overlying rock material, holds the gas in place. When the water pressure is reduced, the gas is released. In the production process, the water pressure is reduced when a well is drilled into a coal seam and the water is gradually pumped out of the seam. This allows the gas to flow to the surface in the well.

Once a well has been drilled, it becomes the only conduit for gas and water to reach the surface. The two products are separated below ground, with water being transferred to centralised collection and treatment points, and the gas being piped to production facilities where it is dried, compressed and piped to market.

CSG water can vary from fresh water (water with very few other elements) to saline or highly turbid. Coal seam gas water from the Surat or Bowen Basins typically has the following characteristics:

- pH of approximately 7 to 11
- Salinity generally ranging from 3,000 to 8,000 mg/L (i.e., brackish) and total dissolved solids (TDS) including sodium salts, bicarbonate salts, chlorides and others
- Suspended solids from the well that will usually settle out over time
- Other ions including calcium, magnesium, potassium, fluoride, bromine, silicon and sulphate (as SO₄)
- Trace metals and low levels of nutrients

The beneficial use of this water is constrained by the salt content, often requiring treatment and/or amendment prior to use. It is understood that CSG water quality typically varies over the life of a well and can also vary between wells in the same location.

2.3 Arrow Operational Areas

Arrow Energy Pty Ltd (Arrow) holds a large number of coal seam gas exploration and production tenures in Queensland and New South Wales.

2.3.1 Queensland Surat Basin

The existing Surat Basin development, known as the Dalby Expansion Project, is located approximately 200 km west of Brisbane and includes the Petroleum Leases (PL) 194, 198, 230, 238, 252, 258 and 260. Arrow is working to expand its coal seam gas operations in the Surat Basin through the Surat Gas Project. The project is expected to cater to the growing demand for gas in the Australian market, and the global liquefied natural gas (LNG) export market. The Surat Gas project development area covers approximately 8,600 km² and 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 (see Figure 1).

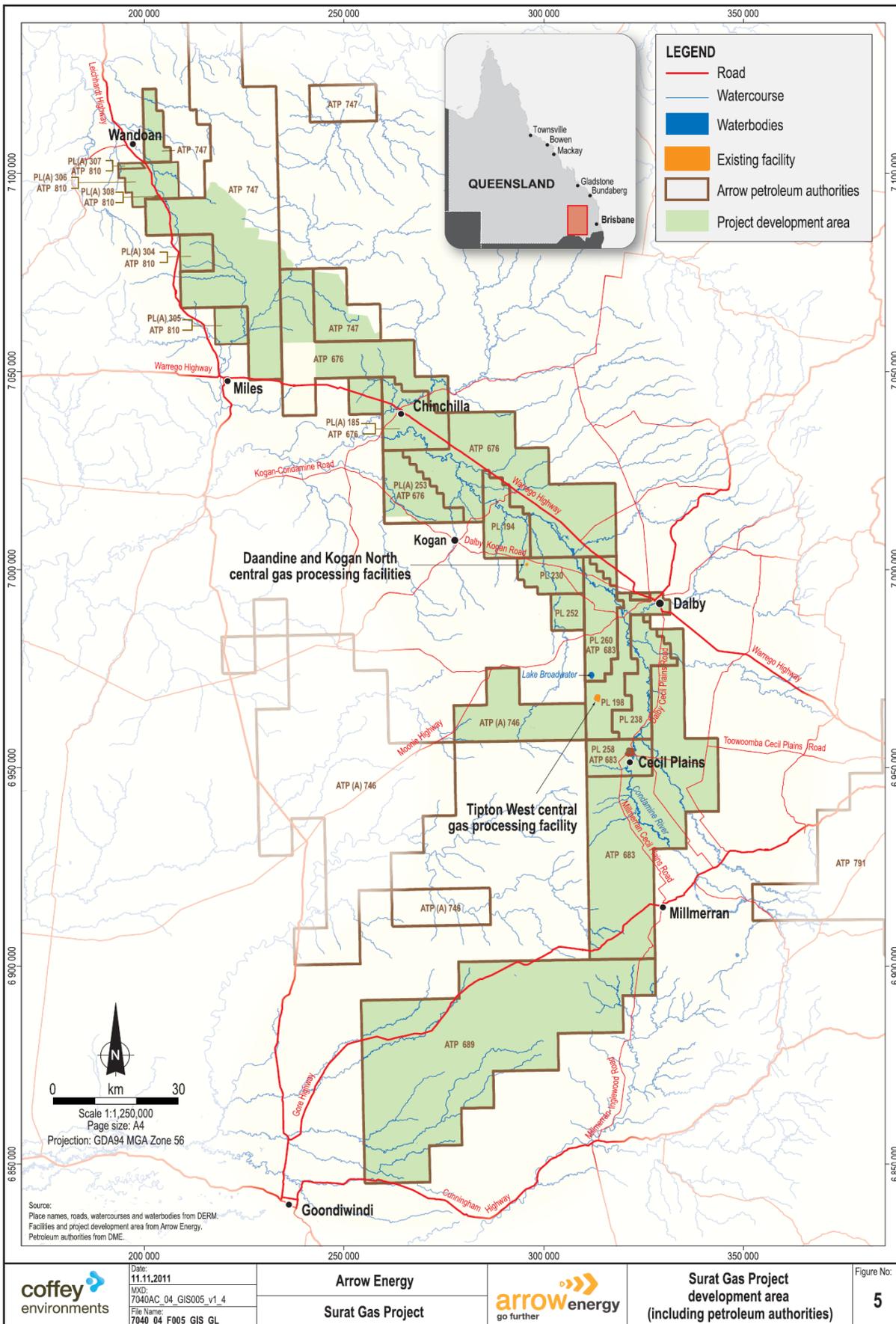


Figure 1: Surat Gas Project development area (including petroleum authorities)

2.3.2 Queensland Bowen Basin

The existing Bowen Basin development, known as the Moranbah Gas Project (MGP), is located near Moranbah and includes the Petroleum Leases (PL) 191, 223, 224 and 196. As in the Surat Basin, Arrow is also working to expand its coal seam gas operations in the Bowen Basin through the Bowen Gas Project. The Bowen Gas Project covers an area of approximately 8000 km² within Arrow's exploration and production acreage, approximately 200 km south west of Mackay, with the bulk of the area extending from 100km north of Moranbah to 100km south of Moranbah (see Figure 2).

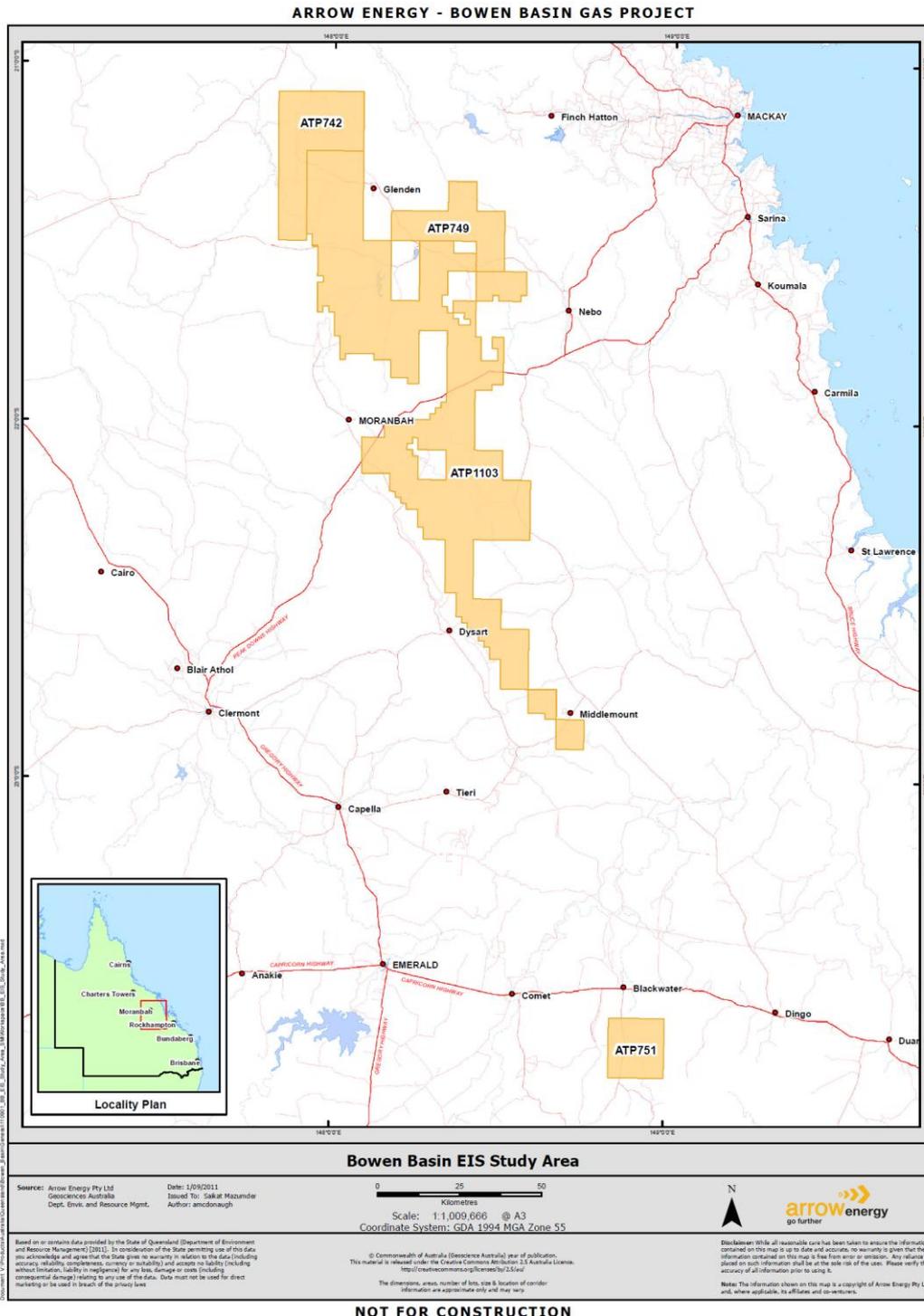


Figure 2: Map of proposed Bowen Gas Project development area

2.3.3 Other Queensland and New South Wales Basins

In addition to the above basins, exploration activities are being undertaken in the following basins for the purposes of gathering information for planning, assessing resources and reserves maturation (see Figure 3):

- Clarence Moreton Basin (QLD and NSW)
- Hillsborough Basin (QLD)
- Nagoorin Graben Basin (QLD)
- Styx Basin (QLD)
- Capricorn Basin (QLD)
- Galilee Basin (QLD)



Figure 3: Map of Queensland and New South Wales Basins

2.4 Coal Seam Gas Water Production Forecasting

Production forecasts are modelled by the reservoir team and managed within the asset operational teams. The procedures and methodology for modelling, including analysis and history matching, are currently being developed into a standard work procedure. This process includes the following key steps:

- Developing key assumptions such as expansion areas, gas sales targets and gas usage for production activities
- Simulating the required production rates using the reservoir model
- Developing a maintenance well program based on forecast timing
- Reviewing model performance against actual production data and history matching

The forecasting process occurs monthly or earlier as a result of significant changes to the field development plan, updated reservoir data or identified production constraints.

2.4.1 Coal Seam Gas Water Production Management

Water balance models are maintained in the asset operating teams and used for short and long term planning of water management infrastructure. The model simulates expected dam capacity based on forecast production rates, assumed seasonal effects and water usage outputs. The following items have been incorporated into the model:

- Forecast water production
- Dam capacity (seasonal working level), surface area and current levels
- Various scenarios of seasonal rainfall and evaporation based on dam surface area and local historical meteorologic conditions
- Natural evaporation factor that comprises of a pan-to-dam factor and a salinity factor
- Beneficial use off-takes
- Treatment capacity, including allowances for plant availability and recovery

The model is reviewed and updated monthly in alignment with the gas production forecasting schedule.

2.5 Coal Seam Gas Water Management Infrastructure

Infrastructure integral to the management of coal seam gas water includes:

2.5.1 Operational Storage Dams

Dams are an integral part of the water management system, providing operational storage or water balance capacity to ensure the containment of coal seam gas water. Existing dams that are not currently connected to the water treatment system will be identified as either key infrastructure for integration into future developments or surplus to requirements, in which case a decommissioning and rehabilitation plan will be developed. The types of dams required to manage the production, treatment and distribution of coal seam gas water are:

- **Aggregation dams (also called feedwater dams)** – required to contain the water collected via gathering pipelines directly from a network of wells. These dams provide a buffer between the variations in production and:
 - Water treatment flows
 - Supply for beneficial use or disposal
 Additional storage allowance is incorporated into the design to ensure operations can be maintained during wet weather events
- **Treated water dams** – required to store treated or ‘clean’ water for beneficial use or disposal (under authorised and controlled situations) to ensure a buffer between the treatment output and beneficial use demand. Additional storage allowance is incorporated into the design to ensure

operations can be maintained during wet weather events and to provide for wet weather storage, particularly when the beneficial use is irrigation

- **Waste water dams** – required for storage of waste lubricants and chemicals used in treatment and compression systems. Additional storage allowance is incorporated into the design to ensure operations can be maintained during wet weather events. Not all locations will require waste water dams.
- **Brine dams** – required for the operational storage of brine extracted via the water treatment process. Additional dams may be required to facilitate concentration of brine in conjunction with additional mechanical, thermal or chemical concentration processes. Additional storage allowance is incorporated into the design to ensure operations can be maintained during wet weather events

Buffer storage is provided in each dam to allow for variation in:

- Daily flows from the field
- Gas to water ratio - controlled by automated level control at each well
- Development of the field to accommodate new wells as required for initial field development and future maintenance wells
- Availability of off-takes and/or downstream processes due to maintenance and other factors
- Levels due to long periods of rain and/or evaporation

2.5.2 Dams in Exploration

Exploration and appraisal activities are generally undertaken in areas remote from water management and treatment infrastructure. Hence dams associated with exploration activities are considered temporary and due to distance are not economically feasible to connect to gathering and treatment facilities at that particular stage in the development. Consequently, relatively small evaporation dams may be constructed. At the conclusion of the activities these dams will be determined as either:

- Inherent to the water management infrastructure for future development and maintained for integration into the future water management network,
- A dam to be transferred to the landholder (at their request) with DERM approval, or
- A dam that is to be decommissioned, with remediation commencing within 6 months of completing the exploration activities.

2.5.3 Water Treatment Facilities

Arrow has undertaken a comprehensive assessment to evaluate the various technologies available for the treatment of coal seam gas water. Currently reverse osmosis (RO) has been selected as the treatment technology of choice, however, Arrow will continue to investigate new and emerging technologies and evaluate their applicability to operations based on:

- Economics
- Energy consumption
- Brine recovery
- Desired water quality commensurate with the end use
- Operational and environmental footprint

Future treatment facilities will generally include ion exchange between the pre-treatment and the RO process to increase recovery and reduce the required size of brine dams.

The need for and size of an RO plant is determined using the water forecast and balance models outlined above. Treatment facilities are constructed in a modular fashion to ensure flexibility in capacity and mobility of units across projects. The treatment facilities will be constructed to accommodate the variation in water volumes predicted through modelling. Contingency measures for diversions from the P₅₀ case include:

| Increased Production | Reduced Production |
|---|---|
| The ability to increase the installed treatment capacity with additional modules | Switch to low operating cost mode when not required to process water at maximum design flows |
| Adequate land area for the addition of more additional modules adjacent to the facility | Rotate membranes to optimise throughput and performance or not replacing membranes at the end of their life |
| Utilise spare capacity to treat water from future developments either in place or by relocating containerised/transportable plant | Take RO elements off line, mothball and return to operation in coordination with other RO elements |

2.5.4 Gathering and Distribution Systems

The types of pipelines required to manage the production, treatment and distribution of coal seam gas water are:

- **Water gathering lines** – a low pressure water gathering system is installed from each well head to aggregation dams at each treatment facility. The construction of water gathering lines within the boundary of the petroleum tenure is authorised under the P&G Act
- **Transfer pipelines** – a transfer pipeline, including associated pumps and controls is constructed to connect dams within and between project treatment facilities to ensure that variations in coal seam gas water production and field development phasing can be managed
- **Distribution pipelines** – a network of distribution pipelines, including associated pumps and controls, conveys treated and/or untreated water to end users in the region

2.6 Construction Standards and Approvals

The regulatory framework for coal seam gas water management infrastructure provides specific guidelines for the design, construction, monitoring and operational maintenance of water storage, treatment and gathering and distribution systems.

| Infrastructure | Requirement | Regulatory Framework |
|----------------------------------|---|--|
| Dams | Dam hazard level/category assessment | <ul style="list-style-type: none"> • DERM Manual for Assessing Hazard Categories and Hydraulic Performance of Dams |
| | Dam design report & certification | <ul style="list-style-type: none"> • DERM Manual for Assessing Hazard Categories and Hydraulic Performance of Dams • DERM Regulated Dams in Environmentally Relevant Activities Guideline • EA conditions |
| | Monitoring, leak detection and audit | <ul style="list-style-type: none"> • EA conditions • Groundwater Monitoring Program |
| | Maintain Regulated Dam Register | <ul style="list-style-type: none"> • EA conditions |
| Gathering and distribution lines | Infrastructure for transporting coal seam gas water within the tenure area is an authorised activity under the P&G Act and the EP Act | Authorised under: <ul style="list-style-type: none"> • P&G Act, subject to coordination agreement with contiguous PL holders • EA conditions (if contained within a single EA), Project EA to facilitate gathering and treatment |
| | Infrastructure for transporting coal seam gas water outside the tenure area | Authorised under: <ul style="list-style-type: none"> • Sustainable Planning Act |

| | | |
|------------------------------|--|--|
| Treatment facility | Construction and commissioning of treatment facility | Authorised under: <ul style="list-style-type: none"> • P&G Act, associated infrastructure integral to petroleum operations • EP Act (requires specific EA condition for Fuel Burning) |
| | Establish and maintain company Fuel Burning Equipment Register | <ul style="list-style-type: none"> • EA conditions |
| Groundwater monitoring bores | Drilling of water bores for sampling – within tenure area | <ul style="list-style-type: none"> • Authorised under P&G Act • Bores to meet water bore completion standards |
| | Drilling of water bores for sampling – outside tenure | <ul style="list-style-type: none"> • Requires Water Monitoring Authority under P&G Act |
| Injection wells | Drilling of injection wells | <ul style="list-style-type: none"> • Authorised under P&G Act • EA conditions – requires specific EA amendment approval • DERM Guidelines for injection activities (yet to be issued) |

Notes:

- Arrangements to be made for cultural heritage, land access and compensation; and
- Ensure all vegetation clearing is authorised under the EA and other legislation.

2.7 Coal Seam Gas Water Management

2.7.1 Coal Seam Gas Water Management Strategy

Arrow’s Coal Seam Gas Water Management Strategy seeks to maximise beneficial use of coal seam gas water and minimise the environmental impacts associated with water use and disposal. It also seeks (where possible) to manage coal seam gas water in such a way as to mitigate the impacts of groundwater depressurisation in aquifers (see also Section 3.2).

In order to achieve these dual objectives, the coal seam gas water produced as a result of undertaking coal seam gas extraction activities will be managed through a hierarchy of management options, described in the following sections.

2.7.2 Coal Seam Gas Water Management Options

Management of coal seam gas water during operations includes both beneficial use and disposal options as shown in Figure 4:

Arrow Conceptual Water Management Strategy

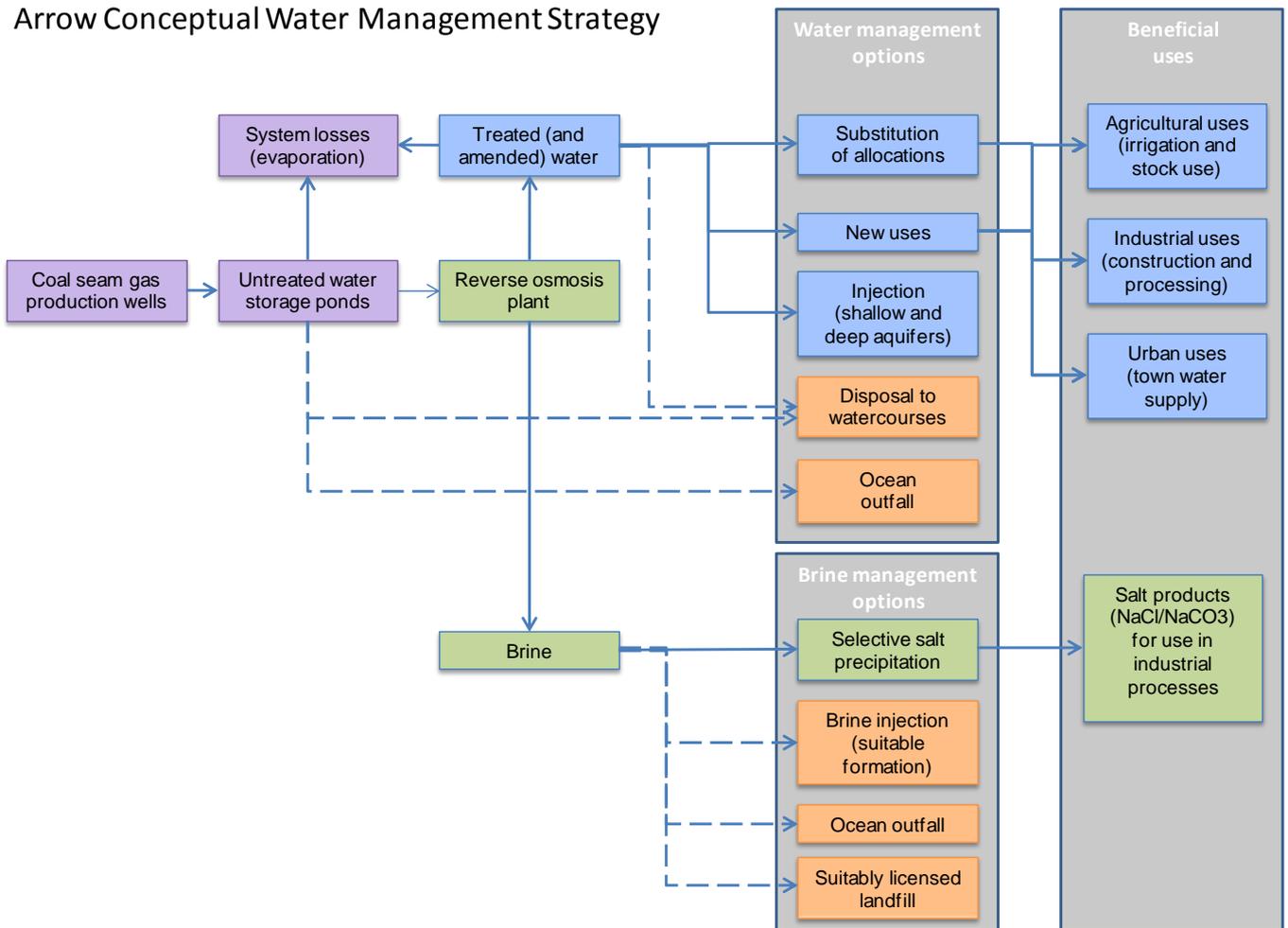


Figure 4. Arrow Conceptual Water Management Strategy

Although coal seam gas water is considered a waste under the Environmental Protection Act 1994 (Qld), 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, depending upon the water quality requirements of the end user. Investigations indicate that there is limited demand for the beneficial use of untreated coal seam gas water in most of Arrow's operational areas (see Section 2.3).

2.7.2.1 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 by third parties in accordance with existing allocations will be replaced with coal seam gas water provided by Arrow. This will normally entail substitution of water allocations for the duration of the given project, until the production of coal seam gas water ceases.

Arrow has commenced discussions with relevant regulatory bodies regarding the appropriate legislative framework that would facilitate this component of Arrow's Coal Seam Gas Water Management Strategy. It is expected that the third-party users will accept responsibility (legally and practically) for the impacts of their use of the water.

2.7.2.2 New Uses

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

2.7.2.3 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 beneficial use.

Arrow conducted an injection feasibility study in 2010 and is preparing environmental authority applications to conduct shallow and deep aquifer injection trials in the Dalby Expansion Project area. 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 would be required to define the extent and feasibility of injection in other operational areas.

An injection trial would typically run for 12 months including preparation, data collection and data evaluation. Initial trials would involve drilling a single injection bore into each target aquifer. The bores would be used to collect geological data and characterise the water geochemistry of those aquifers. Note: at present, the legislative framework to enable injection of coal seam gas water into aquifers has not been fully developed. Arrow is committed to engaging with all relevant stakeholders on this topic to facilitate the development and implementation of a regulatory solution for injection into groundwater aquifers.

2.7.2.4 Disposal to Watercourses

Disposal to watercourses will be considered in the event that beneficial uses of coal seam gas water are unavailable (whether on a temporary or permanent basis), 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 holding or obtaining 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.

2.7.2.5 Ocean Outfall

Disposal of coal seam gas water to the sea via an ocean outfall pipeline is recognised as a possible option for some of Arrow's operational areas, however it is not a 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.

2.7.3 Beneficial Uses of Coal Seam Gas Water

Implementation of the preferred coal seam gas water management options will result in the distribution of coal seam gas water to the following beneficial uses:

2.7.3.1 Agriculture Uses

Irrigation Trials. Arrow holds a specific beneficial-use approval for an irrigation trial on Arrow's Theten property. Further specific beneficial use applications are being considered in the Dalby Expansion Project area. These trials will occur on land classified as good quality agricultural land.

It is Arrow's intention over the next three to five years to develop a 'showcase' farming operation using treated coal seam gas water as a substitute for water drawn from aquifers and establish a framework for supply to third parties. It is not Arrow's intention to operate farms in the medium to long term.

Irrigation. Irrigation is the predominant water use within the Surat Gas Project development area. Arrow is evaluating the options there 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 will 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 of 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 because 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 feedlots).

2.7.3.2 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 third party users and look for further similar opportunities.

2.7.3.3 Urban Uses

Arrow has undertaken a preliminary analysis for augmentation of the Dalby town water supply. On 25 November 2010, the Water Supply (Safety and Reliability) Act 2008 (Qld) was amended to include the requirement that coal seam gas producers must develop an approved recycled water management plan if they propose to release water into a watercourse, aquifer or town drinking water supply. Recycled water management plans are designed to integrate into council drinking water management plans and deal principally with monitoring and communication. Augmenting town water supplies would decrease reliance on potable aquifers.

2.7.4 Brine Management Options

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

Assuming an average salt concentration of 4,500 mg/L in the Surat Gas Project, 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. Concentrations will vary from development to development, however, and may also change over time within a given coal seam gas field. The brine management option(s) selected for a given development will depend upon both the concentration and the total volume of salt expected for that development.

Figure 4 displays the hierarchy of brine management options:

2.7.4.1 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 with commercial enterprises to investigate viable opportunities for the beneficial use of brine for the Surat Gas Project. 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

2.7.4.2 Brine Injection

Should Arrow identify an appropriate formation during the exploration phase of any given 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 for any of Arrow's operational areas.

2.7.4.3 Ocean Outfall

Disposal of brine to the sea via an ocean outfall pipeline is a feasible option for some of Arrow's operational areas. As with coal seam gas water the viability of an ocean outfall will be evaluated at the time of detailed design of the field and facilities.

2.7.4.4 Suitably Licensed Landfill

An assessment of waste disposal facilities indicates that suitably licensed facilities exist in Queensland. It is assumed that other commercial operations will be developed to capitalise on this waste stream if the volumes are large enough (e.g. for the Surat and/or Bowen Gas Projects). Arrow will develop appropriate storage capacity to manage brine until such time as permanent disposal solutions are operational.

2.7.5 Selection of Beneficial Use or Disposal Options

The following risks and uncertainties are considered when determining Arrow's hierarchy of coal seam gas water management options:

- **Production profile** – Water volume forecasts differ across basins and the confidence in predictions also varies depending upon the extent of exploration and field development activities. The coal seam gas water management options will consider basin-specific conditions, and in some cases, further observations of reservoir behaviour are necessary to better inform the model and increase confidence levels in forecast volumes. Timing and quantity of water production is highly dependent upon the timing and extent of coal seam gas development within each basin. The water management options must be tailored to the development plans and have the flexibility to meet a range of outcomes.
- **Commercial agreements** – To enter into contractual arrangements, a **high level of certainty** is required, specifically in terms of the following:
 - Available water volumes
 - The timing of water availability
 - The ability to guarantee that water quality characteristics are fit for the intended application, for example for third-party irrigation, where the water quality must be suitable for the soil type and the intended crop
- **Approvals** – The water management options must be continually revised to meet regulatory requirements into the future, while retaining flexibility to meet a range of outcomes.

2.8 Compliance

A summary of water-related compliance requirements is listed in the table below:

| Compliance Requirements | Type |
|--|---|
| Underground Water Impact Report | Legislative (Water Act and P&G Act) |
| Environmental Authority (EA) | Licence (EP Act) |
| Regulated Dam Register | EA Condition (EP Act) |
| Water Supply | Water Supply Licence (Water Act) |
| Approval to charge for supply of water | Water Service Provider's Licence (Water Act) |
| Beneficial Use Approval | General Beneficial Use Approval, or Specific Beneficial Use Approval (Environment Protection (Waste Management) Regulation) |
| Dam Audit | EA Conditions |
| Removal of Brine/Salt | EA Conditions |
| Emergency discharge to watercourse | EA Conditions |
| Receiving Environment Management Plan (for discharge to watercourse) | EA Conditions |
| Direct or indirect augmentation of drinking water supply | Recycled Water Management Scheme or Exemption (Water Supply (Safety & Reliability) Act) |
| Regional Aquifer Monitoring Program | Legislation, Water Act |
| Coal Seam Gas Water Management Plan (component of EM Plan) | Legislation, EP Act |
| Dam Operating Plan | EA Conditions |
| Infrastructure Groundwater Monitoring Program | EA Conditions |
| Decommissioning Management Plan | EA Conditions |
| Rehabilitation Management Plan | EA Conditions |
| Erosion and Sediment Control Plan | EA Conditions |

2.8.1 Regulated Dam Register

Arrow maintains a Regulated Dam Register that contains the following information:

- Dam name, location and date of entry into Register
- Description of dam purpose and contents
- Hazard category
- Details of composition and construction of any liner
- Dimensions and surface area
- Maximum operational volume
- Design Storage Allowance at Nov 1st each year
- Mandatory Reporting Level
- Date construction certified
- Name and qualifications of certifier
- Dates on which dam was inspected for structural and operational adequacy
- Date on which annual inspection report was provided to administering authority
- Dates on which dam was inspected for detection of leakage through any liner
- Dates on which dam was inspected for ascertaining the available storage capacity on Nov 1st

2.8.2 Dam Operating Plans

The procedures and criteria to be used for operating dams, including management, maintenance and monitoring are defined in individually developed asset operating plans. These operating plans include:

- operating guidelines
- inspections checklists
- regulatory reporting requirements
- the surface and groundwater monitoring programs developed to identify any detrimental impacts on the receiving environment over time

2.8.3 Dam Audits

An audit is undertaken annually to ensure that dams are assessed as structurally sound and compliant with current performance standards. During the audit process, dams are integrity and hazard assessed and determined as either:

- Compliant and fit for purpose
- Compliant to remain in operation for an alternative purpose, e.g. brine storage to treated water storage
- Non-compliant, requiring upgrade or decommissioning and rehabilitation

If the structural integrity of any dam is identified to be deficient, a management plan will be developed defining safe operating parameters and any remediation requirements. The operations team will develop the scope of work and implement the plan.

All new dams will be designed and constructed by a suitably qualified and experienced person in accordance with the hazard assessment and hydraulic performance standards prescribed by DERM (Manual for Assessing Hazard Categories and Hydraulic Performance of Dams) and with Arrow's standard specification for the construction of coal seam gas water dams.

2.8.4 Dam Decommissioning and Rehabilitation

A *Decommissioning and Rehabilitation Management Plan* will be developed as part of the initial dam design documentation for approval by DERM. These plans are reviewed by the Environment Department and by the relevant Asset or Project Team and incorporated into broader rehabilitation plans for all infrastructure and associated disturbance across the project. The plan is specific to the project and is established based on the timeframes for construction, operation and decommissioning of each facility.

In relation to the ultimate disposition of salt, Arrow has made a commitment not to leave the salt in situ, and instead the salt will be removed from the landscape and transported under the regulated waste management framework (Environment Protection (Waste Management) Regulation) to the final receiving environment (see also Section 2.7.4).

At the end of the life of a dam:

- All liquid and solid material must be removed from the dam prior to rehabilitation
- Where used, artificial liners must be removed and transported to a regulated waste facility for disposal
- Brine must be evaporated to dryness and the solid salts must be removed from the dam for appropriate disposal to a regulated waste disposal facility designed for that purpose, or for further treatment, or for use as an input into another production process

3 GROUNDWATER MANAGEMENT

3.1 Groundwater Management Objectives

The objectives for groundwater management are to:

- Minimise impacts due to groundwater level changes
- Minimise impacts to groundwater quality

3.2 Link between Groundwater Management and CSG Water Management

Potential impacts on groundwater systems as a result of coal seam gas activities will be managed through a hierarchy of management options that form the basis for an adaptive management framework. The hierarchy of groundwater management options is linked to the hierarchy of coal seam gas water management options described in Section 2.7. Two of those water management options can help to minimise and/or mitigate potential impacts of CSG activities on groundwater systems:

- Substitution of allocations. Besides putting the coal seam gas water to beneficial use, substituting water allocations in the area is expected to be an effective means for managing groundwater depressurisation impacts in aquifers by reducing third-party extractions from those aquifers
- Injection. Injecting coal seam gas water of a suitable quality into target shallow and/or deep aquifers (if proven technically feasible) may offset groundwater depressurisation impacts in those aquifers

3.3 Adaptive Management Framework

The adaptive management framework is structured to facilitate management decisions based on an increased knowledge base developed over time. Key aspects of the adaptive management framework are detailed below:

- The framework allows protection and management of groundwater values and resources into the future
- The framework is based on the collection of local and regional monitoring data that inform and calibrate numerical models, identifying areas of increased risk and subsequently enforcing the implementation of change where required over time
- Legislative amendments and refined industry-practice environmental management and technologies can be implemented over time and as required

3.4 Hierarchy of Groundwater Management Options

In addition to the two water management options discussed in Section 3.2, Arrow will consider the following hierarchy of monitoring and management options to inform their groundwater adaptive management framework throughout the life of every CSG project:

- Collect relevant geological and hydrogeological data from existing and future production, monitoring and registered third-party wells (where possible) together with information collated collaboratively with other proponents and regulatory authorities. Update and calibrate any geological and/or numerical groundwater models 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 wells that reflect aquifer behaviour during coal seam gas extraction
- Utilise the updated geological and numerical groundwater models (if required) 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
- Install an appropriate regional aquifer groundwater monitoring network (that satisfies Arrow's obligations as described in the UWIR) to:
 - Establish current groundwater level and groundwater quality conditions
 - Assess natural variation (i.e., seasonal variations) in groundwater levels
 - Monitor groundwater levels during the operational phase
 - Monitor groundwater quality during the operational 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 depressurisation as a result of coal seam gas extraction
 - Monitor impacts in accordance with the Water Act and Regulations
- Verify the preferred water management strategy by modelling effectiveness of substitution and/or injection (where conducted) in offsetting groundwater depressurisation impacts
- Consider local biological, groundwater and surface water conditions when identifying sites for coal seam gas water and brine storage dams
- Install an appropriate groundwater monitoring network associated with site infrastructure (e.g. dams), that satisfies the relevant Environmental Authority conditions
- Prepare groundwater monitoring reports in accordance with the P&G Act, EP Act and Water Act
- Develop a structured database to host groundwater data from the project (i.e., groundwater levels and groundwater quality)

3.5 Regional Aquifer Groundwater Monitoring

Hydrogeological data will be collected during development commencing with exploration and appraisal activities. This will include conversion or utilisation of exploration wells for groundwater data collection, detailed description of geology of aquifers overlying target coal seams and completion of baseline assessments of landholder bores in the vicinity of pilot testing.

If required, an underground water impact report (UWIR) will be prepared for the tenure. Where a number of tenements are located in close proximity to one another in the same basin, consideration will be given to preparing a single UWIR which covers all Arrow operated tenure in the basin.

The contents of the UWIR are described by the Water Act 2000. The UWIR is prepared to describe, make predictions and manage the impacts of extraction of underground water by petroleum tenure holders on groundwater resources. The complexity of groundwater modelling used to make predictions will be consistent with the volume of water production from each tenure. For example, relatively little groundwater is extracted during exploration and appraisal activities. Consequently, a relatively low complexity groundwater model will be produced to assess the impacts of these activities. Conversely, relatively more groundwater is extracted during production. Hence the complexity of the groundwater model produced will also be increased in complexity to predict the impacts of these activities.

The UWIR will describe:

- Make good obligations (with respect to groundwater supply to other users within the tenure)
- A groundwater monitoring program to identify impacts on aquifers
- A monitoring program to identify impacts to springs
- A strategy to mitigate impacts on potentially affected springs

A regional aquifer groundwater monitoring network will be installed which:

- Satisfies the requirements of the UWIR
- Addresses basin-specific questions or gaps identified during preceding phases of study or modelling, such as the degree of vertical connectivity between target coal seams and over or underlying aquifers
- Provides new data on aquifer properties such as conductivity, storage and water quality
- Enables regular updating/refinement of the existing groundwater model as new data is recorded or observations are made
- Facilitates simulation of mitigation scenarios

The UWIR will also identify bores (through model predictions) which may be impacted by groundwater extraction due to petroleum activities. Assessments of these bores will be examined, in accordance with the Water Act 2000, to determine whether or not each of these bores will experience an impaired capacity. The outcome of this assessment, and any make good measures agreed between Arrow and the bore owner, will be documented in a make good agreement.

3.6 Infrastructure Groundwater Monitoring

A groundwater monitoring network will be installed around any infrastructure, such as dams constructed for the storage of produced water, which has the potential to impact underlying groundwater resources. This monitoring network will be developed in accordance with the tenure-specific environmental authority and will:

- identify background groundwater quality
- detail the locations of monitoring points, parameters to be measured, frequency of monitoring, and monitoring methodology
- identify trigger values, or the process for developing trigger values, for the measured parameters
- assess the level of impact caused in the event of contamination to underlying groundwater from the monitored infrastructure
- detail additional hydrogeological investigations to assess the extent and significance of potential contamination e.g. geodeitic survey, aquifer testing, groundwater flow mapping