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Memorandum

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Memo date	19/09/2018
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Project number	ENAUABTF20484AA
Memo Subject	SGP Stage 1 CSG WMMP Assessment of impacts and development of management measures memorandum

1. Introduction

This memorandum has been developed to document the assessment of impacts and development of management measures for the Surat Gas Project (SGP) Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP). Together with Arrow's CSG Water Management Strategy (WMS) (Attachment 1) it addresses Approval Conditions 13(l), 13(m) and 13(n) and partially addresses Condition 13(j)iv.

2. Approval conditions and related documents

In addition to the Environmental Impact Statement (EIS) and Supplementary Report to the EIS (SREIS), further supporting assessment for approval conditions is presented in separate memoranda, as summarised in Table 2.1. These documents provide the basis for the identification and assessment of potential impacts arising from the SGP and which may require ongoing monitoring to validate the predictions and allow for the early detection of and response to impacts that eventuate.

Table 2.1: Summary of Stage 1 CSG WMMP supporting assessments

Memoranda	Approval Conditions addressed	Document ID
Groundwater modelling technical memorandum (and referenced documents)	13a, 13b and 13d	ENAUABTF20484AA-M01
GDE and aquatic ecosystem impact assessment technical memorandum	13c and 13p	ENAUABTF20484AA-M03
Flood risk technical memorandum	13o	ENAUABTF20484AA-M02
Subsidence technical memorandum	13g	ENAUABTF20484AA-M05
Groundwater monitoring network and program technical memorandum	13e, 13f	ENAUABTF20484AA-M07
Early warning, limits and triggers memorandum	13j, 13k, 15	ENAUABTF20484AA-M08
Assessment of Impacts and Development of Management Measures Memorandum	13j(iv)	ENAUABTF20484AA-M04 (this document)
Surat Gas Project CSG Water Management Strategy	13l, 13m and 13n	ORG-ARW-ENV-STR-00001

2.1. EIS/SREIS

Environmental impacts of the SGP are primarily addressed through the EIS process, including the SREIS. The EIS/SREIS provides a detailed description of how project activities will be undertaken during the construction, operations and decommissioning phases. Supporting technical studies for surface water and groundwater impacts were undertaken to inform the EIS.

The impact assessment included:

- Identifying the environmental values important to the project development area, including their significance, potential exposure to threatening processes and capacity to adjust to change.
- Reviewing the timing, extent and duration of project activities to determine potential project impacts on environmental values.
- Recommending mitigation and management measures to minimise potential environmental impacts.
- Identifying residual impacts and, where applicable, potential cumulative effects.

The EIS focused on the most significant and important environmental values and potential impacts relevant to the project, enabling mitigation and management measures to be identified.

3. Compliance with approval conditions

This section details how the specific approval conditions are addressed.

3.1. Condition 13(j)iv

Approval Condition 13(j)iv requires: *A groundwater early warning monitoring system, including investigation, management and mitigation actions, including substitution and/or groundwater re-pressurisation, for both early warning indicators and trigger thresholds to address flux impacts on the Condamine Alluvium*.

This memorandum considers those aspects addressing Condition 13(j)iv that include management and mitigation actions that are described in the EIS and SREIS. Accordingly, the condition is only partially addressed here.

Specific actions including investigations, early warning indicators and trigger thresholds to address flux impacts on the Condamine Alluvium are addressed separately in the Limits, Indicators and Triggers Memorandum.

Groundwater re-pressurisation is not currently the SGP reference case solution for addressing flux impacts to the Condamine Alluvium.

3.1.1. Operational commitments for management and mitigation

The EIS/SREIS developed impact avoidance, mitigation and management measures that will be implemented to avoid or minimise potential impacts. The measures are based on the hierarchy of avoid, minimise, manage and mitigate, with the aim of protecting identified environmental values.

The mitigation and management measures set out in the EIS include Arrow's commitments to the effective management of the potential environmental impacts of the project. Many of these commitments were revised in the SREIS, which also included new commitments.

Table A2 in Attachment 2 presents the SREIS/EIS commitments that relate to groundwater and surface water for the SGP operational phase. The SGP WMMP and CSG WMS are key Arrow operational documents for the implementation of these commitments.

The mitigation measures identified in the EIS and SREIS remain relevant for the management of groundwater-related impacts associated with the SGP. Management of cumulative groundwater impacts within the Surat CMA is defined by the UWIR and compliance with the requirements assigned to responsible tenure holders is enforced by DES.

3.1.2. Virtual injection (substitution)

Mitigation of the flux impact to the Condamine Alluvium resulting from the Walloon Coal Measures (WCM) depressurisation[1], is proposed to be achieved through substitution of third-party groundwater allocations with treated CSG water as identified in the EIS. This mitigation method is referred to as 'substitution of allocations' or 'virtual injection' and has the practical effect (demonstrated through numerical groundwater modelling) of minimising the Condamine Alluvium drawdown that would otherwise result from the SGP.

Under the EIS/SREIS, Arrow is committed to mitigating against its component of modelled flux impacts to the Condamine Alluvium in the area of greatest predicted drawdown as a result of CSG water extraction from the WCM through substitution of allocations and purchase of license allocations.

[1] The flux impact is defined as that predicted by the calibrated OGIA Surat CMA Groundwater Model realisation for the period referred to in the UWIR (100 years) for the Surat CMA (QWC, 2012)

It was identified in the SREIS that the average predicted drawdown across the Condamine Alluvium is reduced from 0.18 m (pre-mitigated) to 0.03 m (substitution case), indicating a flux impact reduction. In some areas of the Condamine Alluvium an increase in water level is predicted to result from the application of virtual injection as a mitigation method against flux impacts.

The magnitude of flux Arrow is proposing to substitute is 63 GL. It is anticipated that the modelled flux impact will vary with the development of successive groundwater models by the OGIA (or others). Rather than modifying its substitution mitigation plans upon the release of each new UWIR by the OGIA, Arrow will address any deficit between the 'final' modelled prediction of flux and the amount Arrow actually mitigated against (i.e. the aforementioned 63 GL and any additional substitution or purchase of allocations undertaken) at the end of the Action. If required, Arrow will do this through purchase of further allocation, or other appropriate method.

Arrow will commence additional mitigation during the Action if required due to a trigger threshold or groundwater limit exceedance as described in the Limits, Indicators and Triggers Memorandum (ENAUABTF20484AA-M08).

3.2. Condition 13(l)

Approval Condition 13(l) requires: *A CSG water management strategy for produced salt/brine, which discusses how co-produced water and brine will be managed for the action, including in the context of other coal seam gas activities in the Surat Basin*.

Arrow's Surat Gas Project CSG WMS is provided in Attachment 1. The CSG WMS applies to co-produced water and saline waste (brine and salt) resulting from CSG production. It provides a basis for regulatory compliance, and sets out the method for managing CSG water for Arrow's Surat Basin tenements.

The CSG WMS provides compliance with Condition 13(l). Key considerations in this regard are summarised below, and detailed in the CSG WMS.

It should be noted that the WMS outlines all possible water management options. However, discharge of produced water to surface water systems is not part of the SGP. Should discharge be proposed in the future, the WMMP will require update and approval for discharge will be sought from the Minister.

Management of CSG water

Section 4.2 of the CSG WMS presents Arrow's CSG water management strategy. The approach is consistent with the regulated and conditioned objectives for the management of CSG water, and adopts the hierarchy specified in the DEHP CSG Water Management Policy[2]. This includes consideration of DEHP Priority 1 beneficial uses, including water for Arrow operational supply, for substitution of allocations, and for supply to existing users.

Management of brine

A range of brine management options are identified in Section 4.3 of the CSG WMS, including preferred, reserved and non-preferred options. The current preferred option is non-selective salt recovery and landfill encapsulation in purpose designed regulated waste facilities (DEHP Priority 2). Selective salt recovery (DEHP Priority 1) is retained as a reserved option, but is currently infeasible and without a demonstrated commercial market.

Context of other activities

Section 4.1 of the CSG WMS refers to Arrow's strategy for water and saline waste management, and identifies that opportunities for beneficial use of salt in collaboration with other CSG developers may arise, and that these will be maximised where they result in a material benefit to Arrow. Selective salt

[2] The DEHP prioritisation hierarchy is presented in Section 2.2.1 of the CSG WMS (refer Attachment 1)

recovery investigations have been considered in collaboration with other Surat CSG developers. However, the process has been found to be energy intensive, with substantial transport distances and undemonstrated markets, resulting in issues of safety, cost, and a high emissions intensity for the final product.

3.3. Condition 13(m)

Approval Condition 13(m) requires: *An analysis of how the approval holder will utilise beneficial use and/or groundwater re-pressurisation techniques to manage produced CSG water from the action, and how any potential adverse impacts associated with groundwater re-pressurisation will be managed*.

Arrow's CSG WMS (Attachment 1) presents the CSG water beneficial use strategies for Arrow's Surat Basin tenements, and demonstrates compliance with Condition 13(m). Key considerations in relation to Condition 13(m) are summarised below, and detailed in the CSG WMS.

How the approval holder will utilise beneficial use to manage produced CSG water

Arrow's water and salt management strategy for the SGP aims to maximise beneficial use under an approach consistent with the regulated and conditioned objectives for the management of CSG water, and consideration of the DEHP CSG Water Management Policy hierarchy. A range of end uses for treated and untreated CSG water are presented, including agricultural, industrial, domestic and urban applications. Details are provided in Section 4.2 of the CSG WMS.

Where practical, Arrow's preferred management option for CSG water is beneficial use through substitution of existing Condamine Alluvium groundwater allocations ('virtual injection'). Substitution has the advantage that it constitutes both a beneficial means of managing produced CSG water, and a means of mitigating against the potential impacts of Arrow's CSG production to bore owners with groundwater allocations.

How the approval holder will utilise groundwater re-pressurisation techniques to manage produced CSG water; how any potential adverse impacts associated with groundwater re-pressurisation will be managed

CSG water injection, either for aquifer re-pressurisation or as a means for CSG water management, is not currently proposed in the CSG WMS for the SGP due to the potential risks and the lack of an appropriate regulatory system. Beneficial use including substitution is the base case management option.

Water injection requires site-specific investigation of the technical practicality at specific locations. The primary risks of impact due to water injection are degraded receiving aquifer water quality (impacted environmental value) or altered aquifer properties (mineral precipitation resulting from adverse hydro-chemical conditions). The injection of treated CSG water would require that a suitable receiving aquifer is available, and that the environmental values of the groundwater resource are not adversely affected by the scheme.

Should groundwater re-injection be appraised as viable at some future stage, then to avoid adverse impacts it will be incorporated into future iterations of the WMMP, and progressed operationally under the constraints of an Environmental Authority and in accordance with other regulations such as the Water Supply (Safety & Reliability) Act 2008 which deals with recycled water management schemes.

As it is not currently adopted as a management strategy, there will not be any impacts associated with groundwater re-pressurisation.

3.4. Condition 13(n)

Approval Condition 13(n) requires: *A discharge strategy, consistent with the recommendations and requirements of the Department of the Environment and Heritage Protection in its Assessment Report (pages 94 to 95 and pages 254 to 255) and that includes scenarios where discharge may be required, the quality of discharge water (including water treated by reverse osmosis), the number and location*

of monitoring sites (including upstream and downstream sites), frequency of monitoring and how the data from monitoring will be analysed and reported, including recommendations on any changes or remedial actions that would be required.

Under the Arrow CSG WMS, discharge of produced water to surface water systems is not preferred, therefore a discharge strategy is not required.

Should future project requirements include the need for discharge, Arrow will update the CSG WMMP to include an appropriate monitoring network and program, and seek approval of the updated WMMP from the Minister.

4. References

Arrow Energy, 2012. EIS Commitments Summary. Attachment 8 to the Arrow Energy Surat Gas Project EIS, February 2012.

Arrow Energy, 2013. Commitments Update. Attachment 4 to the Arrow Energy Surat Gas Project SREIS, June 2013.

Coffey, 2012. Arrow Energy SGP Groundwater Impact Assessment Report. Appendix G to the Arrow Energy Surat Gas Project EIS, February 2012.

Coffey, 2013. Supplementary groundwater assessment. Appendix 4 to the Arrow Energy Surat Gas Project Supplementary Report to the EIS, June 2013.

Queensland Water Commission (QWC) (2012). Underground Water Impact Report for the Surat Cumulative Management Area.

Attachment 1: Surat Gas Project CSG Water Management Strategy

Surat Gas Project
CSG Water Management Strategy

Version	Rev1
Released	
Document Owner	
Document Author	
Review Date	
Document Status	Draft
Security Classification	

Please see document administration section for more information

[Contact the DCC for a controlled document number]

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Contents

Figures

Appendices

1. Introduction

This document is the Coal Seam Gas (CSG) Water Management Strategy (CSG WMS) for the Surat Gas Project (SGP). It is derived from Arrow's corporate CSG water management strategy[1] (Arrow Energy, 2012a). It addresses specific requirements for management of CSG co-produced water resulting from activities arising from the SGP Field Development Plan.

The CSG WMS:

- Provides a basis for compliance with government policy,
- Describes the range of management options available to Arrow (and how these relate to government priorities),
- Sets out the method for managing CSG water for Arrow's Surat Basin tenements, and
- Identifies which options have been selected for the Surat Gas Project

The CSG WMS does not provide details on construction of water management infractsructure or facilities which are the subject of detailed planning as project is further developed.

This CSG WMS applies to co-produced water and brine resulting from CSG production activities. It does not apply to CSG exploration activities.

2. Regulatory system

2.1 Legislation

The regulatory system directly relevant to the management and fate of CSG co-produced water comprises both enacted legislation and statutory policy, and has been previously described in Arrow (2012). Updated summary information on legislation and policy relating to specific aspects of CSG water management is provided in Appendix A.

2.1.1 End of Waste (EOW) Framework

A significant change since the SREIS is that the end of waste (EOW) framework under the Waste Reduction and Recycling Act 2011 has replaced the beneficial use approval (BUA) framework as a method of regulating resource recovery opportunities.

A waste, such as CSG water, can be approved as a resource if the Department of Environment and Science considers that it meets specified quality criteria for specific use, and where a waste is approved as a resource under the EOW

[1] Arrow Energy's corporate strategy for management of CSG water is defined in the 'Coal Seam Gas Water and Salt Management Strategy' (Arrow Energy, 2012a). It provided the supporting basis for water management and beneficial use under the Environmental Impact Statement (EIS) and Supplementary Report to the EIS (SREIS).

framework, it is no longer considered a waste under s. 13 of the Environmental Protection Act 1994. If the resource is not used in accordance with the EOW code or approval, it is deemed waste.

Beneficial use of CSG water is also regularly authorised through the Environmental Authority as outlined in Appendix A.

2.2 DES CSG Water Management Policy

The Department of Environment and Science (formerly Department of Environment and Heritage Protection) 'Coal Seam Gas Water Management Policy' (DEHP, 2012) sets out the government's position on the management of CSG water and guides CSG operators to consider the feasibility of using such water to meet the obligations of the EP Act as part of developing their CSG water management strategies and plans.

The policy objective is to encourage beneficial use of CSG water in a way that protects the environment and maximises its productive use as a valuable resource. This objective is achieved when CSG water and saline waste[2] is managed consistently with the prioritisation hierarchies in Section 2.2.1, and the management criteria specified in the policy.

The policy focuses on the management and use of CSG water under the EP Act, and does not change obligations under the separate requirements of the Water Act 2000, including 'making good' any relevant impacts that may result from a CSG operation on bores. Such measures executed under the Water Act may require the provision of water to mitigate impacts.

2.2.1 DES prioritisation hierarchy

The DES prioritisation strategy provides hierarchies for determining the options for management of CSG water and saline waste. The strategy is based on the evaluation of potential management options for water and saline waste against each of the prioritisation hierarchies.

Priority 1 options are to be implemented wherever feasible. Where Priority 1 options are not feasible, Priority 2 options are implemented.

In determining the feasibility of options, factors that may be considered include technical and economic aspects to assess the practicability of such options.

CSG water prioritisation

The objective of the policy is for the management and use of CSG water consistent with the following priority hierarchy:

- Priority 1 – CSG water is used for a purpose beneficial to one or more of the following:
    - the environment
    - existing or new water users
    - existing or new water-dependent industries.

[2] Saline waste includes brine and or solid or semi-solid salt, normally produced as a by-product of water treatment or desalination.

- Priority 2 – After feasible beneficial use options have been considered, treating and disposing CSG water in a way that firstly avoids, and then minimises and mitigates, impacts on environmental values.

Saline waste prioritisation

Desalination of CSG water results in brine and/or solid salts. Operators must demonstrate that the management of these end products is in accord with the following priority hierarchy:

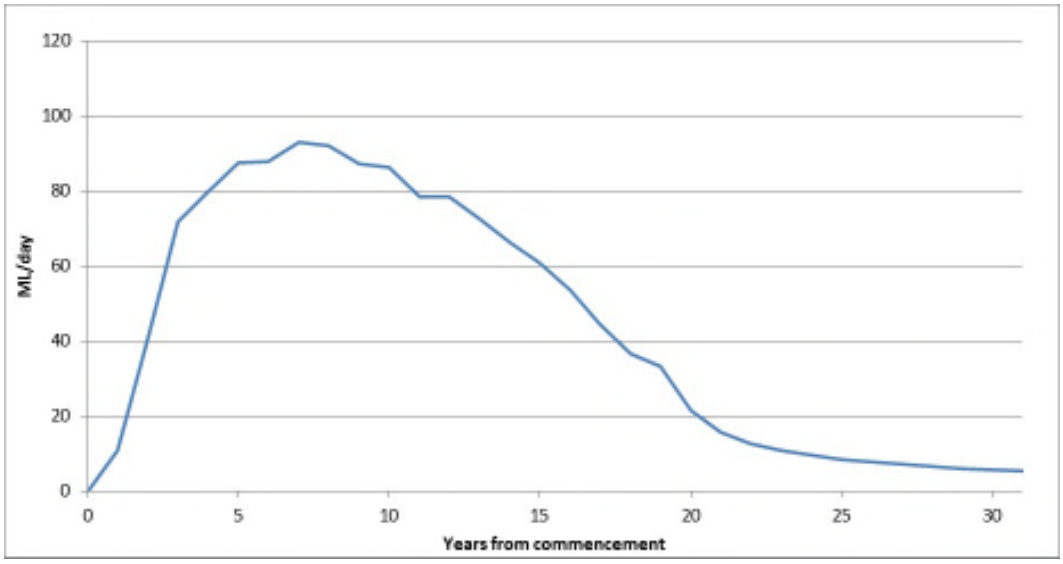
- Priority 1 – Brine or salt residues are treated to create useable products wherever feasible.
- Priority 2 – After assessing the feasibility of treating the brine or solid salt residues to create useable and saleable products, disposing of the brine and salt residues in accordance with strict standards that protect the environment.

3. Water production and infrastructure

Based on the field development plan presented in the Supplementary Environmental Impact Statement, the SGP will produce an average ~13 GL/year CSG water over 40 years, with a total production of 510 GL. The peak production rate is estimated at 34 GL/year.

The predicted annual average coal seam gas water production rates over the life of the project are presented in Figure 3.1.

Figure 3.1 Estimated Surat Gas Project water production (Supplementary EIS production case)



3.1 CSG water production

Planning for the management of CSG water from the SGP requires forecasting of production rates, storage volumes, and quality of CSG water for the life of the project.

It is also important to consider that actual field development changes will be made during the project lifetime as a result of planning and commercial strategy. These may affect the water production forecast. Accordingly, the CSG WMS is applicable under a range of outcomes and ensures that changing water production is managed consistently with the objectives of the DES CSG Water Management Policy.

3.1.1 Water production forecasting

Arrow water production forecasts will be modelled via a process that includes:

- Developing assumptions such as FDP expansion areas, gas sales targets and gas production rates;
- Simulating the required production rates using the reservoir model; and

- Reviewing model performance against actual production data and history matching.

Once in operation, forecasting will also account for changes to the field development plan, and any identified production constraints. Water balance models will be used for short, medium and long term planning of water management and supply infrastructure, including water supply and end use. This will enable an understanding of expected dam storage capacity based on forecast production rates, seasonality and water use. The operations water balance model will take into account:

- Forecast water production;
- Dam storage capacity, surface area and current levels;
- Seasonal rainfall and evaporation scenarios;
- Natural pan evaporation and salinity factors;
- Beneficial use off-takes and disposal; and
- Treatment capacity, including allowances for plant availability and recovery.

3.1.2 CSG raw water quality

CSG water from the Walloon Coal Measures varies from fresh to saline, but is typically brackish with the following characteristics:

- Neutral to alkaline pH (approximately 7 to 11 pH units).
- Salinity typically ranging from 3,000 to 8,000 mg/L, with total dissolved solids (TDS) including sodium salts, bicarbonate salts, chlorides and others.
- Suspended solids from the well that usually settle out.
- Other ions including calcium, magnesium, potassium, fluoride, bromine, silicon and sulfate.
- Trace metals and low levels of nutrients.

CSG water quality may vary over the life of a well. The beneficial use of this water is constrained by the salt content, often requiring treatment and/or amendment prior to use.

3.2 CSG water management infrastructure

Infrastructure required to manage CSG water under this strategy includes gathering and distribution systems, storage facilities (dams), and water treatment systems.

3.2.1 Gathering and distribution systems

The types of pipelines required to manage the production, treatment and storage of CSG water include:

- Water gathering lines – low pressure water gathering system will be installed from each well head to aggregation dams at each treatment facility.
- Transfer pipelines –pipelines including associated pumps and controls are required to transfer raw water, treated water or brine between dams, facilities or to end users.

3.2.2 Storage facilities (dams)

Dams are integral to CSG water management, providing operational storage and water balance capacity to ensure the containment of CSG water under varying supply rates and beneficial use demand.

The types of dams required to manage the production, treatment and distribution of CSG water include:

- Aggregation dams – required to contain the water collected via gathering pipelines directly from the well network. They provide a buffer between the variations in production and water treatment flows, and seasonal fluctuations in demand for beneficial use.
- Treated water dams – required to store treated water for beneficial use (or disposal) to ensure a buffer between the treatment output and end use demand.
- Utility dams – required for the storage of chemical cleaning systems from the water treatment process.
- Waste water dams – required for storage of compression facility waste water, which may contain lubricants and chemicals from compression systems.
- Brine dams – required for the temporary storage of water treatment plant concentrate.

The design dam size will be optimised to ensure that suitable buffer storage capacity is provided, allowing for variation in:

- Daily flows from the field;
- Gas to water ratio (controlled by automated level control at each well);
- Wellfield development (new wells online);
- Availability of downstream off-takes due to maintenance and other factors;
- Water levels due to climate factors, such as long periods of rain; and
- Treatment plant availability and optimisation.

Dam consequence category compliance

All dams will be consequence category assessed to determine the design and compliance requirements of each structure. In order to determine the consequence categorisation of its storage dams, Arrow Energy will implement

the assessment procedure outlined in the latest version of the Manual for Assessing Consequence Categories and Hydraulic Performance of Structures[3]. All Arrow Energy storages are to be designed, built, operated and decommissioned in accordance with the DES guideline and the current Environmental Authority.

Regulated dam register and operating plans

Arrow maintains a Regulated Dam Register to record and manage key information regarding dams, including physical and operational aspects.

The procedures and criteria to be used for operating dams, including management, maintenance and monitoring are defined in regional asset operating plans.

3.2.3 Water treatment systems

Arrow may treat CSG water to a quality suitable for a range of end uses, and treatment may comprise a combination of processes including micro filtration (MF), reverse osmosis (RO), blending (depending on the required end use) and chemical amendment.

Arrow has undertaken a comprehensive assessment to evaluate the various technologies available for the treatment of CSG water. The preferred technologies include a combination of MF and RO.

MF enables the removal of turbidity, bacteria, cysts and other solids from the water to sizes of 0.1 to 3 µm. Following MF, water is treated using RO.

RO involves the separation of salts from solution through a semi–permeable, microporous membrane under elevated hydrostatic pressure, and reduces the concentration of dissolved salts resulting in a high quality treated water and a concentrated brine.

Arrow will continue to investigate new and emerging technologies to treat CSG water and evaluate their applicability to the SGP.

Ancillary treatment processes such as ion exchange between the pre-treatment and the RO process may be used to optimise the performance of the water treatment facility, for example to increase recovery and reduce the size of brine dams.

Treated water quality may be amended to ensure the correct balance of ions for the intended use. This would typically involve the addition of calcium.

[3] Department of Environmental and Heritage Protection, Qld (2103). Note this document supersedes the previous 'Manual for Assessing Hazard Categories and Hydraulic Performance of Dams'.

4. Water and salt management

4.1 Overview

Figure 4.1 is a schematic flow diagram presenting Arrow's corporate strategy for CSG water and brine management (Arrow Energy, 2012a) as reflected in the EIS/SREIS, and illustrating how the conceptual strategy meets the DES prioritisation hierarchies (refer Section 2).

Arrow's water and salt management strategy for the SGP makes reference to the corporate strategy, and aims to maximise beneficial use and reduce the potential for environmental impact. The water management approach is consistent with the regulated and conditioned objectives for the management of CSG water, as well as the DES prioritisation hierarchy.

CSG water will be managed through a combination of options which address Arrow's statutory obligations and commitments. The field development plan (which is refined over time as the project proceeds) and the development sequence for the project will determine the timing, combination and implementation of the management options.

Depending upon the end user water quality requirements, untreated water may be suitable for some of the beneficial use options as shown in Figure 4.1 and hence the management options presented in this section in some cases apply to both treated and untreated water. However beneficial use will be subject to demand, which may be limited in many of Arrow's SGP tenements.

Beneficial uses of CSG water

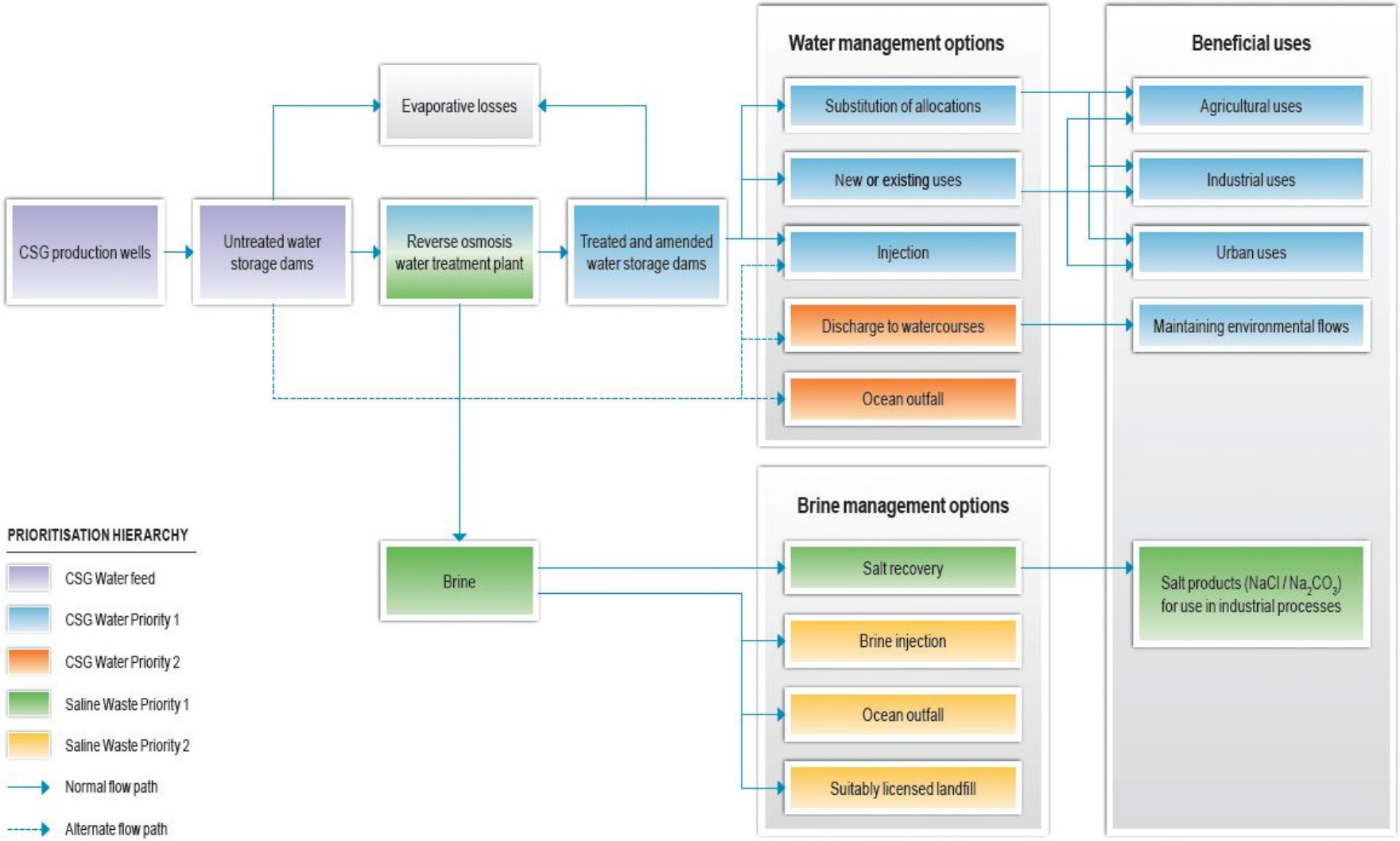
Under the Arrow corporate water management strategy (Arrow Energy, 2012a), treated and untreated CSG water can be supplied to end users or a receiving environment through a range of methods and for a variety of end uses including:

- Agricultural uses;
- Industrial use, including power station cooling, coal washing, and use by Arrow for construction and operations;
- Domestic uses;
- Urban uses such as potential water supply to towns; and
- Injection into aquifers.
- Opportunities for beneficial use in collaboration with other CSG developers may arise, and these will be maximised where they result in a material benefit to Arrow.

Supply framework

For the SGP, CSG water will be supplied to the end user under (as appropriate) Environmental Authority under the EP Act 1994, the EOW framework under the Waste Reduction and Recycling Act 2011, and in accordance with water supply agreements.

Figure 4.1 SGP conceptual water management



4.1.1 Selection of beneficial use or disposal options

To ensure that the most sustainable portfolio of CSG water and saline waste management options is implemented, Arrow evaluates potential options in a systematic process. The performance of each option is assessed against multiple criteria including economic, schedule, operability, reliability, social impact, environmental impact and HSE/compliance.

To reflect differences in the relative importance of the considered criteria, each is assigned a weighting, and the weighted scores are ranked to categorise options as either 'preferred', 'reserved' or 'non-preferred'. Preferred options are prioritised for investment whilst reserved options continue to be evaluated through targeted feasibility studies. Non-preferred options are put on hold.

CSG water management risks and uncertainties

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

- Production profile – Water volume forecasts vary across the basin and the confidence in predictions is dependent on the extent of exploration and appraisal that has occurred.

  The relevant CSG water management options will be determined by 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 CSG 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:

  - Available water volumes;
  - The timing and duration 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; and
  - Long term approvals.

- Approvals – The water management options must meet regulatory requirements into the future, while retaining flexibility to meet a range of outcomes. Long term approvals are a pre-requisite to investment in infrastructure necessary to distribute water to end users or disposal points.

4.2 Water management options

This section presents the water management options considered for the SGP. Saline waste management is discussed in Section 4.3.

Implementation of the preferred CSG water management options will result in the distribution of CSG water to a range of beneficial uses. Currently identified options are described below.

4.2.1 Agricultural uses

Irrigation

Irrigation is the predominant water use within the SGP development area. Options exist to provide water to existing irrigators, to replace other water sources used for irrigation (including through substitution of their existing groundwater allocations), or to supply water to new irrigation projects.

Key considerations for providing CSG water to end users for irrigation will include:

- The ability of end users to take large volumes of water regularly and reliably (end users 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 end users in relation to the water treatment facility (due to the cost of transporting water over large distances);
- The point of transfer of responsibility;
- The approvals framework;
- The extent to which the user is going to become reliant on water supplied by Arrow; and
- The appropriateness of the supply given the short term nature of CSG water availability.

The water and implications of its use will be the responsibility of the end users. 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) or for aquaculture.

Substitution of allocations

Where practical, Arrow's preferred management option for CSG water is beneficial use through substitution of existing groundwater allocations in the operating area (also referred to as 'virtual injection'). Substitution of allocations has the advantage that it constitutes both a beneficial means of managing produced CSG water, and in certain instances, a means of mitigating against the potential impacts of Arrow's CSG production to bore owners with groundwater allocations.

Currently, there is no regulatory basis to facilitate substitution. Therefore Arrow would develop a commercial scheme to support the supply of treated CSG water to groundwater users who hold allocations. Under this scheme end users would receive and utilise water supplied by Arrow in lieu of their groundwater allocations.

Arrow has committed to mitigating against its component of modelled likely flux impacts to the Condamine Alluvium in the area of greatest predicted drawdown, as a result of CSG water extraction from the Walloon Coal Measures. This can be achieved through a beneficial use network that will distribute water to groundwater users within specified areas of the Condamine Alluvium to mitigate the modelled likely flux impact by substitution of their allocations. These users, or other existing users, could be offered excess water in addition to the substitution requirements to manage peaks in the water production profile. As a result, the beneficial use network capacity will be higher than the expected annual average water demand.

4.2.2 Discharge

Discharge of treated CSG water to watercourses is not proposed as a management strategy.

4.2.3 Urban uses

Urban supply remains a potential CSG water end use, but is subject to further negotiation and a suitable supply arrangement that economically satisfies regulatory requirements.

4.2.4 New uses

Over the course of the SGP water demands across areas in which Arrow operate will vary and it is anticipated that new opportunities for use of treated and untreated water may emerge.

Whilst Arrow may choose to evaluate any such opportunities in accordance with the adopted selection methodology (refer Section 4.1), supply to new users is not a preferred water management option. This is because the CSG water supply will only be available for a relatively short period of time, and the development of new water reliant uses may result in potential legacy issues when CSG water is no longer available.

4.2.5 Aquifer injection

Aquifer injection, either for re-pressurisation or as a means for CSG water management, is not currently proposed for the SGP due to the potential risks and the lack of an appropriate regulatory system. Should future economics and supply and demand for CSG water change, injection may be reconsidered, and further studies and trials would be required to define the extent and feasibility of injection in operational areas.

4.2.6 Ocean outfall

Disposal of CSG water to the sea via an ocean outfall pipeline is recognised as a technically feasible option, but currently non-preferred due to environmental and community concerns, and potential schedule impact.

4.2.7 Alignment of Arrow and DES priorities

A summary of the CSG water management options is presented in Table 4.1 which aligns Arrows preferred and non-preferred options with the DES prioritisation hierarchy.

Table 4.1 CSG water management – alignment of Arrow and DES priorities

Arrow priority	Option	Comments	DES Priority
Preferred	Arrow operational supply	Dust suppression, construction, potable, etc.	Priority 1
	Substitution of allocations	Beneficial use to existing abstractors (virtual injection)	Priority 1
	Industrial supply to existing users	Non-Arrow use, where established	Priority 1
Reserved	Urban water supply	Subject to negotiation and approvals	Priority 1
Non-preferred	MAR	Managed aquifer recharge not proposed	Priority 1
	Supply to new users	Non-Arrow use, supply for new users is not proposed	Priority 1
	Ocean outfall	Not proposed due to environmental and community concerns, and potential schedule impact	Priority 2
	Deep aquifer injection	Currently not proposed and no identified target aquifer	Priority 2
	Discharge to watercourse	Currently not proposed	

4.3 Brine and salt management options

Water treatment processes that include desalination, such as reverse osmosis, produce a brine stream by-product.

Assuming an average salt concentration of 4,500 mg/L for CSG water in the Surat Basin, treatment of CSG water to potable supply (~500 mg/L TDS) will generate in the order of 4 tonnes of salt per megalitre of treated water. Raw water feed concentrations vary across tenements and may also change over time within a given CSG field. Brine stream concentrations will therefore change accordingly.

Specific measures are required to manage the storage and use (or disposal) of brine. A range of brine management options are identified, and described in the following sections.

4.3.1 Salt recovery

The concentrated brine by-product of desalinated water from the Surat Basin coal measures is comprised primarily of sodium chloride, sodium carbonate and sodium bicarbonate salts. A range of options for salt recovery are under consideration.

Non-selective salt recovery and landfill

Non-selective recovery can be undertaken in purpose designed, lined solar evaporation ponds, through other thermal processes, or using mechanical crystallisers. The mixed salt product recovered has little or no commercial value, therefore landfill of the solid product is required, either in third-party landfills, or through encapsulation of the solid salts in purpose designed cells.

Selective salt recovery

SSR requires the selective crystallisation of salts from RO brine to provide separate end product streams – typically sodium chloride, sodium carbonate and sodium bicarbonate, enabling commercial opportunity for sale of the product. A waste salt by-product is also produced that is dependent on the chemical characteristics of the brine processed at the salt recovery facility.

SSR is currently a reserved option because work to date has demonstrated that the recovered salt product has only modest value and the market is fully supplied by existing low cost producers. Furthermore, the process is energy intensive, and substantial transport distances to market would present issues of safety and cost. The combined energy and transport requirements would also result in a high emissions intensity for the final product.

4.3.2 Brine injection

Brine injection requires identification of a target formation with permeability and parameters sufficient to enable injection and storage, and where the water quality is such that injection of the brine will not impact the environmental values of the groundwater system.

To date, suitable aquifers have not been identified within Arrow's Surat tenements, and brine injection is not a proposed management option.

4.3.3 Ocean outfall

As for water, disposal of brine to the sea via an ocean outfall pipeline is recognised as a technically feasible option, but currently non-preferred.

4.3.4 Alignment of Arrow and DES priorities

A summary of the brine and salt management options is presented in Table 4.2 which aligns Arrows preferred and non-preferred options with the DES prioritisation hierarchy.

Table 4.2 Saline waste management – alignment of Arrow and DES priorities

Arrow priority	Option	Comments	DES Priority
Preferred	Non-selective salt recovery and landfill encapsulation	Solid product landfill in purpose designed regulated waste facilities	Priority 2
Reserved	Selective salt recovery	Currently uneconomic and unable to demonstrate a commercial market	Priority 1
Non-preferred	Brine injection	Currently not proposed and no identified target aquifer	Priority 2
	Ocean outfall	Not proposed due to community concerns, and potential schedule impact	Priority 2

5. References

Arrow Energy, 2012a. Coal Seam Gas Water and Salt Management Strategy.

Arrow Energy, 2012b. EIS Commitments Summary. Attachment 8 to the Arrow Energy Surat Gas Project EIS, February 2012.

Arrow Energy, 2013. Commitments Update. Attachment 4 to the Arrow Energy Surat Gas Project SREIS, June 2013

Appendix A: Regulatory System

The regulatory system that applies to the extraction and management of CSG water is summarised in Table A1, and includes legislation in conjunction with government policies, guidelines and procedures that must be referred to, and corresponding plans and/or activities that must be prepared or implemented.

Some of the regulated obligations for water management and monitoring are separately addressed in Arrow's WMMP, and also as required through the annual UWIR reporting cycle (Underground Water Information Reports).

Table A1: Regulatory system requirements

Activities	Statutory Obligation/Guideline/Policy	Responsible Regulator
Extraction of Water	• Extraction of water is authorised under the *Petroleum and Gas (Production and Safety) Act 2004 or* Chapter 2 of the *Water Act 2000.* • Impacts from the exercise of underground water rights are managed through Chapter 3 of the *Water Act 2000* including: Baseline Assessments of landholder bores, Underground Water Impact Reports, Water monitoring obligations, Spring impact management strategies, Bore assessments and Make Good obligations. • Impacts to springs associated with species listed as Matters of National Environmental Significance under the *Environmental Protection and Biodiversity Conservation Act (1999)* are regulated through that Act. • Impacts to groundwater environmental values are regulated under the relevant environmental authority granted under the *Environmental Protection Act 2004*. • Any bores constructed by Arrow are subject to the *Minimum Construction Requirements for Water Bores in Australia* and the *Minimum Standards for the Construction and Reconditioning of Water Bores that intersect the Sediments of Artesian Basins in Queensland*	DES[4] DoEE[5]
Treatment and Storage of CSG Water and Brine	• General obligations can be found in the *Environmental Protection Act 1994*, which is also responsible for the grant of environmental authorities which condition the activities for a petroleum tenure. • Dam design, construction, operation and monitoring requirements are outlined in the relevant environmental authority and are based on an assessment under DES's *Manual for Assessing Consequence Categories and Hydraulic Performance of Structures and the Guideline for Structures which are dams or levees constructed as part of environmentally relevant activities.*	DES
Supply of CSG Water for Beneficial Use	• The Queensland Government Coal Seam Gas Water Management Policy (2012) outlines the Government's position with regards to the beneficial use and disposal of CSG water. • Supply of untreated or treated water to a third party is generally regulated through the relevant environmental authority for a petroleum tenure. • In some cases, supply may be regulated through an End of Waste Approval or an End of Waste Code granted through the *Waste Reduction and Recycling Act 2011*. • Supply for urban use would require assessment as part of the service provider's Drinking Water Quality Management Plan under the Water Supply (Safety and Reliability) Act 2008.	DES DEWS[6]
Discharge of CSG Water into Watercourse	• The discharge of CSG water into a watercourse is regulated through the conditions of the relevant environmental authority.	DES

[4] Department of Environment and Science (Queensland)
[5] Department of Environment and Energy (Federal)
[6] Department of Energy and Water Supply (Queensland)

Activities	Statutory Obligation/Guideline/Policy	Responsible Regulator
Injection into an aquifer used or potentially used as a source of supply for drinking	• The injection of CSG water into an aquifer is regulated through conditions in the relevant environmental authority.	
Salt or brine disposal	• The storage, tracking, and disposal of waste is generally regulated through an environmental authority granted under the *Environmental Protection Act 2004.* • There can be additional obligations (e.g. reporting obligations) under the *Waste Reduction and Recycling Act 2011.* • The Queensland Government's overall waste and recycling strategy shapes the obligations in the relevant environmental authority and can be found in the Queensland Waste Avoidance and Resource Productivity Strategy (2014-2024).	DES
Beneficial use of salt or brine	• Beneficial use of salt or brine is regulated through the conditions of an End of Waste Approval or an End of Waste Code under the *Waste Reduction and Recycling Act 2011*. • The Queensland Government Coal Seam Gas Water Management Policy (2012) outlines the Government's position with regards to the beneficial use and disposal of salt and brine.	DES
Land access, including compensation for pipelines and Notice of Entry, ecology and cultural heritage clearances	• P&G Act • EP Act (EA) • Environment Protection and Biodiversity Conservation Act 1999 (Federal) • Nature Conservation Act 1992 • Vegetation clearing permit	DNRM DEE

Attachment 2: EIS/SREIS commitments

Table A2 SREIS operational commitments – groundwater and surface water

Aspect	Number	Commitment	Phase
Surface water	C009	Routinely monitor water quality in dams.	Inspection and Monitoring
Groundwater	C038	Carry out corrective actions immediately upon the identification of any contamination of soil or groundwater that has occurred as a result of project activities.	Planning and Design Construction Operations Decommissioning
Surface water	C066	Discharge water from project activities at a rate and location that will not cause or exacerbate erosion. Install erosion protection measures, including energy dissipation structures, at discharge outlets.	Discharge of produced water to surface water systems is no longer proposed
Groundwater Surface water	C067	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.	Discharge of produced water to surface water systems is no longer proposed
Groundwater	C136	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 timelapse 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).	Operations
Groundwater	C142	Manage potential impacts to groundwater dependent ecosystems (including on identified spring complexes) by: • Supporting the identification of specific aquifers that serve as a groundwater source for the groundwater-dependent ecosystem. • Assessing groundwater-dependent ecosystems that are predicted to be subject to unacceptable impacts through the source aquifer. • Developing monitoring and mitigation strategies to avoid or minimise unacceptable impacts.	Operations
Groundwater	C143	Implement a well integrity management system during commissioning and operation of production wells.	Operations
Groundwater	C144	Minimise impacts of groundwater depressurisation on sensitive areas (e.g., groundwater-dependent ecosystems).	Operations
Groundwater	C145	Develop a procedure for investigating the impaired capacity of third-party bores. The investigation will comprise (but not be 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.	Operations

Aspect	Number	Commitment	Phase
Groundwater	C146	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.	Operations
Groundwater	C147	Include where possible make-good measures such as deepening of bores, modification of pumps, or supply of ground water from an alternative source.	Operations
Groundwater	C148	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).	Operations
Groundwater	C149	Store and manage all waste materials (domestic and industrial) in accordance with industry regulations and EHP conditions. Use licensed waste management contractors. Conduct audits of disposal facilities, disposal permits and onsite operations to ensure adherence to regulations.	Operations
Surface water	C171	Develop and implement incident reporting, emergency response and corrective action systems or procedures. Include systems for reporting, investigation and communications of lessons learned.	Operations
Surface water	C172	Segregate stormwater discharge from potential contaminant process areas.	Operations
Surface water	C173	Inspect rehabilitated watercourse channels and banks following significant flow events and undertake remedial works as required.	Operations
Surface water	C174	Maximise beneficial use of coal seam gas water.	Operations
Surface water	C204	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.	Planning and Design Construction Operations Decommissioning
Groundwater	C504	Install groundwater monitoring bores near dams as a leak detection measure: • The number of monitoring bores and their location will take into account site-specific hydrogeology, preferential pathways and potential receptors of impacts. • Monitoring 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.	Construction Inspection and Monitoring
Surface water	C505	Inspect erosion and sediment control measures following significant rainfall events and carry out repairs and/or maintain as required to retain the effectiveness of the measures.	Inspection and monitoring
Surface water	C507	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.	Inspection and monitoring
Surface water	C509	Routinely monitor buffer zones and project footprint using satellite imagery.	Inspection and monitoring

Aspect	Number	Commitment	Phase
Groundwater	C510	Prepare groundwater monitoring reports in accordance with the P&G Act, EP Act and Water Act.	Inspection and monitoring
Groundwater	C515	Provide chemical monitoring of contaminated soils and groundwater in relevant monitoring bores.	Inspection and monitoring
Groundwater	C521	Ensure methods used to monitor groundwater levels and quality, together with monitoring frequencies and parameters are in accordance with approved regulatory standards.	Inspection and monitoring
Groundwater	C522	Ensure methods used to monitor groundwater levels and quality, together with monitoring frequencies and parameters are in accordance with approved regulatory standards.	Inspection and monitoring
Groundwater	C524	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.	Inspection and monitoring
Groundwater	C525	Comply with inspection and monitoring requirements of the Surat Cumulative Management Area Underground Water Impact Report administered by the Queensland Government Office of Groundwater Impact Assessment.	Inspection and monitoring
Surface water	C526	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.	Inspection and monitoring Discharge of produced water to surface water systems is no longer proposed Stormwater will be managed under existing regulations
Surface water	C527	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.	Inspection and monitoring
Surface water	C529	Measure the volume and quality of coal seam gas water released to surface waters on a routine basis in accordance with legislative requirements and approved release limits.	Inspection and monitoring
Surface water	C530	Routinely measure the volume and quality of treated sewage effluent in accordance with regulatory requirements and approved release limits.	Inspection and monitoring

Aspect	Number	Commitment	Phase
Surface water	C560	Consult with landowners downstream of discharge points on access requirements for vehicular and stock crossings of the affected watercourse reaches, and manage discharges to reduce disruption to existing access arrangements.	Discharge of produced water to surface water systems is no longer proposed
Surface water	C561	Identify reaches vulnerable to bank erosion from the discharge of coal seam gas water and develop site-specific erosion control and management plans for vulnerable reaches.	Discharge of produced water to surface water systems is no longer proposed
Groundwater	C565	Arrow is committed to mitigating against its component of modelled likely flux impacts to the Condamine Alluvium in the area of greatest predicted drawdown as a result of coal seam gas water extraction from the Walloon Coal Measures.	Planning and Design Construction Operations